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Nisikawa Usio · Tadashi Miyashita
Editors

Social-Ecological Restoration in Paddy-Dominated Landscapes

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Front cover: A farmer endeavoring to remove agricultural pest insects using a basket in an organic rice paddy field in Sado Island, Japan (photo by Nisikawa Usio). *Back cover: Left*: A near-threatened *Rana porosa porosa* (Tokyo daruma pond frog) found in a rice paddy field adjacent to an earthen irrigation ditch in Saitama Prefecture, Japan (photo by Aiko Furuya). *Center: Nipponia nippon* (toki) resting on a tree branch in Sado Island, Japan (photo by Hiromu Nakatsu). *Right:* An endangered *Rotala pusilla* (mizumatsuba) growing in a rice paddy field in Tochigi Prefecture, Japan (photo by Aiko Furuya).

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Preface

Anthropogenic activities have led to dramatic loss of biodiversity and ecosystem services worldwide. Among various management practices undertaken to mitigate detrimental impacts on biodiversity and ecosystem services, *land sparing* and *land sharing* are two major land management approaches discussed in conservation or restoration science (Fischer et al. 2008; Tscharntke et al. 2012). Traditionally, much attention has been given to land sparing, in which relatively pristine areas are designated as protected areas for biodiversity conservation while human use of natural resources are restricted in such areas. In recent decades, land sharing, in which biodiversity conservation and human use of natural resources are practiced on the same land, has gained equal attention, especially in agricultural ecosystems. Land sparing and land sharing have complementary roles in biodiversity conservation or restoration (Fischer et al. 2008), and both land management approaches comply with a short-term (i.e., Target 7: by 2020 areas under agriculture, aquaculture, and forestry are managed sustainably, ensuring conservation of biodiversity) and long-term (2050) visions (i.e., living in harmony with nature) proposed in the Strategic Plan for Biodiversity 2011–2020 and the Aichi Targets at the 10th Conference of the Parties (COP10) to the Convention of Biodiversity (CBD 2010).

Japan is among the densely populated countries, where humans have had close affinity with rural biocultural landscapes, also known as Satoyama. Satoyama comprises paddy fields, cropland, farm ponds, streams/ditches, secondary forests, and grassland around villages, where village people have long managed and maintained natural resources through farming and forestry activities. Many endemic species, including endangered species, inhabit Satoyama, and organisms are adapted to moderate levels of disturbances (Katoh et al. 2009). At the same time, village people have maintained economic activities through farming and forestry activities. Therefore, Satoyama is believed to be an ideal model system for land sharing.

However, Satoyama is facing serious threats from two contrasting types of habitat degradation: agricultural intensification and abandonment of farmland–forestry areas (Katoh et al. 2009; Natuhara 2013). Modernization of agriculture led to the use of strong agrochemicals, the associated non-point pollution from farmland, farmland consolidation, and the associated habitat fragmentation. In contrast, depopulation and aging in rural communities led to abandonment of farmland and secondary forests, which in turn accelerated loss of disturbance-dependent organisms and loss of multifunctionality of such secondary ecosystems.

In this book, we focus on ecological restoration of paddy-dominated landscapes, as rice farming has a major role in Japanese agriculture. To restore multifunctionality of paddy fields and to revitalize depopulating and aging rural communities, both ecosystem and human dimensions of ecological restoration need to be considered. Throughout this book, we have used the term "social-ecological" to put equal weight on the two dimensions of ecological restoration. The only exception is Chap. 2, where "socio-ecological" is used because of the history of that term's being used in a political context.

Ecological restoration of farmland has attracted much attention from scientists and policy makers in Europe (e.g., Kleijn et al. 2006; Gabriel et al. 2009), probably because farmland accounts for significant proportions of land areas in many European countries. Although European scientists focus on restoration of degraded dry lands (e.g., cropland or pasture), ecological restoration of paddy fields differs fundamentally in that it focuses on restoration of quasi-natural wetland habitats. Our book is the first to introduce ecological restoration of paddy-dominated landscapes. We hope that this book stimulates further research on social-ecological restoration in paddy-dominated landscapes.

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References

CBD (2010) The Strategic Plan for Biodiversity 2011–2020 and the Aichi biodiversity targets. Available at http://www.cbd.int/cop10/doc/default.shtml. Accessed 28 July 2014

Fischer J, Brosi B, Daily GC, Ehrlich PR, Goldman R, Goldstein J, Lindenmayer DB, Manning AD, Mooney HA, Pejchar L, Ranganathan J, Tallis H (2008) Should agricultural policies encourage land sparing or wildlife-friendly farming? Front Ecol Environ 6:382–387

Gabriel D, Carver SJ, Durham H, Kunin WE, Palmer RC, Sait SM, Stagl S, Benton TG (2009) The spatial aggregation of organic farming in England and its underlying environmental correlates. J Appl Ecol 46:323–333

Katoh K, Sakai S, Takahashi T (2009) Factors maintaining species diversity in satoyama, a traditional agricultural landscape of Japan. Biol Conserv 142:1930–1936

Kleijn D, Baquero RA, Clough Y, Diaz M, De Esteban J, Fernandez F, Gabriel D, Herzog F, Holzschuh A, Johl R, Knop E, Kruess A, Marshall EJP, Steffan-Dewenter I, Tscharntke T, Verhulst J, West TM, Yela JL (2006) Mixed biodiversity benefits of agri-environment schemes in five European countries. Ecol Lett 9:243–254
Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecol Eng 56:97–106
Tscharntke T, Clough Y, Wanger TC, Jackson L, Motzke I, Perfecto I, Vandermeer J, Whitbread A (2012) Global food security, biodiversity conservation and the future of agricultural intensification. Biol Conserv 151:53–59

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Part I
Understanding Agricultural Systems in Japan

Chapter 1
Japan's Agricultural Policies After World War II: Agricultural Land Use Policies and Problems

Takuya Hashiguchi

Abstract After World War II, it was the Japanese government's official policy that farmers should own the land they cultivated. This policy was in effect until 2009, when the Agricultural Land Law was changed drastically. This change was the result of long-term serious discussions regarding which type of agricultural land user was best suited to farming. The discussion was influenced by the problem of abandoned agricultural land, which had become serious around 1990. New policy frameworks were created to prevent abandonment after 2000, and they have been

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very effective. Nonetheless, it is difficult to foresee a promising future for rural areas unless the new policy framework is made more trustworthy and reliable as well as many other policies are mobilized.

Keywords Agricultural Land Law • Abandoned agricultural land • Agricultural land use policies • Agricultural land use reform • Direct payment • Gen-tan policy • Rural communities • Agricultural committee

Introduction

The purpose of this chapter is three-fold: first to review changes to Japan's agricultural land use policies post World War II to the present time; second to highlight the country's new agricultural policies framework, the so-called *direct payment system* introduced after 2000, the year after the Basic Law on Food, Agriculture and Rural Areas had been enacted and replaced the Agriculture Basic Law; third to examine urgent questions with regard to identifying which types of agricultural land users are preferred. In the first section, I will show how Japan's agricultural land use policies had been changed after World War II and established through *agricultural land use reform*. In the second section, I will show that the main purpose of the direct payment system was to prevent the abandonment of agricultural land, and that they were very effective. In the third section, I will describe the current state of the agricultural committees, which continue to exist in almost all municipalities and have a long-standing responsibility for permitting the sale and leasing of agricultural land. I discuss there might be the possibility that rules and customs in rural areas will be changed drastically.

Overview of Post-war Japan's Agricultural Land Use Policies

Agricultural Land Use Reform and Establishment of the Owner Farmer System (Post-war to the First Half of the 1950s)

The most important matter for Japan's post World War II agricultural policy was *agricultural land use reform*. Agricultural land use policies were reviewed at this time, concerning all aspects related to agriculture and food policy. The government's aim was to solve the problem of rural poverty, which had been thought as the background of the war. And another aim was to increase agricultural productivity, which had fallen during the war, and in so doing to save the Japanese people from starvation. It was thought that by establishing many owner farmers this objective would be realized. Before the war, there had been serious conflicts between landowners of large agricultural land areas and tenant farmers with small acreages. The main outcome of Japan's post-war agricultural land use reform was that landowners' agricultural lands were transferred to many tenant farmers (Goda 1997).

The Agricultural Land Law, passed in 1952, was intended to sustain the effects of *agricultural land use reform*. Until 2009, when this law was changed drastically, the accepted principle was that farmers should own the land they cultivated. Conversely, renting and leasing agricultural land was not considered desirable. This principle would prove to be an obstacle later, when the scale of Japanese farms had to be enlarged.

At this point, I would like to note that the government promoted the expansion of agricultural land during this period to increase agricultural production. In fact, the areas of land dedicated to agricultural use in Japan continued to expand until 1961 (Iwamoto 1998).

Rising Prices for Land Caused by High Economic Growth and Difficulties Expanding the Scale of Farms (From the Second Half of the 1950s)

During the second half of the 1950s, on the one hand, the economic situation of Japanese farmers was not good, while on the other hand, the country was experiencing a period of high economic growth. This dichotomy was called the *gap between industry and agriculture*, and was considered a very serious social problem. The Agriculture Basic Law was enacted in 1961 to address this problem. The cause for this income gap between industry and agriculture was thought to be agriculture's low productivity levels, which in turn were thought to be a consequence of each farmer's ability to access only a small and fragmented agricultural land area. Therefore, the objective of the Agriculture Basic Law was to remove these constraints (Kitade 2001; Teruoka 2003; Tashiro 2012).

The expectation was that if the industrial sector continued to develop, it would require a larger labour force, which, in turn, would reduce the size of the labour force available for the agricultural sector. The remaining farmers could then cultivate larger land areas by acquiring the agricultural land of the retired farmers who had moved to industrial occupations. Once the remaining farmers gained larger farms, their productivity levels would be higher. And farmers would earn incomes equivalent to those of industry sector workers. The income gap between industry workers and farmers would be removed.

The expectation of the Agriculture Basic Law was not realized, because rapid economic growth increased the rate at which agricultural land was diverted to other uses, such as factory sites, residential areas, and roads. Additionally, Japan's regulations pertaining to land use were not strictly enforced, and the price of agricultural land had risen so high that it would have been difficult to buy agricultural land and cultivate it economically. Furthermore, many farmers would not sell their land, because there was the possibility that the price of agricultural land would increase. These conditions made it difficult to buy agricultural land and expand the scale of farms. The intentions behind the Agriculture Basic Law were not realized, and consequently many farmers continued as part-time farmers.

It is noteworthy that, as already described, the Agriculture Basic Law was enacted in 1961. The area of agricultural land in production in Japan in that year was maximum and about 6.09 million ha compared to about 4.54 million ha in production in 2013.

Modification of the Principle Behind the Agricultural Land Law to Permit the Renting and Leasing of Agricultural Land and the Use of Positive Promotion (After 1970)

The Agricultural Land Law of 1952 was modified after 1970 to permit the renting and leasing of agricultural land by those who could only farm by exception before 1970. The thinking that led to this change was as follows. If it was difficult to increase the scale of farms by buying agricultural land, it should be possible to increase the scale of farms by renting additional land. A strategy was needed to promote the renting and leasing of agricultural land. To that end, the Agricultural Land Use Promotion Project was initiated in 1975, and the Agricultural Land Use Promotion Law was enacted in 1980. After that, the extent of area rights transferred through leasing exceeded the purchase and subsequent transfer of ownership rights for agricultural land (Imamura 1983).

Another big change that affected agricultural land use, particularly paddy field use, occurred during this period. A new policy, the so-called *Gen-tan*, asked farmers to reduce rice production and to replace rice plants in paddy fields with other plants. As already described, it had been difficult to realize the aim of the Agriculture Basic Law by expanding farm scales in order to increase productivity. On the contrary, the income gap between industrial sector and agricultural sector workers had shrunk, following government's decision to raise the producer rice price. However, raising the producer rice price had led to increasing rice yields and the expansion of paddy field areas.

Some details changed over time with discussions being made about these changes. In essence, however, the *Gen-tan* policy framework had been maintained to this time. Rice production levels had been falling annually. Though *Gen-tan* itself is not an agricultural land use policy, it has strongly affected agricultural land use since 1970. The decision was made to use the strong human ties in rural communities to manage the undesired outcomes of the *Gen-tan* policy (Arahata 2014).

As I described, the maximum extent of Japan's agricultural land use, including paddy fields and upland fields, occurred in 1961, but the extent of paddy fields in cultivation peaked in 1969. After 1970, the area covered by paddy fields began decreasing. The obvious reason for this change was implementation of the *Gen-tan* policy.

Following a period of high economic growth, a low economic growth period began after 1973. After 1986, however, the so-called *economic bubble* influenced all of Japan, including rural areas. The Law for the Development of Comprehensive Resort Areas (the so-called Resort Law) was passed in 1987. During this time, it was difficult to find rural areas that did not have plans to develop golf courses, resort hotels, skiing grounds, marinas, and other resort facilities. Many people living in rural areas, including farmers, thought that the economic bubble would allow them to profit from development, especially from selling agricultural lands and forests and from being employed in the hospitality service sectors. It is often said that the reduction of producer prices for agricultural products during this period was the main reason for the ruin of agricultural land, but I also think that agricultural land conditions were influenced by the unsettled minds of farmers in rural areas caught up in the economic bubble.

I would like to mention an important point with regard to the area of agricultural land. The extent of the cultivation of upland fields peaked in 1958, and a second peak followed in 1987. As already described, paddy field expansion stopped under the *Gen-tan* policy beginning in 1970, and after that, there was an expansion in upland farming, although the level of expansion was not very large compared with its extent before that time. After 1988, the extent of upland fields across Japan began to decline again.

The Problem of Abandoned Agricultural Land and a New Policy Framework

The Abandoned Agricultural Land Problem

In the previous section, I outlined changes to the agricultural land use policies in Japan after World War II, which was established through changes in *agricultural land use reform*. I also explained the principle that farmers should own the land they cultivated. The discussion point against this principle was influenced by the fact that serious problems of abandoned agricultural land had been evident since 1990. In this section, I will describe the problems related to abandoned agricultural land and comment on some new policy frameworks intended to prevent the abandonment of agricultural land.

From the perspective of agricultural land use, the growing extent of abandoned agricultural land is one of Japan's big problems. According to The Census of Agriculture, *abandoned agricultural land* refers to previously cultivated land that has not been used for more than a year (fertility management) with no plans to resume its use within a few years. And land that has already reverted to wilderness is not included in the category of *abandoned agricultural land* (Ministry of Agriculture, Forestry and Fisheries of Japan 2010a). One important point is that abandoned land reported in the Census of Agriculture is not necessarily stock data.

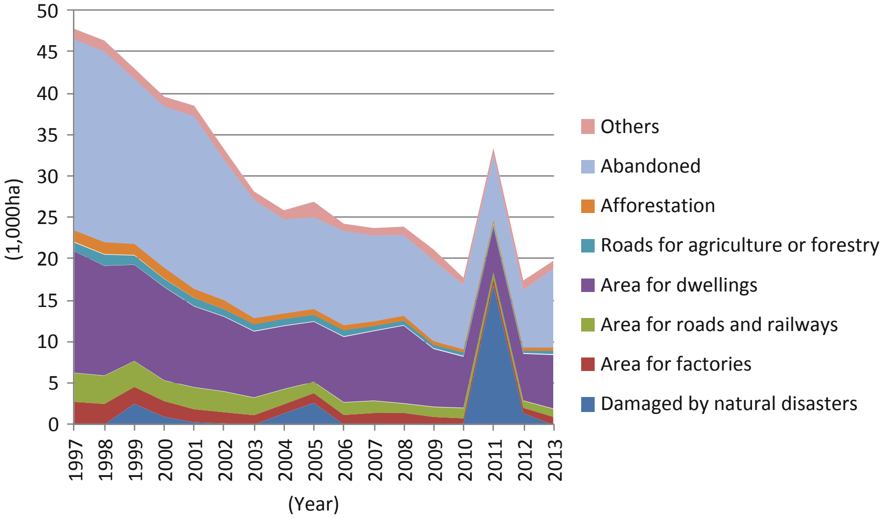

Fig. 1.1 Reasons for the ruination of Japan's agricultural land from 1997 to 2013 (Ministry of Agriculture, Forestry and Fisheries of Japan 2012, 2013). Because the Great East Japan Earthquake damaged extensive areas of agricultural land in the Tohoku region, 2011 was an exceptional year

Figure 1.1 provides summary data provided by Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) for cultivated land and planted areas. As evident from Fig. 1.1, the main reason for ruined agricultural land in recent years (after 1997 apparent) is the abandonment of agricultural land that was formerly cultivated.

Figure 1.2 shows how much land area is abandoned every 5 years, according to the Census of Agriculture. In 2010, the most recent year for which data are available from the Census of Agriculture, about 396 thousand ha of agricultural land were abandoned nationwide. It is sometimes said that the extent of agricultural land abandonment almost equates to the whole area of Japan's Shiga Prefecture or Saitama Prefecture. This expression helps to convey the immensity of the abandoned agricultural land area. Abandoned agricultural land problems became serious in the 1990s, and the areas abandoned in each 5-year period since then have been increasing in size. Figure 1.2 further illustrates the increasing rate at which land is being abandoned.

We can mark some epochs on the trend of the agricultural land area: the year 2000 was a big turning point. The extent of agricultural land in production had been decreasing since 1988, but in some regions, for example northeast Hokkaido and southeast Okinawa, the extent of cultivation in upland fields had been increasing little by little. By 2000, however, the increasing trend had stopped.

In addition, the declining utilization rate of cultivated agricultural land in Japan is also a serious problem. The maximum rate of the use of cultivated agricultural land was 137.6 % in 1956. Since then, the rate of the use of cultivated agricultural land has been declining continuously, with the most recent data in 2013 showing 91.9 %.

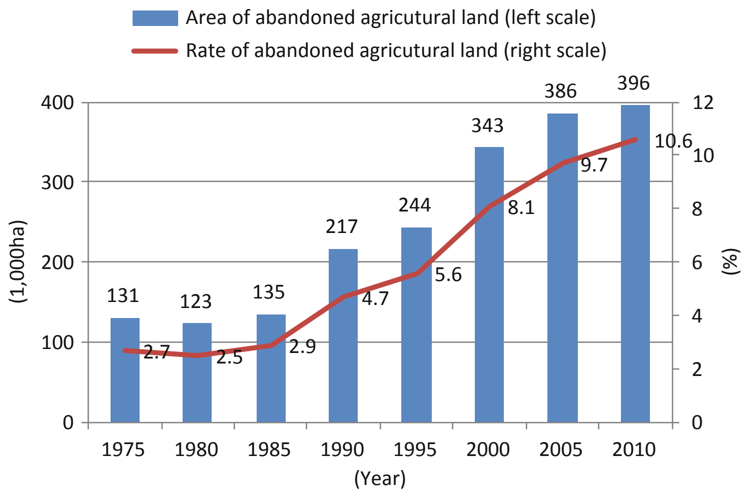

Fig. 1.2 Nationwide area and rate of abandoned land in Japan (Ministry of Agriculture, Forestry and Fisheries of Japan 2010c). Rate of abandoned land = Area of abandoned land/(Area of abandoned land + Area of cultivated agricultural land) × 100 (%)

A new policy framework was drafted to respond to these circumstances. MAFF announced a new rural policy framework beginning in the 2014 fiscal year. The new policy framework is called the Japanese-style direct payment system. The term *Japanese style* is used to emphasize the difference between this payment system and the European payment system, as well as those of other advanced countries. What is the big difference between the Japanese style and the European direct payment system? The big difference between the two systems probably lie in the focus of subsidization. Japan's direct payment system considers and spotlights restoration and reinforcement of the functioning of rural communities while the European payment system aims to support farmer's income. The main purpose of the Japanese direct payment system is to strengthen ties of farmers in rural Japan. An important objective of this new policy framework is to maintain cultivated land and to keep rural areas in good condition.

Earlier I stated that the new rural policy framework was implemented in the 2014 fiscal year. Officially, the new rural policy framework has recently been called *Japanese style* by MAFF. But various existing policies have possibly been combined as part of this framework. One policy already in effect was the Direct Payment to Farmers in the Hilly and Mountainous Areas, which commenced in the 2000 fiscal year. Beginning in the 2007 fiscal year, a policy called the Payment for Conserving Farmland and Water was implemented, with the objective of strengthening ties among various residents (including not only farmers but also non-farmers) in rural communities. The Payment for Conserving Farmland and Water was initially called the Measures to Conserve and Improve Land, Water and Environment when it began in 2007, but the policy name and the framework have since been changed. The Payment for Conserving Farmland and Water applies not only to hilly and mountainous areas but also to Japan's flatland areas. The payment also requires the *agreement of the rural community residents*.

Operation of The Direct Payment to Farmers in the Hilly and Mountainous Areas

The Direct Payment to Farmers in the Hilly and Mountainous Areas policy was implemented in the 2000 fiscal year. I would like to explain some aspects of this policy. Farmers who participate in the system are obliged to conclude an agreement in principle with the rural community group. The agreement is one of the most important aspects of the direct payment system. Farmers with paddy fields of steep degrees 1/20 or above are paid 21,000 Japanese yen (approximately US$210) per 10 a. Farmers with paddy fields of steep degrees less than 1/20, but 1/100 or above, are paid 8,000 Japanese yen (US$80). Therefore, payment amounts depend on the type of agricultural land and the degree of steepness. Policy makers have explained that the difference in payments is based on the different costs required to maintain agricultural land on the flatlands and on slopes. In short, a key aim of the system is to support the cultivation of steep agricultural land.

It can be argued that the direct payment system in the hilly and mountainous areas has been highly effective. Part of its effectiveness is indicated by the results of the 2000 and 2005 Censuses of Agriculture, which show the extent of cultivation before and after implementation of the system. It is especially apparent with regard to paddy fields, where the relationship between the steepness of the land where paddy fields exist and the ratio of decreasing areas of paddy fields is analysed. When compared to the long-term trend from 1960 to 2000, the direct payment system in the hilly and mountainous areas reveals a different trend from 2000 to 2005 (Hashiguchi 2010).

Operation of the Payment for Conserving Farmland and Water

Another new policy framework, the Payment for Conserving Farmland and Water, was implemented in the 2007 fiscal year. This framework includes not only hilly and mountainous areas, but also flatland areas. It supports collaborative activities that contribute to the preservation and qualitative agriculture improvements of local resources, including agricultural land, rivers, channels for irrigation, and farm drainage. It also requires the *agreement of the rural community residents*, which is comparable to that required for the Direct Payment to Farmers in the Hilly and Mountainous Areas.

This payment has been provided to conserve and manage farmlands and farm water resources. And main purpose is to improve the rural environment. Basic payments are as follows: 3,400 Japanese yen (US$34) per 10 a of paddy fields are subsidized in the Hokkaido region, while 4,400 Japanese yen (US$44) per 10 a of paddy fields are subsidized in non-Hokkaido regions, 1,200 Japanese (US$12) yen per 10 a of upland fields in the Hokkaido region, while 2,800 Japanese yen (US$28)

Table 1.1 Rate at which rural communities preserve local resources

Classification of agricultural area	Agricultural land		Reservoirs, lakes and marshes		Rivers and channels for irrigation		Farm drainage	
	Y2005	Y2010	Y2005	Y2010	Y2005	Y2010	Y2005	Y2010
Urban area	5.3	18.5	35.6	54.5	17.4	37.7	51.5	65.5
Flat farming area	10.8	32.2	38.0	59.7	22.2	47.8	58.5	77.3
Hilly farming area	26.7	40.9	39.8	60.1	23.2	47.0	61.8	75.1
Mountainous farming area	33.0	45.5	26.1	42.8	19.4	38.6	60.5	71.8
Nation-wide	19.0	34.6	36.6	56.6	21.1	43.6	58.5	73.1

Source: Ministry of Agriculture, Forestry and Fisheries of Japan (2005, 2010b)
Unit: %

per 10 a to cultivate those in non-Hokkaido regions. The payment amounts are decided by calculating the cost to maintain agricultural land and local resources. This policy provides the framework needed to encourage rural communities to implement repairs and renewal operations. It is also intended to lengthen the service lives of terminal irrigation canals and farm roads.

Table 1.1 summarizes the extent of the conservation measures undertaken by rural communities. A comparison between 2005 and 2010 reveals a large difference. For example, with regard to agricultural land use in 2005, 19.0 % of rural communities conserved agricultural land. However, in 2010, 34.6 % of the rural communities conserved agricultural land. Therefore, the changes have apparently been a result of the Payment for Conserving Farmland and Water.

Other Measures Taken to Recover Abandoned Agricultural Land

Earlier I described two new policies implemented to protect agricultural land from abandonment. In addition to those policies, measures have been taken to return abandoned agricultural land to cultivated agricultural land. Under the Economic and Fiscal Reform 2007 (Basic Policies 2007) approved by the Japanese cabinet, it was agreed that they *intended to dissolve the abandoned agricultural problems in primary agricultural zones within 5 years*. Other measures were taken to stop the abandonment of agricultural land operations. For example, with the objective of reclaiming abandoned agricultural land, the government conducted a field survey to identify where and to what extent agricultural land, which had previously been cultivated, was not being cultivated in the 2008 fiscal year. Another example of other measures taken is the *subsidies for emergency measures* to support efforts made to revitalize and utilize devastated agricultural land and to develop needed facilities.

By approving operating policies aimed at stopping the abandonment of agricultural land and implementing measures to reclaim abandoned agricultural land, the extent of abandoned agricultural land seems to be less compared with the situation before. However, it would be difficult to solve all abandoned agricultural land problems. I would like to comment further on this point in the conclusion of this chapter.

Current Tendency to Use Agricultural Land and Discussion Points

Deregulation of the Right to Use Agricultural Land, and the Appearance of a Variety of Agricultural Land Users

In a previous section, I described some new policy frameworks intended to prevent the abandonment of agricultural land. These frameworks have been relatively effective, but there is still a difficult argument regarding which agricultural land users should be allowed to cultivate land. And there is the strong opinion that the government should help new types of agricultural land users enter the agricultural sector. In this section, I will discuss the current situation regarding agricultural use matters.

In 1999, the Basic Law on Food, Agriculture and Rural Areas replaced the Agriculture Basic Law, which had been in effect since 1961. There had been difficult arguments about Japan's agricultural land use policy after 1961 regarding which type of agricultural land users were best suited to manage agricultural land effectively and sustainably. Big changes were finally happening. As already mentioned, after 1970 the extent of area rights transferred through leasing exceeded the purchase and subsequent transfer of ownership rights for agricultural land. However, the principle behind the Agriculture Basic Law was that owner farmers were the best choice for cultivating agricultural land, and this official stance was maintained until 2009. This exemplifies the double standard policy that had been called the *cultivator principle*. It is difficult to explain this idea, because the *land-owning farmer principle* is a simple concept, but the *cultivator principle* is somehow confusing. It means that those who rent agricultural land must also cultivate that land. It might be seen as common sense, but there is the possibility that the land could be loaned or leased to other people, agricultural workers could be hired to farm the land, or the agricultural land would be neglected.

For this reason, large joint-stock corporations had not been permitted to own or to rent agricultural land, because stockholders are different from cultivators. Owning or renting agricultural land by large joint-stock corporations was believed to contradict to the *cultivator principle*. Other than individual and household farmers, only small, specific, limited corporations and agricultural producers' cooperative corporations had been permitted to use agricultural land. The specific corporations could use agricultural land, but had to meet some requirements regarding the type of corporation, percentage of stockholders, and executives' duty to cultivate the land.

The Law on Special Zones for Structural Reform of 2003 had permitted the use of agricultural land by definite general joint-stock corporations in the district where the law was applied. In addition, a general joint-stock corporation could rent land not only in the district where the Law on Special Zones for Structural Reform was applied, but also anywhere in the country, after the Agricultural Land Law was amended in 2009. This represented a big change and was called *building the foundation of the agricultural land system from possession to use*.

The Current Situation of Agricultural Land Use and Discussion Points

The last discussion point still exists, namely, the question remains whether a general joint-stock corporation can own agricultural land or not. There is strong pressure from big business circles that it should be permitted to buy agricultural land everywhere.

Another fact is also important. Intermediary Agricultural Land Management Institutions were established in every prefecture early in the 2014 fiscal year. The installation of these institutions is intended to speed up the consolidation of agricultural land. Furthermore, the entry of diverse agricultural land users, including big companies, into the agricultural sector will be promoted. This notion was the subject of a difficult argument at the national parliament. These institutions have been given the authority to decide which agricultural land users should be allowed to cultivate specific areas of agricultural land. The point of concern is that the institution might select big companies, which are not necessarily based in rural communities as cultivators.

Another difficult point in the argument is in the spotlight. It concerns the current state of the agricultural committees established in almost all municipalities in 1951, which, for a long time, have played a very important role in permitting the sale and leasing of agricultural land. These agricultural committees are made up of two types of members: those who are appointed by the mayor of the municipality and those who are voted in by farmers who cultivate agricultural land. An important point is that the number of members voted in should be greater than the number of members appointed. In fact, of the total number of members in all agricultural committees nationwide, three quarters are voted-in members.

Discussion has progressed to the point where selecting agricultural committee members by vote would be abolished and all members would be appointed, with the total number of members being reduced. To solve the problem of abandoned agricultural land, the functions of agricultural committees had just been strengthened in 2009. However, I have to wonder whether the recent discussions will lead to improvements.

Conclusion

Data from the Census of Agriculture show that ties within rural communities have indeed been strengthened by some of the new policy frameworks. Currently, however, the average age of farmers in rural areas is almost 5 years older compared to that in 5 years ago. This means it will be difficult to rejuvenate the farming population. Further, the area of cultivated agricultural land is declining while abandoned agricultural land continues to be a serious problem.

I would like to suggest again that the subsidy programs that have proven their effectiveness should be evaluated further. However, I do not think they hold promise for future. Not only farmers, but also all residents in rural communities are mainly old people, so the level of subsidies provided are inadequate for maintaining households, especially for young people.

There are considerable expectations regarding the possible impacts of Japan's new policy framework and some of the programs put in place to revitalize not only less favoured areas but also flatland areas. Nevertheless, it is difficult to foresee a promising future unless the new policy framework is made more trustworthy and reliable as well as many other policies are mobilized with consideration for the future of the beneficiaries and rural areas.

References

Arahata K (2014) 40 years of 'Gen-tan' policy and Japan's agriculture of paddy fields. Norin-Tokei-Syuppan Publishers, Tokyo (in Japanese)

Goda K (1997) History of the non-military activities of the occupation of Japan: 1945–1950, vol 33. The Rural Land Reform, Nihon-Tosyo-Centre Publishers, Tokyo (in Japanese)

Hashiguchi T (2010) Evaluation and prospects of policies for less favoured areas in Japan. In: Paper prepared for presentation at the 118th seminar of the EAAE (European Association of Agricultural Economists), 'Rural development: governance, policy design and delivery' Ljubljana, Slovenia, August 25–27, pp 925–930

Imamura N (1983) Morden agricultural land use policy. Tokyo-Daigaku-Syuppankai Publishers, Tokyo (in Japanese)

Iwamoto N (1998) History of the non-military activities of the occupation of Japan: 1945–1951, vol 41. Agriculture, Nihon-Tosyo-Centre Publishers, Tokyo (in Japanese)

Kitade T (2001) 50 years of Japan's agricultural policy: inspection for food policy. Nihon-Keizai-Hyoron-Sya Publishers, Tokyo (in Japanese)

Ministry of Agriculture, Forestry and Fisheries of Japan (2005) Report on Results of 2005 Census of Agriculture and Forestry in Japan. Available at http://www.maff.go.jp/j/tokei/census/afc/2010/05houkokusyo.html. Accessed 7 Sept 2014

Ministry of Agriculture, Forestry and Fisheries of Japan (2010a) Questionnaire for Survey of Agriculture and Forestry Management Entities in Report on Results of 2010 World Census of Agriculture and Forestry in Japan. Available at http://www.maff.go.jp/j/tokei/census/afc/2010/houkokusyo.html. Accessed 7 Sept 2014

Ministry of Agriculture, Forestry and Fisheries of Japan (2010b) Report on results of 2010 World Census of Agriculture and Forestry in Japan. Available at http://www.maff.go.jp/j/tokei/census/afc/2010/houkokusyo.html. Accessed 7 Sept 2014

Ministry of Agriculture, Forestry and Fisheries of Japan (2010c) Report on results of Longitudinal Census of Agriculture in Japan. Available at http://www.maff.go.jp/j/tokei/census/afc/past/stats.html. Accessed 7 Sept 2014 (in Japanese)

Ministry of Agriculture, Forestry and Fisheries of Japan (2012) Report on results of Longitudinal Statistics on Cultivated Land and Planted Areas. Available at http://www.maff.go.jp/j/tokei/kouhyou/sakumotu/menseki/index.html#l. Accessed 7 Sept 2014 (in Japanese)

Ministry of Agriculture, Forestry and Fisheries of Japan (2013) Report on results of 2013 Statistics on Cultivated Land and Planted Areas. Available at http://www.maff.go.jp/j/tokei/kouhyou/sakumotu/menseki/index.html#l. Accessed 7 Sept 2014

Tashiro Y (2012) Introduction to problems of food and agriculture. Otuki Syoten Publishers, Tokyo (in Japanese)

Teruoka S (ed) (2003) History of Japan's agriculture for 150 years: 1850–2000. Yuhikaku Publishers, Tokyo (in Japanese)

Chapter 2
Socio-ecological Systems in Paddy-Dominated Landscapes in Asian Monsoon

Osamu Saito and Kaoru Ichikawa

Abstract Socio-ecological production landscapes such as Japan's Satoyama have been rapidly declining in many countries because of various factors, including increased rural–urban migration, rapidly aging population, depopulation, land use conversion, and abandonment of traditional agricultural cultivation. In this chapter, current conditions and trends in paddy-dominated landscapes in Asia are reviewed, ways and means of restoring ecosystems and enhancing resilience against

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various changes are explored, and governance models for efficient, equitable, and sustainable management of ecosystem services across a range of stakeholders are identified.

Keywords Satoyama • Monsoon Asia • Socio-ecological production landscapes and seascapes (SEPLS) • Mosaic • Ecosystem service • Resilience • Satoyama Initiative • Comanagement

Introduction

Rice is one of the three major grains produced in the world along with wheat and maize, accounting for 21 % of grain production. Rice is the major staple food in Asia and accounts for approximately 88.5 % (143 million ha) of the global cultivation area and approximately 90.4 % (634 million tons) of the global production of rice in 2010 (FAO 2013). Rice paddy is often developed in flooded and irrigated fields. Asian monsoon rainfall has an important impact on agricultural production particularly on rice production.

Paddy fields are part of the production landscape, which includes land used for other purposes such as forests, upland fields, and water systems. Forests are important for sustaining paddy fields because of their ability to retain water and provide paddies with green manure. Green manure, including leaves and cuttings of annual and perennial plants and trees growing around paddy fields, can cause an increase in the available plant nutrients and in the organic matter content of the soil (Singh 1984). Forests near paddy fields are often used to collect plants and animals for fuel, food, medicine, and construction materials. Irrigation ponds, channels, and ditches not only provide water for agricultural production and livestock but also nurture freshwater fish and other aquatic organisms. In addition, rice paddies support wetland biodiversity by providing important habitats for birds, reptiles, fish, and insects (Ramsar Convention on Wetlands 2008).

Social activities also play an important role in paddy-dominated landscapes. Rice paddy cultivation requires collective management supported and regulated by local institutions. For example, in areas where production is supported by irrigation, appropriate allocation of irrigation water and management of irrigation facilities are critical. Local festivals and rituals in these landscapes are often associated with rice harvest and water regulation.

This socio-ecological system with mosaics of paddy, upland fields, forests, water systems, and human settlements is a typical agricultural landscape not only in monsoon Asian but also in other areas where paddy-dominated landscapes exist such as in Italy, Madagascar, Guinea, Ghana, and California in the USA. These socio-ecological systems are also often integral to people's livelihood, customs, traditions, spirituality, and social relations.

Satoyama is the Japanese term for a socio-ecological production landscape (SEPL) represented by a mosaic of different ecosystem types: secondary forests, timber plantations, farmlands, irrigation ponds, and grasslands—along with human settlements. Satoyama is managed through the interaction between ecosystems and humans to create ecosystem services for human well-being (JSSA 2010; Takeuchi 2010; Duraiappah et al. 2012). Ecosystem services are defined as the benefits obtained from ecosystems, and they include provisioning services such as food and water; regulating services such as regulation of floods, drought, and diseases; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual and other non-material benefits (Millennium Ecosystem Assessment 2005). In this sense, Satoyama landscapes often provide a bundle of ecosystem services. From 2006 to 2010, the Japan Satoyama Satoumi Assessment (JSSA) was conducted with the participation of more than 200 researchers and stakeholders, following and applying the framework of sub-global assessments developed by the Millennium Ecosystem Assessment (MA). In its national level assessment and the subnational (cluster) assessments, changes to ecosystems over the last 50 years were analyzed and plausible alternative futures of the landscapes in the year 2050 were outlined, taking into account various factors such as rural depopulation, ecosystem underuse, governmental and economic policy, climate change, technology, and socio-behavioral responses.

The Japan Biodiversity Outlook (Japan Biodiversity Outlook Science Committee 2010) and Japan's National Biodiversity Strategy and Action Plan (NBSAP) (Ministry of the Environment, Japan 2012) recognized four biodiversity crises that Japan has been facing in recent years. The first crisis stems from development, overexploitation, and water pollution. This crisis has been particularly influential, but the situation has been mitigated because of regulation of developmental activities and slowing of economical development. The second crisis is caused by reduced use and insufficient management of Satoyama landscapes. This tendency continues to intensify because of depopulation and aging of populations in rural areas. Factors of the third crisis include invasive alien species and chemical substances introduced by humans. The effects of invasive alien species are particularly prominent. Climate change, as the fourth crisis, has reinforced the effects of the other crises, causing serious concern about certain particularly vulnerable ecosystems.

To alleviate some of the problems caused by a loss of biodiversity, the Japanese Government and United Nations University proposed a new international initiative called "the Satoyama Initiative," which aims to promote sustainable production landscapes and seascapes through broader global recognition of their value. This initiative promotes developing an international network of organizations working on socio-ecological production landscapes and seascapes (SEPLS) to share knowledge and best practices on a global scale. Globally Important Agricultural Heritage Systems (GIAHS) coordinated by the Food and Agriculture Organization (FAO) is another international initiative that promotes public understanding, awareness, and national and international recognition of agricultural heritage systems including Satoyama and other SEPLS.

This chapter aims to (i) introduce Satoyama as a socio-ecological system, (ii) review current conditions and trends in paddy-dominated landscapes in Japan, (iii) identify challenges and opportunities from a wider perspective and international initiatives, and (iv) discuss potential future approaches of restoring ecosystems and enhancing resilience against various changes.

Satoyama: History and Definition Based on JSSA

Satoyama and Satoyama Landscape

The word *Satoyama* used since the seventeenth century, consists of two Japanese words: *sato*, meaning human settlement, and *yama*, meaning forest and mountains. Therefore, Satoyama literally means forest around a human settlement. By this definition, Satoyama does not imply the inclusion of rural society within a Satoyama landscape, which is how the term is presently used.

In the 1970s, Tsunahide Shidei, a forestry ecologist, revived the Satoyama concept to address ecosystem–human interactions, but he proposed that the word Satoyama should refer to a forest that is utilized for supporting agricultural production or obtaining firewood and charcoal. Over the past five decades, with the decrease in the agricultural landscape, there has been a growing awareness of nature conservation. This trend has given a new definition for the word Satoyama, which encompasses not only the rural society but also the general citizenry. In addition, the academic community has increasingly recognized the importance of the complex inter-relationships among different ecosystem types, which are a part of the agricultural landscape. These ecosystem types include the secondary forest, grassland, rice paddy, fields in which other crops are grown, and human settlements. Many recent developments have highlighted Satoyama as a landscape comprising several different ecosystem types coexisting in harmony with society.

The growing awareness of conservation has increased emphasis on biodiversity conservation and protection. Studies conducted since the 1990s have revealed that structural characteristics and human intervention in Satoyama landscapes are closely related to the biodiversity level. The mosaic pattern of Satoyama represents a structure of diverse land utilization. This mosaic pattern allows a large variety of flora and fauna to flourish, which affects biodiversity as a whole (Miyashita et al. 2015). In addition, some animal species require multiple heterogeneous habitats. A mosaic habitat with appropriate spatial dimensions meets this requirement (Washitani 2003). Furthermore, studies have shown that moderate human intervention has provided habitats to relict species surviving from the ice age (Moriyama 1988).

Ecosystem Assessment of Satoyama: JSSA and Socio-ecological Production Landscapes and Seascapes (SEPLS)

JSSA was initiated in Japan in 2006 to provide scientifically credible and policy-relevant information on the significance of ecosystem services provided by Satoyama (Fig. 2.1 (top)) and Satoumi (managed marine and coastal ecosystems; Fig. 2.1 (bottom)) and their contributions to economic and human development for the use of policy makers. The final JSSA report was published in 2012 (Duraiappah et al. 2012).

Fig. 2.1 Illustration of Satoyama (*top*) and Satoumi (*bottom*) (Saito and Shibata 2012)

The notion of Satoyama has evolved over time and greatly depends on the social and economic background of the specific time period in which the term is used. One of the challenges for JSSA was to clearly define the Satoyama concept. After a series of workshops and discussions, JSSA defined "Satoyama and Satoumi landscapes as dynamic mosaics of managed socio-ecological systems producing a bundle of ecosystem services for human well-being" (Duraiappah et al. 2012, p. 26). As summarized in Fig. 2.1 (top), the characteristics of the Satoyama landscape have also been described as "a mosaic of both terrestrial and aquatic ecosystems comprising woodlands, plantations, grasslands, farmlands, pastures, irrigation ponds, and canals, with an emphasis on terrestrial ecosystems" (Duraiappah et al. 2012, p. 26). In addition, JSSA emphasized that "Satoyama and Satoumi landscapes are managed with a mix of traditional knowledge and modern science (reflective of the socio-ecological contexts)," and that "biodiversity is a key element for the resiliency and functioning of Satoyama and Satoumi landscapes."

Among the many land uses in Satoyama landscape, rice paddies play a central role in maintaining rich biodiversity. In a report titled "All Species in Rice Paddy," 6,138 species (3,173 animal species, 2,136 plant species, and 829 protists) in total were listed (Kiritani 2009). Studies have been conducted to increase understanding on the relationships between environmental factors affecting paddy fields and species distribution and abundance (Kano et al. 2010; Yoshio et al. 2009). Regular human activities, such as farmland and water management, required for rice cultivation creates a unique habitat that fosters the diversity of species.

JSSA reported that Satoyama and Satoumi have undergone significant changes over the past 50 years. These changes have caused a decline in the resiliency of the coupled socio-ecological production systems and their ability to provide a sustainable supply of ecosystem services. In addition, the continued loss of Satoyama and Satoumi landscapes has a potentially negative impact on human well-being and biodiversity.

Another outcome of JSSA is generalizing the Satoyama and Satoumi concepts as *socio-ecological production landscapes*. This description has been used as an overarching concept in the Satoyama Initiative to promote a better understanding and conservation of sustainable production landscapes and seascapes for the benefit of biodiversity and human well-being on a global scale. The Satoyama Initiative has been acknowledged in decisions of the past three meetings of the Conference of the Parties to the Convention on Biological Diversity (CBD COP), starting with its first acknowledgement as a "useful tool to better understand and support human-influenced natural environments" in a decision of the tenth CBD COP in 2010 (UNEP/CBD/COP/DEC/X/32). The term has recently been updated in the Satoyama Initiative to explicitly encompass SEPLS.

Current Conditions and Trends in Paddy-Dominated Landscapes in Japan

In 2012, the total land area occupied by rice paddies in Japan was <2.5 million ha (6.5 % of the country's land area) (Fig. 2.2). In 1969, the total land area occupied by rice paddies was almost 3.5 million ha and has continuously been decreasing since 1970. Thus, Japan has lost 1 million ha of rice paddies in the last 4 decades. The annual conversion from paddy field to other land uses was >40,000 ha from 1970 to 1976 during the later period of Japan's rapid economic growth. However, land conversion continued at a rate of 20,000 ha/annum until 2000. Since that year, the conversion rate has gradually decreased to approximately 10,000 ha/annum except in 2011, when a large area occupied by paddy fields along the Pacific coastal areas was destroyed by the tsunami and the Great East Japan Earthquake.

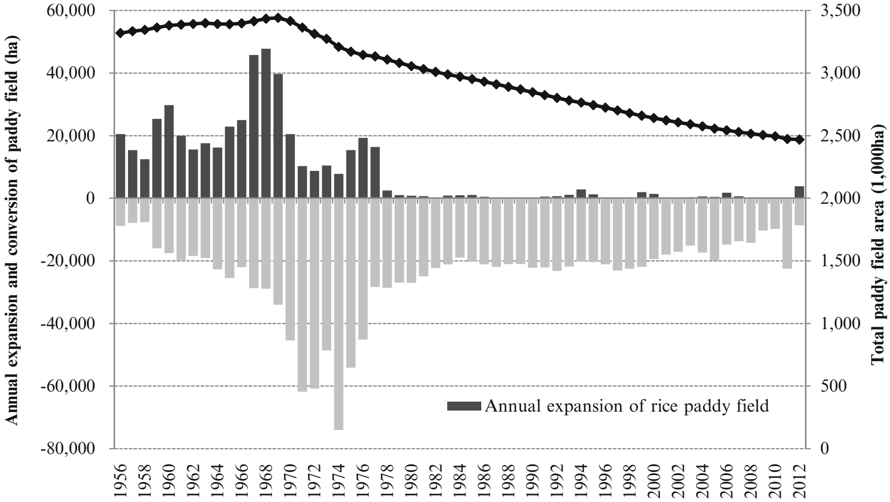

Fig. 2.2 Changes in rice paddy fields in Japan from 1956 to 2012 (Statistics Bureau 2013)

Fig. 2.3 Rice terraces in a Satoyama landscape (Photo taken by Shizuka Hashimoto)

Rice terraces (Fig. 2.3) is one of the typical and traditional paddy fields in Japan in hilly and mountainous areas, which cover approximately 70 % of Japan's total land area. Lowland wetlands suitable for rice paddies are limited. Thus, rural farmers have developed paddy fields on upland hills and valleys in mountainous areas. To secure the production of this staple food for a large population of this small island nation with relatively higher topographic heterogeneity, the size of rice paddies tends to be small and the shape is often irregular (Natori et al. 2011). These limitations hinder the mechanization of rice farming, which often results in relatively lower productivity of upland Satoyamas. Paddy fields in and around Satoyama are often those on the mountain slopes as terraced paddies or in the valleys between hills and uplands (Azuma 2003).

In response to the problems of lower productivity in areas where landforms hinder mechanization, the Japanese government has implemented farmland improvement projects (FIPs) in which farmland is readjusted to maximize production. For example, several small plots may be physically merged and reshaped into one large plot. Moreover, farmland may be consolidated by amalgamating previously dispersed parcels of farmland through plot exchanges among farmers (Arimoto 2011).

FIPs enhance agricultural productivity and enable sustainable and continuous agricultural production, alleviating the trend toward the abandonment of farmland because of depopulation and aging of the population in many rural areas (Fig. 2.4). However, FIPs often cause negative impacts on ecosystem and biodiversity. For example, irrigation waterways may be straightened and cemented through FIPs, resulting in habitat degradation for fish, amphibians, and insects (Miyashita et al. 2015). The Land Improvement Act was amended in 2001 to include environmental conservation as one of the implementation principles, and various efforts have been made to promote more proenvironmental FIPs in many rural areas. The Ministry of Agriculture, Forestry and Fisheries of Japan developed guidelines for environmentally friendly FIPs in 2004 (Ministry of Agriculture, Forestry and Fisheries of Japan 2004). In 2007, the Ministry launched a new project

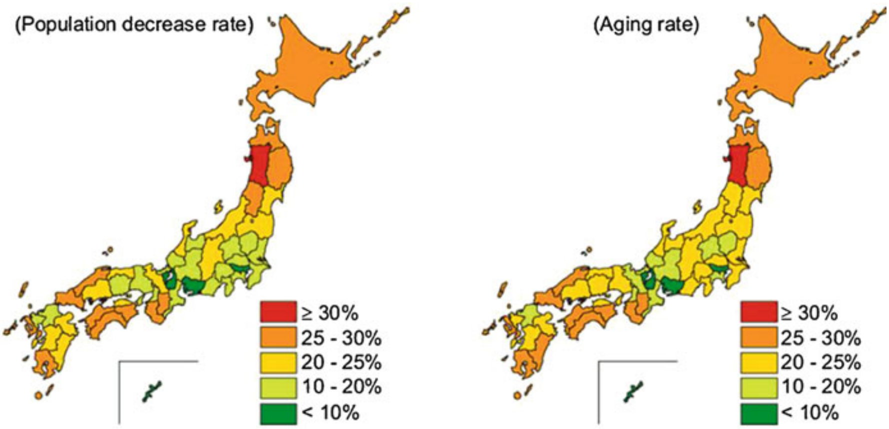

Fig. 2.4 Rates of population decrease (2005–2035) and aging (2035) in less densely inhabited districts (by prefecture) (Source) Estimates by Ministry of Agriculture, Forestry and Fisheries of Japan, based on the population census and population projection by prefecture (May 2007) (National Institute of Population and Social Security Research) (Note: Population decrease (%) = (2005 population–2035 population)/2005 population × 100 Aging rate (%) = Elderly population (above 65 years)/total population × 100)

named the *Measures to Conserve and Improve Land, Water, and the Environment* to provide support for joint activities for land and water preservation and support for farming activities that reduce environmental impacts. Regional efforts of both farmers and non-farmers have been in progress since the introduction of this new project, including joint activities covering 1.43 million ha of land and 19,514 organizations (Ministry of Agriculture, Forestry and Fisheries of Japan 2009).

Japan's rural population is expected to continuously decrease, and migration from rural to urban areas will be further accelerated. According to the future population estimate of the National Institute of Population and Social Security Research (2007), approximately 70 % of the Japanese population will live in densely inhabited districts in 2035 (Fig. 2.4). The population in other areas will decline to 80 % of current totals, but the number of elderly citizens whose age is above 65 years will increase by a factor of 1.2. Furthermore, the proportion of elderly individuals in the general population is projected to reach 36 % (Ministry of Agriculture, Forestry and Fisheries of Japan 2009). In a population trends analysis based on prefecture, the rates of population decrease and aging in less densely inhabited districts tended to be higher in prefectures with a high percentage of those performing agricultural activities among the total population. This demographic change in the overall population (consumers) and in the farming population (suppliers) can affect future rice production in Japan. Farming depopulation may also have a negative impact on some species in agricultural landscapes, which could be maintained through appropriate management (Koyanagi and Furukawa 2013).

Paddy-Dominated Landscapes in Monsoon Asia

Paddy Rice Production and Paddy-Dominated Landscapes in Monsoon Asia

Monsoon Asia is the main producer of rice in the world. The region encompasses East, Southeast, and South Asia and is the most populous region in the world, with 56 % of the world's population living in 17 % of the world's land area. As the name suggests, the area is affected by seasonal wind and higher rainfall. These weather patterns, together with the occurrence of extensive lowlands resulting from the combination of geological instability and high rainfall, enable rice cultivation to dominate in this area (Kyuma 1987). Because of its main function to produce a staple food and its unique characteristics that require ample water as well as flat lands, paddy fields have significantly influenced the formation of the whole landscapes. Terraced paddies have often been developed on the slopes in mountainous areas in monsoon Asia. In such areas, the upper watersheds of the paddy fields are often covered by forests, and cutting of trees is restricted to sustain sufficient water for paddies located downstream. In some areas, practices and institutions associated with irrigation are closely linked with cultural activities of the local communities. For example, in Bali Island in Indonesia, where irrigation is essential for rice cultivation because of the long dry season, elaborate irrigation systems have been created by cutting tunnels through the rock, and aqueducts and bamboo piping systems for carrying water have been constructed. Irrigation systems are controlled by community organizations called Subak. They are responsible for the construction and maintenance of irrigation facilities and for the distribution of water. Moreover, they coordinate the planting and organization of ritual offerings and festivals (Suarja and Thijssen 2003).

Covering an extensive area stretching from tropics, subtropics to temperate zones, the monsoon Asia entails diversity under natural conditions such as hydrology, topography, soil, and climate. Rice is a unique crop that can grow in a wide range of conditions and be cultivated in different forms. Rice cultivation is only possible once a year in temperate climates because of low temperatures during the winter. In the tropics, where temperature is not a limiting factor, multiple cropping is possible under good water conditions, which are influenced by precipitation, topography, and water storage and irrigation facilities. The various forms of rice production have been classified by IRRI into four categories of rice ecosystems: irrigated, rainfed, flood-prone, and upland rice ecosystems (Maclean et al. 2002).

Irrigated Paddy Fields

In irrigated paddy fields, irrigation assures water for one or more crop seasons each year. This type of paddy field is characterized by high productivity and intensive use of agrochemicals. Approximately 79 million ha of rice is grown under irrigated conditions in the world, contributing to 75 % of the rice production (Maclean et al. 2002). Water sources include small rivers or springs in mountainous areas, man-made ponds of various sizes in plains, and creeks in delta areas. Depending on topographic conditions, irrigation has been developed from ancient times, having enabled rice to be produced in wider areas. For example, although Japan does not necessarily enjoy sufficient precipitation in the rice-growing season because of the topographic characteristics such as relatively large watersheds compared to the size of the alluvial plains, sufficient water is provided to paddy fields through irrigation from rivers and ponds. Because small rivers and mountainous topography with slopes allow water to flow down naturally, modern technology for the control of water was not required, and irrigation was easily conducted locally on a small scale from ancient times (Fukui 1987). Irrigation ponds are used as water resources especially in western parts of Japan, where rainfall is relatively low. Today, almost all paddy fields in Japan are irrigated.

Rainfed Lowlands

In rainfed lowlands, rainfall is basically the only source of water for paddy fields. Fields are flooded for at least part of the cropping season. These areas are characterized by erratic rainfall; productivity is low because of droughts, uncontrolled flooding, and poor soil conditions (Maclean et al. 2002). Approximately 54 million ha of rainfed paddy fields are cultivated in the world. In monsoon Asia, rainfed fields mainly predominate in Southeast Asia and South Asia.

Flood-Prone Areas

Rice can also grow in flood-prone areas, which are submerged under water >100 cm deep for several months. In floodplains and deltas of large rivers, such as the Mekong River in Vietnam and Cambodia and Chao Phraya in Thailand, deepwater rice or floating rice is grown because of the ability of these varieties to reach the surface. In these environments, rice yields are low and extremely variable because of the unpredictable combinations of drought and flood as well as poor soil conditions (Maclean et al. 2002).

Upland Rice Ecosystem

Upland rice is grown under dry land conditions without irrigation or puddling. Such areas encompass from low-lying valley bottoms to undulating and steep sloping lands. In Southeast Asia, shifting cultivation was the dominant practice in mountainous areas during the latter half of the twentieth century (Fox and Vogler 2005). In these areas, rice is primarily grown as a subsistence crop. Although it accounts for 13 % of global rice production areas, upland rice contributes only 4 % to global rice production because rice cultivation by this method is constrained by weeds, minimal rainfall, and poor soil fertility (Maclean et al. 2002). Farmers plant rice crops alone or in association with other crops such as maize, yam, beans, and cassava.

Recent Changes to Paddy-Dominated SEPLS

Paddy-dominated landscapes are dynamic and capable of responding to socioeconomic changes resulting from rural transformation including demographic and industrial structure, globalization, commercialization, and diversification of the rural livelihood. Rice production after World War II was characterized by cultivation of new paddies, irrigation of existing rainfed rice fields and upland farmland, and widespread adoption of modern technology. Figure 2.5 shows the transition of rice production and harvesting in Asia since the 1960s. Harvested areas increased until the mid-1970s, and continued increase of production indicates improved productivity. The rice yield increased by 2.4 times from 1961 (1.9 tons/ha) to 2011 (4.5 tons/ha).

The Green Revolution in Asia during the 1960s and 1970s had a dramatic impact on rice productivity. Factors influencing this increased productivity

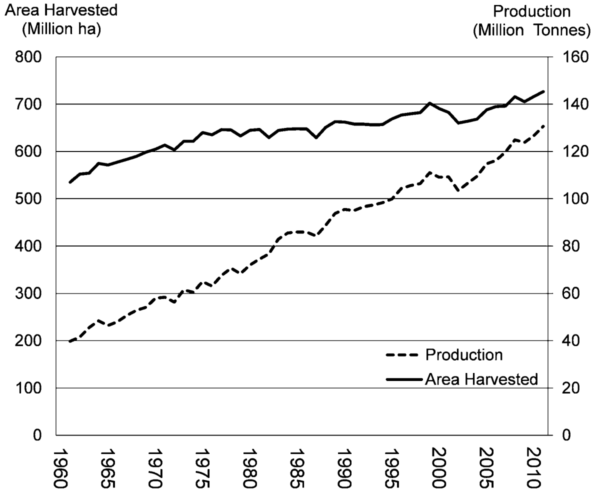

Fig. 2.5 Changes in rice production and harvested areas in Asia since the 1960s (Source: FAOSTAT)

included modern developments in irrigation and improved seeds, fertilizers, and pesticides (Hazell 2010). Modern water resource development projects led by national governments also contributed to an increase in the area of irrigated paddies through the creation of large-scale dams and control of large rivers such as the Mekong and Chao Phraya. High-yielding varieties were developed by making plants more responsive to nutrients and by making their straw shorter and stiffer so that they would be less prone to falling. Varieties were also modified to mature more quickly and to be more resistant to pests and diseases (Hazell 2010). In Cambodia, farmers have begun to plant faster-maturing varieties in many areas previously cultivated with late-maturing varieties because the shorter the time crops spend in the field, the lower the risk of crop failure (McKenney and Tola 2002). While substantially increasing rice productivity, these changes often caused negative impacts to the people and the landscapes. The use of toxic pesticides increases the risk of damaging farmers' health and the environment (Heong and Escalada 1997). Changes in rice varieties have led to concerns about decreasing agrobiodiversity.

While the trend of rice productivity has shown a remarkable increase, many paddy-dominated landscapes in Asia are in transition along with urban and industrial development, the growing impact of the market economy, and population dynamics. The landscapes are under various types of threats including land use conversion to urban or industrial lands, intensified production, and abandonment.

Among the 21 megacities in the world with more than ten million inhabitants, 12 are found in Asia including Tokyo, Delhi, Shanghai, and Dhaka (UNDESA Population Division 2012). Rapid population growth is placing high pressure on the paddy fields surrounding those cities. For example, in delta areas of Thailand and the Philippines, paddy fields in the suburban areas of Bangkok and Metro Manila were replaced for urban land use by reclaiming paddies (Hara et al. 2005, 2008). Such land use conversion required by an increasing population eventually led to changes in the entire landscape structure from rural to urban (Ichikawa et al. 2006).

Influenced by the development of market economies, rice farmers often find it beneficial to change crops. For example, since the 1970s in Kerala, India, there has been a clear shift away from food crops such as rice and cassava in favor of tree crops such as rubber and coconut as well as cash crops such as pepper for export (Kumar 2005). The trend of commercialization has also led to changes in other traditional land uses in the landscapes such as homegardens. In Kerala, a large proportion of the homegardens have been converted into plantations of these cash crops or cropping systems consisting of fewer crops, causing concerns regarding a decline in agrobiodiveristy (Kumar and Nair 2004). Commercialization is also disrupting the social services of homegardens as well as the social relations of villages by reducing equitability and causing fences to be installed around the homestead to protect cash crops (Abdoellah et al. 2006).

The trend toward the abandonment of farmland in rural areas is not only a problem in countries such as Japan and Korea but also in marginal areas in many other countries where agriculture is an economically important industry such as the Philippines. In the rice terraces of the Cordilleras in the Philippines, which is a UNESCO World Heritage Site, interest in rice cultivation in terraced paddy fields among young people has declined, and more men are migrating to find employment outside their communities, making maintenance of rice terraces difficult (Nozawa et al. 2008).

Considering population estimates in Asia for the next few decades, there will be a continuous demand for rice production through effective farming. Pursuit of this demand without further environmental deterioration will be challenging for many countries in monsoon Asia. On the other hand, the issues of the abandonment of paddy fields, depopulation, and aging of the farming population must also be addressed, particularly in marginal areas.

Climate change is also considered a significant additional threat to paddy rice production systems and other production systems (Wassmann et al. 2009) such as fruit orchards (Sugiura et al. 2009) and homegardens (Pushpakumara et al. 2010). In Asia, many farmers recognized some recent changes in rainfall pattern, temperature, sea level, and extreme events such as floods and droughts on a local scale (Mohri et al. 2013).

Responses to Changes and Drivers

Based on the MA conceptual framework (MA 2003, 2005), JSSA summarizes various responses to the recent changes in SEPLs and reviews the effectiveness of these responses including legal responses, economic responses, social and behavioral responses, technological responses, and cognitive responses (Duraiappah et al. 2012). In Japan, there is no integrated legislation that focuses on the conservation and management of Satoyama landscapes. The conservation and sustainable use of Satoyama has relied on various laws and plans including the Urban Park Law, Comprehensive National Land Development Law, Forest Law, Agricultural Land Act, Basic Environmental Law, Law of Promotion of Nature

Restoration, Act on Promotion of Ecotourism, Basic Act on Biodiversity, and the National Biodiversity Strategy. Since the 1990s, local governments have also been promoting the conservation and management of Satoyama through local ordinances, rules, agreements, and local biodiversity strategies (Duraiappah et al. 2012).

Economic responses include incentive-based interventions (tax, usage fee, and emission trading), voluntary responses (eco-labeling, payment for ecosystem services (PES), and forest preservation agreement), financial/monetary measures (relocation payment and fund), and international trade policies. In Japan, the rice terrace owner system is a typical example of payments for ecosystem services. In this system, financial and labor supports provided by urban dwellers to become owners of rice terraces can be used for the maintenance and restoration of the rice terrace landscapes (Yamaji 2006; Duraiappah et al. 2012). Another example of economic response in Japan is a direct payment scheme for hilly and mountainous areas to prevent the abandonment of cultivated agricultural lands and to ensure the continuation of various ecosystem services provided by Satoyama landscapes. Under this scheme, the government provides subsidies not only to farmers but also to farmer groups and councils established for cooperative actions normally on a local community scale.

PES schemes have also been introduced in many Asian countries. China's Sloping Land Conversion Program is the land retirement/reforestation program, having the goal of converting 14.67 million ha of cropland to forests by 2010 (4.4 million ha of which is on land with slopes greater than 25°) (Bennett 2008). This program uses a public payment scheme that directly mobilizes millions of rural households to implement the project, and reaches millions of low-income households with an overall positive effect (Uchida et al. 2007). In Vietnam, direct payments have been made for reforestation and forest protection. Rural people have been offered cash incentives through forest contracts to replant trees and to protect existing forests (Wunder et al. 2005). In the Philippines, PES schemes have been implemented to promote watershed conservation and rehabilitation as well as to improve the livelihoods of upland communities (Cremaschi et al. 2013). In developed countries, PES implementation is often constrained by incomplete information and knowledge about the interaction between ecosystem properties and provision of services, the difficulty in establishing voluntary participation and conditionality of payments and the absence of mechanisms to periodically monitor contract compliance (Wunder et al. 2005; Cremaschi et al. 2013).

Recently, resilience has become one of the central concepts on environmental change and management (Janssen and Ostrom 2006; Cutter et al. 2010). Resilience was originally developed in ecology, indicating a capacity to maintain a population's sustainable relationship with its habitat (Holling 1973). Ecosystems are inherently exposed to various types of changes and shocks such as fires, floods, and droughts. Not only ecosystems but also societies are affected by events such as political unrest and economic crises. These shocks and changes can have a direct and indirect impact on the livelihoods of local communities, for example, by reduced production and drops in prices. Resilience can be defined as "the capacity of a system to absorb disturbances and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks"

(Walker et al. 2004). Resilient systems can cope, adapt, or reorganize without sacrificing the provision of ecosystem services (Folke et al. 2002). With increasing influences outside the field of ecology, especially in the 1990s, including human geography, cultural theory, and other social sciences (Thompson et al. 1990; Scoones 1999; Davidson-Hunt and Berkes 2003), the understanding of resilience started to embrace different dimensions of social change. For instance, Adger (2006) describes social resilience as the ability of social systems to deal with and to withstand external shocks to their organization and infrastructure patterns caused by environmental, economical, or political crises. Maintaining the diversity and multifunctionality of SEPLS plays an important role in providing resilience against the various changes described in the previous section. For example, ecological resilience can be assessed by the magnitude or severity and frequency of disturbances on biodiversity, recovery potential from the disturbance based on the short- and long-term land use change, and changes in the distribution and number of species. On the other hand, socio-economic resilience can be measured by the types of household assets including various forms of land tenure, as well as labor, employment (including income and remittances from outside), access to social services (health care, clean water, transport, education, etc.), non-labor productive assets (land and any machination ownership), and social capital (groups and mutual aid/self-help collective mechanism) (Antwi et al. in press).

There are some international initiatives to promote the conservation and sustainable use of SEPLS. GIAHS initiated by FAO of the United Nations are defined as "remarkable land use systems and landscapes that are rich in globally significant biological diversity evolving from the co-adaption of community with its environment and its needs and aspirations for sustainable development" (Koohafkan and Altieri 2011). The GIAHS Initiative promotes public understanding, awareness, and national and international recognition of Agricultural Heritage systems by selecting GIAHS sites where a conservation program based on adaptive management is in place. Another global effort is the Satoyama Initiative, which aims to promote and support SEPLS to maintain their contribution to human well-being (IPSI Secretariat 2014). The initiative broadly promotes various types of activities undertaken by stakeholders from different sectors to mainstream biodiversity and sustainability in production activities (Takeuchi 2010). This initiative is elaborated in the following section.

The Satoyama Initiative and Indicators of Resilience

Paddy-dominated landscapes in monsoon Asia are not the only landscapes to face challenges. Many other types of production landscapes around the world are also threatened. The factors underlying these challenges are in many cases common as well. Efforts are being made globally to explore ways to conserve the environment while allowing people to continue to earn their livelihood from the land. One of such efforts is the Satoyama Initiative that aims to conserve and revitalize landscapes and seascapes that are formed by human–nature interactions around production activities or SEPLS (IPSI Secretariat 2014). Important issues to be addressed in SEPLS are described in the threefold approach of the Initiative: (1) consolidation of wisdom on securing diverse ecosystem services and values; (2) integration of traditional ecological knowledge and modern science to promote innovation; and (3) exploration of new forms of comanagement systems while respecting traditional communal land tenure (Nakao and Nishi 2011). The International Partnership for the Satoyama Initiative (IPSI), which was launched during CBD COP10 in 2010, serves as a platform for sharing experiences and knowledge on SEPLS among various stakeholders working on different types of activities including policy development, research, and on-the-ground activity. Although a successful experience in one location does not necessarily lead to further success in places with different social and natural conditions, learning and analyzing the causes and mechanisms of success should provide useful insights.

One of the activities implemented under the Satoyama Initiative by its members addresses the issue of resilience. Long-term persistence of SEPLS in many areas proves that they have strengthened resilience sustained by diversity and multifunctionality of the system together with appropriate management practices that have significantly contributed to securing a wide range of ecosystem services (Bergamini et al. 2013). Based on this understanding, the project has developed and improved indicators of resilience aiming to support local communities to deepen their understanding of the resilience of their landscapes and to engage in practices that further strengthen it. The social and ecological components that contribute to resilience of SEPLS were identified as a set of 20 indicators covering five main areas: (1) landscape/seascape diversity and ecosystem protection; (2) biodiversity (including agricultural biodiversity); (3) knowledge and innovation; (4) governance and social equity; (5) livelihoods and well-being (UNU-IAS et al. 2014). The indicators are currently utilized in consultation processes in community development and environmental conservation projects implemented by the United Nations Development Programme.

Future Perspectives

This chapter provided an overview of paddy-dominated landscapes in both Asia and Japan, with a special focus on the Satoyama landscape as a socio-ecological system. Current conditions, trends, and challenges in paddy-dominated landscapes were reviewed.

The Satoyama Initiative is increasingly being recognized in global communities, and it provides a global perspective to promote proactive conservation, restoration, and revitalization of SEPLS such as Satoyama for the restructuring of positive human–nature relationships (Takeuchi 2010). Exploration of potential future scenarios is important to promote restoration of paddy-dominated socio-ecological systems and to enhance their resilience against potential new and unexpected changes. One of the main challenges of the future will be integrating such traditional SEPLS with modern technology and the global economy to enhance the system's resilience. Further empirical research is also required for evaluating the contribution of SEPLS for providing resilience against climate and ecosystem changes.

As highlighted in Japan's new NBSAP 2012–2020 (Ministry of the Environment, Japan 2012), development of a comanagement framework is necessary to promote cooperation and collaboration among different stakeholders, including government, the business sector, farmers, and citizens for ecosystem conservation and agricultural sustainability. Communities connected via the supply and reception of ecosystem services should be recognized as parts of an integrated system of a *socio-ecological sphere*, which is also introduced in Japan's new NBSAP. Relationships between stakeholders in rural and urban areas must be strengthened, and mutual support systems must be created (Ministry of the Environment, Japan 2012). Further scientific investigations of the cobenefits and tradeoffs of restoration and conservation of rice paddy-dominant landscapes will provide a scientific basis for cooperation and collaboration.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was established in April 2012 as an intergovernmental body providing scientific support for policy-making in the area of biodiversity and ecosystem services. The four key functions of IPBES are to provide regular assessments, capacity building, knowledge generation, and policy support, with a focus on regional scales. An international workshop on an Asia-Pacific regional interpretation of the IPBES conceptual framework and knowledge sharing was organized in Seoul from 2 to 4 September, 2013 by inviting over 40 academics, senior policy makers, private sector representatives, and leading non-governmental organizations from across the region to discuss elements for consideration in future regional assessments, gaps in knowledge, and relevant proposals for IPBES. Key messages identified at this workshop include the following:

– integrating biodiversity and ecosystem service co-management across public, private, and civil society sectors
– developing common data storage systems and sharing of knowledge on biodiversity and ecosystem services to track changes over time
– capacity building of practitioner skills for ecosystem assessment and methods for integrating cross-scale stakeholder knowledge and priorities
– creating advanced knowledge systems across scales and institutional levels through the integration of social science, citizen, private sector, indigenous and local knowledge with contemporary science
– developing scientific methodologies for trade-off resolutions that engage cross-scale, non-elite stakeholders (IPBES 2013).

These recommendations should be seriously considered in future research and policy-making on socio-ecological systems in paddy-dominated landscapes in Asian Monsoon.

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References

Abdoellah OS, Hadikusumah HY, Takeuchi K, Okubo S, Parikesit G (2006) Commercialization of homegardens in an Indonesian village: vegetation composition & functional changes. Adv Agrofor 68:1–13

Adger WN (2006) Vulnerability. Glob Environ Chang 16(3):268–281

Antwi EK, Otsuki K, Saito O, Obeng FK, Gyekye KA, John BD, Boafo YA, Kusakari Y, Yiran GAB, Owusu AB, Asubonteng K, Dzivenu T, Avornyo VK, Abagale FK, Jasaw GS, Lolig V, Ganiyu S, Donkoh SA, Yeboah R, Kranjac-Berisavljevic G, Gyasic EA, Minia Z, Ayuk E, Matsuda H, Ishikawa H, Ito O, Takeuchi K (in press) Developing a community-based resilience assessment model in Northern Ghana. J Integr Disaster Risk Manag 4(1)

Arimoto Y (2011) The impact of farmland readjustment and consolidation on structural adjustment: the case of Niigata, Japan, Center for Economic Institutions Working paper series, no. 2011–3. Center for Economic Institutions, Tokyo

Azuma A (2003) Birds of prey living in Yatsuda and Satoyama. In: Washitani I, Tsunekawa A, Yokohari M, Takeuchi K, Brown RD (eds) Satoyama: the traditional rural landscape of Japan. Springer, Tokyo, pp 102–110

Bennett MT (2008) China's sloping land conversion program: institutional innovation or business as usual? Ecol Econ 65(4):699–711

Bergamini N, Blasiak R, Eyzaguirre P, Ichikawa K, Mijatovic D, Nakao F, Subramanian SM (2013) Indicators of resilience in socio-ecological production landscapes (SEPLs), UNU-IAS policy report. United Nations University Institute of Advanced Studies, Yokohama

Cremaschi DG, Lasco RD, Delfino RJP (2013) Payments for watershed protection services: emerging lessons from the Philippines. J Sustain Dev 6(1):90–103

Cutter SL, Burton CG, Emrich C (2010) Disaster resilience indicators for benchmarking baseline conditions. J Homel Secur Emerg Manag 7(1):1–22

Davidson-Hunt I, Berkes F (2003) Learning as you journey: Anishinaabe perception of social-ecological environments and adaptive learning. Conserv Ecol 8(1):5

Duraiappah AK, Nakamura K, Takeuchi K, Watanabe M, Nishi M (eds) (2012) Satoyama-satoumi ecosystems and human well-being: socio-ecological production landscapes of Japan. United Nations University Press, Tokyo

Folke C, Carpenter S, Elmqvist T, Gunderson L, Holling CS, Walker B (2002) Resilience and sustainable development: building adaptive capacity in a world of transformations. Ambio J Hum Environ 31(5):437–440

Food and Agriculture Organization of the United Nations (FAO) (2013) FAO statistical yearbook 2013: world food and agriculture. FAO, Rome

Fox J, Vogler JB (2005) Land-use and land-cover change in montane mainland Southeast Asia. Environ Manag 36(3):394–403

Fukui H (1987) Ecology and technology. In: Watabe T, Takaya Y, Tanaka K, Fukui H (eds) Ecological basis of Asian rice culture: technology and ecology, vol 1, Asian history of rice. Syogakukan, Tokyo, pp 277–331

Hara Y, Takeuchi K, Okubo S (2005) Urbanization linked with past agricultural landuse patterns in the urban fringe of a deltaic Asian mega-city: a case study in Bangkok. Landsc Urban Plan 73(1):16–28

Hara Y, Takeuchi K, Palijon AM, Murakami A (2008) Landfill development in the urban fringe of Metro Manila. GeoJournal 71:127–141

Hazell PBR (2010) The Asian green revolution. In: Spielman DJ, Pandya-Lorch R (eds) Proven successes in agricultural development: a technical compendium to Millions Fed. International Food Policy Research Institute, Washington, DC, pp 67–98

Heong KL, Escalada MM (eds) (1997) Pest management of rice farmers in Asia. International Rice Research Institute, Manila

Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4:1–23

Ichikawa K, Okubo N, Okubo S, Takeuchi K (2006) Transition of the *satoyama* landscape in the urban fringe of the Tokyo metropolitan area from 1880 to 2001. Landsc Urban Plan 78(4):398–410

IPBES (2013) Seoul international symposium and scientific workshop on the regional interpretation of the conceptual framework of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services and knowledge sharing. IPBES/2/INF/12. Available http://www.ipbes.net/images/K1353757.pdf. Accessed 5 Jan 2014

IPSI Secretariat (2014) The International Partnership for the Satoyama Initiative (IPSI): working towards societies in harmony with nature. United Nations University Institute for the Advanced Studies of Sustainability, Tokyo

Janssen M, Ostrom E (2006) Resilience, vulnerability, and adaptation: a cross-cutting theme of the international human dimensions programme on global environmental change. Glob Environ Chang 16:237–239

Japan Biodiversity Outlook Science Committee (2010) Report of comprehensive assessment of biodiversity in Japan. Global Biodiversity Strategy Office, Biodiversity Policy Division, Nature Conservation Bureau, Ministry of the Environment, Japan, Tokyo. http://www.biodic.go.jp/biodiversity/activity/policy/jbo/jbo/files/Japan_Biodiversity_Outlook_EN.pdf. Accessed 17 July 2013

Japan Satoyama Satoumi Assessment (2010) Satoyama-satoumi ecosystems and human well-being: socio-ecological production landscapes of Japan (summary for decision makers). United Nations University, Tokyo

Kano Y, Kawaguchi Y, Yamashita T, Shimatani Y (2010) Distribution of the oriental weatherloach, *Misgurnus anguillicaudatus*, in paddy fields and its implications for conservation in Sado Island, Japan. Ichthyol Res 57(2):180–188

Kiritani K (ed) (2009) All species in rice paddy. Research Center for Agriculture and Nature, Biodiversity Agriculture Support Center, Society of Environmental Rice Farming, Musashino Satoyama Forum and Minkan Inasaku Kenkyujo, Fukuoka

Koohafkan P, Altieri MA (2011) Globally important agricultural heritage systems, a legacy for the future. Food and Agriculture Organization of the United Nations, Rome

Koyanagi FT, Furukawa T (2013) Nation-wide agrarian depopulation threatens semi-natural grassland species in Japan: sub-national application of the red list index. Biol Conserv 167:1–8

Kumar BM (2005) Land use in Kerala: changing scenarios and shifting paradigms. J Trop Agric 42:1–12

Kumar BM, Nair PKR (2004) The enigma of tropical homegardens. Agrofor Syst 62:135–152

Kyuma K (1987) Soil and rice cultivation. In: Watabe T, Takaya Y, Tanaka K, Fukui H (eds) Ecological basis of Asian rice culture: technology and ecology, vol 1, Asian history of rice. Syogakukan, Tokyo, pp 109–136

Maclean JL, Dawe DC, Hardy B, Hettel GP (eds) (2002) Rice almanac, 3rd edn. CABI Publishing, Wallingford

McKenney B, Tola P (2002) Natural resources and rural livelihoods in Cambodia: a baseline assessment. Working paper 23, The Cambodian Development and Research Institute, Phnom Penh

Millennium Ecosystem Assessment (MA) (2003) Ecosystem and human well-being – a framework for assessment. Island Press, Washington, DC

Millennium Ecosystem Assessment (MA) (2005) Ecosystem and human well-being – summary for decision makers. Island Press, Washington, DC

Ministry of Agriculture, Forestry and Fisheries of Japan (2004) Research Plan and Design Guideline for Pro-environment Project Implementation (vol. 3): Farmland Improvement Projects (Rice Paddy and Field). http://www.maff.go.jp/j/nousin/jikei/keikaku/tebiki/03/index.html. Accessed 20 July 2013

Ministry of Agriculture, Forestry and Fisheries of Japan (2009) FY2009 annual report on food, agriculture and rural areas in Japan. http://www.maff.go.jp/e/annual_report/2009/index.html. Accessed 20 July 2013

Ministry of the Environment, Japan (2012) The national biodiversity strategy of Japan 2012–2020: roadmap towards the establishment of an enriching society in harmony with nature. http://www.cbd.int/doc/world/jp/jp-nbsap-v5-en.pdf. Accessed 16 July 2013

Miyashita T, Yamanaka M, Tsutsui MH (2015) Distribution and abundance of organisms in paddy-dominated landscapes with implications for wildlife-friendly farming. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_4

Mohri H, Lahoti S, Saito O, Mahalingam A, Gunatilleke N, Irham I, Van Hoang T, Hitinayake G, Takeuchi K, Herath S (2013) Assessment of ecosystem services in homegarden systems in Indonesia, Sri Lanka, and Vietnam. Ecosyst Serv 5:124–136

Moriyama H (1988) What does environmental conservation mean? Rural Culture Association Japan, Tokyo

Nakao F, Nishi M (2011) Socio-ecological production landscapes: Japanese assessment and international partnership. Environ Conserv Eng 40(8):463–469

National Institute of Population and Social Security Research (2007) Population projection for Japan by prefecture. http://www.ipss.go.jp/pp-fuken/j/fuken2007/t-page.asp. Accessed 20 July 2013

Natori Y, Silbernagel J, Adams MS (2011) Biodiversity conservation planning in rural landscapes in Japan: integration of ecological and visual perspectives. In: Pavlinov I (eds) Research in biodiversity – models and applications. InTech, pp 285–306. http://www.intechopen.com/books/research-in-biodiversity-models-and-applications. Accessed 3 Nov 2014

Nozawa C, Malingan M, Plantilla A, Nozawa JO et al (2008) Evolving culture, evolving landscapes: the Philippine rice terraces. In: Amend T, Brown J, Kothari A, Phillips A, Stolton S (eds) Protected landscapes and agrobiodiversity values, vol 1, Protected landscapes and seascapes. IUCN & GTZ Kasparek Verlag, Heidelberg, pp 71–93

Pushpakumara DKNG, Wijesekara A, Hunter DG (2010) Kandyan homegardens: a promising land management system in Sri Lanka. In: Sustainable use of biological diversity in socio-ecological production landscapes: background to the Satoyama Initiative for the benefit of biodiversity and human well-being, vol 52, CBD technical series, pp 102–108

Ramsar Convention on Wetland (2008) Resolution X.31: enhancing biodiversity in rice paddies as wetland systems. In: 10th meeting of the conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971) "Healthy wetlands, healthy people" Changwon, Republic of Korea, 28 October–4 November 2008. http://www.ramsar.org/pdf/res/key_res_x_31_e.pdf. Accessed 16 July 2013

Saito O, Shibata H (2012) Satoyama–satoumi and ecosystem services: a conceptual framework. In: Duraiappah AK, Nakamura K, Takeuchi K, Watanabe M, Nishi M (eds) Satoyama-satoumi ecosystems and human well-being: socio-ecological production landscapes of Japan. United Nations Press, Tokyo, pp 17–59

Scoones I (1999) New ecology and the social sciences: what prospects for a fruitful engagement? Annu Rev Anthropol 28:479–507

Singh NT (1984) Green manures as sources of nutrients in rice production. In: International Rice Research Institute (ed) Organic matter and rice. IRRI, Manila, pp 217–228
Statistics Bureau, Ministry of Internal Affairs and Communications (2013) Area of cultivated land (7–6) Chapter 7: Agriculture, Forestry and Fisheries, Historical Statistics of Japan. http://www.stat.go.jp/english/data/chouki/07.htm. Accessed 20 July 2013
Suarja IG, Thijssen R (2003) Traditional water management in Bali. Leisa India, September, pp 25–26. http://www.fao.org/prods/gap/database/gap/files/597_WATER_MGMT_BALI.PDF. Accessed 17 July 2013
Sugiura T, Sugiura H, Sakamoto D, Asakura T (2009) Effects of global warming on fruit tree production and adaptation techniques. Glob Environ Res (AIRIES) 14(21):207–214 (in Japanese)
Takeuchi K (2010) Rebuilding the relationship between people and nature: the Satoyama Initiative. Ecol Res 25:891–897
Thompson M, Ellis R, Wildarsky A (1990) Cultural theory. Westview Press, Boulder
Uchida E, Xu J, Xu Z, Rozelle S (2007) Are the poor benefiting from China's land conservation program? Environ Dev Econ 12(4):593–620
UNDESA Population Division (2012) World urbanization prospects: the 2011 revision, CD-ROM Edition. http://esa.un.org/unup/CD-ROM/Urban-Agglomerations.htm. Accessed 17 July 2013
UNU-IAS, Bioversity International, IGES and UNDP (2014) Toolkit for the indicators of resilience in Socio-ecological Production Landscapes and Seascapes (SEPLS). Bioversity International, Rome, Italy
Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, adaptability and transformability in social–ecological systems. Ecol Soc 9(2):5
Washitani I (2003) Satoyama landscapes and conservation ecology. In: Takeuchi K, Brown RD, Watshitani I, Tsunekawa A, Yokohari M (eds) Satoyama: the traditional rural landscape of Japan. Springer, Tokyo, pp 16–23
Wassmann R, Jagadish SVK, Sumfleth K, Pathak H, Howell G, Ismail A, Serraj R, Redona E, Singh RK, Heuer S (2009) Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. Adv Agron 102:91–133
Wunder S, The BD, Ibarra E (2005) Payment is good, control is better: why payments for environmental services in Vietnam have so far remained incipient. Centre for International Forestry Research, Bogor, Indonesia. URL: http://www.cifor.cgiar.org/Knowledge/Publications/Detail?pid=1912. Accessed on 5 Jan 2014
Yamaji E (2006) Enjoyment of rural amenities by ownership program of rice terraces. J Rural Plan Assoc 25(3):206–213 (in Japanese)
Yoshio M, Kato N, Miyashita T (2009) Landscape and local scale effects on the orthopteran assemblages in the paddy agroecosystems on the Sado Island, Japan with implications for the habitat management for the crested ibis. Ecol Civ Eng 12(2):99–107 (in Japanese)

Chapter 3
Column: Promoting Agriculture with a Recognition of Biological Diversity in the Context of Rice Paddy Resolutions

Shinji Minami

Keywords Wetland • Ramsar Convention • Rice Paddy Resolution • Wise use • Biological diversity • Winter-flooded rice farming

Wetlands have a number of functions. They are a habitat for animals and plants as well as a source of food. In addition, they contribute to flood control, stabilization of the coastline, and land reclamation. They also help to preserve the supply of groundwater and contribute to the sedimentation of silt with abundant nutrients; they also filter pollutants and store organic matter (Matthews 1995). Due to the public's inability to recognize the value of wetlands; however, they have been decreasing globally. This is due to the common misconception that wetlands are barren land that should be converted for other uses through such means as land reclamation. A review of the past 100 years reveals that about 50,000 km^2 of wetlands have disappeared in China (Record China 2009). Approximately 2,110.62 km^2 of wetlands existed throughout Japan about 100 years ago during the Meiji and Taisho Eras, but they had decreased to 820.99 km^2 by 1999, which means that approximately 1,300 km^2 (or 61.1 %) of those wetlands have disappeared (Geospatial Information Authority of Japan 2000). On the other hand, there was over 25,000 km^2 of land being used as rice paddies in 2011 (Statistics Bureau 2011). However, much of these rice paddies are believed to have been developed via the natural clearing and filling of wetlands.

There are a variety of perceptions about the characteristics of wetlands, and it is generally held that there is no fixed definition at the present time. The Ramsar Convention on Wetlands (Convention on Wetlands of International Importance Especially as Waterfowl Habitat), however, states in Section 1 under Article 1, that, "For the purpose of this Convention, wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water the

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depth of which at low tide does not exceed six metres." This provides a broad definition of wetlands, and therefore rice paddies are included in the human-made wetlands among the wetland types defined according to the Ramsar Convention, marine/coastal wetlands, inland wetlands, and human-made wetlands (Ramsar Convention 2013).

The Ramsar Convention, adopted in 1971, was the first international treaty that was intended to conserve natural resources on a global scale. Discussions were conducted specifically about building networks of migration sites for the conservation of water birds. However, at present, the treaty is intended to conserve wetlands as a whole, and specific criteria based on water birds are considered for identifying wetlands of international importance, along with criteria for sites containing representative, rare, or unique wetland types, as well as criteria based on species and ecological communities and specific criteria based on fish (Matthews 1995; Ramsar Convention 2013; Ramsar Convention Secretariat 2011). Because the Ramsar Convention is aimed at conserving wetland ecosystems and sustaining biodiversity, official cooperative relationships for the Convention on Biological Diversity were started after the Sixth Meeting of the Conference of the Contracting Parties in Brisbane, Australia, in 1996 (Resolution VI.9), and it has become a collaborative model for similar multinational environmental agreements (Ramsar Convention Secretariat 2011). Obligations for the contracting parties of the Ramsar Convention include registering wetlands of international importance and establishing nature preserves on wetlands; the concept of the *wise use* of wetlands is extremely important.

Wise use of wetlands has been defined as the "their sustainable utilization for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem" (Recommendation 3.3 Annex of the Third Meeting of the Conference of the Contracting Parties in Regina, Canada in 1987), but it was later revised at the Ninth Meeting of the Conference of Contracting Parties, held in Kampala, Uganda in 2005, as "A conceptual framework for the wise use of wetlands and the maintenance of their ecological character: Wise use of wetlands is the maintenance of their ecological character, achieved through the introduction of ecosystem approaches within the context of sustainable development" (Resolution IX.1 Annex A). Furthermore, ecosystem approaches are defined as follows: "an ecosystem approach is a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way." This definition was established at the Fifth Meeting of the Conference of Contracting Parties of the Convention on Biological Diversity (Decision V/6, Nairobi, Kenya in 2000), which was comprised of 12 principles and five operational guidance points (Ramsar Convention 2013; Isozaki 2006; Convention on Biological Diversity 2013).

Because the Ramsar Convention is an international convention aimed at conserving a specific natural ecosystem of wetlands, it does not establish any unifying stipulations for conservation due to the regional characteristics of individual ecosystems, and it relies on domestic laws and the regulations of contracting parties to take practical actions. For this reason, the programmes currently in place at respective nations to guarantee the implementation of the Ramsar Convention vary. The registration conditions in Japan, for instance, are stipulated as (1) corresponding to international criteria, (2) conservation of future natural environment can be sought through laws and regulations of the state, and (3) ability to gain consensus of local residents on registration (Ramsar Convention 2013; Ministry of the Environment, Japan 2013). With regard to item (2), unlike in the Republic of Korea, there is no law in Japan that is intended for direct conservation of wetlands, and responsive actions are being taken using the Wildlife Protection and Hunting Law or laws concerning the preservation of wild species and natural parks.

Rice paddies are included in the definition of wetlands in the Ramsar Convention. The cultivation of rice in paddies has been practiced over several thousand years in the eastern Asian region, with approximately 90 % of the world's rice production occurring in the Asian Monsoon Region. Rice paddies are not only used for the production of rice for food. They also serve some of the purposes originally served by wetlands. For instance, they contribute to flood control, they are a source of groundwater, they prevent soil erosion, and they are a habitat for wildlife. Of the 2,127 sites covering about 2.05 million km^2 of land (as of June 24, 2013) registered as wetlands with the Ramsar Convention, only two sites expressly include the surrounding rice paddies: the "Kabukuri-numa and the surrounding rice paddies" (Osaki City of Miyagi Prefecture) and "Lower Maruyama River and the surrounding rice paddies" (Toyooka City of Hyogo Prefecture), which are both in Japan. There are many convention wetlands that are surrounded by rice paddies, and together, they form a wetland environment, with rice paddies acting as a buffer zone (Ramsar Convention 2013; Ministry of the Environment, Japan 2011; Kurechi 2010). Rice paddies that are managed well, with reduced use of agrichemicals and loading with water during winter, are known to sustain biodiversity, and act as human-made wetlands and agricultural wetlands. In addition, they are a source of groundwater and they serve the purposes of mitigating the effects of climate change, floods, and soil contamination, as well as landslides.

The transformation of the Ramsar Convention to initiate activities pertaining to rice paddies occurred with Resolution VIII.34, "Agriculture, wetlands, and water resource management," at the Eighth Meeting of the Conference of the Contracting Parties to the Ramsar Convention in Valencia, Spain, in 2002. Proactive enhancements of wetland conservation using sustainable agricultural methods and *wise use* were required of agriculture, which had previously emphasized the environmental load on wetlands (Ramsar Convention 2013).

In compliance with this trend, Resolution X.31, "Enhancing biodiversity in rice paddies as wetland systems," was adopted at the Tenth meeting of the Conference of the Contracting Parties in Changwon, Republic of Korea. This Resolution was proposed jointly by Japan and the Republic of Korea, and the adopted details include the following: (1) recognition that rice paddies, as wetland systems, produce rice as well as animal and plant foods and herbs, support the life and health of people in the region, support the wetland ecosystem, including reptiles, amphibians, and fish, and play an important role in the preservation of bird migration and groups of individuals; (2) apprehensions about inappropriate water management and agricultural methods, as well as introduction of new animals and plants, change of land use, etc., which may present a threat to rice paddies and impact the surrounding environments; (3) confirmation that this resolution will be implemented in an internationally agreed upon manner and conducted in concordance with internationally agreed upon development targets and related international liabilities, and that it does not justify the development of human-made wetlands from existing natural wetlands; (4) recalling that rice paddies, when appropriate, can be designated as, or included in, wetlands of the Ramsar Convention; and (5) a call for investigations, information exchange, and identification of agricultural methods considering the fact that flooding of rice paddies is being conducted while they are not in use to provide a habitat for animals, and activities to control weeds and insect pests have been implemented. In other words, it recognizes that a wise use of wetlands can be achieved by the appropriate management of rice paddies, which are wetlands (Ramsar Convention 2013).

In adopting this resolution, non-profit organizations in Japan and the Republic of Korea played a major role in preparing the draft proposal for the resolution, approaching governments of the contracting parties, and conducting side events. In relation to this resolution, Resolution XI.15, "Agriculture-wetland interactions: rice paddy and pest control" was adopted at the Eleventh Meeting of the Conference of the Contracting Parties in Bucharest, Romania in 2012. The *winter-flooded rice farming* performed in a number of countries, including the Republic of Korea, can be cited as an example for item (5). Winter-flooded rice farming can be conducted simultaneously with crop cultivation, which does not involve the use (or reduces the use) of agrichemicals and chemical fertilizers and is considered an environmentally friendly farming, a sustainable agricultural production method that conserves biodiversity. When Resolution X.31 was adopted, examples of rice paddies registered with the Ramsar Convention, such as the "Kabukuri-numa and the surrounding rice paddies" (4.23 km^2) registered in 2005, served as a driving force behind the adoption of the resolution, In addition to this, we also describe the site "Lower Maruyama River and the surrounding rice paddies" (5.6 km^2), which was registered later in 2012, primarily regarding the agricultural activities with considerations for biodiversity, such as winter-flooded rice farming. Winter-flooded rice paddies and other agricultural undertakings that account for biodiversity will be featured at the core of the explanations.

The winter-flooded rice paddies are those that neighbour the Kabukuri-numa pond in Tajiri Town of Miyagi Prefecture (currently Osaki City, since the town was incorporated due to a municipal merger that occurred in 2000). Practical studies were conducted for these winter-flooded rice paddies over 8 years, ranging from 1998 to 2006. The initial objective of cultivating winter-flooded rice paddies was to manage rice paddies as artificial ponds by flooding them during winter. The flooded ponds would be utilized as habitats for a diverse range of life forms, primarily water birds, and benefits for agricultural management include (a) the manufacture of soil via the effects of fungi, sludge worms, and chironomids that populate rice paddies that are flooded after harvesting rice, and (b) formation of ice during winter, which provides a weed-inhibiting effect (Washitani 2006). The fact that wise use would be beneficial to local farmers was emphasized when "Kabukuri-numa and the surrounding rice paddies" known to be a site with numerous migratory birds such as the greater white-fronted geese (*Anser albifrons*) were registered with the *surrounding rice paddies* included, which is significant because this had an important role to play in obtaining the approval of the local community. Rice cultivated in winter-flooded rice paddies in the environs of Kabukuri-numa gained added value by being branded as the *winter-flooded rice paddy rice*, being traded at higher rates than rice cultivated by conventional methods and contributing to the farm management (Asano et al. 2012).

Toyooka City cites the promotion of environment-creating agriculture while they aim to re-introduce the Oriental white stork (*Ciconia boyciana*), which went extinct in the wild. They have been implementing a project named "Natural Regeneration Project for Rice Paddies that Coexist with Oriental White Storks," which features the regeneration of wetlands and the expansion of winter-flooded rice paddies, as well as the agricultural method for nurturing safe rice and fostering animals simultaneously, known as the *white stork-friendly farming method*. The latter is an undertaking designed to add value through a concept of safe rice harvested in rice paddies where even Oriental white storks can live, by inhibiting weeds and securing the ecosystem while enabling wise use and management of the environment. Rice paddies have become feeding grounds for Oriental white storks on the one hand, while investigations have proven that treading by Oriental white storks does not adversely impact revenues (Washitani 2006). Such activities led to the incorporation of regions of rivers dotted with the rice paddies that undertake the *white stork-friendly farming method* in the "Lower Maruyama River and the surrounding rice paddies" registered as a Ramsar Convention wetland in 2012.

Currently in Japan, activities relating to the *living creature mark* add value to agricultural products by linking products with production in a space where living creatures can inhabit, such as the case of the *White-stork-friendly rice*. The *living creature mark* features the implementation of agriculture, forestry, and fisheries with considerations for biodiversity and the utilization of products for communication. It requires no special certifications or qualifications, although, in the case of the *white stork-friendly farming method* in Toyooka city, the certification criterion has been made clear (Minami 2011). Although agricultural methods that account for biodiversity are being promoted with focusing on the functions of rice paddies as agricultural wetlands, there are issues such as the amount of crops or labour. The production of *winter-flooded rice paddy rice* and the *white stork-friendly method* are supported by subsidies and commissions provided by the city. Accordingly, cited issues for the future include the combination of biodiversity and increased production of rice, as well as the establishment of agricultural management that is independent and does not rely on policies for supporting environmental conserving agriculture (Kurechi 2010; Minami 2011).

The Rice Paddy Resolution is significant because an international convention recognizes rice paddies as agricultural wetlands that can potentially contribute to biodiversity. Although contracting countries must make the effort to implement the resolution, issues relating to systems and economy must be overcome in order to make it more prevalent.

References

Asano T, Mitsutake S, Hayashi K, Enomoto T (2012) Conservation and utilization of Ramsar Convention Wetland "Kabukuri-numa and the surrounding rice paddies". Bull Hiroshima Univ Mus 4:1–11

Convention on Biological Diversity (2013) COP5 decision V/6 http://www.cbd.int/decision/cop/default.shtml?id=7148. Accessed 24 June 2013

Geospatial Information Authority of Japan: Lake and Wetland Survey (2000). Change in Wetland Area throughout Japan (Survey Summary) http://www1.gsi.go.jp/geowww/lake/shicchimenseki1.html. Accessed 24 June 2013

Isozaki H (2006) Environmental treaty guide that is good to know. Chuohoki Publishing, Tokyo, pp 36–39

Kurechi M (2010) Winter-flooded rice paddies for wise use of wetlands. Environ Res Q 157:46–54

Matthews GVT (1995) The Ramsar Convention on Wetlands: its history and development translation by Satoshi Kobayashi. Kushiro International Wetland Centre, Kushiro, pp 1–78

Minami S (2011) Protection of biodiversity in local government~legal policy for protecting Oriental Stork and Japanese Crested Ibis~. Environ Law J 36:127–147

Ministry of the Environment, Japan (2013) Ramsar Convention and Convention Wetlands. http://www.env.go.jp/nature/ramsar/conv/2-1.html. Accessed 24 June 2013

Ministry of the Environment, Japan (2011) Successful cases on sustainable rice paddy farming practices and wetland conservation in Asia—based on "the international workshop on rice paddy and wetland conservation: best practices in Asia" held in Takashima, Japan on August 6–7, 2010, pp 1–32

Ramsar Convention (2013) Kiribati joins the Ramsar Convention http://www.ramsar.org/cda/en/ramsar-home/main/ramsar/1_4000_0_. Accessed 24 June 2013

Ramsar Convention Secretariat (2011) Ramsar's Liquid Assets-40 years of the Convention on Wetlands. http://www.ramsar.org/sites/default/files/documents/pdf/Ramsar40_booklet/Ramsar_LiquidAssets_E.pdf. Accessed 24 June 2014

Record China (2009) <Kidneys of Earth> Rapid decline of wetland areas in 100 years – Institute of Remote Sensing Applications, the Chinese Academy of Sciences http://www.recordchina.co.jp/group/g28928.html. Accessed 24 June 2013

Statistics Bureau, Ministry of Internal Affairs and Communications: Statistics of Japan (2011) Chapter 7, Agriculture, forestry and fisheries, statistical tables 7–10, cultivated acreage http://www.stat.go.jp/data/nihon/07.htm. Accessed 24 June 2013

Washitani I (ed) (2006) Rice paddy regeneration to bring back local community and environment to life. Ienohikari Association, Tokyo, pp 70–146

Chapter 4
Distribution and Abundance of Organisms in Paddy-Dominated Landscapes with Implications for Wildlife-Friendly Farming

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Abstract A consensus now holds that biodiversity conservation in agricultural landscapes is important in addition to the protection of pristine habitats, and the role of wildlife-friendly farming is increasing in this context. Paddy-dominated landscapes harbor a variety of organisms that primarily depend on wetlands, as opposed to those that inhabit dry arable fields. Because rice fields are highly dynamic systems whose physical structures change dramatically from periodic water flooding and draining, surrounding environments at multiple spatial scales, from paddy infrastructure (e.g., ditches and levees) to landscape composition (e.g., forest cover), play an important role in the persistence of populations. Agricultural intensification has caused severe declines in many organisms, not only by deteriorating the quality of rice fields as wetland habitats, but also by disrupting the connectivity among different habitats and preventing the completion of life cycles. Although we have limited evidence, the effectiveness of wildlife-friendly rice farming appears to be highly landscape-dependent, and the pattern is probably different from what is reported in dry arable fields due to the ubiquitous existence of organisms that require multiple habitats. An urgent need exists to test this hypothesis, which could help implement efficient spatial designs for wildlife-friendly farming to conserve biodiversity in paddy-dominated landscapes.

Keywords Biodiversity • Rice field • Land sharing • Spider • Anuran • Landscape complementation

Wildlife-Friendly Farming and Biodiversity: General Introduction

An Alternative to Protected Areas

The global trend of rapid biodiversity loss with the development of human society in the last century is still continuing in the twenty-first century (Butchart et al. 2010). With this background, the Convention on Biological Diversity (CBD) established so-called *Aichi Targets* to conserve biodiversity and its sustainable use (www.cbd.int/sp/targets/). One of the major goals until 2020 is to increase protected areas, at least 17 % on land and 15 % in the ocean. Although these values were largely determined for political reasons and do not have a solid scientific background, such actions may be effective if protected areas are properly selected and preserved. However, programs to establish protected areas such as national parks and nature reserves that include huge areas that restrict human activities are not easy to implement because of the growing demand for food production. Another important point to consider is that not all endangered organisms inhabit pristine habitats such as primary forests and large wetlands. Increasing evidence indicates that a large number of species now depend on human-dominated landscapes, particularly agricultural landscapes (Pimentel et al. 1992; Rosenzweig 2003; Tscharntke et al. 2005), because these organisms use early successional habitats that need human disturbance and require different habitats to complete their life cycles. Rural agricultural landscapes often harbor mosaic landscapes due to traditional human land-use activities, providing suitable habitats for many organisms for thousands of years (e.g., Washitani 2001; Kleijn et al. 2009; Fahrig et al. 2011). However, modern agricultural practices or agricultural intensification have led to the homogenization of landscape structures and the deterioration of habitat quality in crop fields themselves (e.g., Tscharntke et al. 2005; Natuhara 2013). As a result, organisms living in such landscapes have declined and more than a few have been designated as threatened species (Kato 2001). In this situation, the management of human-dominated landscapes and the conservation of the species therein is an important and urgent issue for halting the worldwide decline in biodiversity, alongside the establishment of protected areas.

Land Sharing vs. *Land Sparing*

Wildlife-friendly farming is an effective way to reconcile the trade-off between food production and biodiversity conservation because it improves habitat quality for wildlife while producing foods that are safe for human health. The notion of *land sharing* is almost synonymous with wildlife-friendly farming (Fischer et al. 2008), especially in temperate regions such as Europe, North America, and Japan, which aims to create mosaic landscapes that provide habitats for organisms. In contrast, *land sparing* is based on the zoning concept, which separates land into areas for high food production with intensive agricultural practices and areas for biodiversity conservation by strictly restricting human activities.

The question of which land management strategy (land sharing or land sparing) is more effective for halting the loss of biodiversity is one of the hottest topics in conservation biology (Green et al. 2005; Fischer et al. 2008; Hodgson et al. 2010; Phalan et al. 2011). In this context, the regional species pool largely determines which method is more effective. Theoretical analyses showed that if species richness exhibits a convex response with an increasing degree of intensification, land sharing is a better strategy (Green et al. 2005) because weak human disturbances do not reduce habitat quality for organisms as much (Fig. 4.1a). In contrast, if organisms exhibit a concave response, land sparing is recommended because even a slight degree of intensification reduces species richness disproportionately (Fig. 4.1b). Note that the nature of the species pool may be ultimately determined by the history of landscapes in a region. For example, regions with complex topography harbor historically mosaic landscapes, and those with an increasing history of agriculture have also maintained heterogeneous landscapes over a long period of time. These historical landscapes have allowed many organisms to adapt to disturbed and mosaic habitats (Kleijn et al. 2009; Kato 2001) or eliminated species that once lived in pristine habitats (Balmford 1996; Chazdon et al. 2009; Gardner et al. 2009). Because most temperate regions have a long history of agricultural land use, and hence many species may have adapted to heterogeneous

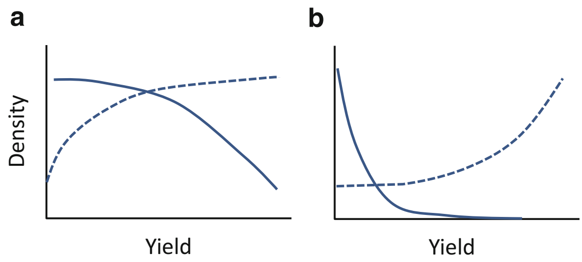

Fig. 4.1 Schematic representation of how an increase in crop yield (a measure of agricultural intensification) influences the population density of organisms. (**a**) Land sharing is preferable because species achieve their highest population densities when land is formed at moderate levels of yield. (**b**) Land sparing is preferable because species achieve their highest population densities when land is formed at the highest permissible yield or when land is conserved. *Solid* and *broken lines* indicate species that prefer forests and open land, respectively (Modified after Phalan et al. 2011)

landscapes, land sharing appears to be appropriate (Hodgson et al. 2010). In contrast, in tropical regions where human disturbance has been less extensive historically, many endangered or rare species may exist that are sensitive to landscape alterations (Didham 2011; Laurance et al. 2011) such that land sparing is more appropriate. However, when land sparing is unrealistic for social reasons, land sharing, such as agroforestry, may be an optional strategy.

Wildlife-Friendly Farming in a Landscape Context

The effectiveness of wildlife-friendly farming varies depending on the place in which it is conducted. This seems intuitively evident because if the target organisms are completely absent from a region, it is impossible for them to colonize there. Even when they are present in the regional species pool, their abundances may not become high if the environments surrounding fields are not suitable. Thus, consideration of environmental factors at the landscape level is crucial in predicting the outcome of wildlife-friendly farming.

At least two reasons exist as to why the abundance and species richness of organisms in paddy fields are associated with surrounding landscape structures, as well as local farming practices. First, the source habitat of some organisms is not the crop field itself, but surrounding habitats, including grasslands, woodlots, and creeks (e.g., Kunin 1998; Tscharntke et al. 2012). For example, parasitoids and predators of insect pests often spill over from such habitats into crop fields and sometimes control the abundance of insect pests (e.g., Thies and Tscharntke 1999; Bianchi et al. 2006). In this case, wildlife-friendly farming does not necessarily enhance species richness and abundance at the landscape level. Second, organisms inhabiting agricultural landscapes often use multiple habitats, and their density or probability of occurrence becomes high in heterogeneous or mosaic landscapes.

For example, some birds and bees use forests as nesting sites, but they also use crop fields for foraging (e.g., Katoh et al. 2009; Kennedy et al. 2013). For some amphibians and aquatic insects that breed and spend their nymphal stage in water bodies in rice paddies, the presence of nearby forests is essential when they move from aquatic habitats to forests after reaching adulthood (Osawa and Katsuno 2001; Higashi 2010). Such *landscape complementation* or *landscape supplementation* (Dunning et al. 1992) seems to be common in traditional agricultural landscapes because organisms have had a long history in which to adapt to heterogeneous environments with frequent human disturbance, or organisms that are preadapted to such environments, such as floodplains and fire-maintained grasslands, have colonized there (Kato 2001). In the case of landscape complementation or supplementation, local wildlife-friendly farming practices are likely to enhance population size and species richness at the landscape level.

Increasing evidence indicates that landscape heterogeneity affects the effectiveness of organic farming or wildlife-friendly farming. Studies conducted mostly in European countries show that positive effects of organic farming are pronounced in simple landscapes that consist of 2–10 % cover of non-cropland or seminatural habitats, while no discernible effects are observed in complex landscapes (>20 % seminatural habitats; Tscharntke et al. 2005; Kleijn et al. 2011; Batary et al. 2011). This is because crop fields in complex landscapes have already attained an apparently *good condition* by the spillover of species from seminatural habitats, masking field-level management effects. Alternatively, some open-land specialists inhabiting farmland patches may experience negative effects in landscapes with a low area of cropland (Gabriel et al. 2010). When including the range of cleared landscapes that have very low levels of seminatural habitats, however, the relationship between landscape complexity and the effectiveness of local management exhibits a hump-shaped pattern (Tscharntke et al. 2005, 2012; Concepción et al. 2012) because spillover from seminatural habitats is unlikely to occur in cleared landscapes that have a poor species pool. Thus, intermediate levels of landscape heterogeneity are expected to be the most effective for wildlife-friendly farming. However, this hypothesis has not yet been tested in paddy dominated landscapes.

Other than landscape heterogeneity, the spatial extent of organic fields may determine the effectiveness of local practices because large areas that have high habitat quality are likely to enhance population density through rescue effects or improved survival rates during dispersal. Although such studies are still lacking, good evidence indicates that the positive effect of organic farming at the farm level is more pronounced in landscapes with high amounts of organic land, although the effect at the farm level is slightly more important (Gabriel et al. 2010). The interactive effect of the extent of organic farming and landscape heterogeneity is a promising field of work that should be addressed in the future.

Paddy Fields and Surrounding Landscape Elements as Substitutes for Natural Habitats

Organisms in Paddy Fields

Rice paddies occupy 11 % of farmland worldwide, and over 90 % of them are located in Asian countries (FAO Statistics Division 2008). With the development of rice cultivation, most natural wetlands have already been converted to paddies. Although rice cultivation was thus a major driver of reductions in wetland areas, most rice paddies are flooded during at least the growing season of rice plants. Thus, they have become substitutes for natural wetlands in terms of both biodiversity conservation and ecosystem functioning (e.g., Elphick 2000; Lawler 2001; Natuhara 2013). Note that rice cultivation systems require infrastructure other than paddy fields, including irrigation ditches (or canals) and levees. Therefore, these infrastructure elements also serve as substitutes of natural creeks and grasslands. Another important point is that most modern rice fields are temporal wetlands because shallow water is retained during the growing period of rice plants (early spring through late summer), while fields are usually drained before harvesting (early autumn through winter). Thus, one should keep in mind that paddy fields are highly dynamic ecosystems, both spatially and temporally, and that this characteristic should affect the abundance and species richness of organisms (e.g., Amano et al. 2008; King et al. 2010).

Birds are among the world's most well-studied organisms that use paddy fields. In Japan, China, and Korea, where paddy-associated landscapes predominate, a large number of water birds are now dependent on paddy fields for foraging and occasionally resting sites (Fujioka et al. 2010; Wood et al. 2010). In particular, at least 11 (22 %) of the world's 49 threatened bird species in Japan and Korea use rice fields, including the crested ibis (*Nipponia nippon*), Oriental white stork (*Ciconia boyciana*), black-faced spoonbill (*Platalea minor*), and red-crowned crane (*Grus japonensis*; Fujioka et al. 2010). Although waterbirds obviously prefer flooded paddy fields, some grassland species also prefer flooded paddy fields in winter, probably due to high invertebrate abundances (Maeda and Yoshida 2009).

Many freshwater fish species also use rice fields and irrigation ditches in Japan, mainly for breeding. One hundred six fish species have been recorded in Japanese irrigation ditches, and at least 17 native species move from ditches to rice fields, consisting mainly of loaches, catfish, and cyprinids (Natuhara 2013). Two advantages exist for fish to spawn eggs in rice fields. First, high abundances of plankton and aquatic invertebrates are produced in rice fields (Kikuchi et al. 2012), probably due to high nutrient concentrations and temperatures. Second, predatory fish are almost absent, and therefore egg and fry survival rates appear to be quite high. Thus, rice fields are ideal habitats for fish species that are tolerant to harsh physical conditions, such as high temperatures and occasional desiccation. Among the species that use rice fields, the Oriental weather loach (*Misgurnus anguillicaudatus*) is by far the most abundant species (Saitoh et al. 1988; Katayama et al. 2011). After rice fields are flooded, loaches in ditches move upstream to rice fields and the number of individuals found in rice fields increases rapidly (Katayama et al. 2011). As the biomass of loaches moving downstream to ditches was two to three times larger than that moving upstream (Mizutani 2000), rice fields appear to play an important role in population increases of loaches.

Amphibians are one of the most conspicuous groups of organisms found in rice fields due to their active calling during the breeding season. Eleven of 16 species of native amphibians living in mainland Japan, except for Hokkaido, use rice fields for breeding, including the Sado frog (*Rugosa susurra*), which was described in 2012 and is endemic to Sado Island (Sekiya et al. 2012). Because modern rice fields are drained during the nongrowing season of rice plants, almost all of the species use habitats that surround rice fields, such as ditches, levees, and forests. Therefore, linkages between rice fields and other habitats are essential for the persistence of populations.

A large number of arthropod species depend on rice fields, including endangered species, insect pests, and natural enemies of pests. The firefly *Luciola lateralis* and the dragonfly *Sympetrum frequens* are the two iconic insect species in rural landscapes of Japan, and numerous adults emerge from rice fields all over Japan. However, their populations have declined severely in the last several decades (Fukui 2012; Koji et al. 2012). Diving beetles *Cybister japonicus* and water bugs *Lethocerus deyrollei* are typical examples of paddy-using endangered species (Kato 2001); they spend their larval periods in water and migrate to other habitats when they become adults. As natural enemies of insect pests, spiders are one of the commonest generalist predators in rice fields, and their role as biological control agents has long been studied by applied entomologists (e.g., Kiritani and Kakiya 1975). *Tetragnatha* spiders are often found building their horizontal webs between leaf blades of rice plants. The webs not only capture insect pests but also appear to force them onto the ground and thereby into the hunting zones of wolf spiders (Takada et al. 2013). As in most other organisms, these spiders inhabit ditches and levees during the nongrowing season of rice plants.

For wetland plants, the extent to which they are dependent on rice fields has still not been well evaluated. A case study using specimens of vascular plants from Okayama Prefecture, Japan, showed that 6 of 22 species (or species group) listed in the Risk Data Bank of Japan exhibited a high dependency on rice fields (Hidaka et al. 2006).

Aside from aquatic habitats (rice fields and ditches), levees, as grassland habitats, have an important function for purely terrestrial organisms. In particular, terrace paddy fields usually have a smaller paddy size with wider levees in comparison with lowland paddy fields due to the steepness of the topography. The total area of grasslands in levees is estimated to be 2,336 km^2 (Matsumura 2008), representing more than half of the total grassland area in Japan. In fact, some endangered and threatened butterfly species (e.g., *Shijimiaeoides divinus*, *Lycaeides argyrognomon*) and herbs (e.g., *Platycodon grandiflorus*, *Vincetoxicum pycnostelma*) are found there. These populations are maintained by intermediate levels of human disturbance, including mowing and burning (Baba et al. 2003; Koda 2011).

Effects of the Surrounding Landscape Structure on Organisms

Rice cultivation in East Asia has traditionally been conducted in heterogeneous landscapes consisting of rice paddies, secondary forests, grasslands, and creeks (Washitani 2001; Wood et al. 2010). This is because of inherent topographic complexities, as well as the need to create mosaic land-use to obtain various resources, including green manure from grasslands, fuel from secondary forests, and water from creeks. When considering biodiversity conservation in paddies, a landscape perspective is essential. Three principal mechanisms operate by which species richness is enhanced in these landscapes (Fig. 4.2). First, different types of habitats are present, which results in a high beta diversity, which represents the turnover of species composition between different habitats, or between-habitat diversity. This is self-evident because different habitats harbor different species assemblages in response to different environmental conditions. According to fragmentation theory, mosaic landscapes that contain small habitats can represent a double-edged sword for species richness because small habitats impose a higher risk of local extinction for habitat specialists, which results in a low alpha diversity (within-habitat diversity). However, this negative effect may be overcompensated in terms of total species richness (gamma diversity) by the higher beta diversity in agricultural landscapes (Tscharntke et al. 2002), and this is likely to be true in Satoyama landscapes. The second mechanism that enhances species diversity in Satoyama landscapes is periodic disturbances by human activities (e.g., mowing of grasses for green manure and livestock food, and coppicing of trees for fuel), which prevents vegetation succession to closed canopy forests, allowing a large number of species to coexist under nonequilibrium ecological conditions (Kato 2001). This obviously enhances alpha diversity. Third, many species of organisms require multiple habitats to complete their life cycles, such as amphibians and aquatic insects. For these species, a combination of different habitats (or niches) can be considered an *emergent niche* (Miyashita et al. 2014), which is not divisible for the persistence of these populations. In this sense, landscape heterogeneity creates emergent niches through landscape complementation, enhancing both alpha and gamma diversity.

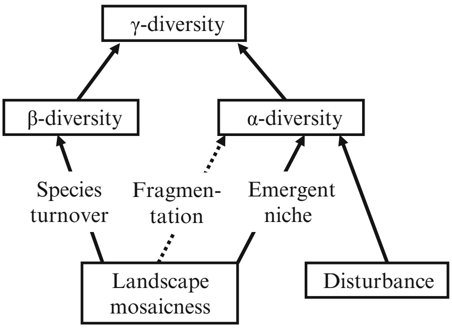

Fig. 4.2 Three processes by which species diversity is enhanced in mosaic landscapes. *Solid lines* indicate positive effects and the *broken line* represents a negative effect

The montane brown frog (*Rana ornativentris*) and the forest green tree frog (*Rhacophorus arboreus*) move from rice fields to nearby forests after metamorphosis and come back to rice fields for breeding after reaching sexual maturity. In these anurans, forest cover surrounding rice fields is an important factor determining the local abundance of egg masses; the montane brown frog showed its highest densities in landscape with an intermediate level of forest cover (50–60 %), while the forest green tree frog showed a monotonic increase with forest cover in the landscape (Kato et al. 2010). The species richness of spiders inhabiting strips of grasslands near rice paddies exhibits a hump-shaped pattern with respect to surrounding forest cover (Miyashita et al. 2012), implying that heterogeneous landscapes harbor high species richness. Moreover, a substantial proportion of individual species also showed such a pattern, indicating that landscape heterogeneity *per se* enhances the occurrence of many species, which probably increases species richness. However, the effective spatial scale differs between species, ranging from a 200 to >1,000 m radius from a focal grassland. This suggests that multi-scale spatial heterogeneity, which appears to be common in fractal-like landscapes, is required to maintain a high spider density at the community level. The reason why spider species richness and abundance are higher in such landscapes is not clear, but we consider that prey subsidies from nearby forests may enhance prey supply, and/or forest edges could serve as refuges when grasslands are mowed.

Note, however, that not all organisms living in and around rice fields exhibit positive responses to landscape heterogeneity. The grasshopper *Oxya yezoensis* is one of the commonest insects in rice fields and was regarded as a pest in the past when pesticides were not used. The abundance of grasshoppers on levees increased with the area of rice paddies in the surrounding landscape (Yoshio et al. 2009). This finding seems plausible because the habitat of the grasshopper is primarily confined to rice fields and levees, and other landscape elements, such as forests, do not appear to enhance habitat quality. Likewise, Oriental loach populations in rice fields have increased in abundance with the area of paddy fields in the landscape (Kano et al. 2010). This is also reasonable because the loach mainly breeds in shallow water such as rice fields, and hence is likely to increase in abundance in landscapes that contain a large amount of paddies.

Although inconclusive, we consider that landscape heterogeneity generally increases species richness, although some species that are specialized on rice field habitats may benefit from landscape homogeneity with regard to widely distributed rice paddies.

Effects of Modernization of Paddy Fields on Organisms

The intensification and modernization of agricultural practices are believed to have severely reduced the abundance and species richness of organisms in paddy-dominated landscapes, but solid scientific evidence has only recently been accumulated. Three major factors appear to have detrimental effects on organisms that inhabit paddy-dominated landscapes. First, the widespread use of pesticides and herbicides induces high mortality in organisms. Second, water drainage in winter and partly in summer, so that plowing and harvesting machines can be used, may have dramatically reduced populations of water-dependent organisms. Third, the consolidation of ditches that have a large/deep size may have prevented organisms from entering rice fields from ditches, which implies that a disruption of connectivity or the network among habitats has occurred. The effects of pesticides and herbicides are rather obvious, and therefore we do not mention them further (see Kiritani 2000 for details).

Amphibians and fish provide well-studied examples of species that have experienced detrimental effects following the consolidation of deep ditches. For example, frogs without disks, such as the Tokyo Daruma pond frog (*Rana porosa porosa*) and the Japanese brown frog (*Rana japonica*), have declined in abundance in rice fields that have consolidated large/deep ditches, but species with disks, such as the Japanese tree frog (*Hyla japonica*) and the forest green tree frog, did not decline in the presence of these ditches (e.g., Fujioka and Lane 1997; Kato et al. 2010; Tsuji et al. 2011). This is because once they are dropped into consolidated ditches, frogs with disks are able to climb up vertical deep walls while those without disks cannot. The Tokyo Daruma pond frog and its relatives use ditches as alternative habitats when rice fields contain no water, and the two brown frog species mainly inhabit forest floors as adults. In either case, consolidated ditches disrupt movement between rice fields and another habitat necessary to complete their life cycle. This is also true for the Oriental loach and other fish species that use rice fields for breeding. The species richness of fish in ditches was higher when fishes were able to easily invade rice fields (Katano et al. 2003). Also, the abundance of the Oriental loach in rice fields was strongly affected by the horizontal gap between fields and ditches (Katayama et al. 2011; Fig. 4.3). As large gaps are a characteristic of deep consolidated ditches, they disrupt the habitat networks of fishes that inhabit paddy-dominated landscapes.

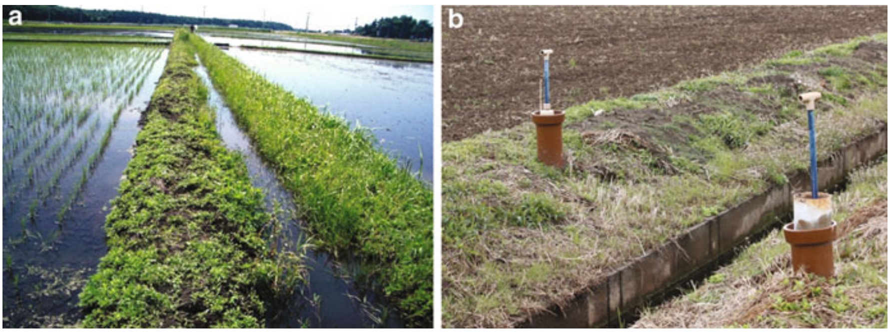

Fig. 4.3 Two types of ditches around rice fields. (**a**) Traditional earth ditches with shallow depth, used for irrigation and drain water; (**b**) modern consolidated drain ditches consisting of deep vertical walls, with drain cocks along the levees (Photos by K. Tanaka and N. Katayama)

The modernization of paddy fields could indirectly affect organisms through food webs. The simplest, and probably a ubiquitous, example is a decrease in higher-level predators because of bottom-up limitation. The intermediate egret (*Egretta intermedia*), which mainly feeds on aquatic organisms in rice fields during flooding periods, aggregates in rice fields that use traditional irrigation practices where loaches and other fishes are more abundant instead of fields that use modern practices (Lane and Fujioka 1998; Katayama et al. 2012). The grey-faced buzzard (*Butastur indicus*) is a representative top predator in mosaic landscapes in Japan, and it probably depends on landscape complementation. The buzzard uses rice fields to forage primarily on frogs in spring to early summer, but with the decline in frog abundance in rice fields, it shifts to foraging in secondary forests, where it feeds on large insects (Katoh et al. 2009). The probability of occurrence of this species was primarily determined by the abundance of frogs in rice fields, which was indirectly reduced by modern irrigation practices (Fujita et al. 2014).

Indirect effects of modernization could lead to unexpected positive effects. As mentioned above, modern irrigation systems reduce the abundance of the Oriental loach, but this in turn increases the abundance of Japanese tree frog tadpoles (Katayama et al. 2013). The loach is an omnivore (Kubota et al. 1965), although predation on tadpoles had been unknown. However, laboratory experiments showed that loach actively consume eggs and small tadpoles of the Japanese tree frog (Katayama et al. 2013). Because the Japanese tree frog does not experience detrimental effects from the presence of deep consolidated ditches, the frog appears to experience an indirect positive effect through predator release. Although such positive indirect effects might not be very common, especially for rare species, disentangling the complex interactions in food webs in and around rice fields seems to be important for predicting consequences for ecosystem functioning and ecosystem services, which are thought to be driven by common species (Tscharntke et al. 2012).

How Do Landscape Structures Influence the Effectiveness of Wildlife-Friendly Rice Farming?

As described in the "Wildlife-friendly farming and biodiversity: general introduction" section, the effects of organic farming or wildlife-friendly farming on biodiversity are occasionally context-dependent with regard to landscape structures. However, such considerations have rarely been addressed in paddy-dominated landscapes.

On Sado Island in Japan, the number of farmers undertaking wildlife-friendly farming has been increasing since the start of a reintroduction project for the crested ibis (Usio et al. 2015). The primary aim is to increase prey abundance for the crested ibis, such as loaches and amphibians, but the restoration of biodiversity, including rare species and natural enemies of insect pests, is increasingly being considered important. Paddy fields on this island are distributed from lowland plains to hilly areas; therefore, a rich variety in landscape structures exists surrounding rice fields. Thus, the extent to which wildlife-friendly farming increases biodiversity and the abundances of species of conservation concern, and how these increases are affected by landscape structures, are important issues for predicting the outcomes of restoration practices across the whole island. Winter flooding of rice fields and the construction of *e* (shallow, unconsolidated diversion ditches in rice fields) are two common practices in wildlife-friendly farming on Sado Island. These efforts are expected to be effective for mitigating the negative impacts of water drainage in midsummer because they can provide important refuges for aquatic organisms. Our previous study demonstrated that the construction of *e* dramatically increased the number of montane brown frog egg masses in rice fields with >50 % forest cover in the surrounding landscape, while similar actions resulted in only small increases in egg masses in rice fields with <30 % surrounding forest cover (Uruma et al. 2012; Fig. 4.4). This indicates a higher performance by wildlife-friendly farming practice in more heterogeneous landscapes, i.e., in landscapes with more non-crop areas. Because the brown frog needs both rice fields and forests to complete its life cycle (Osawa and Katsuno 2001), in a typical example of landscape complementation (Kato et al. 2010), improvements in local habitat quality appeared to contribute little to enhancing population density when landscape-level effects critically limited the distribution.

Tetragnatha spiders are among the most ubiquitous species in rice fields, and they can be used as an indicator of the effectiveness of organic rice farming (Amano et al. 2011). Our preliminary study conducted in central Japan indicated

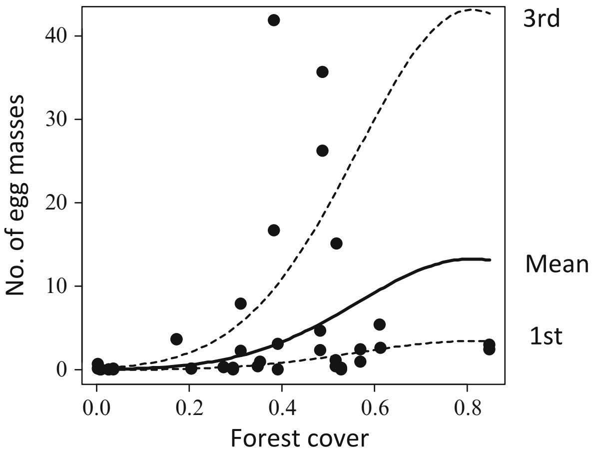

Fig. 4.4 Abundance of montane brown frog egg masses in rice fields as a function of forest cover in the surrounding landscape (<1 km radius) and number of *e* constructed in rice fields. *Solid line* represents the expected number of egg masses in rice fields with the mean number (0.4) of *e* per rice field, and *dashed lines* indicate the 1st and 3rd quintiles of the observed number of *e* (0 and 0.75 of *e*, respectively) (Modified from Uruma et al. 2012)

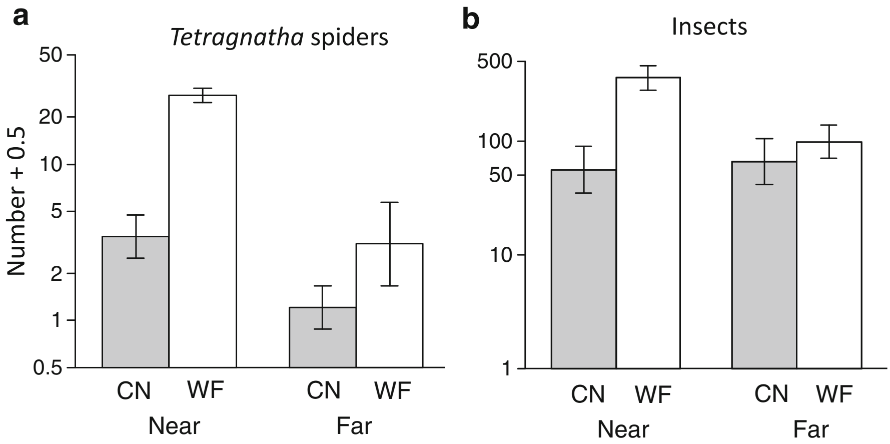

Fig. 4.5 Mean number (±SE) of two *Tetragnatha* spider species combined (**a**) in rice fields with conventional (CN) and wildlife-friendly (WF) farming practices per 40 net sweeps, and that of small insects (<3 mm body length); (**b**) caught by sticky traps with 25 cm^2 area (Tsutsui et al. unpublished). "Near" and "Far" represent rice fields located <100 m and ≥100 m from the forest edge, respectively

that two *Tetragnatha* species (*T. maxillosa* and *T. extensa*) highly dependent on rice fields were more abundant in rice fields where insecticides were not used compared to conventional fields when rice fields were located near forests (Fig. 4.5a). However, the abundance of spiders was extremely low in rice fields that were far from forests and no discernible difference was detected between management types (Fig. 4.5a). Similar patterns were observed in the abundances of insect that were caught by sticky traps (Fig. 4.5b), which consisted mainly of nematocerans, the major prey of *Tetragnatha* (Yoshida 1987). Thus, the effectiveness of wildlife-friendly farming increases with proximity to forests, probably because of differences in the degree of bottom-up limitation to spiders. Why dipterans increased disproportionately in rice fields that were in close proximity to forests is not clear, but milder microclimates formed by forest edges might enhance habitat quality in rice fields, or forest edge habitat *per se* might provide refuges. One should keep in mind that the study followed a *patch-landscape* approach (McGarigal and Cushman 2002) rather than landscape-level replications, but this evidence is nevertheless suggestive in future research on wildlife-friendly farming for natural enemies and hence pest control services in rice fields.

The effects of landscape structure on the performance of organic farming or wildlife-friendly farming have mostly been examined in Europe (Batary et al. 2011; Kleijn et al. 2011; Tscharntke et al. 2012). These studies showed a general trend that wildlife-friendly farming is more effective in simple landscapes because many species are already widespread in complex heterogeneous landscapes, while the enhancement of local habitat quality facilitates the colonization of many species from source habitats in simple landscapes. However, we consider that the opposite tendency is common in paddy-dominated landscapes. For example, the abundance of the montane brown frog increased dramatically in rice fields with >50 % of forest cover in the surrounding landscape, and these landscapes were clearly involved in a *complex landscape*, as defined by earlier studies (Tscharntke et al. 2005; Batary et al. 2011; Kleijn et al. 2011). We suspect that such a pattern may be common for organisms in paddy-dominated landscapes because many species require both rice fields and surrounding forests or forest edges to complete their life cycles. Actually, most anurans, aquatic insects, and some bird species, such as the Grey-faced Buzzard, are able to maintain their populations in heterogeneous landscapes, including secondary forests, seminatural grasslands, and rice fields (Kato 2001; Osawa and Katsuno 2001; Katoh et al. 2009). With low levels of surrounding forest cover, these species are unlikely to establish populations even when local habitat quality in rice fields is enhanced. Earlier studies in Europe targeted dry croplands; therefore, both croplands and non-croplands were terrestrial habitats and were structurally more or less similar. In this situation, source–sink dynamics mediated by simple spillover from non-crop habitats appears to be common. However, paddy-dominated landscapes consist of contrasting habitat types, i.e., rice fields are aquatic systems while forests and grasslands are terrestrial. Thus, rather than simple spillover effects, habitat complementation appears to play a major role. The distinction between spillover effects and habitat complementation has thus far received little attention (Tscharntke et al. 2012), but this should be explicitly recognized. We propose that the nature of the species pool, which reflects a long history of regional environmental filtering, is an important determinant of how the effectiveness of farming practices varies with landscape structure. With an increasing proportion of species that show habitat complementation, the effectiveness of wildlife-friendly farming practices would not decrease with increasing landscape complexity, and it could even become stronger (Fig. 4.6). This hypothesis should of course be tested in the future.

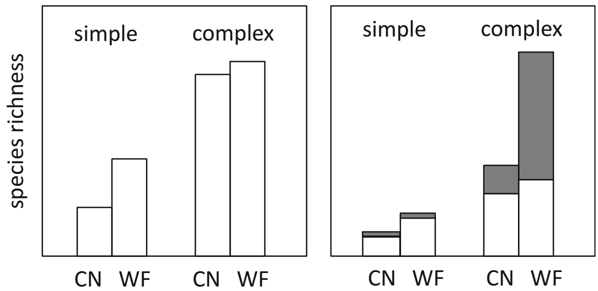

Fig. 4.6 Hypothetical patterns of species richness in conventional and wildlife-friendly rice farming practices in simple and complex landscape structures. *Shaded bars* indicate species that require different habitats to complete their life cycles. *Right* and *left* panels indicate regions with and without species showing habitat complementation

Future Perspectives

Biodiversity conservation in paddy-dominated landscapes has a relatively short history in comparison to the conservation of pristine habitats and croplands in Europe. Nevertheless, a large number of studies have accumulated over the last two decades, and the characteristics of species composition and distribution patterns in relation to spatiotemporal variability in environments are being understood. Here, we propose three avenues of research to advance our understanding of and develop effective practices for wildlife-friendly farming.

First, in addition to landscape measures that are spatially implicit, such as the percentage of non-cropland or forest cover, spatially explicit population structures at multiple spatial scales should be considered. Population structures at different spatial scales may provide different implications for conservation and restoration practices. In a larger-scale, population structure formed by long-term history could be used to determine management or conservation units. Preserving these units as they are is important because the existence of genetic diversity across spatial scales, called *genetic beta diversity* (Tscharntke et al. 2012), may provide insurance against changing environmental conditions and may even result in the evolution of new species. Our preliminary study on the Sado frog detected three genetically differentiated clusters that were recognized using microsatellite DNA, which could be used to determine management units for this endemic species. In this situation, the effectiveness of wildlife-friendly farming should be evaluated separately for each unit. In a smaller spatial scale, the network structure of habitats within a management unit should be considered to identify priority areas for wildlife-friendly farming. This approach would be particularly useful for conserving rare and threatened species because the decision as to which habitat to restore first could have a strong effect on population persistence (Baguette et al. 2013). Genetic markers could clarify genetic hot spots and gene flow among populations, which cannot be determined from abundance data. Because organisms in agricultural landscapes are subject to frequent disturbance and hence their populations are probably in a nonequilibrium state, a poor correlation seems to exist between population density and genetic diversity, which is actually the case for the Sado frog (Fig. 4.7). In this situation, habitat restoration should be prioritized in places where genetic diversity is high while population density is low, because such action may efficiently increase effective population size in a given effort. To estimate network links, the recent development of landscape genetics allows us to estimate dispersal corridors and matrix resistance for freshwater animals that disperse through terrestrial habitats (e.g., Murphy et al. 2010; Phillipsen and Lytle 2013), which would be useful for identifying network hubs.

Second, this paper focused on agricultural modernization or intensification, which have detrimental effects on biodiversity, but the abandonment of agriculture practices, especially in hilly and mountainous areas, is becoming a serious problem. Indeed, the Ministry of the Environment, Japan listed the under-use of land as one

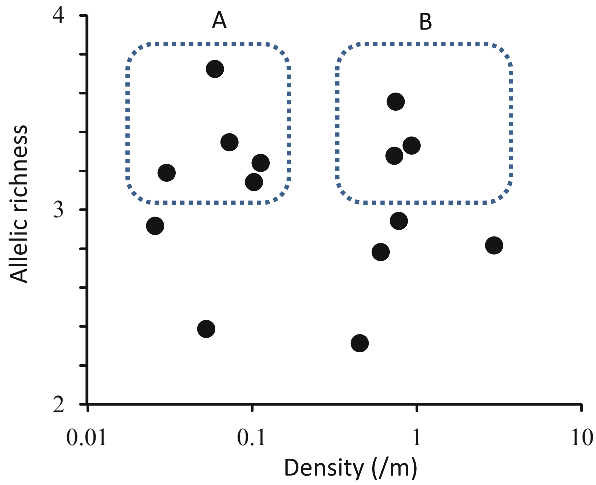

Fig. 4.7 Relationship between density and genetic diversity (allelic richness) in local populations of Sado frog (*Rugosa susurra*) endemic to Sado Island (Yamanaka et al. unpublished). A high priority for restoration to enhance habitat quality should be given to populations indicated by *A*, while current environmental conditions should be maintained in populations denoted by *B*. Allelic richness was calculated from seven microsatellite DNA loci, and density is expressed as per unit length of levees along rice fields

of the four major drivers of biodiversity loss (http://www.biodic.go.jp/biodiversity/about/initiatives3/nbsap_e.html). We still have limited knowledge about the effects of rice field abandonment in comparison with agricultural intensification. Many wetland- and grassland-dependent species are considered to have lost their habitats and become endangered, particularly in Satoyama landscapes. For example, the abundance of frogs decreased dramatically when rice fields were abandoned and converted into tall grasslands (Tomioka 2000). Abandonment could also reduce endangered herbs by promoting succession to shrubs and trees (Uematsu et al. 2010) and could facilitate invasions by alien species (Yamaguchi et al. 1998). The identification of key locations for restoring abandoned rice fields could contribute greatly to halting the decline in regional biodiversity in paddy-dominated landscapes.

Third, in the face of future global warming, suitable areas for rice cultivation will shift northward. If the range shifts of organisms follow this change, no problems may occur, but for species that have limited dispersal abilities, such as anurans, tracking their distribution change in rice fields will be difficult. In this case, assisted colonization (Hoegh-Guldberg et al. 2008) and/or the establishment of *climate corridors* (Vos et al. 2008) by creating wildlife-friendly rice fields in appropriate locations might become necessary. Also, landscape structures may differ among regions. For example, the most northern mainland in Japan, Hokkaido, appears to have different landscape structures compared to Honshu, where mosaic landscapes are predominant (Fig. 4.8). For species groups that can increase in

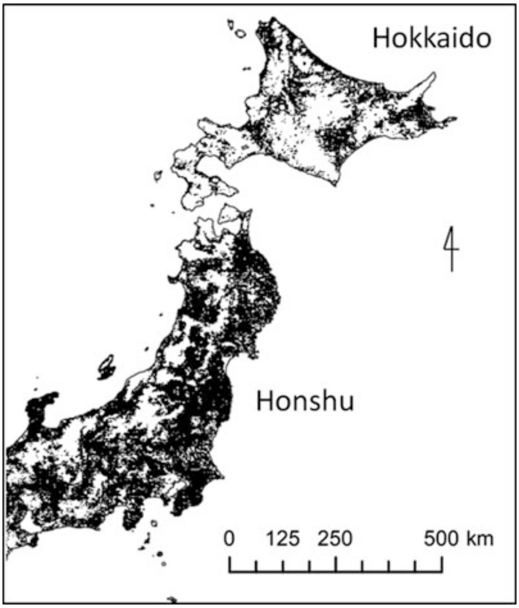

Fig. 4.8 Distribution of mosaic landscapes in eastern Japan. *Black* areas denote Satoyama landscapes that have a land-cover mixture of agriculture fields, secondary forests, and seminatural grasslands. Data are drawn from a "biodiversity evaluation map" (Ministry of the Environment, Japan). See extra details for the definition from the following Web site: http://www.biodic.go.jp/biodiversity/activity/policy/map/map04/index.html

abundance in fractal-like landscapes, a *landscape mismatch* in Hokkaido is likely to become a problem. In this case, areas where wildlife-friendly rice farming is effective could be restricted; thus, we should pay more attention to where we undertake such practices.

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References

Amano T, Kusumoto Y, Tokuoka Y, Yamada S, Kim EY, Yamamoto S (2008) Spatial and temporal variations in the use of rice-paddy dominated landscapes by birds in Japan. Biol Conserv 141:1704–1716

Amano T, Kusumoto Y, Okamura H, Baba YG, Hamasaki K, Tanaka K, Yamamoto S (2011) A macro-scale perspective on within-farm management: how climate and topography alter the effect of farming practices. Ecol Lett 14:1263–1272

Baba T, Sonehara N, Itoh S (2003) Vegetation change by grass cutting control on the paddy field embankment in Obasute area, Nagano Prefecture. J Fac Agric Shinshu Univ 39:23–36 (in Japanese)

Baguette M, Blanchet S, Legrand D, Stevens VM, Turlure C (2013) Individual dispersal, landscape connectivity and ecological networks. Biol Rev 88:310–326

Balmford A (1996) Extinction filters and current resilience: the significance of past selection pressures for conservation biology. Trends Ecol Evol 11:193–196

Batary P, Andras B, Kleijn D, Tscharntke T (2011) Landscape-moderated biodiversity effects of agri-environmental management: a meta-analysis. Proc R Soc B 278:1894–1902

Bianchi FA, Booij CH, Tscharntke T (2006) Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. Proc R Soc Lond 273:1715–1727

Butchart SHM, Walpole M, Collen B et al (2010) Global biodiversity: indicators of recent declines. Science 328:1164–1168

Chazdon RL, Peres CA, Dent D, Sheil D, Lugo AE, Lamb D, Stork NE, Miller SE (2009) The potential for species conservation in tropical secondary forests. Conserv Biol 87:542–548

Concepción ED, Díaz M, Kleijn D, Báldi A, Batáry P, Clough Y, Gabriel D, Herzog F, Holzschuh A, Knop E, Marshall EJP, Tscharntke T, Verhulst J (2012) Interactive effects of landscape context constrain the effectiveness of local agri-environmental management. J Appl Ecol 49:695–705

Didham RK (2011) Life after logging: strategic withdrawal from the Garden of Eden or tactical error for wilderness conservation? Biotropica 43:393–395

Dunning JB, Danielson BJ, Pulliam HR (1992) Ecological processes that affect populations in complex landscapes. Oikos 65:169–175

Elphick CS (2000) Functional equivalency between rice fields and seminatural wetland habitats. Conserv Biol 14:181–191

Fahrig L, Baudry J, Brotons L, Burel FG, Crist TO, Fuller RJ, Sirami C, Siriwardena GM, Martin J-L (2011) Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. Ecol Lett 14:101–112

FAO Statistics Division (2008) FAO, Rome

Fischer J, Brosi B, Daily GC, Ehrlich PR, Goldman R, Goldstein J, Lindenmayer DB, Manning AD, Mooney HA, Pejchar L, Ranganathan J, Tallis H (2008) Should agricultural policies encourage land sparing or wildlife-friendly farming? Front Ecol Environ 6:380–385

Fujioka M, Lane SJ (1997) The importance of changing irrigation practices in rice fields on frog populations of the Kanto plain, central Japan. Ecol Res 12:101–108

Fujioka M, Lee SD, Kurechi M, Yoshida H (2010) Bird use of rice fields in Korea and Japan. Waterbirds 33:8–29

Fujita G, Naoe S, Miyashita T (2014) Modernization of drainage systems decreases gray-faced buzzard occurrence by reducing frog densities in paddy-dominated landscapes. Landsc Ecol Eng

Fukui M (2012) Records of decrease in *Sympetrum* species population at Shizuoka Pref. Nat Insect 47:5–9 (in Japanese)

Gabriel D, Sait SM, Hodgson JA, Schmutz U, Kunin WE, Benton TG (2010) Scale matters: the impact of organic farming on biodiversity at different spatial scales. Ecol Lett 13:858–869

Gardner TA, Barlow J, Chazdon R, Ewers RM, Harvey CA, Peres CA, Sodhi NS (2009) Prospects for tropical forest biodiversity in a human-modified world. Ecol Lett 12:561–582

Green RE, Cornell SJ, Scharlemann JPW, Balmford A (2005) Farming and the fate of wild nature. Science 307:550–555

Hidaka K, Mineta T, Enomoto T (2006) Evaluation of the agricultural dependency of endangered RDB wetland plant taxa : an example of habitat records attached to wetland voucher specimens. Jpn J Conserv Ecol 11:124–132 (in Japanese)

Higashi T (2010) Population dynamics of the Japanese skimmer, *Orthetrum japonicum* (Odonata: Libellulidae), in a forest-paddy field complex. Nat Insect 45:16–19 (In Japanese)

Hodgson JA, Kunin WE, Thomas CD, Benton TG, Gabriel D (2010) Comparing organic farming and land sparing: optimizing yield and butterfly populations at a landscape scale. Ecol Lett 13:1358–1367

Hoegh-Guldberg O, Hughes L, McIntyre S, Lindenmayer DB, Parmesan C, Possingham HP, Thomas CD (2008) Assisted colonization and rapid climate change. Science 321:345–346

Kano Y, Kawaguchi Y, Yamashita T, Shimatani Y (2010) Distribution of the oriental weatherloach, *Misgurnus anguillicaudatus*, in paddy fields and its implications for conservation in Sado Island, Japan. Ichthyol Res 57:180–188

Katano O, Hosoya K, Iguchi K, Yamaguchi M, Aonuma Y, Kitano S (2003) Species diversity and abundance of freshwater fishes in irrigation ditches around rice fields. Environ Biol Fish 66:107–121

Katayama N, Amano T, Saitoh D, Miyashita T (2011) Effects of modern drainage system on the spatial distribution of loach in rice ecosystems. Aquat Conserv 21:146–154

Katayama N, Amano T, Fujita G, Higuchi H (2012) Spatial overlap between the intermediate egret *Egretta intermedia* and its aquatic prey at two spatiotemporal scales in a rice paddy landscape. Zool Stud 51:1105–1112

Katayama N, Goto T, Narushima F, Amano T, Kobori H, Miyashita T (2013) Indirect positive effects of agricultural modernization on the abundance of Japanese tree frog tadpoles in rice fields through the release from predators. Aquat Ecol 47:225–234

Kato M (2001) SATOYAMA and biodiversity conservation: SATOYAMA as important insect habitats. Glob Environ Res 5:135–149

Kato N, Yoshio M, Kobayashi R, Miyashita T (2010) Differential responses of two anuran species breeding in rice fields to landscape composition and spatial scale. Wetlands 30:1171–1179

Katoh K, Sakai S, Takahashi T (2009) Factors maintaining species diversity in *satoyama*, a traditional agricultural landscape of Japan. Biol Conserv 142:1930–1936

Kennedy CM, Lonsdorf E, Neel MC, Williams NM, Ricketts TH, Winfree R, Bommarco R, Brittain C, Burley AL, Cariveau D, Carvalheiro LG, Chacoff NP, Cunningham SA, Danforth BN, Dudenhoffer JH, Elle E, Gaines HR, Garibaldi LA, Gratton C, Holzschuh A, Isaacs R, Javorek SK, Jha S, Klein AM, Krewenka K, Mandelik Y, Mayfield MM, Morandin L, Neame LA, Otieno M, Park M, Potts SG, Rundlof M, Saez A, Steffan-Dewenter I, Taki H, Viana BF, Westphal C, Wilson JK, Greenleaf SS, Kremen C (2013) A global quantitative synthesis of local and landscape effects on wild bee pollinators in agroecosystems. Ecol Lett 16:584–599

Kikuchi E, Takagi Y, Shikano S (2012) Surveys of plankton (aquatic microorganisms) communities in rice fields. Res Bull Environ Educ Cent Miyagi Univ Educ 14:7–15 (in Japanese)

King S, Elphick CS, Guadagnin D, Taft O, Amano T (2010) Effects of landscape features on waterbird use of rice fields. Waterbirds 33:151–159

Kiritani K (2000) Integrated biodiversity management in paddy fields: shift of paradigm from IPM toward IBM. IPM Rev 5:175–183

Kiritani K, Kakiya N (1975) An analysis of the predator-prey system in the paddy field. Res Popul Ecol 17:29–38

Kleijn D, Kohler F, Baldi A, Batary P, Concepcion ED, Clough Y, Diaz M, Gabriel D, Holzschuh A, Knop E, Kovacs A, Marshall EJP, Tscharntke T, Verhulst J (2009) On the relationship between farmland biodiversity and land-use intensity in Europe. Proc R Soc B Biol Sci 276:903–909

Kleijn D, Rundlof M, Scheper J, Smith HG, Tscharntke T (2011) Does conservation on farmland contribute to halting the biodiversity decline? Trends Ecol Evol 26:474–481

Koda K (2011) Ecological studies to conserve the endangered lycaenid butterflies living in Satoyama: for recovery of *Shijimiaeoides divinus barine* (Leech) (Lepidoptera: Lycaenidae) population. Jpn J Environ Zool 22:207–219 (in Japanese)

Koji S, Nakamura A, Nakamura K (2012) Demography of the Heike firefly *Luciola lateralis* (Coleoptera: Lampyridae), a representative species of Japan's traditional agricultural landscape. J Insect Conserv 16:819–827

Kubota Z, Hayama K, Kuriyama Z (1965) Influence of pH and agricultural chemicals on the loach, *Misgurnus anguillicaudatus* (Cantor). J Shiminoseki Univ Fish 6:327–336 (in Japanese with English summary)

Kunin WE (1998) Biodiversity at the edge: a test, of the importance of spatial "mass effects" in the Rothamsted Park Grass experiments. Proc Natl Acad Sci USA 95:207–212

Lane S, Fujioka M (1998) The impact of changes in irrigation practices on the distribution of foraging egrets and herons (Ardeidae) in the rice fields of central Japan. Biol Conserv 83:221–230

Laurance WF, Camargo JLC, Luizao RCC, Laurance SG, Pimm SL, Bruna EM, Stouffer PC, Williamson GB, Benitez-Malvido J, Vasconcelos HL, Van Houtan KS, Zartman CE, Boyle SA, Didham RK, Andrade A, Lovejoy TE (2011) The fate of Amazonian forest fragments: a 32-year investigation. Biol Conserv 144:56–67

Lawler SP (2001) Rice fields as temporary wetlands: a review. Isr J Zool 47:513–528

Maeda T, Yoshida H (2009) Response of birds in rice fields to winter flooding. Jpn J Ornithol 58:55–64 (in Japanese)

Matsumura T (2008) Change of levee slope area between cultivated fields and its factor in Awaji Island. Bull Awaji Landsc Plan Horic Acad 9:27–29 (in Japanese)

McGarigal K, Cushman SA (2002) Comparative evaluation of experimental approaches to the study of habitat fragmentation effects. Ecol Appl 12:335–345

Miyashita T, Chishiki Y, Takagi SR (2012) Landscape heterogeneity at multiple spatial scales enhances spider species richness in an agricultural landscape. Popul Ecol 54:573–581

Miyashita T, Amano T, Yamakita T (2014) Effects of ecosystem diversity on species richness and ecosystem functioning and services: a general conceptualization. In: Nakano S, Yahara T, Nakashizuka T (eds) The biodiversity observation network in the Asia-Pacific region: integrative observations and assessments of Asian biodiversity. Springer, Tokyo

Mizutani S (2000) Migration of the loach to the paddy fields. Rural Environ 16:70–76 (in Japanese)

Murphy MA, Dezzani R, Pilliod DS, Storfer A (2010) Landscape genetics of high mountain frog metapopulations. Mol Ecol 19:3634–3649

Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecol Eng 56:97–106

Osawa S, Katsuno T (2001) Dispersal of brown frogs *Rana japonica* and *R. ornativentris* in the forests of the Tama Hills. Curr Herpetol 20:1–10

Phalan B, Onial M, Balmford A, Green RE (2011) Reconciling food production and biodiversity conservation: land sharing and land sparing compared. Science 333:1289–1291

Phillipsen IC, Lytle DA (2013) Aquatic insects in a sea of desert: population genetic structure is shaped by limited dispersal in a naturally fragmented landscape. Ecography 36:731–743

Pimentel D et al (1992) Conserving biological diversity in agricultural/forestry systems. Bioscience 42:354–362

Rosenzweig ML (2003) Reconciliation ecology and the future of species diversity. Oryx 37:194–205

Saitoh K, Katano O, Koizumi A (1988) Movement and spawning of several freshwater fishes in temporary waters around paddy fields. Jpn J Ecol 38:35–47 (in Japanese)

Sekiya K, Miura I, Ogata M (2012) A new frog species of the genus *Rugosa* from Sado Island, Japan (Anura, Ranidae). Zootaxa 3575:49–62

Takada MB, Kobayashi T, Yoshioka A, Takagi S, Washitani I (2013) Facilitation of ground-dwelling wolf spider predation on mirid bugs by horizontal webs built by *Tetragnatha* spiders in organic paddy fields. J Arachnol 41:31–35

Thies C, Tscharntke T (1999) Landscape structure and biological control in agroecosystems. Science 285:893–895

Tomioka K (2000) Long-term dynamics of breeding activity of two brown frogs *Rana japonica* and *R. ornativentris* in a bottomland rice paddies in the northern Kanto Plain, Japan. J Nat Hist Mus Inst Chiba 3:9–16 (in Japanese)

Tscharntke T, Steffan-Dewenter I, Kruess A, Thies C (2002) Contribution of small habitat fragments to conservation of insect communities of grassland-cropland landscapes. Ecol Appl 12:354–363

Tscharntke T, Klein AM, Kruess A, Steffan-Dewenter I, Thies C (2005) Landscape perspectives on agricultural intensification and biodiversity-ecosystem service management. Ecol Lett 8:857–874

Tscharntke T, Tylianakis JM, Rand TA, Didham RK, Fahrig L, Batáry P, Bengtsson J, Clough Y, Crist TO, Dormann CF, Ewers RM, Fründ J, Holt RD, Holzschuh A, Klein AM, Kleijn D, Kremen C, Landis DA, Laurance W, Lindenmayer D, Scherber C, Sodhi N, Steffan-Dewenter I, Thies C, Van der Putten WH, Westphal C (2012) Landscape moderation of biodiversity patterns and processes – eight hypotheses. Biol Rev 87:661–685

Tsuji M, Ushimaru A, Osawa T, Mitsuhashi H (2011) Paddy-associated frog declines via urbanization: a test of the dispersal-dependent-decline hypothesis. Landsc Urban Plan 103:318–325

Uematsu Y, Koga T, Mitsuhashi H, Ushimaru A (2010) Abandonment and intensified use of agricultural land decrease habitats of rare herbs in semi-natural grasslands. Agric Ecosyst Environ 135:304–309

Uruma H, Nishijima S, Kobayashi R, Miyashita T (2012) Effectiveness of conservation-oriented agricultural practices on amphibians inhabiting Sado Island, Japan, with a consideration of spatial structure. Jpn J Conserv Ecol 17:155–164 (in Japanese)

Usio N, Saito R, Akanuma H, Watanabe R (2015) Effectiveness of wildlife-friendly farming on aquatic macroinvertebrate diversity on Sado Island in Japan. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_7

Vos CC, Berry P, Opdam P, Baveco H, Nijhof B, O'Hanley J, Bell C, Kuipers H (2008) Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones. J Appl Ecol 45:1722–1731

Washitani I (2001) Traditional sustainable ecosystem 'Satoyama' and biodiversity crisis in Japan: conservation ecological perspective. Glob Environ Res 5:119–133

Wood C, Qiao YI, Peng LI, Ding P, Baozhong LU, Yongmei XI (2010) Implications of rice agriculture for wild birds in China. Waterbirds 33:30–43

Yamaguchi H, Umemoto S, Maenaka H (1998) Floral composition of the vegetation on levees of traditional and reconstructed paddies in Sakai city, Japan. J Weed Sci Tech 43:249–257 (in Japanese)

Yoshida M (1987) Predatory behavior of *Tetragnatha praedonia* (Araneae: Tetragnathidae). Acta Arachnol 35:57–75

Yoshio M, Kato N, Miyashita T (2009) Landscape and local scale effects on the orthopteran assemblages in the paddy agro-ecosystems on the Sado Island, Japan with implications for the habitat management for the crested ibis. Ecol Civ Eng 12:99–107 (in Japanese)

Part II
Restoring the Multifunctionality of Paddy-Dominated Landscapes

Chapter 5
Environmentally Friendly Farming in Japan: Introduction

Nisikawa Usio

(Photo by Aiko Furuya)

Abstract Rice paddy fields are a typical component of the Satoyama (human-dominated) landscape in Japan, and they have multiple functions beyond their role in rice production. However, agricultural intensification and farmland abandonment have led to the degradation of rice paddy fields in Japan. To conserve

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or restore the multiple functions of paddy fields, much attention has focused on environmentally friendly farming practices. As a guide to Part 2, this chapter summarizes representative environmentally friendly farming practices in Japan.

Keywords Multifunctionality • Wildlife-friendly farming • Labor-saving farming • Production-intensive farming • Hazard-mitigation farming • Agricultural practice

Introduction

Rice farming is among the most productive forms of agriculture in terms of its long history of cultivation (8,000–10,000 years) and the total land area covered by paddy fields (163 million hectares) (Greenland 1997; FAOSTAT 2014). In addition, rice farming has multiple functions beyond its primary role in food and fiber production, including management of natural resources, protection from natural hazards, conservation of biodiversity, and provision of aesthetic and cultural values (Table 5.1). After such multiple functions of agriculture were addressed in the Agenda 21 documents of the Rio Earth Summit in 1992 (UNCED 1992), the concept of *multifunctionality* of farmland has attracted much attention from scientists and policy makers.

Approximately 70 % of the land area of Japan is covered with forest. Farmland accounts for only 12 % of the total land surface (e-Stat 2014). Rice farming is among the major types of agriculture in Japan with rice paddy fields accounting for 6.5 % of the total land area. In 2012, rice sales were 2,029 billion yen (equivalent to 20.29 billion US dollars) (see Table 5.2), which accounted for 24 % of all sales of agricultural products in Japan.

Table 5.1 Ecosystem services provided by paddy fields

Ecosystem services	Examples
Freshwater	Water storage, stream-flow regulation, groundwater recharge, drought relief
Food, fiber, and fuel	Rice, lotus, reed, peat
Other biological products	Wildlife trade, harvestable resources (e.g., fish, crayfish, duck)
Biological regulation	Food chain support, pollination, control of invasive nonnative species
Nutrient cycling and soil fertility	Agricultural production
Atmospheric and climate regulation	Mitigation of summer air-temperature
Human health control	Water-quality improvement
Waste processing and detoxification	Denitrification, pathogen removal, and waste assimilation
Flood, storm, and erosion protection	Flood peak reduction, erosion control (shoreline and bank stabilization)
Cultural and amenity benefits	Heritage, recreation, ecotourism, education, water transport

Modified from Yoon (2009)

Table 5.2 Economic value of representative ecosystem services provided by Japanese paddy fields (1 yen = 0.01 US dollars)

Ecosystem services	Million yen
Rice production[a]	2,028,600
Flood control[b]	3,498,800
Ground water recharge[b]	1,517,000
Soil erosion prevention[b]	331,800
Landslide prevention[b]	478,200
Organic waste treatment[b]	12,300
Climate regulation[b]	8,700
Recreation[b]	2,375,800

[a]Data from Ministry of Agriculture, Forestry and Fisheries of Japan (2012a)
[b]Data from Science Council of Japan (2001)

Although rice farming is one of the major forms of agriculture in Japan, the area of cultivated rice paddies declined by 28 % from 1969 to 2012, and that of rice plantations declined by as much as 50 % in the same period (Ministry of Agriculture, Forestry and Fisheries of Japan 2012b). Many factors are responsible for the degradation of rice paddy fields in Japan, which has led to the loss of multi-functionality in these fields. Two problems are apparent: agricultural intensification and farmland abandonment. Major drivers for the degradation of rice paddy fields include the introduction of an acreage reduction program, depopulation and aging in rural communities, changes in farmland management practices over time, the introduction of large machinery, invasion by non-native species, and overuse of agrochemicals such as pesticides and chemical fertilizers (Natuhara 2013).

Implementing environmentally friendly farming is a sound approach to restore degraded paddy fields and to revitalize depopulated and aging rural communities. In this chapter, I first introduce a farming schedule for modern, conventional rice farming in central Japan. Subsequently, I summarize representative environmentally friendly farming practices in Japan. Although many ecological engineering techniques have been proposed and implemented in paddy-dominated landscapes (reviewed in Natuhara 2013), I will introduce mainly those adopted by farmers as part of direct payment schemes (equivalent to the Agri-environmental scheme in Europe) or sustainable farming activities. Finally, I introduce the overall structure of Part 2.

Rice Farming in Japan

Before addressing the main topic, I will summarize a farming schedule for modern, conventional rice agriculture in central Japan (Fig. 5.1). Rice (*Oryza sativa*) is typically cultivated once per year as a monoculture. In some regions, however, crop rotation systems including two crops are used, e.g., barley (*Hordeum vulgare*) is cultivated after the rice is harvested in autumn. In early spring, rice seeds are

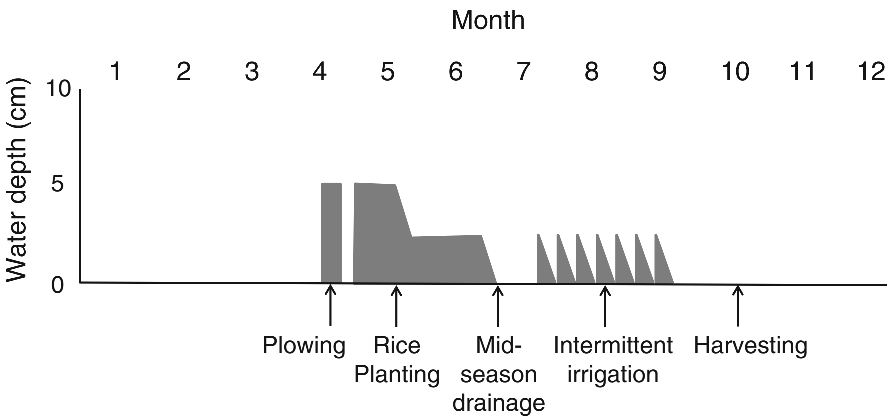

Fig. 5.1 A farming calendar for modern, conventional rice farming on Sado Island in Niigata Prefecture, Japan

sown in nursery boxes and rice seedlings are then cultivated in vinyl greenhouses. Paddy fields are flooded in early to mid-April, after which the paddy fields are tilled and puddled to make the bottoms flat. Subsequently, nursery plants are transplanted to the paddy fields. To halt tillering of the rice plants, the water in the paddy fields is drained for 10–14 days in mid-June until the bottom shows light cracks (known as mid-season drainage). During the mid-season drainage, water is kept only in narrow ditches constructed in the paddy fields and alongside the levees. After the mid-season drainage, water is supplied intermittently (intermittent irrigation) and then drained completely before harvest in autumn. Paddy fields undergo drastic fluctuations in water levels during the cultivation period.

Environmentally Friendly Farming

Environmentally friendly farming involves environmental conservation or restoration for wildlife, humans, or both. Although classifications are largely arbitrary, environmentally friendly farming in Japan can be grouped into three categories depending on the primary aim of the farming practice or the background of the researchers examining such farming. The first is *wildlife-friendly farming* with an emphasis on the conservation or restoration of paddy field biodiversity, while simultaneously maintaining farming activities. A second is *human-friendly farming*, which is largely concerned with techniques designed to reduce the burden of farming activities in depopulated and aging communities or to increase production through the simultaneous implementation of farming and aquaculture. A third is *hazard-mitigation farming*, which is intended primarily to prevent flooding and erosion in mountain or hill areas, to reduce emissions of greenhouse gases such as methane from paddy fields, or to mitigate water pollution from drainage. Note that some farming practices can be classified into more than one category.

For example, agrochemical reduction can be considered both a wildlife-friendly and a hazard-mitigation farming practice. Reducing the inputs of agrochemicals may improve the habitat quality for aquatic and semiaquatic wildlife as well as mitigate water pollution from drainage. Since most of the chapters in Part 2 report the effectiveness of representative environmentally friendly farming practices, this chapter provides an overview of these farming practices.

Wildlife-Friendly Farming

Land sparing and *land sharing* are two major frameworks for biodiversity conservation or restoration (Miyashita et al. 2015). Wildlife-friendly farming is a type of land sharing. Typical wildlife-friendly farming practices are described in the following sub-subsections.

Special Cultivation and Organic Farming

In rice farming, pesticides (i.e., insecticides, herbicides, and fungicides) and chemical fertilizers are commonly applied during the cultivation period. Efforts to reduce the use of agrochemicals typically involve 30–80 % reductions of the total agrochemical inputs compared with those of conventional farming. Rice cultivation that uses 50 % or less of the agrochemical inputs of conventional farming is referred to as *tokubetsu-saibai* [special cultivation], and rice produced under special cultivation is called *tokubetsu-saibai-mai* [specially cultivated rice] (Ministry of Agriculture, Forestry and Fisheries of Japan 2007). However, the standard amounts of agrochemicals used in conventional rice farming in Japan differ among prefectures and even among regions within the same prefecture (Ministry of Agriculture, Forestry and Fisheries of Japan 2007). In the case of Sado Island (Niigata Prefecture), the standard amount of agrochemicals used in conventional farming includes 18 active pesticide compounds (insecticides, herbicides, and fungicides) and 6 kg/10 a (1,000 m^2) of nitrogen. The amount of agrochemical reduction is often assessed by considering the combined input of pesticides and chemical fertilizers. Therefore, specially cultivated rice produced in Sado is grown using nine active pesticide compounds and nitrogen inputs of 3 kg/10 a.

Agrochemical-free farming is a type of special cultivation that employs no pesticides or chemical fertilizers throughout the entire cultivation period. Rice cultivated in an agrochemical-free environment for at least 3 years prior to and during rice cultivation is eligible for certification by the JAS (Japanese Agricultural Standards Association) (Ministry of Agriculture, Forestry and Fisheries of Japan 2012c). Once certified, the rice can be sold as *organic rice* with JAS-certified labels. In agrochemical-free or organic cultivation, farmers use manure to supply nutrients (e.g., nitrogen) to paddy soil.

The use of agrochemicals has a clear influence on rice paddy field biodiversity. Although insecticides that exhibit high fish-toxicity are now banned or restricted in most parts of Japan, modern insecticides (e.g., neonicotinoids) affect the nervous systems of invertebrates and are lethal to a range of aquatic macroinvertebrates (Hayasaka et al. 2012; Jinguji et al. 2013). The application of chemical fertilizers also affects the composition of aquatic communities (Kimura 2005). Reducing insecticide and chemical fertilizer inputs may mitigate detrimental impacts on aquatic organisms. Organic farming has been shown to enhance paddy field biodiversity, including spiders that prey on pest insects (Nakanishi et al. 2009; Tanaka and Ihara 2012). Therefore, implementing organic farming can enhance paddy field biodiversity as well as suppress agricultural pest insects through integrated biodiversity management (Kiritani 2000).

Early-Spring Flooding

In the plain areas of central Japan, farmers generally start to flood their paddy fields in early to mid-April to prepare for rice planting in early to mid-May. However, some amphibians, such as the montane brown frog (*Rana ornativentris*) and Japanese black salamander (*Hynobius nigrescens*), start spawning as early as February depending on the area (Uchiyama et al. 2002). To facilitate the reproduction of early-spawning amphibians, some regions in Japan encourage farmers to start flooding rice paddies about 1 month earlier than the usual farming schedule. Such water management is called *early-spring flooding*.

Winter Flooding

Winter flooding is generally practiced from November to February for at least 2 months excluding months with snow cover. The main aims of winter flooding practices are to provide forage habitats for wading birds, enhance aquatic macroinvertebrate diversity, suppress weeds, and promote straw decomposition (Lawler and Dritz 2005; Tajiri and Ohkawara 2013) (Fig. 5.2). Under the direct payment scheme of environmentally friendly farming managed by the Ministry of Agriculture, Forestry and Fisheries of Japan, winter flooding generally meets the program requirements if farmers flood their paddy fields with enough water to cover the stubble of postharvest rice plants. However, in the case of Sado Island in central Japan, a special type of winter flooding qualifies farmers under the Sado certification initiative when only tractor ruts are filled with rainwater. Such shallow flooding is believed to facilitate foraging of the reintroduced crested ibis (*Nipponia nippon*).

Summer Flooding

In Japan, barley is sometimes cultivated as part of crop diversification or a two-crop system. Crop diversification refers to shifting from one type of agriculture to another such as from rice to barley farming. A two-crop system refers to cultivating two different crops in a fiscal year. Depending on the region, barley is generally

Fig. 5.2 Swans (*Cygnus*) wading in winter-flooded paddy fields (Photo by Masahiro Nishizawa)

harvested in April–July, after which summer flooding is performed from July through early September. Traditionally, summer flooding has been used by farmers to suppress the growth of weeds, such as wild oat (*Avena fatua*), and to mitigate damage caused by continuous farming of the same crop. In recent years, much attention has been given to the effects of summer flooding on shorebirds (especially the suborders Charadrii and Scolopaci) and egrets (Fig. 5.3). Summer flooding has been implicated in (1) an increased abundance of macroinvertebrates that spawn and hatch within a short time [e.g., the wandering glider (*Pantala flavescens*) and Chironomidae], (2) breaking dormancy of crustaceans such as zooplankton, tadpole shrimps (Triopsidae), and fairy shrimps (Chirocephalidae), and (3) providing refuge habitats for aquatic insects in paddy fields whose habitats are lost due to mid-season drainage (Oryzanet 2010). The increase in the abundance of macroinvertebrates in turn provides food sources for migrating shorebirds and egrets (Oryzanet 2010).

Postponed Mid-season Drainage

In modern rice farming, mid-season drainage is generally performed to halt the tillering of rice plants and to harden the bottoms of paddy fields to facilitate the operation of agricultural machinery in autumn. However, mid-season drainage has been shown to have devastating effects on metamorphosing *Rana* frogs (Fig. 5.4)

Fig. 5.3 Greenshank (*Tringa nebularia*) wading in summer-flooded barley fields (Photo by Aiko Furuya)

Fig. 5.4 Tadpoles trapped in a small puddle during the mid-season drainage. In central Japan, mid-season drainage is generally employed for 10–14 days beginning in mid-June. Such water management has been shown to reduce methane emissions, while it may pose serious threats to metamorphosing amphibians

and emerging *Sympetrum* dragonflies (Aoda et al. 2013), both of which are important predators of agricultural pest insects. In the Tajima region (Hyogo Prefecture), the local governments and the Japan Agricultural Cooperatives (JA) encourage farmers to postpone the start of mid-season drainage by 2 weeks so that *Rana* frogs and *Sympetrum* dragonflies can complete metamorphosis or emergence.

Fallow Flooding

Given adjustments to rice production levels beginning in 1970, fallow fields are common in the Japanese agricultural landscape. To suppress the growth of weeds, fallow flooding is commonly implemented during fallowing. In some areas, flooded fallows are known as *biotopes*, and they provide opportunities for biodiversity conservation and public education. Flooded fallows can provide refuge or foraging habitats for a range of aquatic and semiaquatic wildlife (Fig. 5.5) because such habitats are generally flooded year-round and agrochemicals are not applied.

Fig. 5.5 Flooded fallows (also known as *biotopes*) can enhance aquatic biodiversity and suppress the growth of agricultural weeds

Fig. 5.6 Diversion ditches have traditionally been constructed to warm spring or creek water in mountain or hill areas. In recent years, much attention has been given to their function as refuge sites for aquatic animals during the mid-season drainage

Diversion Ditch Construction

In mountain or hill areas, irrigation water is usually taken directly from cold springs or creeks. In such areas, diversion ditches are constructed along the inlet of paddy fields to warm the water (Fig. 5.6) because cold water has detrimental effects on rice production. In different regions, diversion ditches are known by various local names such as *e* (Sado City, Niigata Prefecture), *soyo* (Kariwa District, Niigata Prefecture), *nurume* (Minami-azumi District, Nagano Prefecture), *hiyari* (Suo-oshima Town, Yamaguchi Prefecture), or *hiebori* (Taga District, Ibaraki Prefecture) (National Museum of Japanese History 2010). Although rarely evaluated scientifically, diversion ditches should provide refuge habitats for aquatic animals during mid-season drainage because water remains in the ditches during the drainage period.

Fishway (Fish Ladder) Implementation

In modern paddy fields, a drainage system is often constructed using concrete, and a large gap exists between the drainage system and the adjacent paddy field. Implementing a fishway between a drainage system and its adjacent paddy field

Fig. 5.7 A fishway constructed from a corrugated pipe to increase habitat connectivity between a paddy field and its adjacent drainage

increases habitat connectivity and can facilitate the migration of aquatic animals such as fish and decapod crustaceans (Sato et al. 2008; Kano et al. 2010). Fishways made of concrete or wood are costly but those made of corrugated pipes have attracted attention from farmers as an economical means to facilitate animal migration (Fig. 5.7).

Cover Cropping

Planting cover-cropping plants or green manure may minimize the use of agro-chemicals. Traditionally, Fabaceae plants have been used as cover-cropping plants in rice farming. The Chinese milk vetch (*Astragalus sinicus*) is among the most commonly used cover-cropping plant in Japanese rice farming. Planting cover-cropping plants in paddy fields increases soil fertility by providing nitrogen and suppresses weed growth via shading and the production of organic acids, thereby functioning as manure and as weed control (Ueno 2004; Asagi and Ueno 2009). Furthermore, Hidaka (1993) reported that planting Chinese milk vetch in paddy fields in winter led to increased abundance of wolf spiders (Lycosidae), a major natural enemy of agricultural pest insects. Planting cover-cropping plants on levees may also suppress weed growth. Ichihara et al. (2014) reported that planting five species of cover-cropping plant (*Eremochloa ophiuroides*, *Phyla canescens*, *Phlox subulata*, *Zoysia japonica*, and weedy vegetation dominated by *Digitaria ciliaris*) enhanced the abundance of crickets on levees, which in turn increased cricket consumption of nonnative weed (*Lolium multiflorum*) seeds. The effects of cover-cropping plants on farmland biodiversity have been reported for dry cropland in Europe (Radicetti et al. 2013), but little is known about the effects on paddy field biodiversity.

No-Till Farming

In modern rice farming, tilling is generally performed after rice harvest in autumn and/or prior to rice planting in spring so that rice stubble is plowed into the soil to facilitate the operation of rice-planting machines in the spring. Tilling is followed by soil puddling to prevent leakage of water from paddy fields. Some organic farmers use no-till farming to suppress weeds. No-till farming enhances the abundance of oligochaetes that inhabit the sediments of paddy fields (Ito et al. 2011) and thereby facilitates natural plowing through bioturbation activities of the oligochaetes.

Human-Friendly Farming

Human-friendly farming is intended for sustainable farming. Representative labor-saving and production-intensive farming practices are introduced in the following sub-subsections.

Direct Seeding

To reduce the burden of farming activities in depopulated and aging communities, the no-till V-furrow direct-seeding method was developed as an alternative to conventional rice farming methods for use in central Japan (Aichi Agricultural Research Center 2007). With the direct-seeding method, rice seeds are sown directly onto paddy fields, thereby eliminating the use of insecticides commonly applied to seedling boxes employed in conventional farming. Another feature of the direct seeding method is that rice seeds are sown under dry conditions. The dry conditions are maintained until the rice plants reach a certain height after which the paddy fields are flooded continuously until early September. Paddy fields that are cultivated using the direct seeding method have a delayed and long-lasting irrigation period relative to conventional rice paddies leading to enhanced diversity of large aquatic insects (Watanabe et al. 2013). The area of land on which the direct seeding method has been implemented increased rapidly from the late 1990s in Aichi Prefecture. In the 2010 fiscal year, the technique was adopted in 16 prefectures across the country (Hayashi 2011).

Rice–Fish Culture

Rice–fish culture is the simultaneous culturing of fish and rice, and has a history of more than 1,700 years of use in China (Mackay 1995). In Japan, the Saku Region (Nagano Prefecture) was probably among the first locations to implement rice–fish culture. Since rice–fish culture has been practiced for more than 170 years in the Saku Region (Tansuigyo-kenkyukai 1984), it is considered to be a traditional farming practice in the area.

In rice–fish culture, fish act as natural fertilizers, herbicides, and insecticides. Direct consumption and bioturbation by fish suppress weed growth while fish predation reduces the abundance of agricultural pest insects. At the end of the rice cultivation period, both fish and rice are harvested for human consumption. Similar culture techniques have been reported using crayfish in the southern United States (McClaine and Romaire 2004) or ducks in Japan (Hossain et al. 1992).

Hazard-Mitigation Farming

Implementing hazard-mitigation farming is expected to reduce environmental impacts of regional to global environmental change or degradation. Flooding (often accompanied by landslides) is a major catastrophic event in mountain areas of Japan. Therefore, much attention has been given to farming practices that actively mitigate flooding hazards in mountain areas. For atmospheric and water pollution, greenhouse gas emission (e.g., CO_2, CH_4, and N_2O), acidic gas emission (e.g., NO_X, SO_X, and NH_3), and nutrient load (e.g., TN and TP) are considered major environmental burdens. Life cycle assessment (LCA) is commonly used to assess the overall impacts of atmospheric and water pollution from farming activities (reviewed in Masuda 2006). In this sub-subsection, flooding-, greenhouse gas emission-, and water pollution-mitigation farming practices are briefly overviewed.

Paddy Field Dams

Paddy fields have an innate flood mitigation function (Table 5.1). The water storage capacity of Japanese paddy fields has been estimated to be 4.4 billion m^3 (Science Council of Japan 2001). Based on this estimate, the estimated cost for the construction of dams with equivalent storage capacity is approximately 3,499 billion yen (Table 5.2).

In Japan, farming populations have declined dramatically in recent decades. Consequently, many paddy fields in rural areas where the risk of landslides is of high concern have been abandoned or consolidated. In addition, global warming increases the risk of heavy and unusual rainfall events. To mitigate flooding hazards, a runoff control device was introduced into paddy fields of Kamihayashi Village (Niigata Prefecture) in central Japan (Yoshikawa et al. 2010). Such an active flood-mitigation system is called a *paddy field dam*.

Greenhouse Gas Emission-Mitigation Farming

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) contribute 60, 15, and 5 %, respectively, to the global anthropogenic greenhouse effect (Rohde 1990). Although direct estimates of greenhouse gas emissions are controversial, paddy fields are known to emit tremendous amounts of methane that contribute to the acceleration of global warming (Donald 2004). The emission of methane from soil is promoted significantly by anaerobic conditions. Draining practices such as mid-season drainage and no-till farming create aerobic conditions in the soil, thereby reducing methane emissions (Yagi et al. 1996; Harada et al. 2007). In a 2-year study of nine Japanese regions, Itoh et al. (2011) demonstrated that prolonging mid-season drainage by about 1 week suppressed methane emission by 30 % on average compared with that from conventionally managed paddy fields. In addition, many other techniques have been developed to reduce methane emission such as the addition of organic amendments, use of sulfate-rich fertilizers, and selection of appropriate cultivars (Donald 2004). Shiga Prefecture in western Japan included prolonged mid-season drainage (by 1 week) as part of the direct payment scheme for the regional rice certification initiative (Shiga Prefecture 2014).

Water Pollution-Mitigation Farming

Owing to applications of pesticides and chemical fertilizers, non-point-source pollution from farmland is among the major sources of water pollution in the form of agricultural runoff and drainage (Vu et al. 2006; Phong et al. 2010). Farming practices that reduce or minimize the input of agrochemicals (e.g., special cultivation and cover cropping) and those that consider integrated biodiversity management help to mitigate water pollution from paddy fields (Shiga Prefecture and Kyoto Prefecture 2012). Additionally, Vu et al. (2006) recommend implementing high drainage gates in paddy fields to hold excess water during significant rainfall events and increasing the water-holding period to at least 10 days (rather than the typical 2–3 day period) after pesticide applications.

Structure of Part 2

In Japan, ecological restoration is often promoted using charismatic wildlife as icons. In some areas, reintroduced wildlife species such as the Oriental white stork (*Ciconia boyciana*) in Toyooka and the crested ibis (*Nipponia nippon*) in Sado are used as icons for farmland restoration. In North America and Oceania, wildlife species are typically reintroduced in remote areas such as islands or national parks with the aim of restoring threatened or locally exterminated wildlife species or the food chains associated with the reintroduced species (Fischer and Lindenmayer 2000; Kauffman et al. 2010). In contrast, in Japan, the primary aims of reintroduction programs are to restore degraded paddy field biodiversity and to revitalize depopulated and aging human communities. Thus, the two reintroduced bird species play important roles as iconic species for both the ecosystem and human aspects of ecological restoration. Kato (2015) introduces the current status and future directions of reintroduction or *ex situ* conservation programs in Japan.

The use of wildlife-friendly farming is a sound approach to restore degraded paddy fields and to revitalize rural communities. In Japan, local governments and the Ministry of Agriculture, Forestry and Fisheries of Japan provide economic incentives to farmers in return for implementing wildlife-friendly farming. Using the crested ibis and Oriental white stork as examples of iconic species, Usio et al. (2015) and Naito et al. (2015), respectively, show the effectiveness of wildlife-friendly farming practices on paddy field biodiversity. The Toyooka and Sado regions lead in the adoption of social-ecological restoration programs because the iconic birds have high economic value for both the tourism and farming industries.

Given that the sustainability of rice farming is a major concern in Japan, some areas implement human-friendly farming. Labor-saving farming is a sound means to sustain farming activities in depopulated and aging communities in rural areas. Koji et al. (2015) introduce the no-till V-furrow direct seeding method, which was developed primarily to reduce the burden of farming activities in rural areas. By contrast, rice–fish culture is labor-intensive, but implementing such simultaneous culture enables one to earn a high income from farming and aquaculture. Ohtsuka (2015) introduce rice–fish culture in the Lake Biwa basin and Koseki (2015) summarizes the multifunctionality of such culture. Although direct seeding practices and rice–fish culture have been adopted to sustain primary industries in depopulated and aging communities in rural Japan, evaluations of their effectiveness in fostering paddy field biodiversity are increasingly appreciated by policy makers and conservationists. The respective chapters by Ohtsuka (2015) and Koji et al. (2015) investigate the effect of rice–fish culture and the direct seeding method on paddy field biodiversity.

Based on economic analysis, the greatest benefit to the ecosystem provided by paddy fields is flood control through the regulation of hydrological processes (Table 5.2). Yoshikawa (2015) shows how paddy fields can be used as quasi-natural dams to mitigate flood hazards in flood-prone areas in central Japan.

References

Aichi Agricultural Research Center (2007) Manual for the no-till V-furrow direct-seeding cultivation. Nougyou-no-shingijyutu, vol 74, 4th edn. Aichi Prefecture (in Japanese)

Aoda T, Katano U, Toyama K, Jinguji H (2013) Assessment of paddy environment using emergence husks of red-dragonflies with civic participation. Bull Fac Agric Niigata Univ 65:131–135 (in Japanese with English abstract)

Asagi N, Ueno H (2009) Nitrogen dynamics in paddy soil applied with various ^{15}N-labelled green manures. Plant Soil 322:251–262

Donald PF (2004) Biodiversity impacts of some agricultural commodity production systems. Conserv Biol 18:17–37

e-Stat (2014) Portal site of official statistics of Japan. Available at: http://www.e-stat.go.jp/. Accessed 11 Mar 2014

FAOSTAT (2014) FAO statistical database. Available at: http://faostat3.fao.org/. Accessed 11 Mar 2014

Fischer J, Lindenmayer DB (2000) An assessment of the published results of animal relocations. Biol Conserv 96:1–11

Greenland DJ (1997) The sustainability of rice farming. CAB International Publishing, Wallingford

Harada H, Kobayashi H, Shindo H (2007) Reduction in greenhouse gas emissions by no-tilling rice cultivation in Hachirogata polder, northern Japan: life-cycle inventory analysis. Soil Sci Plant Nutr 53:668–677

Hayasaka D, Korenaga T, Suzuki K, Saito F, Sanchez-Bayo F, Goka K (2012) Cumulative ecological impacts of two successive annual treatments of imidacloprid and fipronil on aquatic communities of paddy mesocosms. Ecotoxicol Environ Saf 80:355–362

Hayashi M (2011) The no-till V-furrow direct-seeding cultivation. Nougyou-gijyutsu-taikei, Sakumotsu-hen 2–1: Gi 361–367. Nousan-gyoson-bunka-kyoukai, Tokyo (in Japanese)

Hidaka K (1993) Farming systems for rice cultivation which promote the regulation of pest populations by natural enemies: planthopper management in traditional, intensive farming and LISA rice cultivation in Japan, Extension Bulletin, 374. ASPAC Food and Fertilizer Technology Center, Taipei, pp 1–15

Hossain ST, Sugimoto H, Ahmed GJUA, Islam MR (1992) Effect of integrated rice-duck farming on rice yield, farm productivity, and rice-provisioning ability of farmers. Asian J Agric Dev 2:79–86

Ichihara M, Matsuno K, Inagaki H, Saiki C, Mizumoto S, Yamaguchi S, Yamashita M, Sawada H (2014) Creation of paddy levees to enhance the ecosystem service of weed seed predation by crickets. Landsc Ecol Eng. doi:10.1007/s11355-014-0254-y

Ito T, Kawase R, Hara K, Kon C (2011) Ecology and function of aquatic oligocheates in winter-flooded rice fields with organic farming. Soil Microorg 65:94–99 (in Japanese)

Itoh M, Sudo S, Mori S, Saito H, Yoshida T, Shiratori Y, Suga S, Yoshikawa N, Suzue Y, Mizukami H, Mochida T, Yagi K (2011) Mitigation of methane emissions from paddy fields by prolonging midseason drainage. Agric Ecosyst Environ 141:359–372

Jinguji H, Thuyet DQ, Ueda T, Watanabe H (2013) Effect of imidacloprid and fipronil pesticide application on *Sympetrum infuscatum* (Libellulidae: Odonata) larvae. Paddy Water Environ 11:277–284

Kano Y, Kawaguchi Y, Yamashita T, Shimatani Y (2010) Distribution of the oriental weatherloach, *Misgurnus anguillicaudatus*, in paddy fields and its implications for conservation in Sado Island, Japan. Ichthyol Res 57:180–188

Kato M (2015) Endangered species in Japan: ex situ conservation approaches and reintroduction in the wild. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_6

Kauffman MJ, Brodie JF, Jules ES (2010) Are wolves saving Yellowstone's aspen? A landscape-level test of a behaviorally mediated trophic cascade. Ecology 91:2742–2755

Kimura M (2005) Populations, community composition and biomass of aquatic organisms in the floodwater of rice fields and effects of field management. Soil Sci Plant Nutr 51:159–181

Kiritani K (2000) Integrated biodiversity management in paddy fields: shift of paradigm from IPM toward IBM. Integr Pest Manag Rev 5:175–183

Kobayashi R (2015) Sado wrinkled frog: an alternative symbol for wildlife-friendly farming on Sado Island? In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_8

Koji S, Ito K, Akaishi D, Watanabe K, Nomura S, Utsunomiya D, Pei H, Tuno N, Hidaka K, Nakamura K (2015) Responses of aquatic insect, terrestrial arthropod, and plant biodiversity to the V-furrow direct seeding management in rice fields. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_12

Koseki Y (2015) Rice-fish culture: the contemporary significance of a traditional practice. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs, Springer, Tokyo. doi:10.1007/978-4-431-55330-4_11

Lawler SP, Dritz DA (2005) Straw and winter flooding benefit mosquitoes and other insects in a rice agroecosystem. Ecol Appl 15:2052–2059

Mackay KT (1995) Rice–fish culture in China. International Development Research Centre, Ottawa

Ministry of Agriculture, Forestry and Fisheries of Japan (2007) Guidelines on labelling of specially cultivated agriculture products. Available at: http://www.maff.go.jp/j/jas/jas_kikaku/tokusai_a.html. Accessed 11 Mar 2014 (in Japanese)

Ministry of Agriculture, Forestry and Fisheries of Japan (2012a) Statistics for agricultural production rate. Available at: http://www.maff.go.jp/j/tokei/kouhyou/nougyou_sansyutu/index.html. Accessed 11 Mar 2014 (in Japanese)

Ministry of Agriculture, Forestry and Fisheries of Japan (2012b) Statistics for crop return. Available at: http://www.maff.go.jp/j/tokei/kouhyou/sakumotu/sakkyou_kome/index.html. Accessed 11 Mar 2014 (in Japanese)

Ministry of Agriculture, Forestry and Fisheries of Japan (2012c) JAS guidelines for organic agricultural products. Available at: http://www.maff.go.jp/j/jas/jas_kikaku/yuuki.html. Accessed 11 Mar 2014 (in Japanese)

Masuda K (2006) LCA (life cycle assessment) research trend on the agricultural sector in Japan. Rev Agric Econ 62:99–115 (in Japanese)

McClaine WR, Romaire RP (2004) Crawfish culture: a Louisiana aquaculture success story. World Aquacult 35:31–35

Miyashita T, Yamanaka M, Tsutsui MH (2015) Distribution and abundance of organisms in paddy-dominated landscapes with implications for wildlife-friendly farming. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_4

Naito K, Sagawa S, Ohsako Y (2015) Using the oriental white stork as an indicator species for farmland restoration. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_9

Nakanishi K, Tawa K, Kanbara B, Noma N, Sawada H (2009) Comparisons of macro-aquatic animal communities among paddy fields under different cultivation management systems. Jpn J Environ Entomol Zool 20:103–114 (in Japanese with English abstract)

National Museum of Japanese History (2010) A lexicon of Japanese folkloric expressions. Available at: http://www.rekihaku.ac.jp. Accessed 11 Mar 2014

Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecol Eng 56:97–106

Ohtsuka T (2015) Nursery grounds for round crucian carp, *Carassius auratus grandoculis*, in rice paddies around Lake Biwa. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_10

Oryzanet (2010) Summary report on the effectiveness of summer flooding on biodiversity. Oryzanet, Koshigaya, Japan (in Japanese)

Phong TK, Yoshino K, Hiramatsu K, Harada M, Inoue T (2010) Pesticide discharge and water management in a paddy catchment in Japan. Paddy Water Environ 8:361–369

Radicetti E, Mancinelli R, Campiglia E (2013) Impact of managing cover crop residues on the floristic composition and species diversity of the weed community of pepper crop (*Capsicum annuum* L.). Crop Prot 44:109–119

Rohde H (1990) A comparison of the contribution of various gases to the greenhouse effect. Science 248:1217–1219

Sato T, Sato M, Inagaki M, Sato T, Anjitu C, Tsuchida K, Misawa S (2008) Ascending migration of loach *Misgurnus anguillicaudatus* affected by water management practices of paddy fields and installation conditions of corrugated pipes as water fishways to paddy fields. J Rural Plan 4:434–441 (in Japanese)

Science Council of Japan (2001) Evaluating the multi-functions of agriculture and forests related to the global environment and human beings. 2001 report in response to an inquiry from the Minister of Agriculture, Forestry and Fisheries, Science Council of Japan (in Japanese)

Shiga Prefecture (2014) Guidelines for the direct payment scheme for environmentally friendly agriculture. Available at: http://www.pref.shiga.lg.jp/g/kodawari/kodawarishien.html. Accessed 29 Apr 2014 (in Japanese)

Shiga Prefecture, Kyoto Prefecture (2012) Lake Biwa water quality preservation plan, 6th term. Available at: http://www.pref.kyoto.jp/suishitu/1333588400294.html. Accessed 30 Apr 2014 (in Japanese)

Tajiri H, Ohkawara K (2013) The effects of flooding and plowing on foraging site selection by wintering dabbling ducks in rice fields. Ornithol Sci 12:127–136

Tanaka K, Ihara F (2012) Biodiversity research for the development of indicator organisms in environment-preserving agriculture. In: Nakano S, Yahara T, Nakashizuka T (eds) The biodiversity observation network in the Asia-Pacific region: toward further development of monitoring, Ecological research monographs. Springer, Tokyo, pp 375–385

Tansuigyo-kenkyukai (1984) The history of Saku carp. Daiichi Houki Shuppan, Nagano (in Japanese)

Uchiyama R, Maeda N, Numata K, Seki S (2002) A photographic guide: amphibians and reptiles in Japan. Heibonsha, Tokyo (in Japanese)

Ueno H (2004) Use of cover crops in lowland rice cultivation. Jpn J Farm Work Res 39:165–170 (in Japanese)

UNCED (1992) Agenda 21 – an action plan for the next century. United Nations conference on environment and development, New York

Usio N, Saito R, Akanuma H, Watanabe R (2015) Effectiveness of wildlife-friendly farming on aquatic macroinvertebrate diversity on Sado Island in Japan. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_7

Vu SH, Ishihara S, Watanabe H (2006) Exposure risk assessment and evaluation of the best management practice for controlling pesticide runoff from paddy fields. Part 1: Paddy watershed monitoring. Pest Manag Sci 62:1193–1206

Watanabe K, Koji S, Hidaka K, Nakamura K (2013) Abundance, diversity, and seasonal population dynamics of aquatic Coleoptera and Heteroptera in rice fields: effects of direct seeding management. Environ Entomol 42:841–850

Yagi K, Tsuruta H, Kanda K, Minami K (1996) Effect of water management on methane emission from a Japanese rice paddy field: automated methane monitoring. Glob Biogeochem Cycle 10:255–267

Yoon CG (2009) Wise use of paddy rice fields to partially compensate for the loss of natural wetlands. Paddy Water Environ 7:357–366

Yoshikawa N (2015) Can paddy fields mitigate flood disaster? Possible use and technical aspects of the Paddy Field Dam. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_13

Yoshikawa N, Nagao N, Misawa S (2010) Evaluation of the flood mitigation effect of a Paddy Field Dam project. Agric Water Manag 97:259–270

Chapter 6
Column: Endangered Species in Japan: Ex Situ Conservation Approaches and Reintroduction in the Wild

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Keywords Ex situ conservation • Reintroduction in the wild • Japanese crested ibises • Tsushima leopard cats • Law for the Conservation of Endangered species of Wild Fauna and Flora • The Japanese Red List

Wildlife in Japan: Current Conditions and Conservation

A diverse range of fauna and flora inhabit the 38 million hectares that form Japan's land area. It is notable that a large share of these species is endemic to the country, living only in Japan. Approximately 40 % of the land-dwelling mammals and vascular plants, 60 % of the reptiles, and 80 % of amphibians living in Japan are endemic to Japan.

In 1991, the Ministry of the Environment published the Red List of endangered wildlife in Japan, and this list has been updated at regular intervals, and thus the Ministry closely tracks the status of wildlife in the country.

The fourth and most recent edition of the Red List, published in 2012–2013, lists 3,597 endangered species across ten taxonomic groups. This represents an increase of 442 species from the third edition of the Red List, which was published in 2006–2007. The wildlife in Japan is in crisis.

In Japan, there are systems and concrete approaches to protect domestic endangered species designated by the *Law for the Conservation of Endangered Species of Wild Fauna and Flora*. Conservation programs for some of the above species are implemented and taken into force. At present (as of 2013) there were conservation programs in place for 49 species, including the Japanese crested ibis (*Nipponia nippon*), Tsushima leopard cat (*Prionailurus bengalensis euptilurus*), grouse (*Lagopus muta japonica*), and Blakiston's fish owl (*Ketupa blakistoni blakistoni*).

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Ex Situ Conservation and Reintroduction in the Wild

It is typical to protect endangered species by means of *in situ conservation*, the way of conserving the number of endangered wild fauna and flora living in their natural habitat. Important in situ measures include prohibition of hunting and development in the habitat, identifying the reasons for population decline, and trying to improve the habitats for endangered species. However, in reality, population can decline for a variety of reasons, and it is not easy to determine and remove the actual cause; it often takes a great deal of time. Thus, an effective method of avoiding extinction for some species in crisis is to preserve a portion of those species in a safe facility outside their natural habitat, raise them, and thus increase the number of surviving animals. This is known as *ex situ conservation*. Ex situ conservation may be used to help the population proliferate within its habitat, especially if the habitat or living conditions have worsened. It may also be used to temporarily conserve some species where they continued existence within their natural habitats are threatened.

Ex situ conservation includes when some threatened species are raised or cultivated in zoos, aquariums, or botanical gardens. At present there are increasing needs for endangered species to be protected by an approach that employs both in situ (within their habitat) and ex situ (outside their habitat) conservation methods, which are considered equally indispensable, like two wheels on a cart.

The Ministry of the Environment is engaged in some ex situ conservation programs such as for Japanese crested ibises, Tsushima leopard cats, and Okinawa rails; a number of other entities are also involved in conservation efforts. The Japan Association of Botanical Gardens is conserving over half of the plant species listed in the Ministry of the Environment's Red List. Members of the Japanese Association of Zoos and Aquariums have established successful artificial breeding programs in various facilities across the nation. There are also many examples of local governments and NPOs leading approaches across the country.

The Ministry of the Environment has established the *Basic Policy for Ex-situ Conservation of Endangered Species of Wild Fauna and Flora in Japan* (January 2009) which sets out what sort of planning should be involved and what areas require particular attention when engaging in ex situ conservation. It specifies the roles of the key entities responsible for ex situ conservation efforts: the Ministry of the Environment, the Japanese Association of Zoos and Aquariums, and the Japan Association of Botanical Gardens. The Ministry of the Environment also expresses hope that other entities will be able to take more appropriate measures when engaged in their own ex situ conservation efforts by following the principles outlined in the policy.

To gather knowledge about the effects of specific approaches, the Ministry of the Environment conducted 15 model projects of ex situ conservation of endangered species during the 5 year period 2008–2012 and has collected and published the outcomes. Based on the results, the Ministry of the Environment also created and released a manual of planning methods for ex situ conservation.

Returning species reared in captivity to their habitat both helps to increase populations and garners additional benefits. In the cases of Oriental white storks and Japanese crested ibis, for example, reintroduced species in the wild have been highly beneficial to society as well, revitalizing local culture and energizing local society. However, there are also risks associated with these approaches, and some might damage the local ecosystem. For example, returned species will affect the food chain and pathogens or disease-carrying parasites may be unwittingly introduced when the target species is returned to its habitat. It is thus necessary to take a cautious approach under the guidance of experts.

The Ministry of the Environment has also formulated a *Basic Concept on Returning Endangered Species of Wild Plants and Animals to the Wild* (March 2011). This outlines what to consider and how best to proceed when planning and implementing a return of species to the wild; these guidelines apply to all species. It is essential for all entities and parties involved in a project of returning species to the wild to look, in advance, at the necessity and feasibility of doing so. Based on the result of such consideration in advance, Execution Plans for Returning Endangered Species to the Wild should be developed at first and after that implementation of the entire reintroduction process, from returning the animals to the wild to confirming self-supporting should be carried out in concert with in situ conservation efforts.

Ex Situ Conservation Projects of the Ministry of the Environment

We introduce two cases in which the Ministry of the Environment has spearheaded projects: that of the Japanese crested ibis and that of the Tsushima leopard cat.

The Conservation Program for the Japanese Crested Ibis

The Japanese crested ibis was designated as a special natural monument of Japan in 1952, listed as a designated national endangered species under the Law for the Conservation of Endangered species of Wild Fauna and Flora in 1993, and the conservation programs defined by the law was formulated in the same year. The Ministry of the Environment's Red List now lists it as the category of extinct in the wild (EW).

In ancient times, the Japanese crested ibis was seen all over Japan, to the extent that it was considered a harmful animal for damaging rice paddies. From the latter half of the eighteenth century, it was subject to overhunting for its meat and beautiful plumage, and the deforestation of its breeding areas also took its toll; as a result, the population declined rapidly. In the 1950s, with a population in the wild under 20 animals, it was on the verge of extinction. In 1981, when five birds were trapped in Sado for artificial breeding purposes, it became extinct in the wild. The last bird in captivity died in 2003; its death signaled the extinction of the Japanese crested ibis born in Japan.

Independently, the Ministry has been returning Japanese crested ibises to the wild. It started a breeding program in 1999 with a mating pair donated by China. Since 1999, China has donated a further three birds over two occasions; from this founding population of five birds, the breeding program has continued and, as a result, there were 212 birds in captivity (mainly at the Sado Toki Conservation Center) at the end of July 2013. Starting in September 2008, releases were conducted on Sado Island, Niigata Prefecture on eight occasions; as of July 2013, there were 85 Japanese crested ibises in the wild (Figs. 6.1 and 6.2). This total included 12 that hatched in the wild in the breeding seasons of 2012 and 2013. One milestone has been reached on the way to reintroduce the once-extinct species in the wild, and it has entered a new phase. The hatchings in the wild represented the first in 36 years (since 1976), and were a big step towards reintroduction the species in the wild.

In the surrounding rural areas, measures to conserve the wetland environment where the ibises forage and the forests that contain the tall trees where they build their nests are progressing. In Sado City, Niigata Prefecture, farmers are adopting environmentally friendly farming to allow the ibises and the animals they prey on to

Fig. 6.1 Adult and first chick of Japanese crested ibis (*Nipponia nippon*) to be hatched in the wild in 2012

Fig. 6.2 Released Japanese crested ibises looking for food in a rice paddy

thrive. Farmers reduce the usage of pesticides and chemical fertilizers; conduct biodiversity surveys twice a year; and build fishways or diversion ditches alongside the rice paddies. Certified rice paddies now encompass more than 20 % of the entire rice paddy areas in Sado City (around 6,000 ha). The certified ibis-friendly rice is sold in major supermarkets.

Artificial breeding alone is not enough to reintroduce a once-extinct species in the wild; it is essential to also restore the natural habitat that will enable the species to survive in the wild. To this end, the understanding and cooperation of the local residents is important; long-term efforts on this approach are proceeding well.

The Conservation Program for the Tsushima Leopard Cat

The Tsushima leopard cat is a subspecies of the Bengal wildcat *(P. bengalensis)*, which is widely distributed in Southeast Asia, throughout China and on the Korean peninsula, but in Japan is found only in Tsushima Island, Nagasaki Prefecture (Fig. 6.3). In 1971, it was designated as a national natural monument, and listed in 1994 as a designated national endangered species under the Law for the Conservation of Endangered species of Wild Fauna and Flora. In 1995, conservation efforts began under the conservation programs defined by the law. In the Ministry of the Environment's Red List, it is listed in the category of an endangered species IA (CR): *extremely high risk of extinction in the wild.*

Fig. 6.3 The Tsushima leopard cat (*Prionailurus bengalensis euptilurus*)

Tsushima Islands divided into Kamijima in the north and Shimojima in the south. The Tsushima leopard cat is thought to be widely distributed through the entire island until the 1960s. However, in surveys performed during the 1980s, the cat was still found throughout Kamijima, but in Shimojima its habitats had either shrunk or become fragmented. Since then, the population appears to have been declining; recent surveys in the 2010s have estimated the number of adults about at most 100 animals and indicated that the numbers of adults were flat or slightly down compared with those of a decade ago.

The reduction in suitable natural habitat is the first possible reason for the decline in numbers. The home range of Tsushima leopard cat is very large, encompassing paddies, grasslands, and forests. The Tsushima leopard cat needs a surrounding where the rice paddies, fields, and grasslands in which it hunts are contiguous. However, in recent years, road and river maintenance and deforestation, as well as the establishment of cedar and the Japanese cypress plantations, have changed and destroyed the rural environment. The quality of the habitat has deteriorated, and areas with a suitable environment have shrunk.

Traffic accidents are another major factor. From 1992, when statistics began to be collected, to April 30, 2013, the number have reached 75 (including 66 deaths) of Tsushima leopard cats involved in traffic accidents. With a new record of 15 cases, including 13 deaths, 2012 was a terribly tragic year. When healthy individuals capable of breeding are lost by traffic accidents from the population, this threatens the Tsushima leopard cat. Other possible threats include the risk of disease transmission from domestic cats and predation by wild dogs.

While the habitat in Shimojima has accelerated to shrink, and the collection of accurate information was interrupted from 1984, there has been evidence of habitation from 2007, after a 23-year interval. However, since then we can get very little new information; the population in Shimojima is very likely to be tiny. Establishing the method to enable an ex situ increase in numbers through captive breeding of the population, with an eye on ultimate reintroduction to the wild, has become a matter of urgency.

One of the measures to avoid the extinction of the Tsushima leopard cat is a combination of in situ conservation and a captive breeding program as ex situ conservation; such efforts began in 1996. To avoid extinction of wild population of the Tsushima leopard cat which is small at present in number, 32 cats are kept in nine zoos nationwide (as of July 2013), thanks to the cooperation of the Japanese Association of Zoos and Aquariums. The populations in captivity play a number of important roles. They ensure that the species will not be entirely lost; they can help to bolster the wild population; they allow the collection and analysis of scientific data; and they are used in nationwide public awareness campaigns. All of these are important to the conservation effort. Some Tsushima leopard cats have been smoothly bred and raised in captivity, but it is not succeeded in these 4 years from 2010. Therefore, it is too early to conclude that the method to breed successive generations in captivity is sufficiently developed. More efforts are needed in this regard.

The Ministry of the Environment is planning the next steps. It has built a large outdoor cage that mimics the open air habitat of Shimojima. It plans to conduct surveys and investigations as well as to develop systems aimed at establishing method that would enable reintroduction of the species in the wild. If conducted, this would be the first time that a mammal is reintroduced in the wild in Japan. Because this approach is without precedent, it is likely to be a challenging task in many respects. Local governments, experts, NPOs, and local communities are cooperating by improving the surrounding habitat and monitoring activities.

The habitat of Tsushima leopard cat often overlaps with living area of human beings, and its suitable habitat is shrinking with the destruction of the countryside. Many traffic accidents, which shrink the population of Tsushima leopard cat, occur in populated areas of Tsushima. Also, around 90 % of the land in Tsushima is privately owned. Then, for further conservation of the Tsushima leopard cat, it will be indispensable that the Tsushima citizens understand, cooperate with and participate in conservation activities.

To advance conservation efforts of the Tsushima leopard cat, it is necessary to review the present state of the regional society and promote economic activity harmonized with conservation of the natural environment.

The Tsushima leopard cat is a symbol of natural environment in Tsushima. If this natural environment in Tsushima as a whole is healthy, the Tsushima leopard cat will be able to live there comfortably. Also, the abundant natural environment is beneficial to ecosystems, e.g. enrichment of human life, and the safe and comfortable surroundings cannot exist without it. Awareness of the value of the surrounding where the Tsushima leopard cat, too, can live in security should encourage the local citizens to become involved in conservation. Measures to conserve the Tsushima leopard cat will be promoted continuously in future with the idea that it is important to create the regional society where the Tsushima leopard cat can live in harmony with human beings.

Chapter 7
Effectiveness of Wildlife-Friendly Farming on Aquatic Macroinvertebrate Diversity on Sado Island in Japan

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Abstract Paddy fields are important as alternative wetland habitats for a range of aquatic and semi-aquatic wildlife that once inhabited floodplain habitats. However, depopulation and aging in rural communities have led to the loss of biodiversity across rural areas of Japan. In Japan, wildlife-friendly farming is typically implemented using charismatic wildlife as an icon, and much attention has been given as a means for restoring paddy field biodiversity. Sado Island in central Japan is among the leading areas for such wildlife-friendly farming in terms of the implemented area. Nevertheless, scientific evaluation is largely lacking for the effectiveness of wildlife-friendly farming on paddy field biodiversity. Using four aquatic macroinvertebrate taxa as indicator groups, we surveyed over 300 paddy fields in winter and summer across Sado Island. In winter, although most indicator groups were significantly associated with the percentage of water coverage in paddy fields, winter flooding had limited effects on aquatic macroinvertebrate abundance or richness, because of large variations in water coverage among paddy fields. In contrast, implementing diversion ditches provided additional habitats for aquatic macroinvertebrates that prefer deep-water habitats, resulting in the separation of macroinvertebrate composition between paddy fields and their adjacent ditches in both winter and summer. Furthermore, agrochemical reduction and fallow flooding were effective in enhancing aquatic macroinvertebrate abundance and richness in summer. Overall, diverse practices of wildlife-friendly farming contributed to the enhancement of aquatic macroinvertebrate diversity on Sado Island.

Keywords Environmentally friendly farming • Paddy field • Rice agriculture • Biodiversity • GIAHS • Ecological restoration • Benthic macroinvertebrate

Introduction

In many lowland areas of Monsoon Asia, natural wetlands have been completely transformed into paddy fields (Donald 2004; Elphick 2000). In such areas, paddy fields are known to serve as alternative wetland habitats, providing refuge and foraging areas for a range of aquatic wildlife that once inhabited natural wetland habitats (Fujioka et al. 2010; Mukai et al. 2005). Owing to high fluctuations in water permanence, paddy fields are generally inhabited or visited by species with a high dispersal rate (e.g., opportunistic species) or those with high resistance to disturbance. Nevertheless, over 5,000 wildlife species, such as birds, amphibians, fish, invertebrates, plants, fungi and viruses have been recorded in or around paddy fields, including red list species (Kiritani 2010). However, biodiversity in human-dominated wetland habitats is threatened in many Asian countries, because of the overuse of agrochemicals (i.e., herbicides, insecticides, fungicides and chemical fertilizers), land consolidation, invasion by nonnative species and changes in management styles over time (Natuhara 2013). Thus, paddy fields that were initially created for rice production are now widely recognized as high-value conservation areas for aquatic and semi-aquatic wildlife (Elphick 2000; Natuhara 2013).

In Japan, the role of paddy fields as alternative wetland habitats has led to considerable attention being given to their restoration, with the implementation of wildlife-friendly farming (Natuhara 2013). Typical wildlife-friendly farming practices include the reduction or omission of agrochemicals, creation of non-crop habitats within or adjacent to paddy fields, or implementation of winter flooding. In addition, wildlife-friendly farming is typically implemented using charismatic wildlife as an icon, such as the crested ibis (*Nipponia nippon*), Oriental white stork (*Ciconia boyciana*), or Japanese medaka (*Oryzias*) (Ministry of Agriculture, Forestry and Fisheries of Japan 2010). Biomonitoring has been introduced in many parts of Japan as an incentive to farmers for paddy field restoration. It has been suggested through a nationwide program that the effectiveness of wildlife-friendly farming be monitored using Odonata, Coleoptera/Hemiptera, Anura, Tetragnathidae, and Lycosidae as indicator groups, as these animals are expected to serve as major predators for agricultural pest insects (Ministry of Agriculture, Forestry and Fisheries of Japan 2012). Although these indicator groups were selected on the basis of increases in abundance under a range of wildlife-friendly farming practices across Japanese paddy fields, their responses to specific management practices are largely unknown.

Sado Island in central Japan is among the leading areas for wildlife-friendly farming in terms of the implemented area. The island-wide practice of sustainable, wildlife-friendly farming throughout the human-dominated landscape (i.e., Satoyama) and indigenous culture led to the designation of Sado Island as a Globally-Important Agricultural Heritage System (GIAHS) site in 2011.

In this chapter, we first introduce Sado's rice certification initiative. We subsequently discuss the results of biological surveys conducted in paddy fields across Sado Island. Finally, we propose recommendations and future challenges for wildlife-friendly farming on Sado Island.

Toki-to kurasu sato dukuri—Sado's Rice Certification Initiative

Starting from the fiscal year of 2008, the Sado Municipal Government introduced a rice certification initiative called Toki Brand Rice Certification Initiative, which is known by the local name *Toki-to kurasu sato dukuri*. To be approved by the rice certification initiative, farmers must comply with all of the following: (1) grow Koshihikari rice plants on Sado Island, (2) be approved as an eco-friendly farmer, (3) perform biological surveys twice in the cultivation period (once in June and once in August), (4) apply 50 % or less of the agrochemicals of conventional farming, and (5) implement one of four *Ikimono-wo hagukumu nouhou* or Biodiversity-enhancing practices (hereafter termed BEPs). In Sado's conventional farming, a total of 18 active pesticide (i.e., herbicides, insecticides, and fungicides) compounds and 6 kg/10 a (1,000 m^2) of nitrogen fertilizer are applied in the cultivation period from April to September. Under Sado's rice certification initiative, a total of nine active

Fig. 7.1 Biodiversity-enhancing practices (BEPs) of the *Toki-to kurasu sato dukuri* rice certification initiative of the Sado Municipal Government, Japan. Financial incentives are given to farmers in return for implementing one or more BEPs. The subsidies are based on produce for the fiscal year of 2013 (1 yen ≈0.01 US dollars: (**a**) Winter flooding (2,000 yen/10 a), (**b**) Fishway (4,000 yen/1 set), (**c**) Diversion ditch (3,000 yen/10 a), and (**d**) Fallow flooding (0 yen/10 a)

pesticide compounds and 3 kg/10 a of nitrogen fertilizers can be used in the cultivation period.

BEPs include the implementation of winter flooding (flooded for a 2-month period between November and February), diversion ditch (locally known by the name *e*) construction within paddy fields along levees, fishways, and fallow flooding (Fig. 7.1). Under Sado's rice certification initiative, fallow flooding qualifies if it is implemented adjacent to a cultivated paddy field, although very few farmers implement such a practice. Nevertheless, some farmers implement fallow flooding instead of cultivating rice, because it is an easy way to suppress weeds during the fallowing period. For fallow flooding, we evaluated its effectiveness on aquatic macroinvertebrate communities in the fallow per se.

Although most farmers implement one of the four BEPs, some farmers implement two or more BEPs at a time in a single paddy field. Upon successful approval, subsidies are given on the basis of the type or combinations (if any) of BEPs. Among the four BEPs, the most common practice is winter flooding, followed by the implementation of a diversion ditch (Fig. 7.2). In contrast to the *Nouchi mizu hozen kanri shiharai koufukin* or Payment for Conserving Farmland and Water by

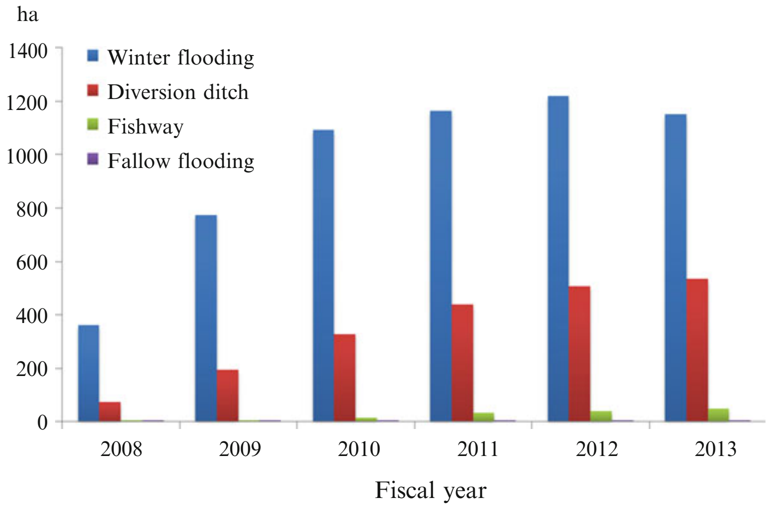

Fig. 7.2 The cultivation areas (ha) for four Biodiversity-enhancing practices (BEPs) on Sado Island. Winter flooding and diversion-ditch implementation are two common BEPs

the Ministry of Agriculture, Forestry and Fisheries of Japan, in which winter flooding typically qualifies only when farmers flood their rice paddy fields to about 15 cm depth to facilitate straw decomposition and to enhance aquatic wildlife, winter flooding under Sado's certification initiative is typically performed with rainwater only. Under Sado's certification initiative, farmers should only intentionally fill ruts from tractors with rainwater (Fig. 7.1a). The reason for keeping the water depth of paddy fields low in winter is that the crested ibis is believed to avoid foraging in deep-water paddy fields in winter, as indicated from empirical evidence of ibis use of wetlands in winter (Colwell and Taft 2000). Thus, the winter flooding practice performed under Sado's rice certification initiative can be considered to be a special type of winter flooding.

The certified *Toki-to kurasu sato* rice or Toki Brand rice is distributed as high value-added rice. At Itoyokado, one of the major supermarkets in Japan, *Toki-to kurasu sato* rice is sold at 2,880 yen (including 5 % tax) (approximately 28.8 US dollars) per 5 kg (as of March 2014), which is 668 yen higher than that of the average Niiigata Koshihikari retailed from February 2013 through January 2014 (2,212 yen (22.1 US dollars) per 5 kg; Ministry of Agriculture, Forestry and Fisheries of Japan 2014).

Indicator Groups

We used four aquatic macroinvertebrate groups (Gastropoda, Heteroptera, Odonata and Coleoptera) to assess the effectiveness of wildlife-friendly farming on biodiversity. These aquatic macroinvertebrate groups have been suggested as indicator groups for biodiversity in lentic habitats (Le Viol et al. 2009; Oertli et al. 2005), because they (1) represent animal communities in lentic habitats; (2) have different ecological requirements, life cycles, feeding modes and dispersal abilities; (3) respond differently to physicochemical gradients (Bilton et al. 2006; Oertli et al. 2005); and (4) are highly complementary in aquatic macroinvertebrate food webs (Downing 2005). We used the abundance of each taxonomic group and the total family richness of the four taxonomic groups (GHOC richness) as indicators of aquatic macroinvertebrate diversity in paddy fields.

Island-Wide Surveys

We performed aquatic macroinvertebrate surveys at 392 paddy fields in winter (December 2009 to March 2010) and 396 paddy fields in summer (June to July 2010) across Sado Island in central Japan (Fig. 7.3). Owing to overlap with

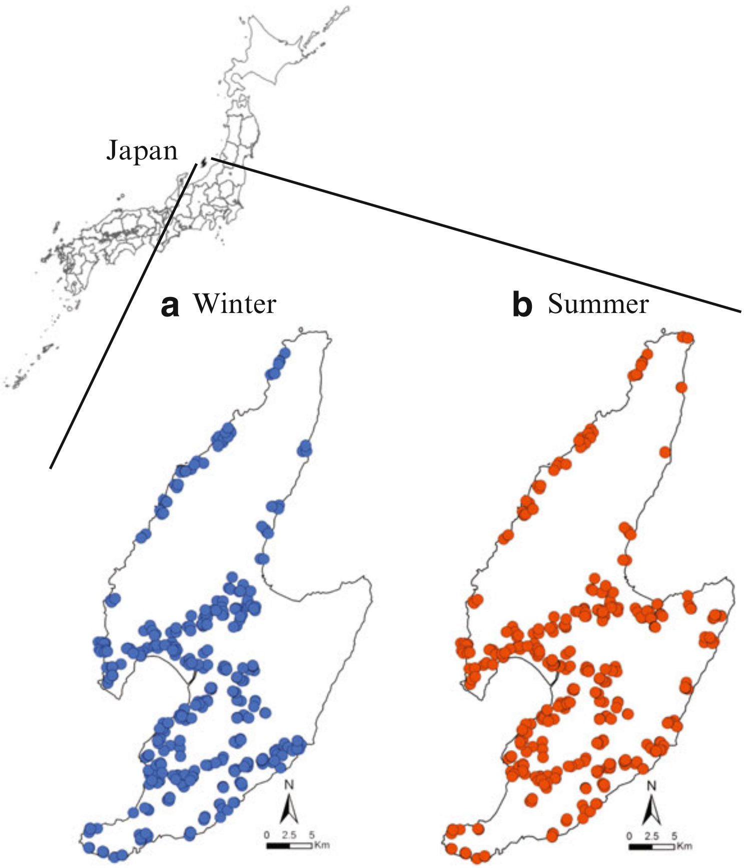

Fig. 7.3 Map of winter (**a**; N = 392) and summer (**b**; N = 396) paddy survey sites for aquatic macroinvertebrates on Sado Island

another ongoing survey in paddy fields, the winter survey was not performed in southeastern Sado. In each season, the field surveys were conducted by three or four groups, with each group consisting of staff of an environmental consulting company (Sanwacon) and two farmer volunteers. The research groups concurrently surveyed different regions of the island. At the time of the study, rice grown under conventional farming could no longer be legally distributed through the Japan Agricultural Cooperatives, and most farmers had reduced agrochemicals by at least 30 % relative to conventional farming. The type of wildlife-friendly farming practice of each paddy field was recorded on the basis of Sado's unpublicized farmland management data and, when available, through direct communications with farmers. The study sites were either dominated by deciduous forests (e.g., *Quercus*) in the mountains, or by paddy fields in the plains.

At each paddy field, we haphazardly sampled two sites each from the long sides and one site each from the short sides of the levee for a total of six sites. Because many farmers are concerned about damage to rice plants from wading inside the paddy fields, we did not perform sampling in the central part of paddy fields.

At each levee side, we placed a water-resistant cardboard quadrat (areas 1 m^2 in winter and 0.81 m^2 in summer) below the levee to collect aquatic macroinvertebrates. Two field crews swept the water column and sediments inside the quadrat using D-framed nets (width 20 cm × depth 15 cm, mesh 1 mm) for 5 min. Although some paddy fields had little water in winter, we nevertheless sampled a total of six sites at each paddy field. When a paddy field was associated with a diversion ditch, we sampled three additional quadrat samples from the ditch. In the field, we sorted the net contents from sediments by eye and, when possible, identified Gastropoda, Heteroptera, Odonata, and Coleoptera to the family level with the aid of available keys (Kawai 1985). Owing to financial and time constraints, we did not attempt to identify these aquatic macroinvertebrates to lower taxonomic levels. For Odonata larvae in winter, we grouped the data into the order level, because of logistical problems associated with identification in the field and volunteer training. In the summer survey, we transported all samples to the laboratory for taxonomic identification or confirmation.

The paddy fields examined had a range of farmland management and rice plantation. For the purpose of the present chapter, we used subsets of the datasets that implemented one of the following practices with the Koshihikari strain: reduced inputs of agrochemicals by 30 % (reference sites), reduced inputs of agrochemicals by 50 %, or fallow flooding. Consequently, we used 361 paddy sites from the winter survey and 328 paddy sites from the summer survey for further analyses.

Data Analysis and Statistical Models

Aquatic macroinvertebrate communities are expected to be influenced by both local and landscape variables such as farming practices, the physicochemical environment of paddy fields, and landscape components around paddy fields.

We, therefore, evaluated the importance of each wildlife-friendly faming practice relative to other local and landscape variables.

We used ArcGIS version 10.1 (ESRI, Redlands) to calculate the percent coverage of paddy fields, forests and non-crop vegetation (i.e., fallows and grassland) as well as the density of farm ponds within 10 multi-scale buffers ranging from 50 to 2,000 m in radius (i.e., 50, 100, 200, 300, 500, 700, 1,000, 1,200, 1,500, and 2,000 m). We created buffers from the center of each paddy field that had a shape identical to that of the paddy field. Within these buffers, we calculated the percent coverage of each land use according to the latest vegetation and land-use map (scale 1:25,000) of the Japan Integrated Biodiversity Information System (Ministry of the Environment, Japan 2000). On the basis of aerial photos taken between July and October 2010, we added polygon data for abandoned paddy fields or fallows to the existing map.

To explore the influence of the geographic location of paddy fields on indicator groups, for each study site we calculated the horizontal distance to the nearest forest edge (area $\geq$ 1,000 m^2) and to the sea. In addition, we computed the altitudinal difference between the study site and the nearest forest edge as measures of accessibility to the nearest forest.

The importance of landscape variables on farmland biodiversity depends on spatial scales (Raebel et al. 2012). Using a generalized linear model (GLM) with negative binomial or Poisson distributions, we analyzed each of the ten landscape sectors separately and tested at each radius how family richness or the abundance of each indicator group responded to the percentage of each landscape sector. Prior to performing GLM, we employed arcsine-square-root transformation to achieve normal distribution for percentage data. For each landscape sector, we selected the best spatial scale on the basis of the lowest Akaike Information Criterion (AIC) (Burnham and Anderson 2002). Note that we only considered one spatial scale from each landscape sector for each macroinvertebrate indicator in further analyses. When none of the spatial scales showed sufficient explanatory power relative to the null model ($\Delta AIC < 2$), we did not include the landscape sector as an explanatory variable in further analyses.

The relationship between species and environment is often non-linear, so we employed a statistical model that accounts for such non-linear relationships. For this purpose, we performed a generalized additive model (GAM) to examine the relationships between environmental variables and the family richness or abundance of indicator groups. Prior to performing GAM analyses, we examined collinearity among explanatory variables using correlation analyses and scatter plots. When highly correlated variables ($r > 0.7$) were identified, we excluded one of the variables from further analyses. A preliminary analysis indicated that the percent coverage of forest and paddy fields were highly correlated at most spatial scales. Therefore, we omitted the data for the percent coverage of forest from further analyses.

In GAM, we treated response variables as either negative binomial or Poisson distributions. We used ten environmental variables (excluding X and Y) as explanatory variables and the best spatial scale of each landscape sector for explaining the variation for each of the five response variables (i.e., indicator abundance and richness). Exclusion of the environmental variables in GAM was based on backward stepwise selection with reference to decreases in AIC (Burnham and Anderson 2002). The existence of spatial autocorrelation in model residuals can lead to underestimation of the importance of each predictor variable (Dormann et al. 2007). Therefore, we calculated Moran's I statistics to test for the existence of spatial autocorrelation in the residual of each GAM model, following the procedure described in Dormann et al. (2007). We evaluated the model performance by explained deviance (D^2), the equivalent of R^2 in standard least square regression analysis (Guisan and Zimmermann 2000). We assessed the relative importance of four representative farming practices (reduced inputs of agrochemicals, fallow flooding, winter flooding, and diversion-ditch implementation) in two ways: their statistical significance by analysis of variance (ANOVA) and their effects on the explained deviance by comparing the explained deviance in the model excluding each farming practice from predictors to that of the full model.

Because water is generally deeper in a diversion ditch than an adjacent paddy field, the diversion ditch was expected to provide an additional habitat for aquatic macroinvertebrates that prefer deep water. Using nonmetric multidimensional scaling (NMDS) and random permutations of the data (with 999 runs), we tested whether aquatic macroinvertebrate composition differed between diversion ditches and their adjacent paddy fields.

Effectiveness of Wildlife-Friendly Farming on Aquatic Macroinvertebrate Abundance and Richness

In winter, Gastropoda, Heteroptera, and Coleoptera were identified in paddy fields while no Odonata larvae were found in any rice paddy fields (average GHOC richness = 0.7 families ± 1.1 SD; range 0–5, N = 361). Although some Odonata larvae are expected to over-winter in or around paddy fields, such over-wintering larvae were only found in diversion-ditch habitats (see section "Effectiveness of diversion-ditch implementation on aquatic macroinvertebrate composition"). The abundance and richness of the indicator groups were significantly associated with the percentage of water cover in paddy fields (Fig. 7.4; Table 7.1). Among the wildlife-friendly farming practices, winter flooding showed moderate to high contributions to the abundance of Gastropoda and Coleoptera, as indicated by both ANOVA ($P < 0.01$) and changes in explained deviance (2.7–5.7 %) when the winter-flooding term was excluded from the GAM models. In contrast, other wildlife-friendly farming practices, such as reduced inputs of agrochemicals, implementation of flooded fallows, and implementation of diversion ditches, had little effect on aquatic macroinvertebrate diversity. Although some wildlife-friendly

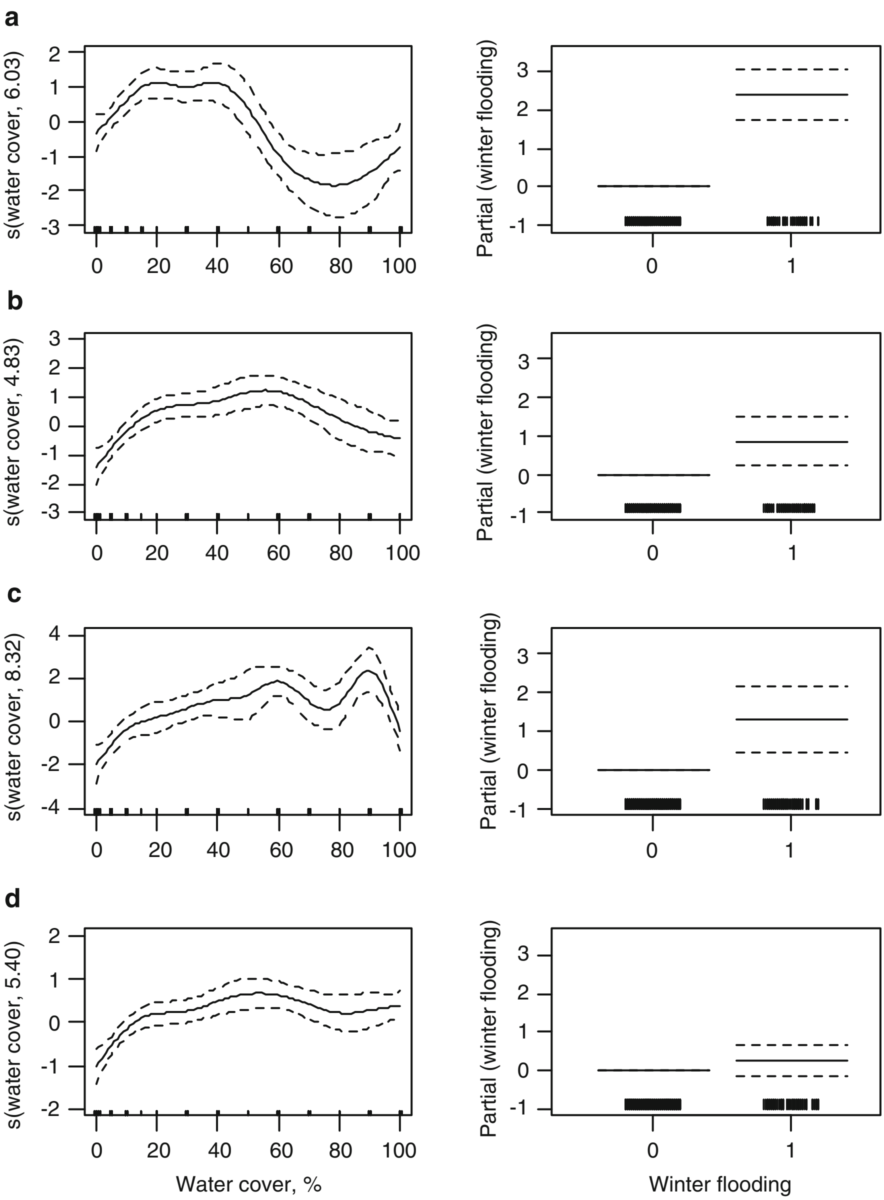

Fig. 7.4 Partial plots for the effects of percentage water cover and winter flooding practice (0 = unimplemented (N = 298), 1 = implemented (N = 63)) on the simplified, generalized additive models of (**a**) Gastropoda abundance, (**b**) Heteroptera abundance, (**c**) Coleoptera abundance, and (**d**) GHOC (Gastropoda, Heteroptera, Odonata, and Coleoptera) family richness from the winter survey. The dashed lines indicate approximate 95 % confidence limits. The y-axis label indicates the estimated degrees of freedom for the smooth spline term. The rug plot along the x-axis indicates sampling effort

Table 7.1 Contributions of wildlife-friendly farming, morphometric variables, and landscape variables for aquatic macroinvertebrates in simplified, generalized additive models (GAM) from the winter survey on Sado Island, Japan

Source	Gastropoda	Heteroptera	Coleoptera	GHOC family richness
χ^2 values				
Agrochemical reduction (1/0)	removed	removed	removed	4.60^{*}
Fallow flooding (1/0)	15.12^{***}	removed	6.89^{**}	removed
Winter flooding (1/0)	51.91^{***}	7.06^{**}	9.27^{**}	removed
Diversion ditch (1/0)	10.46^{**}	1.22	removed	removed
Autumn plowing (1/0)	4.02^{*}	28.90^{***}	15.52^{***}	8.61^{**}
s(% water cover)	60.48^{***}	43.15^{***}	63.29^{***}	39.64^{***}
s(paddy area)	38.86^{***}	9.6	40.54^{***}	17.19^{*}
s(elevation)	66.66^{***}	19.21^{*}	54.42^{***}	21.84^{*}
s(distance to forest edge)	20.68^{**}	12.61^{**}	3.50	3.04
s(altitudinal difference between forest edge and studied paddy field)	50.18^{***}	0.85	39.12^{***}	removed
s(distance to sea)	89.04^{***}	17.22^{*}	23.70^{**}	5.07
s(PON300)	49.96^{***}	–	–	–
s(PON700)	–	–	–	removed
s(PON2000)	–	–	46.42^{***}	–
s(PAD2000)	–	–	removed	–
s(NCV200)	–	–	72.68^{***}	5.17^{*}
s(NCV700)	–	39.44^{***}	–	–
s(RAC)	–	15.20^{*}	26.73^{**}	32.03^{***}
Deviance explained (%)				
Simplified model	56.9	52.3	71.9	33.5
With agrochemical reduction	57.3	52.5	71.8	33.5
Without agrochemical reduction	56.9	52.3	71.9	32.7
With fallow flooding	56.9	52.3	71.9	33.7
Without fallow flooding	55.9	52.3	71.2	33.5
With winter flooding	56.9	52.3	71.9	33.7
Without winter flooding	51.2	51.6	69.2	33.5
With diversion ditch	56.9	52.3	71.9	33.6
Without diversion ditch	56.5	50.6	71.9	33.5

For each landscape sector (i.e. PON, PAD, and NCV), only the spatial scale that showed the best explanatory power (based on preliminary generalized linear models and model selections) was included as an explanatory variable in the subsequent GAM. When none of the spatial scales showed sufficient explanatory power, the landscape sector was omitted from GAM (see text)
A "–" indicates that the variable was not used in the model, while "removed" indicates that the variable was removed from the simplified model. The numbers followed by three-letter characters indicate the buffer radii used to calculate the area or density of the landscape sector. 1 = implemented, 0 = unimplemented, PON = pond density, PAD = paddy field area, NCV = non-crop vegetation area, RAC = residual autocovariate, and GHOC = Gastropoda, Heteroptera, Odonata, and Coleoptera. $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

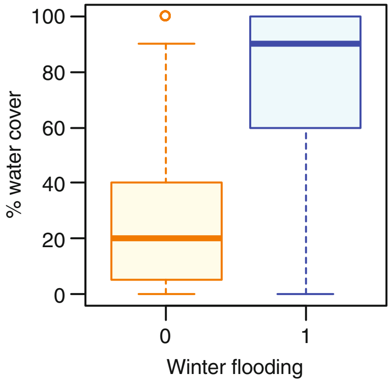

Fig. 7.5 Box plots of percentage water cover in paddy fields with (1; N = 63) and without (0; N = 298) winter flooding practices. The edges of the each box mark the interquartile range, with the thick horizontal line indicating the median. The whiskers indicate 1.5 times the interquartile range

farming terms showed statistical significance in ANOVA, explained deviance changed little (≤1 %) when these terms were excluded from the GAM models.

Why was the winter flooding term not always associated with the abundance or richness of indicator groups? When the percentage of water cover was compared between paddy fields that implemented or did not implement winter flooding, large variations in interquartile ranges were apparent in both types of paddy fields (Fig. 7.5). Under Sado's rice certification initiative, farmers can qualify only if they fill the ruts of tractors with rainwater. Because of climatic differences according to the geographic location of paddy fields and different drainage abilities associated with differential types of soil, the extent of winter flooding likely differed greatly from damp soil through swamp to flooded land. Likewise, paddy fields that did not implement winter flooding showed large variations in moisture conditions due to variability in climatic or geographic factors.

The residuals of preliminary GAM models for Heteroptera abundance, Coleoptera abundance, and GHOC family richness in winter showed signs of spatial autocorrelation (Moran's I: all $P < 0.05$), suggesting that the indicator diversity was high where these indicator groups were abundant or taxa rich in surrounding paddy fields (Table 7.1).

In summer, all of the four indicator groups were identified from paddy fields (average GHOC richness = 2.6 families ± 1.7 SD; range 0–9, N = 328). Agrochemical reduction was among the significant terms that explained Gastropoda abundance, Heteroptera abundance, Odonata abundance, and GHOC family richness (all $P < 0.001$), and model performance dropped moderately to greatly (3.6–10.1 %) when the agrochemical-reduction term was excluded from the model, as indicated by the explained deviance (Fig. 7.6; Table 7.2). Furthermore, Odonata abundance was greatly influenced by fallow flooding, as indicated by ANOVA ($P < 0.001$) and the marked change in explained deviance (6.7 %) following the exclusion of the term. Spatial autocorrelation was not evident in any indicator groups in summer (Moran's I: all $P > 0.05$).

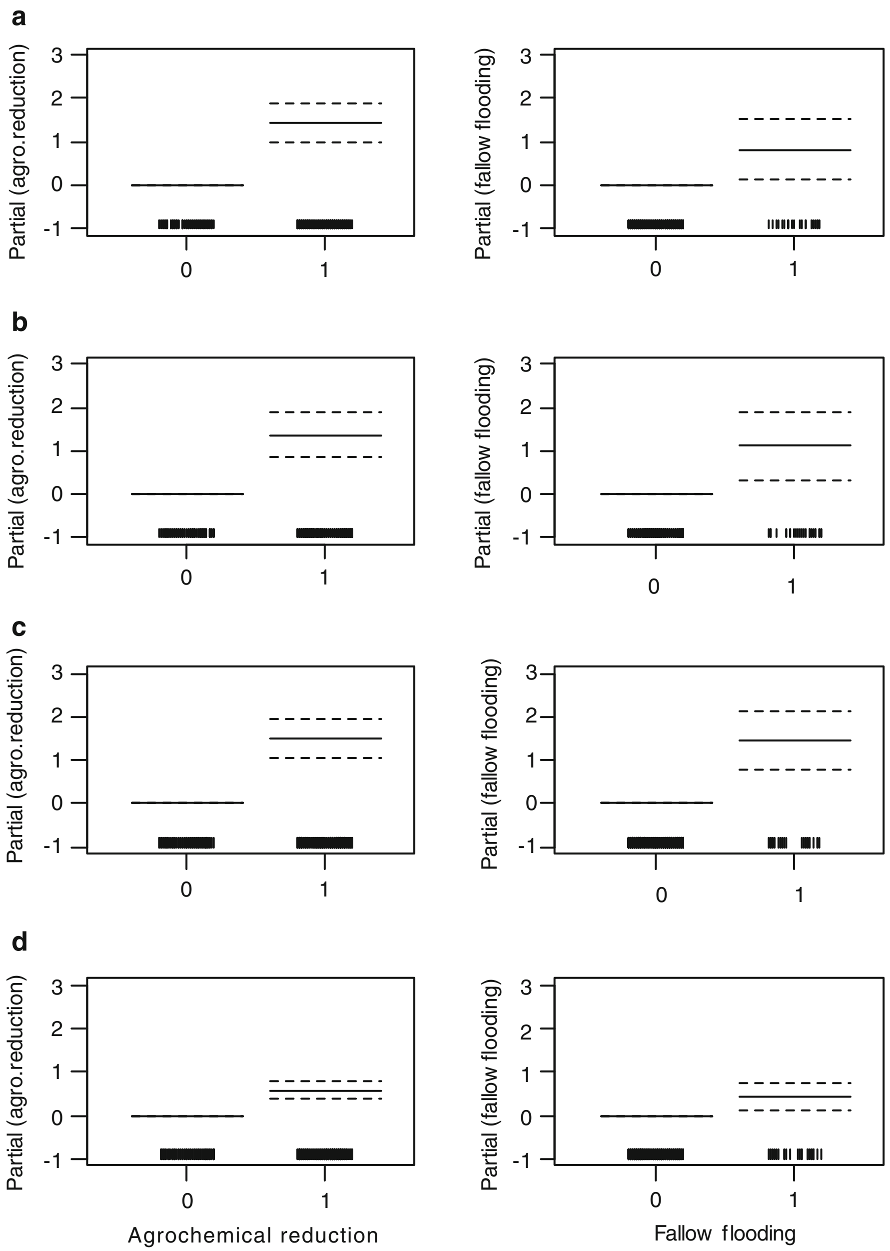

Fig. 7.6 Partial plots for the effects of agrochemical reduction (agro.reduction) (0 = unimplemented (N = 100), 1 = implemented (N = 228)) and fallow flooding practices (0 = unimplemented (N = 302), 1 = implemented (N = 26)) in the simplified, generalized additive models of (**a**) Gastropoda abundance, (**b**) Heteroptera abundance, (**c**) Odonata abundance, and (**d**) GHOC (Gastropoda, Heteroptera, Odonata, and Coleoptera) family richness from the summer survey. The dashed lines indicate approximate 95 % confidence limits. The rug plot along the x-axis indicates sampling effort

Table 7.2 Contributions of wildlife-friendly farming, morphometric variables, and landscape variables for aquatic macroinvertebrates in simplified, generalized additive models from the summer survey on Sado Island, Japan

Source	Gastropoda	Heteroptera	Odonata	Coleoptera	GHOC family richness
χ^2 values					
Agrochemical reduction (1/0)	43.91***	28.46***	44.41***	removed	33.02***
Fallow flooding (1/0)	5.53*	8.12**	18.43***	removed	7.57**
Winter flooding (1/0)	removed	removed	6.52*	removed	removed
Diversion ditch (1/0)	removed	removed	removed	removed	4.63*
Autumn plowing (1/0)	removed	removed	4.55*	5.26*	removed
s(% water cover)	21.49**	11.53*	21.49**	10.94	removed
s(paddy area)	5.13	3.28	26.45**	11.14	removed
s(elevation)	37.58***	13.48**	37.63***	removed	14.71**
s(distance to forest edge)	23.52**	removed	18.08*	5.78*	14.69***
s(altitudinal difference between forest edge and studied paddy field)	22.62**	removed	removed	removed	removed
s(distance to sea)	65.57***	14.54**	47.27***	10.23**	16.18**
s(PON100)	removed	–	–	–	–
s(PON700)	–	9.08	–	removed	
s(PON1500)	–	–	–	–	removed
s(PAD300)	–	–	20.66*	–	–
s(PAD500)	–	14.87**	–	–	–
s(PAD700)	–	–	–	5.29*	–
s(PAD2000)	–	–	–	–	removed
s(NCV100)	25.21**	–	–	–	–
s(NCV700)	–	25.11***	–	–	–
s(NCV1500)	–	–	removed	–	9.83**
s(NCV2000)	–	–	–	6.02*	–
s(RAC)	–	–	–	–	–
Deviance explained (%)					
Simplified model	39.0	31.8	32.5	16.4	20.1
With agrochemical reduction	39.0	31.8	32.5	17.1	20.1
Without agrochemical reduction	35.4	27.5	22.4	16.4	12.1
With fallow flooding	39.0	31.8	32.5	16.3	20.1
Without fallow flooding	38.0	30.4	25.8	16.4	18.5
With winter flooding	39.0	32.1	32.5	16.5	20.1
Without winter flooding	39.0	31.8	31.5	16.4	20.1
With diversion ditch	39.1	32.4	32.6	16.6	20.1
Without diversion ditch	39.0	31.8	32.5	16.4	19.1

A "–" indicates that the variable was not used in the model, while "removed" indicates that the variable was removed from the simplified model. The numbers followed by three-letter characters indicate the buffer radii used to calculate the area or density of the landscape sector. 1 = implemented, 0 = unimplemented, PON = pond density, PAD = paddy field area, NCV = non-crop vegetation area, RAC = residual autocovariate, and GHOC = Gastropoda, Heteroptera, Odonata, and Coleoptera. $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

Effectiveness of Diversion-Ditch Implementation on Aquatic Macroinvertebrate Composition

The NMDS 3-dimensional plots based on the abundance data of the four indicator groups showed different aquatic macroinvertebrate composition between diversion-ditch and paddy habitats in both winter and summer (Fig. 7.7). In winter, paddy

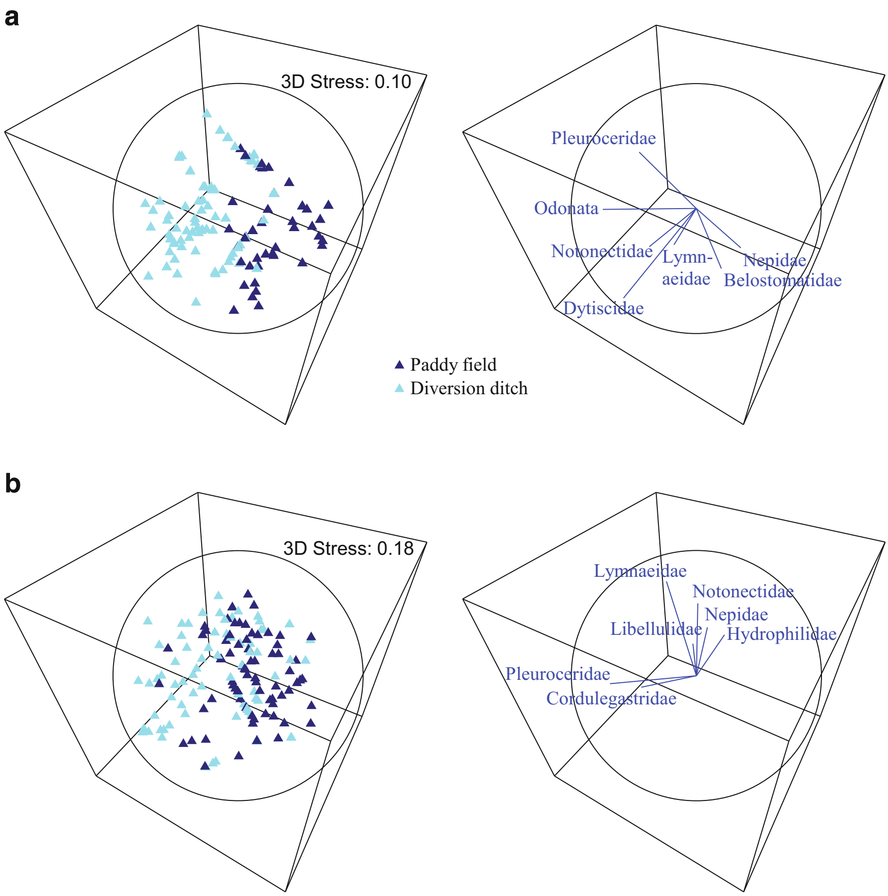

Fig. 7.7 Three-dimensional nonmetric multidimensional (NMDS) scaling ordinations of aquatic macroinvertebrate compositions in paddy fields and their adjacent diversion ditches in: (**a**) winter (Global $\rho = 0.139$, $P = 0.001$, Number of permutations = 999; N = 116) and (**b**) summer (Global $\rho = 0.084$, $P = 0.001$, Number of permutations = 999; N = 86). Only the data for paddy fields equipped with diversion ditches were used in the NMDS analyses. For clarity, only macroinvertebrate taxa that showed Pearson correlation coefficients equal to or greater than 0.4 are shown on the graphs. Note that the order-level data were used for Odonata larvae in winter, because of logistical problems associated with identification in the field and volunteer training. 3D-stress refers to the fitness to the NMDS model

habitats were associated with two aquatic Heteroptera families (Nepidae and Belostomatidae), while the adjacent diversion-ditch habitats were associated with Pleuroceridae (Gastropoda), Lymnaeidae (Gastropoda), Notonectidae (Heteroptera), Odonata, and Dytiscidae (Coleoptera). In summer, separation in aquatic macroinvertebrate composition between diversion-ditch and paddy habitats was less clear; representative families of the four indicator groups were always associated with the diversion-ditch habitat but no aquatic macroinvertebrate family appeared to represent the paddy habitat.

Conclusions and Recommendations

Scientific evaluation of the effectiveness of wildlife-friendly farming on farmland biodiversity is largely lacking from paddy-dominated landscapes (but see: Amano et al. 2011; Bang et al. 2012). Our chapter is the first attempt to report the effectiveness of wildlife-friendly farming on paddy field biodiversity on the entirety of Sado Island, which is among the leading areas for wildlife-friendly farming practices.

Overall, our results show that diverse practices of wildlife-friendly farming contribute to the enhancement of aquatic macroinvertebrate diversity on Sado Island. Specifically, reduced input of agrochemicals and fallow flooding lead to enhanced aquatic macroinvertebrate abundance and richness in summer. Although the effectiveness of diversion-ditch implementation for enhancing aquatic macroinvertebrate diversity in paddy habitats was less clear, ditches provide additional habitats for aquatic macroinvertebrates that prefer deep water in both summer and winter, as shown by different aquatic macroinvertebrate composition in the respective seasons. In winter, separation in taxonomic composition between paddy and ditch habitats was more pronounced relative to summer, with some taxonomic groups (e.g., Odonata larvae) only found in the ditch habitats. In winter, however, the effectiveness of wildlife-friendly farming practices on paddy field macroinvertebrate diversity under Sado's certification initiative was less clear. Although the percentage of water cover was shown to be among the significant factors that explain aquatic macroinvertebrate diversity in winter, the winter flooding practice under Sado's rice certification initiative had less obvious effects on aquatic macroinvertebrate diversity, because of the fact that the percentage of water cover was variable.

For winter flooding we recommend that the entire paddy field be covered with enough water, because such a protocol has been demonstrated to be effective in enhancing aquatic macroinvertebrate diversity in paddy fields as well as promoting straw decomposition (Elphick and Oring 1998; Lawler and Dritz 2005). Although the precise mechanisms for the significant spatial autocorrelation in winter are unclear, the percentage of water on paddy surfaces might explain such aggregated distributions of aquatic macroinvertebrates.

In general, irrigation water does not run in the non-cultivation season on Sado Island unless farmers implement the irrigation system on their own. When water is limited in winter, we recommend filling a diversion ditch with water rather than attempting to fill in the entire paddy field. As shown by our study, implementing diversion ditches is effective in enhancing aquatic macroinvertebrate diversity in both winter and summer. Thus, winter flooding in diversion ditches may provide an alternative certification prerequisite when flooding the entire paddy field could not be performed because of irrigation reasons. Given that biological communities show spatial and temporal variations and that agricultural policies on Sado Island may change over time, scientific evaluation is best performed periodically to monitor the up-to-date effectiveness of wildlife-friendly farming on paddy field biodiversity.

Future Challenges

Evaluation of the effectiveness of wildlife-friendly farming is best performed using multiple sets of indicator groups (Billeter et al. 2008). However, using multiple sets of indicator groups may involve so much effort that scientific evaluation cannot be performed without sacrificing sample size (i.e., study sites) unless many researchers are involved in the study. In this chapter we used a subset of aquatic macroinvertebrates as indicators for biodiversity to maximize the sample size for island-wide bioassessment (cf. Vellend et al. 2008). Because paddy fields are alternative wetland habitats that are inhabited or utilized by both aquatic and terrestrial fauna, future studies should incorporate both aquatic and terrestrial indicator groups. Wandering spiders, web-building spiders, amphibians, and adult Odonata (also exuviae) are candidates for indicator groups, as these taxonomic groups are not only important as predators for agricultural pest insects but also known to be susceptible to farmland management such as inputs of agrochemicals or moisture conditions (Amano et al. 2011; Tanaka and Ihara 2012). In addition, aquatic plants may serve as indicators for fallow flooding, as macrophytes and algae are commonly used as indicators of the biodiversity of farm ponds (Usio et al. 2013), another representative wetland habitat in Satoyama. Because implementing wildlife-friendly farming involves much labor, burdens for implementing each practice are ideally taken into account when evaluating the effectiveness of wildlife-friendly farming. Using a range of indicators from taxonomically distant groups and taking into account burdens for implementing each wildlife-friendly farming practice may allow for the evaluation of the cost-effectiveness of wildlife-friendly farming on paddy field biodiversity.

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References

Amano T, Kusumoto Y, Okamura H, Baba YG, Hamasaki K, Tanaka K, Yamamoto S (2011) A macro-scale perspective on within-farm management: how climate and topography alter the effect of farming practices. Ecol Lett 14:1263–1272

Bang H-S, Han M-S, Na Y-E, Kim M-H, Kang K-K, Lee J-T (2012) Biodiversity of inhabitants of animals and vascular plants in Korean paddy field ecosystem. In: Nakano S, Yahara T, Nakashizuka T (eds) The biodiversity observation network in the Asia-Pacific region: toward further development of monitoring, Ecological research monographs. Springer, Tokyo, pp 387–402

Billeter R, Liira J, Bailey D, Bugter R, Arens P, Augenstein I, Aviron S, Baudry J, Bukacek R, Burel F et al (2008) Indicators for biodiversity in agricultural landscapes: a pan-European study. J Appl Ecol 45:141–150

Bilton DT, McAbendroth L, Bedford A, Ramsay PM (2006) How wide to cast the net? Cross-taxon congruence of species richness, community similarity and indicator taxa in ponds. Freshw Biol 51:578–590

Burnham KP, Anderson DR (2002) Model selection and multimodel interference: a practical information-theoretic approach, 2nd edn. Springer, New York

Colwell MA, Taft OW (2000) Waterbird communities in managed wetlands of varying water depth. Waterbirds 23:45–55

Donald PF (2004) Biodiversity impacts of some agricultural commodity production systems. Conserv Biol 18:17–37

Dormann CF, McPherson JM, Araujo MB, Bivand R, Bolliger J, Carl G, Davies RG, Hirzel A, Jetz W, Kissling WD et al (2007) Methods to account for spatial autocorrelation in the analysis of species distributional data: a review. Ecography 30:609–628

Downing AL (2005) Relative effects of species composition and richness on ecosystem properties in ponds. Ecology 86:701–715

Elphick CS (2000) Functional equivalency between rice fields and seminatural wetland habitats. Conserv Biol 14:181–191

Elphick CS, Oring LW (1998) Winter management of Californian rice fields for waterbirds. J Appl Ecol 35:95–108

Fujioka M, Don Lee S, Kurechi M, Yoshida H (2010) Bird use of rice fields in Korea and Japan. Waterbirds 33:8–29

Guisan A, Zimmermann NE (2000) Predictive habitat distribution models in ecology. Ecol Model 135:147–186

Kawai T (ed) (1985) An illustrated book of aquatic insects of Japan. Tokai University Press, Tokyo (in Japanese)

Kiritani K (2010) A comprehensive list of organisms associated with paddy ecosystems in Japan. The revised edition edn. The Institute of Agriculture and National Environments, Tokyo (in Japanese)

Lawler SP, Dritz DA (2005) Straw and winter flooding benefit mosquitoes and other insects in a rice agroecosystem. Ecol Appl 15:2052–2059

Le Viol I, Mocq J, Julliard R, Kerbiriou C (2009) The contribution of motorway stormwater retention ponds to the biodiversity of aquatic macroinvertebrates. Biol Conserv 142:3163–3171

Ministry of Agriculture, Forestry and Fisheries of Japan (2010) Ikimono-mark guidebook (Eco-label guidebook) (in Japanese). http://www.maff.go.jp/j/kanbo/kankyo/seisaku/s_ikimono/guidebook/index.html. Accessed 1 Apr 2014

Ministry of Agriculture, Forestry and Fisheries of Japan (2012) Manual of biodiversity indicators for agriculture – I. Survey and evaluation methods (in Japanese). http://www.niaes.affrc.go.jp/techdoc/shihyo/index.html. Accessed 27 Feb 2013

Ministry of Agriculture, Forestry and Fisheries of Japan (2014) Monthly rice report (in Japanese). http://www.maff.go.jp/j/seisan/keikaku/soukatu/mr.html. Accessed 1 Apr 2014

Ministry of the Environment, Japan (2000) Japan integrated biodiversity information system (J-IBIS). Available from http://www.biodic.go.jp/. Accessed 19 Dec 2013

Mukai Y, Baba N, Ishii M (2005) The water system of traditional rice paddies as an important habitat of the giant water bug, *Lethocerus deyrollei* (Heteroptera: Belostomatidae). J Insect Cons 9:121–129

Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecol Eng 56:97–106

Oertli B, Auderset-Joye D, Castella E, Juge R, Lehmann A, Lachavanne JB (2005) PLOCH: a standardized method for sampling and assessing the biodiversity in ponds. Aquat Conserv 15:665–679

Raebel EM, Merckx T, Feber RE, Riordan P, Thompson DJ, Macdonald DW (2012) Multi-scale effects of farmland management on dragonfly and damselfly assemblages of farmland ponds. Agric Ecosyst Environ 161:80–87

Tanaka K, Ihara F (2012) Biodiversity research for the development of indicator organisms in environment-preserving agriculture. In: Nakano S, Yahara T, Nakashizuka T (eds) The biodiversity observation network in the Asia-Pacific region: toward further development of monitoring, Ecological research monographs. Springer, Tokyo, pp 375–385

Usio N, Imada M, Nakagawa M, Akasaka M, Takamura N (2013) Effects of pond draining on biodiversity and water quality of farm ponds. Conserv Biol 27:1429–1438

Vellend M, Lilley PL, Starzomski BM (2008) Using subsets of species in biodiversity surveys. J Appl Ecol 45:161–169

Chapter 8
Column: Sado Wrinkled Frog: An Alternative Symbol for Wildlife-Friendly Farming on Sado Island?

Raita Kobayashi

Keywords Anuran • Amphibian • Conservation • Endemic species • Overwintering tadpole • Rice cultivation • *Rugosa susurra* • Sado city • Iconic species • Water management

Wildlife-Friendly Farming Methods

With increasing interest in food safety and low environmental impact, wildlife-friendly farming methods with reduced use of pesticides and chemical fertilizers have been introduced throughout Japan. The aim of such farming methods is to restore the agricultural ecosystem. A number of rice paddies cultivated using the above methods use iconic species such as the crested ibis *Nipponia nippon* (Sado City, Niigata Prefecture), Oriental white stork *Ciconia boyciana* (Toyooka City, Hyogo Prefecture), greater white-fronted goose *Anser albifrons* (Osaki City, Miyagi Prefecture), and nigorobuna carp *Carassius auratus grandoculis* (Takashima City, Shiga Prefecture) (Natuhara 2013).

Sado Island is approximately 855 km^2 and is located in the Japan Sea, about 35 km off the coast of Niigata, on the northwest coast of Honshu. Rice farming is one of the major industries on Sado Island, and the ratio of rice paddy area to land is approximately 12.6 %. The island is also known as the location of the last surviving wild crested ibis population in Japan.

The crested ibis is one of the most famous birds in Japan because of its unique appearance and conservation history. The bird was once distributed throughout East Asia, including China, Japan, Korea, Russia, and Taiwan (Yamashina and Nakanishi 1983). However, changes in land use and human activities, such as the modernization of farming, deforestation, and hunting, are believed to have caused a decline in the populations of the birds during the middle of the past century (Li et al. 2009). In 1981, the last five individuals born in the wild were captured

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on Sado Island. Although a captive breeding effort was undertaken by using the five captured individuals, the Japanese local population became extinct in 2003. In 2008, crested ibises derived from the captive breeding of individuals from China were reintroduced to Sado Island. The reintroduced ibises mainly used paddy fields for foraging and fed on wetland organisms such as fish, insects, crustaceans, worms, and frogs (Nagata 2012; Endo and Nagata 2013).

The Sado Municipal Government has operated the Toki (Japanese name for the crested ibis) Bland Rice Certification Initiative since 2008. The aims of this system are to restore habitats within paddy fields for organisms such as insects, amphibians, and loach, and to support the reintroduction of the crested ibis.

Under the above certification initiative, rice plants must be cultivated (1) in Sado; (2) by *eco-farmars* certified by the Niigata Prefecture; (3) using 50 % less chemical pesticides and fertilizers compared with conventional farming methods; and (4) using at least one of the wildlife-friendly farming methods such as winter flooding from November to February and constructing *e* (a small diversion ditch inside a paddy), fish-way, or an adjacent biotope. In addition, farmers have to research about organisms in the paddies twice a year, in June and August. The number of certified paddies has been increasing yearly, and in 2011, more than 22 % of rice-cultivated areas were operating under the certification initiative (Watanabe 2012).

The Sado Wrinkled Frog

The Sado wrinkled frog *Rugosa* (*Glandirana*) *susurra* was described as a new species in December 2012 (Sekiya et al. 2012) (Fig. 8.1). *R. susurra* was discovered within paddy fields and farm ponds in the paddy systems on Sado Island. The snout-vent length of this frog is about 4 cm. The dorsal side is muddy brown and several short ridges are present on the back, whereas the ventral posterior surfaces of the body and the backside of the limbs were deep yellow. The specific epithet *susurra* means *whispering* and was used because the mating call of *R. susurra* is much quieter than that of the other indigenous frogs on Sado Island (Sekiya et al. 2012). Another wrinkled frog *Rugosa rugosa,* which is genetically close to *R. susurra*, is also distributed on Sado Island. However, *R. susurra* is endemic to Sado Island, whereas *R. rugosa* is distributed in Honshu, Shikoku, Kyusyu, the adjacent islands of Yaku, Oki, and Sado, and the islands composing the Goto Group in Japan (Maeda and Matsui 2003). Different trends in the distribution and habitats of the two wrinkled frogs have been observed, and the local distribution of the two frog species rarely overlaps. For example, *R. susurra* is found in the Kuninaka Plain and its surrounding area located in the center of the island, whereas *R. rugosa* is found in the southern mountains and in the northern coastal areas of the Island (Fig. 8.2). *R. susurra* is found in wetlands such as paddy fields, biotopes, and farm ponds, whereas *R. rugosa* is mostly found in farm ponds. Therefore, *R. susurra* appears to be adapted to a paddy field environment more than *R. rugosa*.

Fig. 8.1 *Rugosa susurra* in a paddy field

Nine of 14 species/subspecies of indigenous frogs on the Kyusyu, Shikoku, and Honsyu Islands of Japan use paddy fields as breeding habitats (Hasegawa 1998). However, the duration of paddy field use differs for each frog species. For example, the Nagoya daruma pond frog *Rana porosa brevipoda* uses paddy fields throughout the year, whereas the Japanese brown frog *Rana japonica* and green tree frog *Rhacophorus arboreus* use only paddy fields during the breeding season, and they inhabit forest areas during the non-breeding season (Maeda and Matsui 2003; Natuhara 2013). Kato et al. (2010) reported that the densities of the Montane brown frog *Rana ornativentris* and *R. arboreus* were affected by local and landscape factors such as water depth and the ratio of adjacent forest areas around breeding sites. In contrast, the presence of *R. susurra* only appears to be affected by local factors such as the presence of the *e* ditch in the paddy field (Uruma et al. 2012).

Frogs may play important roles in paddy field food webs, because they are intermediate predators that serve as predators of small invertebrates and prey of carnivorous animals such as snakes, egrets, and weasels (Hasegawa 1998; Naito 2012). The Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) published a research and evaluation manual to indicate the useful organisms in agriculture in six areas of Japan (Ministry of Agriculture, Forestry and Fisheries of Japan 2012). Anuran species, including the daruma pond frog, brown frog, Japanese tree frog, wrinkled frog, and Indian rice frog *Rana limnocharis limnocharis*, were shown as indicator species in paddy systems. *Rugosa susurra* was also known as an intermediate predator in paddy field food webs, as they have been observed to

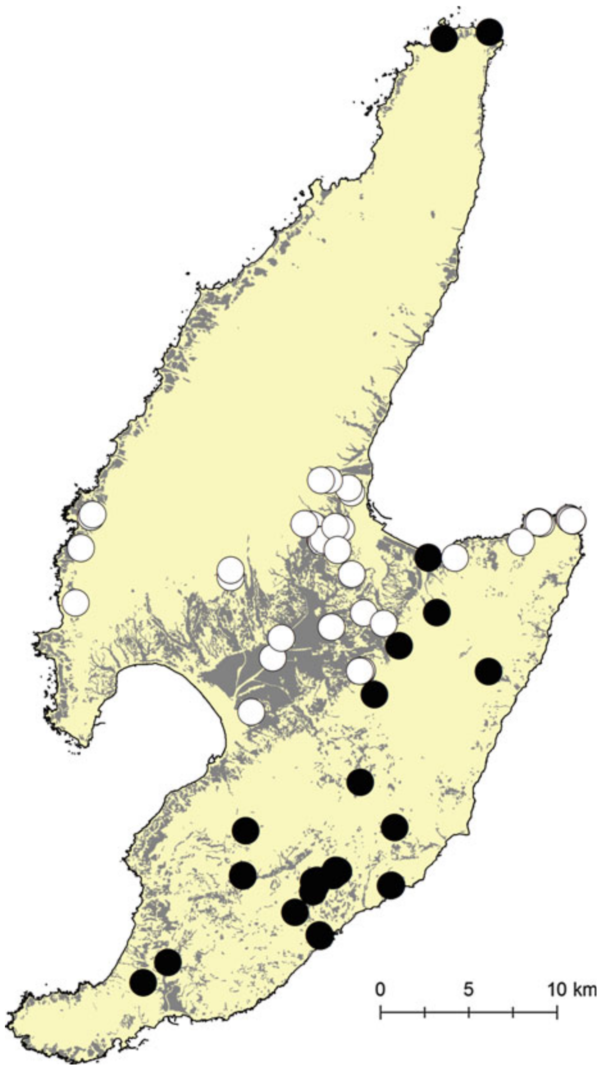

Fig. 8.2 The distributions of wrinkled frogs on Sado Island. *Open* and *closed circles* indicate those of *R. susurra* and *R. rugosa*, respectively. *Grey areas* show paddy fields

feed on small invertebrates such as ants, beetles, and worms and were preyed upon by vertebrates such as the tiger keelback snake *Rhabdophis tigrinus*, bullfrog *Rana catesbeiana*, and crested ibis *Nipponia nippon*. Although *R. susurra,* described in December 2012, was not listed in the MAFF manual, it may be used as an indicator species on Sado Island.

Crisis of *Rugosa susurra*

R. susurra is considered to be facing a crisis of population decline because of the three main reasons: habitat loss, habitat change by modern farming, and invasive species. First, the farming paddy area has been decreasing in Sado Island because of the rice acreage reduction policy and the falling price of rice. Consequently, non-cultivated paddy areas have been increasing (Watanabe 2012). The abandoned paddy field often becomes an unsuitable habitat for *R. susurra* because the soil dries out and vegetation succession occurs. Second, the modernization of paddy systems, such as the use of irrigation and drainage systems, may affect its movements and life cycle. Because this frog does not have suckers, it is not capable of escaping from deep, concreted ditches, thus, modern irrigation and drainage systems may restrict its movements and cause habitat fragmentation. Third, *R. susurra* is rarely found in farm ponds that are inhabited by invasive species such as bullfrog *R. catesbeiana*. It is likely that *R. susurra* is preyed upon by *R. catesbeiana* which have immigrated from newly constructed ponds nearby. Therefore, caution must be exercised during the construction of deep permanent water systems such as farm ponds and *e*, to ensure that other invasive species are not transferred across the water.

Only limited information is available on the ecology and life cycle of *R. susurra*. According to observations in wild conditions, the breeding of *R. susurra* occurs in shallow waters from mid-May to early August. Tadpoles growing experiments in outdoor environments and observations in wild conditions showed that hatched tadpoles hibernated and metamorphosed early in the following summer. However, it is unclear whether all the hatched tadpoles metamorphosed during the following summer in the wild, because a few tadpoles were observed to metamorphose within the hatching year in laboratory rearing experiment (Sekiya personal communications). As described above, wetland environments throughout the year are important for their life cycle. However, water flooding in paddies is limited during the rice-growing season. In conventional rice farming on Sado Island, paddies are watered in April, the nursery rice plant is transplanted in early May, and wet conditions are retained from early spring to late summer, except for the *nakaboshi* (mid-season drainage) period. *Nakaboshi* is a water management method used to strengthen the roots of rice plants by drying the soil for 1–2 weeks in the period from mid-June to early July. After the *nakaboshi* period, paddies are re-flooded intermittently and then drained before harvest. Consequently, it is difficult for tadpoles to survive in conventional paddies (Fig. 8.3). In fact, paddies in which *R. susurra* was recorded were rare and locally distributed in the Kuninaka Plain. These paddies may have refuges such as *e*, small pools, and adjacent biotopes, or connections with suitable habitats such as farm ponds. Uruma et al. (2012) reported that *R. susurra* was likely to be found in paddy areas where several *e* have been constructed. In order to conserve *R. susurra* in paddy systems, it is important not only to maintain wet conditions throughout the year but also to maintain connections between habitats and management of invasive species.

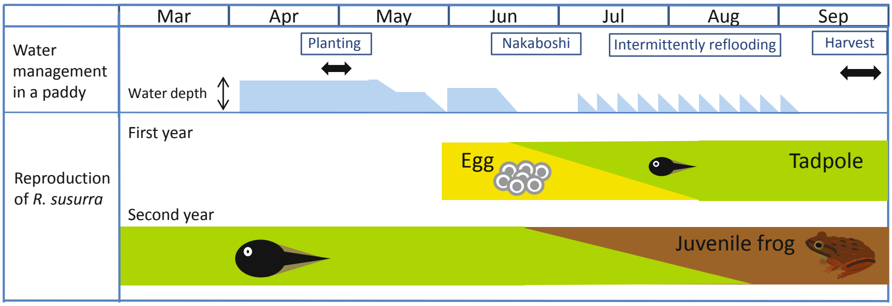

Fig. 8.3 Relationship between the reproduction of *Rugosa susurra* and water managements in the conventional farming paddies

R. susurra has characteristics that could make it an iconic species in the paddy systems of Sado Island. First, this frog is one of the two endemic vertebrates on Sado Island. Second, this frog constructs predator-prey relationships in paddy food webs. Third, this frog is relatively easy to catch and to be identified without specific tools. Finally, *R. susurra* is likely to observe in the paddies related to wildlife-friendly farming methods such as *e*. Although *R. susurra* is a modest and quiet organism compared to the crested ibis, it can be expected to become a new symbol for wildlife-friendly farming on Sado Island.

References

Endo C, Nagata H (2013) Seasonal changes of foraging habitats and prey species in the Japanese crested ibis *Nipponia nippon* reintroduced on Saso Island, Japan. Bird Conserv Int 23:445–453

Hasegawa M (1998) The population of frogs depend on the rice cultivation. In: Ezaki Y, Tanaka T (eds) Conservation of riparian area. Asakura Publishing Co., Ltd., Tokyo, pp 53–79 (in Japanese)

Kato N, Yoshio M, Kobayashi R, Miyashita T (2010) Differential responses of two anuran species breeding in rice fields to landscape composition and spatial scale. Wetlands 30(6):1171–1179

Li X, Tian H, Li D (2009) Why the crested ibis declined in the middle twentieth century. Biodivers Conserv 18:2165–2172

Maeda N, Matsui M (2003) Frogs and toads of Japan, Revised edn. Bun-ichisogo Press, Tokyo (in Japanese)

Ministry of Agriculture, Forestry and Fisheries of Japan (2012) A research and assessment manual of useful indicator organisms of biodiversity for agricultures. http://www.niaes.affrc.go.jp/techdoc/shihyo/index.html#mokuji1. Accessed 15 Jan 2014

Nagata H (2012) The current status of the reintroduction program of Crested Ibis Nipponia nippon and its perspective on Sado Island. Reintroduction 2:11–16 (in Japanese)

Naito R (2012) Perspectives of conservation of pond-breeding frogs (focusing on the Nagoya Daruma pond frog) in rice paddy areas in Japan. Land Ecol Manag 17:57–73

Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecol Eng 56:97–106

Sekiya K, Miura I, Ogata M (2012) A new frog species of the gens Rugosa from Sado Island, Japan (Anura, Ranidae). Zootaxea 3575:49–62

Uruma H, Kobayashi R, Nishijima S, Miyashita T (2012) Effectiveness of conservation-oriented agricultural practices on amphibians inhabiting Sado Island, Japan, with a consideration of spatial structure. Jpn J Conserv Ecol 17:155–164 (in Japanese)

Watanabe R (2012) For community development of Sado Island in coexistence of human and ibises. Reintroduction 2:17–19 (in Japanese)

Yamashina Y, Nakanishi G (1983) Newton books: Nipponia nippon. Kyoikusha, Tokyo (in Japanese)

Chapter 9
Using the Oriental White Stork as an Indicator Species for Farmland Restoration

Kazuaki Naito, Shiro Sagawa, and Yoshito Ohsako

Abstract In 1971, the native population of the Oriental white stork became extinct from the wild in Japan. Soon after, a captive-breeding and reintroduction program was started in the Toyooka Basin, the last habitat for this large bird. The Oriental white stork usually feeds on a range of small wetland animals, such as fish, frogs, and insects, particularly in paddy fields and their surrounding areas, serving as a biodiversity indicator in such rural areas. Land consolidation projects have deteriorated paddy ecosystems, resulting in drier conditions, fragmented water systems, and wider application of agrochemicals. Therefore, alternative and balanced rice farming schemes, combining nature conservation and economic activities, to

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restore the paddy ecosystem were essential for successful reintroduction of the Oriental white stork. In this chapter, the authors describe the role of the *white stork-friendly farming method* and related techniques in the reintroduction of this species, including its effects on local ecosystems.

Keywords *Ciconia boyciana* • Dissolved oxygen concentration • Fishway • Flooding • Foraging habitat • Habitat restoration • Paddy field • Oriental white stork • Reintroduction • Umbrella species

Ecological Feature and Current Status of the Oriental White Stork

Large, conspicuous, and/or rare animals are often treated as umbrella species to promote ecological conservation of a region (Caro and O'Doherty 1999; Roberge and Angelstam 2004) because such species need large areas to thrive. The Oriental white stork, *Ciconia boyciana*, is one of the largest birds inhabiting Japan. The species can be regarded as umbrella species in rural areas, and its presence is an indicator of the sustainable ecological pyramid in a given ecosystem. The Oriental white stork is carnivorous and preys on a range of species, implying that it requires a sufficient amount of diet to survive under such habitat condition.

The Oriental white stork can now be found in China, Russia, Korea, Japan, and irregularly in the Philippines, north-eastern India, Myanmar, and Bangladesh. Its primary breeding areas are natural wetlands along the border between China and Russia and, after the breeding season, it migrates south to southern China and the Korean Peninsula for wintering. The natural breeding site at the border between China and Russia is sparsely populated and exposed to relatively low human pressure compared to Japan and probably in Southern China, and Korea. In those areas, it is mainly found in highly altered habitat such as paddy fields, including ditches and rivers nearby, indicating that human activities directly influence the habitat quality of this species.

At present, the global population of the mature Oriental white storks is estimated to be 1,000–2,500 and continues to decrease, being classified as endangered by International Union for Conservation of Nature (IUCN 2013). Therefore its international trade is regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). There are also domestic conservation schemes such as the Endangered Species Preservation Act, which corresponds to the CITES international scheme, and the Law for the Protection of Cultural Properties because the species is designated as a special natural monument in Japan.

The Japan's breeding population of the Oriental white stork became extinct in the wild in 1971; however, long-term efforts to re-establish the population have been made ever since, leading to a captive breeding program in 1965 and the regional reintroduction of the species in 2005. This *in situ* conservation program is closely related to paddy rice farming because it is one of the main habitats of the white stork in rural Japan. Farmers, farming associations, and local governments have supported the conservation programs for this species and are linked to agricultural production.

In this chapter, we present the role of the Oriental white stork as an indicator species for farmland restoration in rural Japan.

Conservation History and Reintroduction of the Oriental White Stork

According to historical manuscripts, Oriental white storks were common in Japan until the beginning of the Meiji Era (1868–1912), when it could be found in more than 20 regions from Tohoku in the north-east to the Kyushu Island district in the south (Japan Wildlife Research Center 1987). Although the main breeding sites are found in continental China, the historical records document the presence of breeding pairs in some region in Japan, providing evidence of partial migration, with some storks staying in Japan throughout the year. Hunting pressure is believed to have taken its toll on the species, and its distribution rapidly shrunk during the Meiji Era, with only two breeding sites remaining in central-west Japan, the Tajima region in the northern part of the Hyogo Prefecture and a sector of the Fukui Prefecture.

The breeding site in the Tajima region was found in the Toyooka Basin, in a low and flat area downstream of the Maruyama River in the northern part of the region. This area was designated as a natural monument in 1921 by the national government (Kikuchi and Ikeda 2006). In the 1920s, approximately 100 individuals, including both young and adults, were estimated in the area (Ikeda 2000, Fig. 9.1). Efforts were then made to maintain the stork population in and around the basin (Iwasa 1936a, b); however, the population decreased in the area because of a series of complex factors, including the disturbance of the breeding site, overuse of agrochemicals that pollute and alter the food chain, and habitat degradation associated to paddy fields and river alterations. This continuous population decline led to inbreeding depression, which further reduced the number of individuals. Despite continuous conservation efforts in the basin from 1955, this breeding population and consequently the last wild population of Oriental white stork in Japan eventually became locally extinct in 1971.

Amid this rapid population decline, a captive breeding program was established in 1965; however, this program was not successful until 1989, when the first chick hatched from a pair of storks introduced from Russia. The program success led to the gradual increase in the captive population, reaching 100 individuals in 2002. Encouraged by the growth of the captive-bred population, a reintroduction program was developed in cooperation with various stakeholders within the local community.

The pilot release of the Oriental white storks into the wild started in 2005, and a total of 27 individuals had been released into the basin by 2010. The released individuals formed a breeding pair in 2006, and reproduced in the wild in 2007. In 2013, there were nine wild breeding pairs in the region, and by the end of that year the number of individuals in the wild had reached 70, with more than

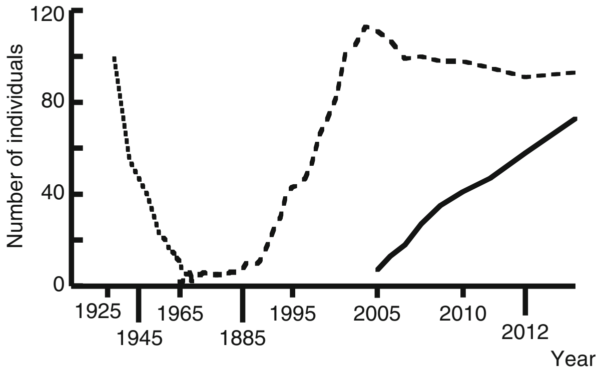

Fig. 9.1 Variation in the Oriental white stork population in the Toyooka Basin. *Dotted line* indicates the number of individuals in the wild before local extinction, *broken line* shows the density of captive-bred individuals in Toyooka, and *solid one* shows the number of individuals in the wild originated by reintroduction. (Partially based on Ikeda 2000 and Naito et al. 2011)

50 wild-born individuals. The reintroduced population is mainly distributed within the Toyooka Basin, although spill-over outside the basin have been recorded. Additional releases were also carried out in 2013 with the intention to expand the distribution of the reintroduced population outside the basin. One of current targets of the reintroduction project is to form a stable and self-sustained population that is established in habitat restoration and ensuring prey abundance (Hyogo Park of the Oriental White Stork 2012).

Paddy Field as a Foraging Habitat for the Oriental White Stork

Observations of a wild stork in the Toyooka Basin in 2002, prior to the release of captive-bred individuals, showed that this individual foraged in paddy fields, ditches, rivers, and marginal grassland (Naito and Ikeda 2007). This lone wild individual was not influenced by previous captive experience or the presences of other conspecifics, and its behavior and seasonal pattern reflect the typical foraging habitat of the Oriental white stork. The pattern of foraging site selection of reintroduced individuals and their descendants are similar to the pattern observed for wild individuals, although reintroduced specimens tend to be more strongly dependent on paddy fields and associated habitats.

These observations also showed an apparent seasonal variation in the relative importance of each foraging habitat, i.e., the stork mainly forage in and around paddy fields between May and June, when the fields are flooded and the rice shoots are still short (Fig. 9.2). They can feed on a range of aquatic organisms, including dragonfly larvae, diving beetles, frogs, tadpoles, and fish. Among these, tadpoles are the most abundant diet resource during breeding season, which spans from May to June for the Oriental white storks.

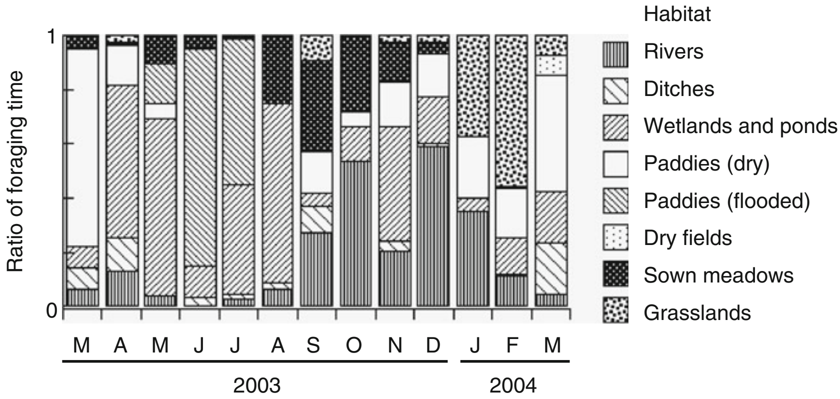

Fig. 9.2 Seasonal change in foraging habitats of the wild Oriental white stork that arrived in the Toyooka Basin in 2002, when no other individual inhabited in the wild. Data are based on continuous focal observations from March 2003 to March 2004, when the seasonal foraging pattern of the individual appeared to be stable and accumulated foraging time in each habitat was calculated (Naito and Ikeda 2007)

During summer, the storks primarily forage in marginal grasslands adjacent to paddy fields or river dikes or in sown meadow along upper riverbeds, where rice grasshoppers, mainly *Oxya yezoensis*, and other insects are abundant. In early autumn, after rice harvesting, the storks often feed on grasshoppers and other insects found in dry paddy fields. Rice grasshoppers are an important diet resource for storks in this season. We found over 40 grasshopper specimens in the esophagus of a stork that accidentally died in August 2013. Later in this chapter, we will discuss the population density of grasshoppers in relation to rice farming methods (section "Stork feeding sites and wildlife-friendly farming").

During winter, the storks often forage in ditches along the paddy fields or in river shallows, where they can find fish such as the Oriental weather loach *Misgurnus anguillicaudatus*, or the red swamp crayfish *Procambarus clarkii*. Therefore, the Oriental white storks appear to occupy paddy fields and their surroundings throughout the year, highlighting the importance of these habitats and emphasizing the importance of rice farming activities in maintaining habitat quality for the Oriental white stork.

Development of a Wildlife-Friendly Farming Method

The Toyooka Basin is located in the lower reaches of the Maruyama River nearly at sea level. Water from its tributaries often accumulates at its bottom, sometimes leading to flooding of the basin after heavy rains. The risk of flooding and high water content of the agricultural land prompted the development of a land consolidation project, which involved elevating the paddy fields, separating the water supply and drainage systems, and enlarging the size of each paddy field.

This program resulted in further habitat degradation and a loss of aquatic species in and around paddy fields. Although the paddy fields were once a good substitute for the natural flood plain, presenting a suitable habitat for aquatic species, the land consolidation project resulted in drastic changes in the paddy ecosystem, leading to a serious threat to local biodiversity. This, added to an increasingly uncertain future of rice farming because of declining prices and retiring farmers, stresses the need of alternative agricultural methods for both economic and ecological reasons.

To facilitate the restoration of foraging habitat for storks, an alternative environmentally friendly rice cultivation system, the so-called *white stork-friendly farming method* (hereafter, WSF farming method), was tested during 2003 in a small area 2 years before the reintroduction of the storks in the Toyooka Basin (Nishimura 2006; Naito and Ikeda 2007; Naito 2011). The use of the WSF farming method has increased yearly ever since, exceeding 200 ha (2 million m^2) in 2010. This farming method, which involves both rice cultivation and the provision of habitat for aquatic and terrestrial organisms, includes a water management system generally aimed to extend the flooded period, the utilization of organic materials while reducing the use of agrochemicals, and wildlife conservation (Fig. 9.3). With this method, the water is retained in the paddy field for as long as possible. In contrast to conventional rice farming, when the field is flooded 5 days or less before rice planting, in the WSF farming method the field is flooded in early spring and the mid-season drainage is delayed for about 2 weeks. These techniques are essential characteristics of the WSF farming method and are intended to control weed, provide a nurturing environment for aquatic organisms, and enhance biological diversity.

Similar water management practices, such as winter flooding, have been applied in other regions in Japan (Mineta et al. 2008; Kurechi 2007). Such practices are intended to create suitable foraging/roosting habitats for wintering birds such as wild geese and ducks (Fasola and Ruiz 1996; Elphick and Oring 1998; Elphick et al. 2010; Yamamoto et al. 2003) and/or to control paddy weed without using herbicides. Winter flooding and fertilization increases the density of aquatic oligochaetes, which are known to promote the development of a soft organic sediment layer. Aquatic oligochaetes bury seeds of weeds and the soft organic sediment layer prevents weed germination (Ito et al. 2011).

Nevertheless, our study demonstrated that paddy fields under the WSF farming method resulted in higher coverage and species diversity of paddy weeds, with considerably high variation among stands and plots, compared with those under conventional farming, which showed extremely low weed cover (Naito and Sagawa 2014). Therefore, farmland management could strongly influence the resulting habitat condition.

The WSF farming method also reduces the need of herbicides and pesticides by 75–100 % compared with conventional methods. Agrochemicals can be replaced by alternatively low biological impact chemicals and organic fertilizers can be selectively used. Habitat management for aquatic organisms, the final step, is optional but may include constructing fishways between paddy fields, ditches, and deep areas in the corners or the edges of the paddy fields to provide shelter for aquatic organisms during dry periods. The function of the fishways will be described later in this chapter (section "Role of small-scale fishways to compensate fragmentation").

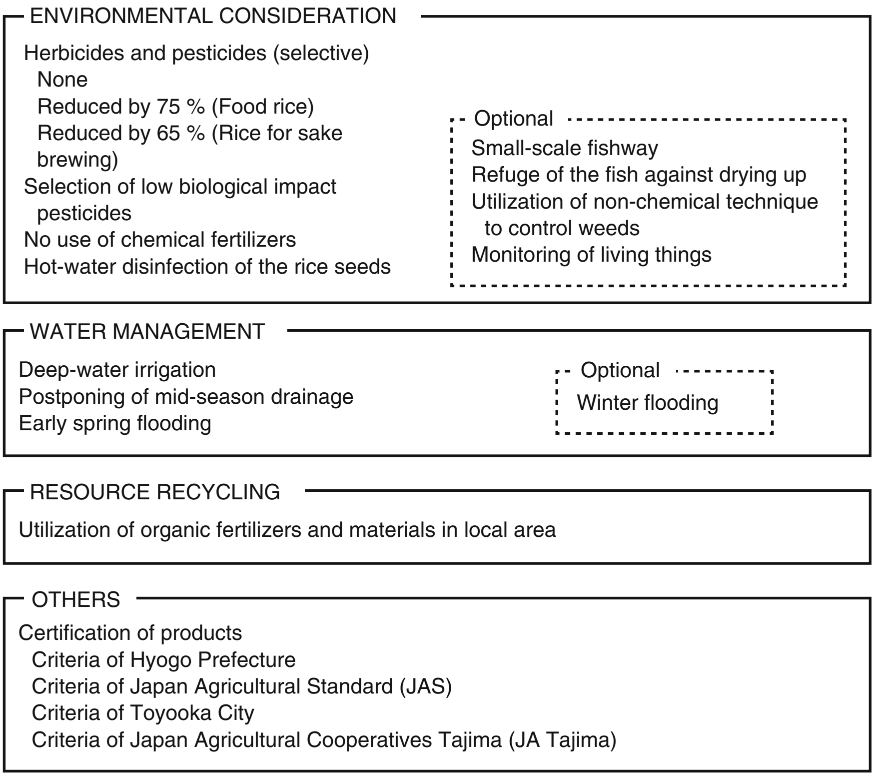

Fig. 9.3 Summarized criteria of the white stork-friendly (WSF) farming method (according to the data from Toyooka Agricultural Extension Center). The criteria included environmental considerations, water management, resource recycling, and certification of products, and consist of essential items and some optional ones. They were originally defined by the project team composed by members of the Toyooka Agricultural Extension Center and related municipal departments during 2002–2003

Effects of Wildlife-Friendly Farming on Paddy Communities

Stork Feeding Sites and Wildlife-Friendly Farming

The distribution of the paddy fields under the WSF farming method influenced the selection of foraging sites by the storks. The relative foraging time per unit area was larger near, within 400 m, paddy fields under the WSF farming method and decreased with the distance from these fields (Fig. 9.4). Two storks occasionally visited extremely distant, more than 1 km away, non wildlife-friendly paddy fields. These results were based on autumn observations, from September to December, on post-harvest dried up paddy fields.

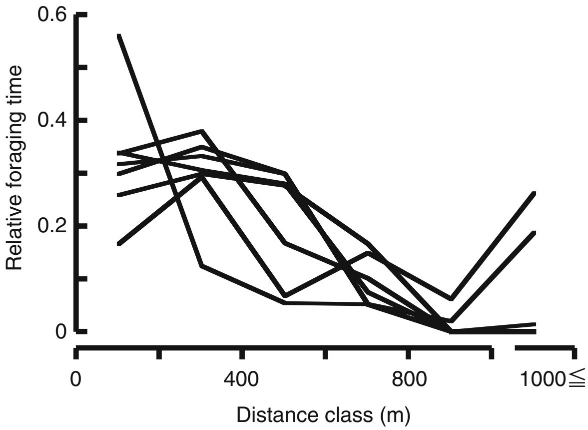

Fig. 9.4 Relative foraging time per unit area in paddy fields of seven Oriental white storks released from two sites in the Toyooka Basin in September 2006, showing distance from paddy fields where the white stork-friendly (WSF) farming method was applied. Data are based on the focal observation, usually 9 h every day, from the released dates, September 23 or 24 to the end of December

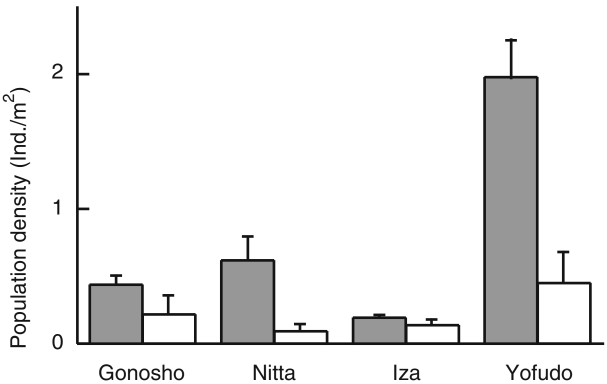

Fig. 9.5 Comparison of the population density of grasshoppers between white stork-friendly (WSF) farming paddy fields (*hatched box*) and in those under conventional farming (*open box*). The survey was conducted at levees in four sites. The population density of each site and each farming method is the average of two paddy fields shown with standard error. The densities significantly differed both between the farming methods and among sites (Tukey–Kramer test, $p = 0.002$ for farming practice, $p = 0.010$ for site, and $p = 0.237$ for farming practice x site)

Data from a field survey carried out in four sites in the Tajima region, showed that the population densities of grasshoppers, the most dominant autumn prey, being different among sites (Fig. 9.5); however, within each site, grasshopper density was higher in WSF farming paddy fields than those under conventional farming. This difference is likely related to the differences in the use of herbicides and pesticides between wildlife-friendly and conventional farming methods. Approximately 90 % of the total number of grasshoppers belonged to the species *O. yezoensis*, representing the most important prey in that season. As the density of *O. yezoensis* is also influenced by the concentration of paddy fields (Yoshio et al. 2009), sustainable paddy agriculture including conventional ones remains essential.

Tadpoles of the black-spotted pond frog *Rana nigromaculata* appeared to be the most important prey during the breeding season, from May to June, for storks under the current habitat conditions. According to the field study of population density of candidate diet animals in paddy field where breeding storks foraged/not foraged, only population density of tadpoles whose size was larger than 50 mm in total length, and mostly identified as *R. nigromaculata*, was significantly higher in paddy field where storks foraged comparing with where they did not (Sagawa 2012a, Fig. 9.6). In contrast, there was no such tendency in the population density of adult

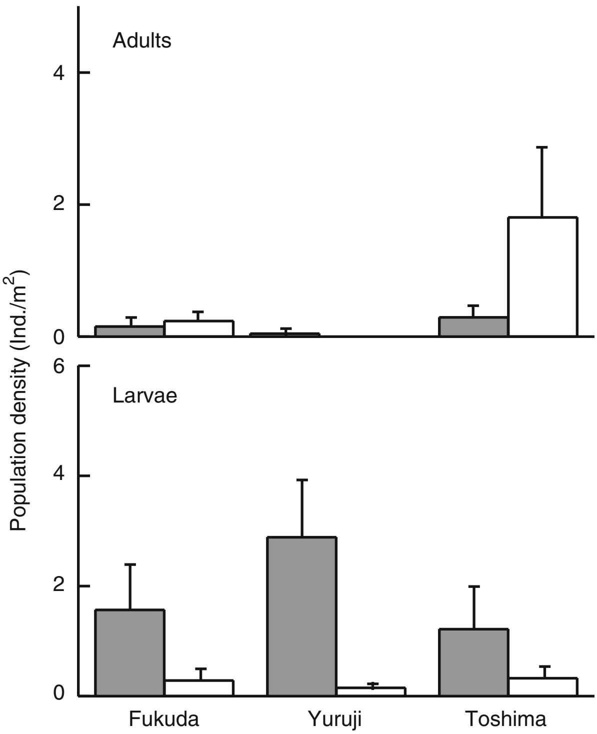

Fig. 9.6 Comparison of the population density of frogs (adults, larvae larger than 50 mm long) between paddy fields foraged by breeding the Oriental white storks (*hatched box*) and in those not foraged by (*open box*). The survey was conducted in three sites where different pair of storks nested. The population density of each site, foraged and not foraged, respectively, is the average of five paddy fields shown with standard error. As for larvae, the densities significantly differed between farming methods, but did not differ among sites (Tukey–Kramer test, $p = 0.001$ for farming practice, $p = 0.470$ for site, and $p = 0.227$ for farming practice x site). Whereas, as for adults, the densities significantly differed among sites, but did not differ between farming methods (Tukey–Kramer test, $p = 0.015$ for site, $p = 0.147$ for farming practice, and $p = 0.154$ for farming practice x site) (Sagawa 2012a)

frogs or total tadpoles including smaller ones. Other small animals were present in paddy fields at lower densities, such as fish, aquatic insects, and crustaceans (crayfish). The tadpoles were the most abundant organisms and easier to catch, representing the main prey for storks during breeding season. As previously discussed, the land consolidation and modernization of the paddy systems has altered the diversity and density of freshwater fish; however, they still have sufficient ecological potential within the river network, ditches, and paddy fields to restore fish populations under the right management.

Dissolved Oxygen Concentration of Paddy Waters

The WSF farming method management scheme may affect the dissolved oxygen concentration (DO) of paddy waters, which at the same time can critically determine habitat suitability and survival of aquatic organisms living in paddy field. Our preliminary study showed an apparent decline in DO concentration in the bottom layer along with an increase in water depth in paddy fields under the WSF farming method, whereas such trend was not found in paddy fields under conventional farming (Fig. 9.7 upper). DO often was lower than 1 mg/L at points

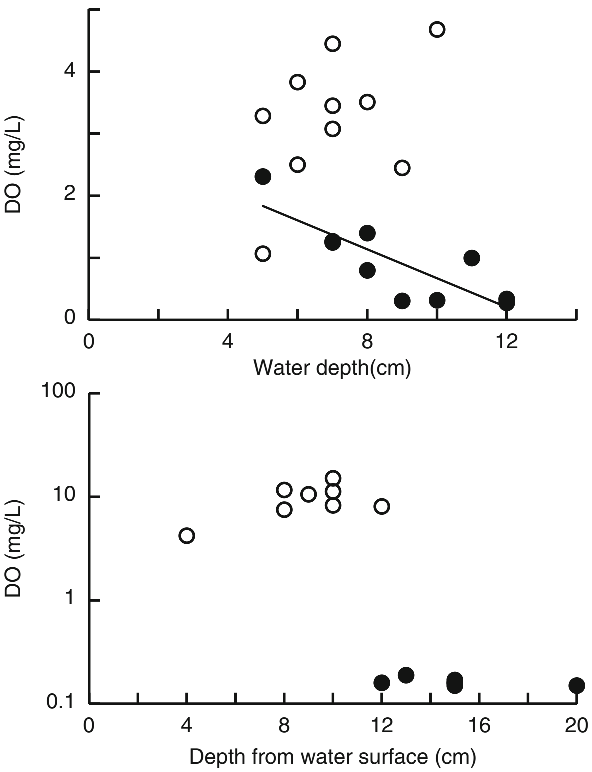

Fig. 9.7 Dissolved oxygen (DO) concentrations of water in paddy fields. The *upper graph* demonstrates the difference between paddies of conventional (*open circle*) and under the white stork-friendly (WSF) farming method (*closed circle*) (t-test, $p < 0.0001$). DO in WSF paddy fields was negatively correlated with water depth ($y = 3.00 - 0.23x$, $r^2 = 0.680$). The *lower graph* shows the difference in DO concentrations between the water column (*open circle*) and soft mud layer (*closed circle*) in a WSF paddy field (t-test, $p < 0.0001$). Measurements were conducted at similar time but on separate sites/days; therefore, standard DO values are not same between the two graphs

where the water depth exceeded 8 cm. Furthermore, DO concentrations remarkably differ between the lower water layer and the soft mud layer (Fig. 9.7 lower). DO concentration was much lower than 1 mg/L, suggesting that aquatic organisms could not survive in such anoxic conditions (Negishi et al. 2012).

DO concentration in paddy water changes with night and day (Usui and Kasubuchi 2013) because of a range of factors including the effect of aspiration of aquatic organisms, phytoplankton photosynthetic activity, and water circulation. The application of herbicide has been previously reported to decrease DO concentration (Usui and Kasubuchi 2011) because of a decline in photosynthetic activity. Therefore, conventional farming can also have a negative effect on DO concentration. Under WSF farming, lower DO concentration probably resulted due to the turbidity of water because of the application of organic materials like rice bran, which promotes the development of soft mud layer. Further, we suggest that water management based on deeper water depths, which is intended to suppress germination and establishment of weeds in paddy field, may lead to lower DO concentrations compromising the survival of aquatic organisms. This difference in DO concentration possibly lead to the differences found in the density of tadpoles and other animals, between conventional and WSF farming.

Effect of Wildlife-Friendly Farming on Frogs

In general, *R. nigromaculata* larvae metamorphoses in late June to September (Maeda and Matsui 1999), implying that mid-season drainage, usually conducted approximately 35 days after rice planting, can influence tadpole survival in paddy fields. Therefore, postponing the drying up phase has been regarded as a key technique in the WSF farming method to conserve frog populations. An earlier study monitoring the effect of the introduction of the WSF farming method on the population of *R. nigromaculata* in paddy fields showed a population increase 2 years after this farming system was applied (Toyooka City 2006). These results do not follow our prediction that tadpole survival in WSF paddy fields would be compromised because of insufficient DO concentration. While winter flooding of the paddy fields, a characteristic of this wildlife-friendly farming method, may alter the frog overwintering habitat because they often use post-harvested paddies, levees, and dry fields. Further studies are needed to better understand the negative and positive effects of the WSF farming method and the relationship between this farming method, DO concentration, and the dynamics of aquatic organisms. As previously described, weed germination relates to DO concentration (Kataoka and Kim 1978); therefore, low DO density is probably beneficial to control paddy weeds, while potentially having a negative impact on the habitat for aquatic organisms.

Small Scale Fishways as Potential Restoration Technique

Effects of the Land Consolidation Project on Paddy Ecosystems

Frogs and tadpoles are an important prey for the Oriental white stork because currently their biomass is relatively large; however, freshwater fish may also breed within paddy fields (Saitoh et al. 1998), potentially representing secondary prey. Yet, because nearly the entire Toyooka basin has undergone land consolidation, the presence of fish in paddy fields has received little attention.

Habitat degradation because of land consolidation in paddy fields has been repeatedly reported in studies on fishes (Katano et al. 2001), birds (Lane and Fujioka 1998), and frogs (Fujioka and Lane 1997). Habitat fragmentation by the disconnection between water supply and drainage systems, the decrease of levees by enlargement of each paddy field, and dried soil condition by padding of the paddy field and drainage system have been pointed as the main factors leading to habitat degradation in this system.

Reproductive Potential of Paddy Field

According to an experimental trial carried out in a paddy field around Lake Biwa, western Japan, the release of *Carassius auratus grandoculis* adults just before laying eggs or the release of juveniles can lead to a higher juvenile growth rate in paddy fields compared with that of artificial breeding conditions or reed natural habitat (Kanao et al. 2009). Warmer waters in paddy fields caused by shallow water depth and abundance of water fleas and other small aquatic organisms were the two main factors affecting juvenile growth rate. These juveniles grow up to 25 mm long in the paddy fields to then flow downstream through the ditches.

These results of higher reproduction of juveniles in paddy fields imply a high potential of freshwater fish as diet resource for the Oriental white storks. Under the standard farming scheme, paddy field is dried up once approximately 35 days after rice planting and 2 weeks later in paddy fields under the WSF farming method. This promotes the downstream flow of juvenile fish to potentially reproduce in the rivers, while some individuals remain in the paddy field as prey for storks.

Role of Small-Scale Fishways to Compensate Fragmentation

Small-scale fishways represent an engineering technique to mitigate water network fragmentation, connecting paddy fields and ditches and allowing freshwater fish to enter to paddy fields to reproduce. Several studies have reported the effect of these fishways on paddy ecosystems (Suzuki et al. 2000, 2001). On the basis of those studies, small-scale fishways have been installed in some areas in the Toyooka Basin from 2002. In particular, 58 fishways were installed within 33 ha in the Akaishi district and lower section of the Maruyama River watershed between 2002 and 2004 as a pilot work to mitigate the effects of a land consolidation project.

The fishways were used by more than ten freshwater species, including the Oriental weather loach *M. anguillicaudatus*, Japanese common catfish *Silurus asotus*, *Carassius* sp., and *Gnathopogon elongatus* (Naito et al. 2005). Some of these species, *M. anguillicaudatus*, *Silurus asotus*, and *Carassius* sp. were found to reproduce in paddy fields and flowed out into ditches when the paddy field was drained during rice cultivation.

Although confirming whether fish species can move between paddy fields and ditches across fishways is essential to optimally design the fishways, other factors are also crucial to ensure their success. The fishways are ultimately meant to promote reproduction within the paddy fields. From this point of view, factors such as presence/absence of a source population, the distance from it, and the presence of a solid ecological network connecting the source population with the paddy field are also essential to identify possible dispersal barriers.

As previously discussed, the paddy fields in the Toyooka Basin are occasionally flooded by heavy rains. Therefore, the reproduction potential of paddy fields varies among sites. After comparing the density of recruited fish among three paddy fields where fishways were installed, a previous study revealed that the distance to the main drainage canal can significantly affect fish density (Sagawa 2012b). This previous study also showed that the density of fish eggs or larvae is negatively influenced by the presence of tadpoles and other aquatic insects, which may feed on fish eggs or larvae; however, this interaction has not been studied yet for paddy fields.

It is essential for the farmer to understand the effect that paddy fields and fishways management have to continuously supply water and ensure fish spill over, facilitating fish movement and adjusting water depth that potentially influences fish reproduction. Compared with the WSF farming method, small-scale fishways are not a popular choice in the Toyooka basin partly because of financial and labor costs for installation and maintenance. Most fishways installed in the past were financially supported by the local governments. The strategic expansion of fishways is needed to enhance fish reproduction and the distribution of storks for effective restoration.

Conclusion

Organic farming, providing high quality products in ecological harmony has become increasingly popular in Japan since the 1990s. This organic farming movement is associated with healthy food and the conservation of species inhabiting rural areas, such as the bean goose, *Anser fabalis*, crested ibis, *Nipponia nippon*, and the Oriental white stork. Many species are associated with organic farming, including the Japanese rice fish, *Oryzias latipes*; crucian carp, *Carassius* sp.; predaceous diving beetle, *Cybister japonics*; and giant water bug, *Lethocerus deyrollei*. Most of these species have become increasingly rare and threatened in rural areas. Recently, the Ministry of Agriculture, Forestry and Fisheries of Japan has been promoting the use of wildlife-friendly farming practices, which are usually characterized by environmental labelling for agricultural products, such as eco-label and creature brand, based on local representative animal or plant species to promote public understanding of projects that contribute to the conservation of nature and familiar wildlife and to promote the national biodiversity strategy of Japan.

Although a positive attitude from the general public is important, the level of involvement of each local farmer is essential to promote and maintain wildlife-friendly farming methods. We found that farmers who have already applied the WSF farming method appreciated not only the economic merits of the farming method (Naito et al. 2014) but also its positive effect on biodiversity and landscape ecology (Kikuchi 2012). Therefore, the improvement of farming techniques is expected to further adjust and conserve the ecology and biodiversity of paddy fields.

Nevertheless, paddy fields managed through conventional farming systems can also play a fundamental role in stork conservation. Conventional farming differs from wildlife-friendly farming, which may increase tadpole density. Therefore, an equilibrated mosaic of conventional and wildlife-friendly fields may further enhance the habitat quality for storks.

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References

Caro TM, O'Doherty G (1999) On the use of surrogate species in conservation biology. Conserv Biol 13:805–814

Elphick CS, Oring LW (1998) Winter management of Californian rice fields for waterbirds. J Appl Ecol 35:95–108

Elphick CS, Baicich P, Parsons KC, Fasola M, Mugica L (2010) The future for research on waterbirds in rice fields. Waterbirds 33(sp1):231–243. doi:10.1675/063.033.s117

Fasola M, Ruiz X (1996) The value of rice fields as substitutes for natural wetlands for waterbirds in the Mediterranean region. Colonial Waterbirds 19:122–128

Fujioka M, Lane SJ (1997) The impact of changing irrigation practices in rice fields on frog populations of the Kanto Plain, central Japan. Ecol Res 12:101–108
Hyogo Park of the Oriental White Stork (2012) Grand design for the reintroduction of Oriental white stork. Hyogo Park of the Oriental White Stork, Toyooka. http://www.stork.u-hyogo.ac.jp/reintr/reintr_file/grand_design.pdf. (in Japanese, title was translated by the present authors)
Ikeda H (2000) Toward the reintroduction of Oriental white stork. Kagaku 70:569–578 (in Japanese, title was translated by the present authors)
Ito T, Kawase M, Hara K, Kon C (2011) Ecology and function of aquatic oligochaetes in winter-flooded rice fields with organic farming. Soil Microorg 65:94–99 (in Japanese)
IUCN (2013) The IUCN red list of threatened species. Version 2013.2. http://www.iucnredlist.org. Downloaded on 21 Nov 2013
Iwasa S (1936a) Oriental white stork. Bull Hyogo Nat Hist Soc 11:21–27 (in Japanese, title was translated by the present authors)
Iwasa S (1936b) Oriental white stork (II). Bull Hyogo Nat Hist Soc 12:59–61 (in Japanese, title was translated by the present authors)
Japan Wildlife Research Center (1987) Report on past distribution of birds and animals (in Japanese, title was translated by the present authors)
Kanao S, Ohtsuka T, Maehata M, Suzuki N, Sawada H (2009) Effectiveness of paddy fields as an initial growth environment for larval and juvenile nigorobuna *Carassius auratus grandoculis*. Nippon Suisan Gakkaishi 75:191–197 (in Japanese with English abstract)
Katano O, Hosoya K, Iguchi K, Aonuma Y (2001) Comparison of fish fauna among three types of rice fields in the Chikuma River basin. Jpn J Ichthyol 48:19–25 (in Japanese with English abstract)
Kataoka T, Kim SY (1978) Oxygen requirement for seed germination of several weeds. Weed Res 23:9–12 (in Japanese with English abstract)
Kikuchi N (2012) Report of hearing survey to farmers engaging in "Oriental white stork-friendly farming method" in Tyooka City, Hyogo Prefecture. Reintrodution 2:103–119 (in Japanese)
Kikuchi N, Ikeda H (2006) The Oriental white stork in Tajima. Tajima Cultural Association, Toyooka, 304 p. (in Japanese, title was translated by the present authors)
Kurechi M (2007) Restoring rice paddy wetland environments and the local sustainable society–project for achieving co-existence of rice paddy agriculture with waterbirds at Kabukuri-numa, Miyagi Prefecture, Japan. Glob Environ Res 11:141–152
Lane SJ, Fujioka M (1998) The impact of changes in irrigation practices on the distribution of foraging egrets and herons (Ardeidae) in the rice fields of central Japan. Biol Conserv 83:221–230
Maeda N, Matsui M (1999) Frogs and toads of Japan, Rev edn. Bun-ichi Sogo Shuppan, Tokyo (in Japanese with English abstract)
Mineta T, Koizumi N, Ishida K (2008) Contribution of winter flooding in multifunctionality of paddy fields. J Rural Plann Assoc 27(Special Issue):335–340 (in Japanese)
Naito K (2011) Restoration for the reintroduction of Oriental white stork in Toyooka Basin. Bull Kansai Organ Nat Conserv 33:9–13 (in Japanese)
Naito K, Ikeda H (2007) Habitat restoration for the reintroduction of Oriental white storks. Glob Environ Res 11:217–221
Naito K, Sagawa S (2014) Preliminary report on the vegetation of paddy field where employ the white stork-friendly farming method. Reintroduction 3:51–55 (in Japanese with English abstract)
Naito K, Ohsako Y, Ikeda H (2005) Reintroduction project of the Oriental white stork and nature restoration of a rural area. In: Kameyama A, Kuramoto N, Hioki Y (eds) Nature restoration and rehabilitation: using an ecotechnological approach. Soft Science Inc., Tokyo (in Japanese)
Naito K, Kikuchi N, Ikeda H (2011) Reintroduction of oriental white storks: ecological restoration and preparation for release into the wild based on the guidelines of IUCN. Jpn J Conserv Ecol 16:181–193 (in Japanese with English abstract)

Naito K, Kikuchi N, Ohsako Y (2014) Role of the Oriental white stork in maintaining the cultural landscape in the Toyooka Basin, Japan. In: Hong SK, Bogaert J, Min Q (eds) Biocultual landscapes: diversity, functions and values. Springer, Dordrecht, pp 33–44. doi:10.1007/978-94-017-8941-7_4

Negishi JN, Sagawa S, Kayaba Y, Sanada S, Kume M, Miyashita T (2012) Mussel responses to flood pulse frequency: the importance of local habitat. Freshw Biol 57:1500–1511. doi:10.1111/j.1365-2427.2012.02803.x

Nishimura I (2006) Agriculture which facilitates the reintroduction of the Oriental white stork. In: Washitani I (ed) Restoration of paddy fields. Ieno Hikari Kyokai, Tokyo, pp 125–146 (in Japanese, title was translated by the present authors)

Roberge J-M, Angelstam P (2004) Usefulness of the umbrella species concept as a conservation tool. Conserv Biol 18:76–85

Sagawa S (2012a) Process of environmental restoration for reintroduction of Oriental white stork (*Ciconia boyciana*). Reintrodution 2:27–31 (in Japanese)

Sagawa S (2012b) Contributing factors to natural fish reproduction in the rice paddy with fish pass. Reintrodution 2:83–88 (in Japanese with English abstract)

Saitoh K, Katano O, Koizumi A (1998) Movement and spawning of several freshwater fishes in temporary waters around paddy fields. Jpn J Ecol 38:35–47 (in Japanese with English synopsis)

Suzuki M, Mizutani M, Goto A (2000) Development of small-scale fishway for preserving ecosystem in paddy fields. J Agri Eng Soc Jpn 68:19–22 (in Japanese)

Suzuki M, Mizutani M, Goto A (2001) Trial Manufactures and experiments of small-scale fishways to ensure both upward and downward migration of freshwater fishes in the aquatic area with paddy fields. Ecol Civ Eng 4:163–177 (in Japanese)

Toyooka City (2006) Report on the monitoring of plants and animals in paddy fields. Toyooka City. 24 p (in Japanese, title was translated by the present authors)

Usui Y, Kasubuchi T (2011) Effects of herbicide application on carbon dioxide, dissolved oxygen, pH, and RpH in paddy-field ponded water. Soil Sci Plant Nutr 57:1–6. doi:10.1080/00380768.2010.541868

Usui Y, Kasubuchi T (2013) Diurnal variation in CO_2, dissolved oxygen (DO), pH and RpH and their correlations in ponded paddy field water. Jpn J Limnol 74:15–20. doi:10.3739/rikusui.74.15

Yamamoto H, Oohata K, Yamamoto K (2003) The effects of water flooding and provision of the food for wintering ducks on rice fields – a preliminary study for establishing a stable wintering duck population at Katano-kamoike, III. Strix 21:111–123 (in Japanese with English abstract)

Yoshio M, Kato N, Miyashita T (2009) Landscape and local scale effects on the orthopteran assemblages in the paddy agroecosystems on the Sado Island, Japan with implications for the habitat management for the crested ibis. Ecol Civ Eng 12:99–107 (in Japanese with English abstract)

Chapter 10
Nursery Grounds for Round Crucian Carp, *Carassius auratus grandoculis*, in Rice Paddies Around Lake Biwa

Taisuke Ohtsuka

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Abstract Since the turn of the twenty-first century, two means of promoting the use of rice paddies as fish nursery ground have been implemented around Lake Biwa in Japan. One involves fish culture: newly hatched or pre-flexion larvae are released into rice paddies after the rice transplantation, and then reared to juveniles before the mid-season drainage. The other involves the installation of fish passes to enhance the entry of adult fish into paddies and encourage their natural reproduction there. These efforts mainly aim to enhance the reproduction of round crucian carp (nigorobuna), *Carassius auratus grandoculis*, an endangered

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endemic subspecies inhabiting Lake Biwa, which is also the principal ingredient in *funa-zushi*, a specialty food of Shiga Prefecture. Both methods are regarded as environment-friendly and thus are well supported by local people. Our studies on the rice paddy food chain revealed, however, that the impact of round crucian carp larvae/juveniles on aquatic biota in rice paddies is profound. Fish predation results in an extreme reduction of Cladocera, and a concomitant increase in the food species and competitors of cladocerans. Through their benthic foraging, juvenile fish also cause a rise in total phosphorus concentration and phytoplankton in the paddy water. In addition, scarce competitors and predators in the paddies contribute to the rapid growth and low mortality of the fish larvae/juveniles. Although the employment of rice paddies as fish nursery ground may be effective for the conservation of round crucian carp, other approaches are also needed to enhance the overall biodiversity of rice paddy areas around Lake Biwa.

Keywords Biodiversity • Bottom-up effects • *Carassius auratus grandoculis* • Chironomids • Cladocerans • Fish ladder • Indirect effects • Social capital • Rice paddy • Top-down trophic cascade

Introduction

Biodiversity enhancement of paddy fields has become the subject of increased attention in various countries as a result of two international agreements, the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention) and the Convention on Biological Diversity (CBD). Ramsar COP 10 (Changwon, Republic of Korea, 2008) adopted Resolution X.31, "Enhancing biodiversity in rice paddies as wetland systems", which recognized the contributions of rice paddies to wetland biodiversity and encouraged planning, farming practices, and water management systems that enhance the natural biodiversity, ecosystem services, and sustainability of rice paddies. CBD-COP 10 (Nagoya, Japan, 2010) adopted Decision X/34, "Agricultural biodiversity", which welcomed this latter Resolution X.31 and invited relevant Parties, as appropriate, to fully implement it. Ramsar COP 11 (Bucharest, Romania, 2012) again adopted a resolution related to the biodiversity of rice paddies, Resolution XI.15, "Agriculture-wetland interactions: rice paddy and pest control".

Resolution X.31 of the Ramsar Convention encouraged Contracting Parties to promote further research on flora, fauna, and ecological functions in rice paddies. In Japan, the flora and the fauna of paddies have been relatively well studied. A notable achievement was the compilation of "A comprehensive list of organisms associated with paddy ecosystems in Japan" (Kiritani 2010), although some insufficiencies, mainly concerning smaller organisms, have been pointed out (e.g. Ohtsuka and Suzuki 2012). Meanwhile, our knowledge about ecological functions is still scant. In particular, ecological functions seemingly irrelevant to rice production have been little studied. Integrated biodiversity management

(IBM), in which IPM and conservation are reconciled and made compatible with each other, has been proposed as a key concept for sustainable agriculture with enhanced biodiversity (Kiritani 2000). This concept, however, encounters practical difficulties in that it requires a comprehensive understanding of the functions and structures of the whole ecosystem of a given paddy area.

Rice-fish farming is practiced in many countries in the world, particularly in Asia (dela Cruz et al. 1992; Halwart and Gupta 2004). It seems to provide a nutritionally complete combination of foods and alleviates poverty (Halwart and Gupta 2004), and is now also regarded as an environment-friendly activity. For instance, Lu and Li (2006) reviewed rice-fish farming systems in China and demonstrated that such systems reduce pesticide application 50 % compared to modern, high-input rice production, and also reduce emission of CH_4 by nearly 30 % compared with traditional rice farming. The rice-fish system for grow-out operation has declined in Japan, except in limited areas (Fernando 1993; Ikuta and Yamaguchi 2005). In contrast, another type of rice-fish system, i.e., a nursery system for fish culture, has come to be practiced in Japan, especially in Shiga Prefecture. It mainly involves the stocking of larvae/juveniles of round crucian carp (nigorobuna; *Carassius auratus grandoculis*) and willow shiner (honmoroko; *Gnathopogon caerulescens*), which are culturally important endemic fishes of Lake Biwa.

In addition, fish passes connecting rice paddies to their drainage canals have been increasingly installed in Japan. As a result of land improvement programs, most rice paddies in Japan sit much higher than the water level of the connecting drainage canal. Because this vertical disparity prevents fish runs into the paddies, establishing fish passes between the paddies and the adjacent drainage ditches is necessary (Hata 2002b). Usually the purpose is not to catch fish, but to enhance fish reproduction by encouraging spawning in rice paddies (Hata 2002a); therefore, it is appreciated as a good practice that enhances biodiversity (e.g., Hazama and Hori 2012; Kim et al. 2012).

It requires careful examination, however, in order to judge whether rice-fish culture or fish pass installation in fact enhances the biodiversity in rice paddies. Fishes in paddy fields often prefer Cladocera as prey to the other small arthropods (e.g., Hurlbert and Mulla 1981; Yamazaki et al. 2010), while cladocerans themselves are known as strong competitors among the zooplankton (Brooks and Dodson 1965). Some of these fishes, such as mosquitofish (*Gambusia affinis*) and Far Eastern catfish (*Silurus asotus*) are higher level consumers preying upon carnivorous insects and other fishes (Bence 1988; Tomoda 1978). They might be keystone predators with disproportionately strong effects on the paddy field ecosystem (Mills et al. 1993). In addition, some of these fishes, such as Prussian carp (*Carassius auratus gibelio*) and common carp (*Cyprinus carpio*), are known as *ecosystem engineers* that create or significantly modify habitats in lakes (Paulovits et al. 1998; Matsuzaki et al. 2007).

Strong effects of fish on the rice paddy ecosystem can reveal relationships between organisms that have been little appreciated or understood (Vromant et al. 2001; Yamazaki et al. 2010; Nishimura et al. 2011). Land improvement and paddy consolidation have produced homogeneous rice paddy parcels from which fishes are excluded. For this reason, such parcels provide convenient experimental enclosures for fish-stocking experiment designed to reveal the interactions between organisms. Comparisons of community dynamics between parcels with and without stocked fish can provide valuable information about biological interactions in rice paddies (Ohtsuka et al. 2012).

In this chapter, I introduce the practices adopted around Lake Biwa for using rice paddies as nursery grounds for round crucian carp. This fish is especially important among the fishes that spawn in rice paddies because it is an endemic subspecies of Lake Biwa that is designated as endangered in the Ministry of the Environment, Japan's national red list, but is nonetheless a major fishery resource as the principal ingredient in *funa-zushi*, a specialty food of Shiga Prefecture. Two types of nursery system, based respectively, on the stocking of larvae/juveniles and the installation of the fish passes (*Sakana-no-yurikago-suiden*), are practiced. The impacts of the larvae/juveniles on the rice paddy ecosystems and the ecological implications of the success of these practices are also discussed.

Rice Paddy Fish Nursery System Around Lake Biwa

Background of the Venue

Paddy fields around Lake Biwa are important as an alternative form of back marsh of the lake, and many of them have actually replaced satellite lakes or marshes (Hanafusa 2000). Conservation and restoration of the paddies around the lake are, therefore, important issues in lake management (Ohtsuka 2012). The lake itself is the largest and the oldest in Japan, inhabited by many endemic taxa. It was designated a UNESCO Ramsar Wetland in accordance with the Ramsar Convention in 1993. Nishino-ko, the largest extant satellite lake attached to Lake Biwa, was added to this designation in 2008.

More broadly, because paddy fields comprise a large part of Lake Biwa's catchment, wise use of the paddies is a key to conserving the water system. The catchment of lake Biwa is 4,017 km^2 in area, encompassing ca. 80 % of the total area of Shiga Prefecture. In 2012, rice paddies covered 467 km^2 of the area, excluding the levees. Rice acreage was 327 km^2 while the rest of the area was fallow or planted with other crops (Kinki Regional Agricultural Administration Office 2013). During the growing season for rice plants, the paddies clearly comprise the majority of the marshy wetland in this basin; the flooded area is almost equal to half the area of Lake Biwa's water surface (670 km^2).

The paddy fields in Lake Biwa's basin have a history that dates back to at least 300 B.C. (Ueda 2012). Coevolution of biodiversity and culture in the setting provided by Lake Biwa has been the source of a unique local culture. This is represented by *funa-zushi*, lacto-fermented fish pickled with rice, which is a traditional food of

Shiga Prefecture made from the round crucian carp (Horikoshi 2012). Although the balance between the natural and cultural aspects of this coevolution has been altered, even damaged, by the modernization of rice farming, diverse organisms, including many threatened ones, and related aspects of the regional culture still persist.

Stocking of Larvae/Juveniles for Culture In Situ

The maintenance and recovery of the food resource provided by the round crusian carp is an important one in terms of conservation, fishery production, and local culture (see above). Shiga Prefecture started to release juveniles and young fish raised in ponds into Lake Biwa in 1983. Around the same period, however, the fish catches of crucian carps (including *C. auratus langsdorfii*, *C. a. grandoculis*, and *C. cuvieri*) in Lake Biwa began to decline rapidly. The causes were presumed to be a decline of reed beds as spawning grounds, feeding upon the larvae/juveniles by non-native fishes such as largemouth bass (*Micropterus salmoides*) and bluegill sunfish (*Lepomis macrochirus*), and water level manipulation contrary to natural water level fluctuations (Fujioka 2006; Kanao et al. 2009). While more than 500 t of crucian carp had been fished yearly before 1987, only about 100 t were caught after 1995. Above all, the catches of female round crucian carp, the best ingredient of *funa-zushi*, declined to about 30 t per year (Kinki Regional Agricultural Administration Office 1959–2011, 2012–2013; Fig. 10.1).

In the beginning of the 2000s, researchers at the Shiga Prefectural Fisheries Experiment Station and their collaborators showed that rice paddies are ideal nurseries for round crucian carp. Fish larvae/juveniles in paddies exhibited rapid growth and extremely high survival rates (Kanao et al. 2009). As a result, a fish nursery system involving rice paddies was started around Lake Biwa in 2003.

In nursery stocking, newly hatched or pre-flexion larvae of round crucian carp are released into rice paddies after rice transplantation has been completed. They are then reared in the paddies usually for a month or more and grow to juveniles of about 30 mm in total length (Fig. 10.2). During the mid-season drainage of the paddies, they are released into drainage canals connecting to Lake Biwa. Recently, about 10^7 juveniles per year have been raised in rice paddies without artificial feeding, and have been released into Lake Biwa (Fujioka and Maehata 2012).

The proportion of round crucian carp initially reared in rice paddies can be estimated by checking their otoliths. Those of a known proportion of the larvae/juveniles are marked with alizarin complexone. Continuous monitoring by the Shiga Prefectural Fisheries Experiment Station has shown that they accounted for 9 to 22 % of the youngest year-class of round crucian carp in Lake Biwa from 2004 to 2010 (Nemoto et al. 2013). After the start of this program, the first-year stock of round crucian carp increased, although the fish catch itself has not recovered as much as was hoped.

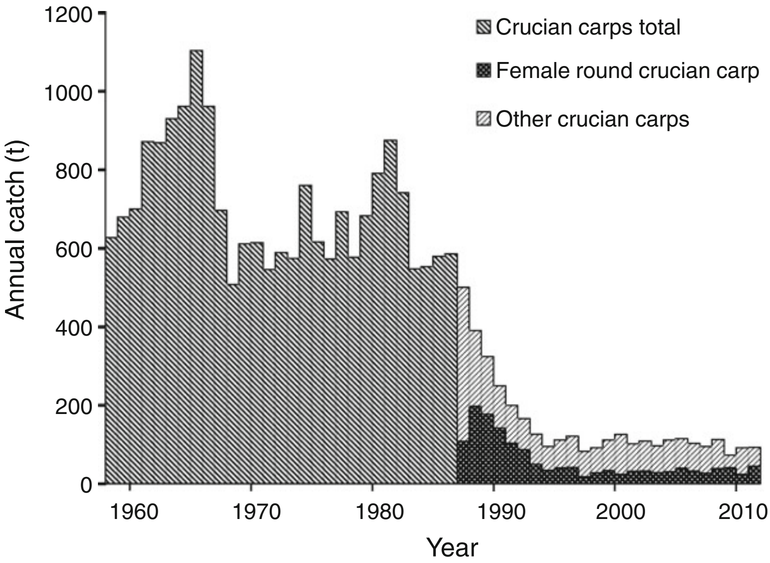

Fig. 10.1 Change in catch of crucian carps (*Carassius* spp.) in Lake Biwa. Data issued by the Kinki Region Agricultural Administration Office (1959–2011, 2012–2013) are summarized. Data for female round crucian carp (*C. auratus grandoculis*), the most prized fish for producing *funa-zushi*, have been reported separately only since 1987

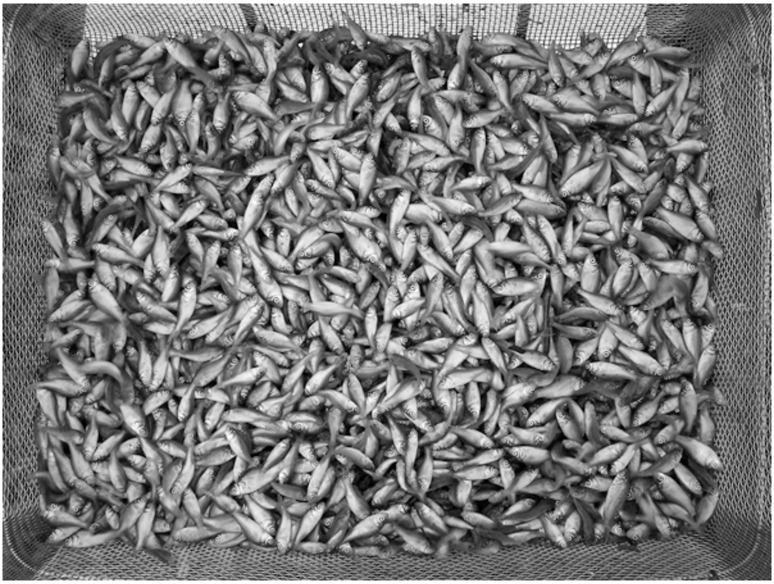

Fig. 10.2 Round crucian carp juveniles raised in a rice paddy (Photo by Shigefumi Kanao)

Fish Pass Installation

In Lake Biwa's basin, many fish taxa are known to inhabit rice paddies and/or adjacent temporary waters such as lateral drainage canals at some stage of their life history. At least 30 fish taxa have been reported from these habitats (Kanao 2005; Kanao and Ueno 2005; Kanao et al. 2010; Hazama and Hori 2012; Maehata 2013; Table 10.1). Especially, the paddy fields have drawn attention as actual or potential nursery grounds for fishes. Many fishes of Lake Biwa can grow in paddy fields in their larval and juvenile stages (e.g., Kanao et al. 2009). In addition, some fish enter

Table 10.1 Fishes reported from rice paddies and/or associated temporary waters such as lateral drainage canals around Lake Biwa

Taxon	References
Abbottina rivularis	5
Acheilognathus rhombeus	1, 4, 5
Carassius auratus grandoculis	1, 2, 4, 5
Carassius auratus langsdorfii	1, 2, 3, 4, 5
Carassius cuvieri	1
Channa argus	1, 5
Cobitis biwae	3
Cobitis magnostriata	3
Cobitis minamorii oumiensis	3
Cottus reinii	5
Cyprinus carpio	1, 4, 5
Gnathopogon elongatus	1, 3
Gymnogobius urotaenia	1, 5
Lefua echigonia	3
Lepomis macrochirus	1, 5
Micropterus salmoides	5
Misgurnus anguillicaudatus	1, 2, 3, 4, 5
Nipponocypris sieboldii	1, 5
Nipponocypris temminckii	5
Odontobutis obscura	1, 3
Oryzias latipes	1, 2, 3, 4, 5
Paramisgurnus dabryanus	2, 4
Plecoglossus altivelis subsp.	1, 5
Pseudorasbora parva	1, 4
Rhinogobius kurodai	1, 2, 3, 5
Rhinogobius sp. BW	1
Rhodeus ocellatus ocellatus	2, 5
Silurus asotus	1, 2, 4, 5
Tridentiger brevispinis	1
Zacco platypus	1, 5

The cited references as follows. 1. Kanao (2005); 2. Kanao and Ueno (2005); 3. Kanao et al. (2010); 4. Hori and Hazama (2012); 5. Maehata (2013) paddies for spawning if they can find an adequate pathway (e.g., Maehata 2007). Among these fish, the round crucian carp is especially important (see above).

In 2001, Shiga Prefecture started its *Sakana-no-yurikago-suiden* project, that is, Restoration of Fish Breeding Mechanism in Paddy Fields, around Lake Biwa. This project aims at rural environmental improvement be encouraging the resumption of fish migration between paddies and Lake Biwa. According to Kada (2012), the project was originally inspired by the results of a comprehensive research program on paddy fields conducted by the Lake Biwa Museum from 1996 to 1998. This program examined the ecology of fishes that inhabit paddy fields at some stage of their life history (e.g., Maehata 2007). As part of the study, a researcher released a pair of adult *C. a. grandoculis* into a rice paddy and obtained a few tens of thousands of fish juveniles. Dr. Yukiko Kada, the principal researcher of this research project (and later the governor of Shiga Prefecture), persuaded officers of the Department of Agriculture and Fisheries, Shiga Prefecture, to undertake an official project to enhance fish breeding in rice paddies. An official project to develop fish passes and to design experiments to confirm the utility of rice paddies as fish nurseries was started in 2001. Soon after, local people in various parts around Lake Biwa began taking steps to implement these ideas.

Participants in this project construct fish passes to enhance fish breeding in the paddies, and thus receive a subsidy since 2006. The subsidy system went through a transition, and it became a part of the System of Direct Payment for Environment-friendly Agriculture of Shiga Prefecture in 2011. The amount of subsidy was 3,000 JPY (ca. 30 US dollars) per 1,000 m^2 of paddies involved. By 2011 this program had expanded to about 1.2 km^2 of paddy fields. In addition, about half of the rice produced in such paddies is certified as *Sakana-no-yurikago-suiden-mai*, that is, fish-friendly rice, and commands a premium price. The rice is sold at a price up to 20 % higher than conventional rice (Nishimura et al. 2012a, b).

Two types of fish pass are used in this area. One is a fish-ladder that connects a drainage canal and an adjacent paddy directly. Another is a fish-ladder cascade that works by elevating the water level of the upper reaches of a drainage canal through the installation of a series of successively higher flashboards; this sort of installation enables fish to enter the paddies adjacent to the canal by way of their drains (Fig. 10.3). The latter, the so-called Shiga-model system, was established in 2004. It is technically easier to install but socially more difficult to set up and manage than the former, because it requires agreement among the all farmers sharing the drainage canal. Nevertheless, In Shiga Prefecture, it has been more frequently adopted than the usual fish-ladder. This indicates that a rich social capital has been maintained in the rural areas (Tanaka 2006). So far, the Shiga-model system has not yet been introduced into other prefectures except in Tsubata town, near Kahokugata Lagoon in Ishikawa Prefecture.

The effects of Shiga-model fish pass installation have been demonstrated repeatedly. For instance, Hazama and Hori (2012) set a scoop net over each drain outlet at the time of the mid-season drainage to catch all fishes exiting from the *Yurikago Suiden* paddies (comprising an area of 0.322 km^2 in total) into drainage canals in four villages in Yasu city, southwest of Lake Biwa. The fish caught were identified and counted, although these numbers were underestimates because

Fig. 10.3 A fish-ladder cascade installed in a drainage canal as part of the *Sakana-no-yurikago-suiden* fish nursery program in rice fields (Photo by Shigefumi Kanao)

some fish were left stranded in the paddies. In total, about 10,000 individuals of fish larvae/juveniles and 2,600 adult fish were caught. Among the seven identified species, crucian carp *Carassius auratus* (including the two subspecies *C. a. langsdorfii* and *C. a. grandoculis*) were dominant. Fish ran down from 94 % of the paddies connected to fish ladders; the proportion ranged from 80 to 100 % depending on site. These high success rates demonstrate that the objective of the project, the enhancement of fish spawning/breeding in paddies otherwise inaccessible to fish, was largely accomplished.

Factors Behind the *Unusual* Success of Fish Nurseries in Rice Paddies

Rapid Initial Growth

Initial growth of round crucian carp larvae is always fast in rice paddies (Fig. 10.4). Release of pre-flexion larvae and follow-up investigations of their growth have been done in many paddies around Lake Biwa. Because pre-flexion larvae are difficult to recapture in paddies, their initial growth was estimated by fitting to Richards' growth model (Richards 1959). At 5 days of age, daily growth rates in terms of total length and body weight were 8.3–12.0 % and 36.0–57.7 % day^{-1}, respectively (Kanao et al. 2009).

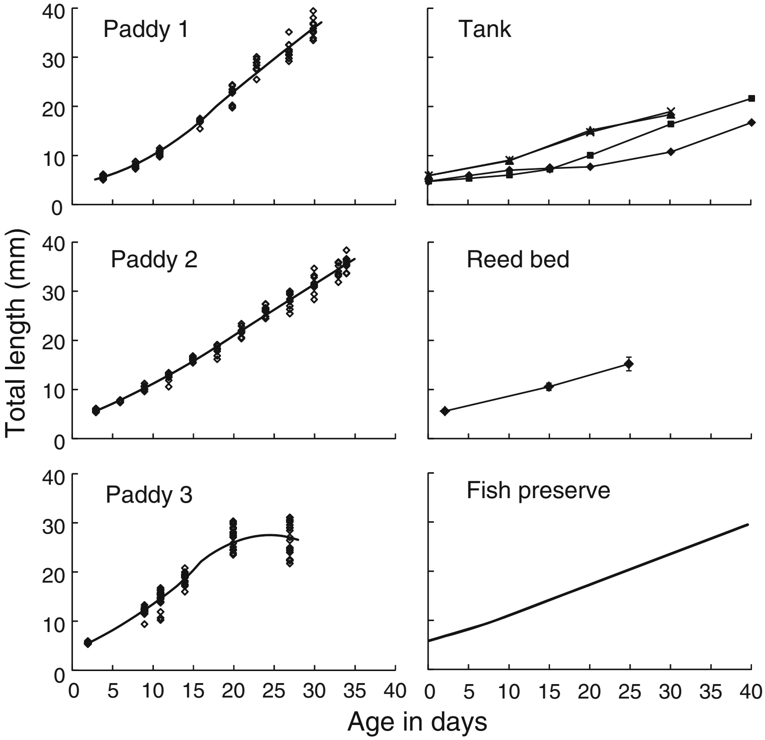

Fig. 10.4 Growth curve of round crucian carp larvae/juveniles in term of total length (TL) in rice paddies and some other habitats. The three curves in the rice paddies are estimated using a locally weighted scatter plot smoother (LOWESS). The data for fish tanks, a reed bed, and a fish preserve are respectively cited from Yagi (1977), Ujiie et al. (1993), and Fujiwara (2010). Originally the latter two were shown as standard body length (SL), here converted to total length using the following formulae: $TL = SL \times 1.1$ ($SL \leq 8$ mm), $TL = 1.421 \times SL - 2.705$ ($SL > 8$ mm; Kanao et al. 2009). Of the original 12 fish tank trials, only four in which *Brachionus* served as the initial prey are shown, because otherwise the survival rates were usually low. Error bars for TL in the reed bed study indicate standard deviation. The line in the fish preserve study is derived from the linear regression of Fujiwara (2010)

The initial growth of round crucian carp in rice paddies is usually faster than in other nursery habitats. This is usually attributed to the richness of prey animals in rice paddies, but this does not seem to be the only reason. Fujiwara (2010) reared round crucian carp larvae/juveniles to document their growth. He continuously pumped pond water containing abundant zooplankton such as *Brachionus calyciflorus* and *Moina macrocopa* into a fish preserve set in the pond to prevent food shortages. As a result, relatively fast larval growth was obtained. Calculations based on his results, however, show daily growth rates in terms of standard body length and body weight of 6.0 % and 27.7 % day^{-1}, respectively. This growth was faster than in fish tanks or reed beds (cf. Yagi 1977; Ujiie et al. 1993), but appreciably slower than in rice paddies (cf. Kanao et al. 2009). The relatively high water temperature in paddies also probably contributes to rapid fish growth. The optimum growth temperature of *C. auratus* (goldfish) have been reported as 28 °C and 25–28 °C in the larval and juvenile stages, respectively (Kestemont 1995; Wismer and Christie 1987). In addition, Laurila et al. (1987) reported that larvae and juveniles of *Carassius carassius* grew fastest at 28–30 °C.

In the juvenile stage, the growth of round crucian carp varies among rice paddies (Fig. 10.4). Juveniles often maintained good growth, with the standard body length increasing approximately linearly throughout the stocking period, and the daily growth increment of their body weight increasing monotonically (Ohtsuka 2013). In other paddies, though, the daily growth increments of standard body length decreased over time, and sometimes the fish even stopped growing at some point in the juvenile stage (Kanao et al. 2009). The main cause of this difference is presumed to be the prey condition in the paddies, which itself may be controlled by the predation of the fish. Before discussing juvenile growth in detail, a review of the effects of fish on their prey animals is essential.

Low Mortality Rate

The initial mortality rate of round crucian carp larvae/juveniles is usually low in rice paddies. Kanao et al. (2009) reported mortality rates of 25.8–77.0 % from eggs to 27-day-old juveniles, and 9.2–77.7 % from four-day-old pre-flexion larvae to 38-day-old juveniles. The mean instantaneous mortality rates during the experimental periods were calculated as 1.9–31.7 % week^{-1}. These were much lower than those in a reed bed reported by Fujiwara et al. (1993), where survival rates of 0.3 % and 0.04 % from 2-days-old larvae to 30- and 32-days-old juveniles, corresponded to mean instantaneous mortality rates of 76.6 % and 84.1 %. Because cyprinid fish usually suffer high rates of mortality at the larval stage (Mills 1991), the relatively low mortality rates in rice paddies indicate that starvation and predation, which are two main causes of the death of larval fish, are not critical for fish larvae in rice paddies.

Sufficient Food Supply

The uniformly rapid initial growth of round crucian carp discussed above indicates that pre-flexion larvae are always able to obtain prey. Because starvation in this stage can be critical (Mills 1982), adequate abundance of prey is clearly an important factor in reducing larval mortality.

In the juvenile stage, the growth of round crucian carp in paddies either maintained a smooth pace or slowed, depending on the paddy (Ohtsuka 2013). When the mortality rate was relatively high, juvenile growth also tended to be slowed (Kanao et al. 2009). This may be explained by differences in food availability. Chironomid larvae, the main prey of the juveniles in the present study, are often very abundant in rice paddies around Lake Biwa. Their density was about 2,000–3,000 individuals m^{-2} in the plots with juvenile fish, almost the same as in the plots without fish (Yamazaki et al. 2010). In such paddies, juvenile fish growth maintained a smooth pace, suggesting an adequate food supply. At other locations, a deficiency of prey such as chironomid larvae might have been a cause of slowed growth of juvenile fish, because the abundance of chironomids varies greatly between paddies (Tsuruta et al. 2009).

Unexpectedly, pesticide use can result in an increase in the abundance of chironomid larvae and thereby support juvenile fish growth and survival in rice paddies. Takamura and Yasuno (1986) reported that the abundance of chironomid larvae and ostracods was greater in paddies with pesticide use (herbicide and herbicide + insecticide + fungicide) than in a paddy with no pesticides, and they attributed this result to a pesticide-related decrease in predatory odonate and dytiscid larvae. Similarly, Tsuruta et al. (2009) found that Oligochaeta and chironomid larvae in rice paddies were more abundant in areas where carnivorous insects were scarce. Among the carnivorous insects, dragonfly nymphs are similar to the larvae/juveniles of round crucian carp in terms of prey choice. *Sympetrum frequens*, the most common dragonfly in Japanese paddy fields, has declined, at least partly because of pesticide treatment of rice seedling boxes, especially using fipronil (Jinguji et al. 2013). Any such decline in carnivorous insects may favor the success of fish nurseries through the alleviation of competition for food, although use of fipronil itself in rice paddies is now strongly discouraged in Shiga Prefecture. Conversely, imidacloprid, another common insecticide used for treating rice seedling boxes, can cause a collapse of fish nurseries. Sánchez-Bayo and Goka (2006) demonstrated a decrease in aquatic organisms in imidacloprid paddies, in particular the absence of *Chironomus yoshimatsui* (Diptera; Chironomidae) and typical paddy ostracods. Loss of such important components of the prey fauna may results in a food deficiency for juveniles of round crucian carp.

Low Predation Pressure

Low mortality rates imply low predation pressure on fish larvae/juveniles in the rice paddies around Lake Biwa, irrespective of the existence of various potential predators. For instance, egrets such as *Egretta garzetta* and *Ardea intermedia* are frequently observed foraging in rice paddies in this area. Although these birds often prey on fishes in/around rice paddies (Kosugi 1960), juveniles of round crucian carp might not be a favored prey because of their small size (Trexler et al. 1994). In addition, as the fish grow to a size attractive to avian predators, the rice plants also grow and provide shelter for the fish.

No aquatic insects have been confirmed to prey selectively on fish in rice paddies around Lake Biwa (Ohtsuka et al. 2012). Local people say, however, that though much of the twentieth century, giant water bugs (*Kirkaldya deyrolli* = *Lethocerus deyrolli*) were common around Lake Biwa. These insects mainly prey on frogs and tadpoles (Hirai and Hidaka 2002; Hirai 2007), but are also known to prey on fishes if available (Ohba et al. 2008, 2012). In the past, these large predatory insects were regarded as a great threat to rice-fish culture (Matsui 1948). Absence of giant water bugs therefore favors the use of paddies as fish nurseries, although the bug itself has already decreased in abundance in Japan and is designated as vulnerable in the Ministry of the Environment, Japan's national red list.

Nowadays, the most important predators of round crucian carp larvae/juveniles in rice paddies are presumably juveniles of Far Eastern catfish (*S. asotus*). Their adults often ascend into rice paddies through fish passes to spawn. The catfish larvae initially prey on zooplankton, but change to mainly preying on zoobenthos as they grow to juveniles (Tomoda 1978). This ontogenetic change in prey is similar to that of the round crucian carp, but the catfish grows faster (Dr. Toshinori Funao, personal communication). Catfish thus can be a tough competitor for round crucian carp in their early developmental stages. Thereafter, the catfish juveniles begin to prey on fish larvae/juveniles of other fish (Tomoda 1978), and such intraguild predation will naturally reduce the round crucian carp's population in the rice paddy. Juveniles of both Far Eastern catfish and crucian carp sometimes exited from the same paddy at the mid-season drainage, but the number of crucian carp was much less than those exiting neighbor paddies without catfish (personal observation). This problem may only arise where fish passes have been installed; otherwise, the water-level difference between the rice paddy and the drainage canal usually prevents catfish from entering and spawning in the rice paddy.

Ecological Consequences of the Use of Rice Paddies as Nursery Grounds for Round Crucian Carp

Overall Effects of Fish Predation on the Rice Paddy Ecosystem

An experimental study to clarify the feeding habits of larvae/juveniles of round crucian carp and their impact on the rice paddy ecosystem was conducted at the Shiga Prefecture Agricultural Technology Promotion Center in Azuchi Town (currently merged with Omi-hachiman City), Japan (35°10′25″N, 136°7′52″E). Six experimental plots were established in a paddy field there, each covering 80 m^2. The six treatments included all combinations of rice-straw plowing in either autumn or spring or no such plowing, and the presence or absence of stocked fish larvae. In each plot, rice *Oryza sativa* cv. *kinuhikari* was cultivated by conventional methods. The depth of the irrigation water was kept between 3 and 7 cm. Three-day-old larvae were released into the three fish-stocking plots 13 days after the onset of irrigation, at a stocking density of 20 individuals m^{-2} (Yamazaki et al. 2010; Nishimura et al. 2011). The experiment was repeated three times from 2007 to 2009. Mainly the first year's results are described below because most of the results of the subsequent 2 years have not been published.

Putting the studies by Yamazaki et al. (2010) and Nishimura et al. (2011) together, the overall direct/indirect effects of fish juveniles in the present

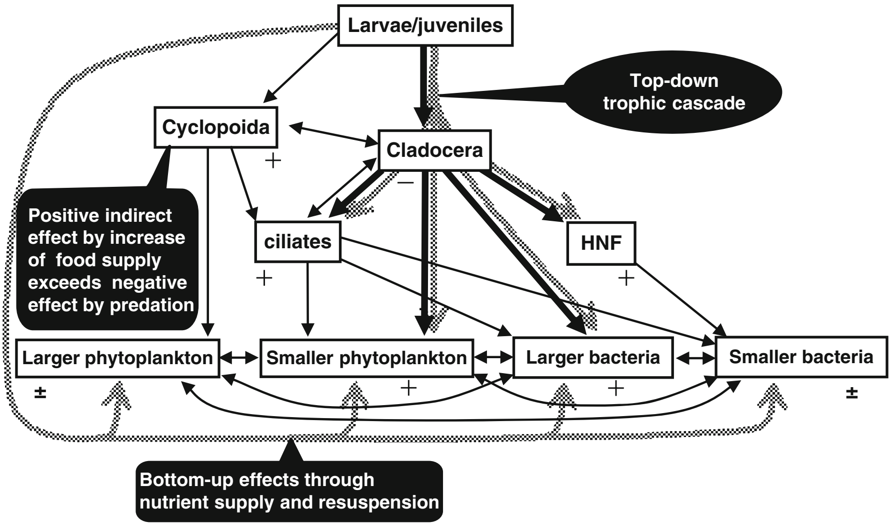

Fig. 10.5 Schematic diagram of impacts of round crucian carp larvae/juveniles on the aquatic community in rice paddies (From Ohtsuka et al. 2012). *Double-* and *single-headed solid arrows* indicate predation/grazing and competition, respectively. *Halftone lines with arrowheads* indicate indirect effects. The signs +, −, and ± respectively indicate positive, negative, and canceled total effects of fish stocking on particular groups of organisms

experiment are illustrated in Fig. 10.5. The larvae/juveniles of round crucian carp positively selected Cladocera as a food item and, eventually, mostly excluded it from the rice paddies. The disappearance of cladocerans, strong keystone grazers/predators, resulted in an increase in their prey, such as smaller phytoplankton, HNF (heterotorophic nanoflagellates), and filamentous bacteria (top-down trophic cascade). Fish stocking also resulted in an increase in small ciliates and Euglenophyta, which ordinarily are suppressed by cladocerans through predation and exploitive competition. Food selectivity of the fish shifted to benthic chironomid larvae in the juvenile stage. The benthic feeding of the fish enhanced phytoplankton growth by pumping nutrients from the sediment into the water column through excretion and/or bioturbation (bottom-up indirect effects). The mechanisms for these changes are discussed in the following sections.

Prey Selection of Fish Larvae/Juveniles

The larvae/juveniles of round crucian carp usually prey on small crustaceans. Hirai (1972) showed that the wild larvae mainly prey on *Chydorus* (Cladocera) in the macrophyte zone of Lake Biwa, while the range of foods available to them becomes wider as they grow to juveniles. Fujiwara et al. (2011) showed that the larvae mainly prey on copepods (adults and copepodids), whereas smaller fish of less than 8 mm in standard body length in the reed beds of Lake Biwa more often select cladocerans.

The main food item of the fish shifted from cladocerans to chironomid larvae as the fish grew. At least 15 orders of aquatic organisms were found in the guts of examined fish. Taking size into account, Cladocera, Cyclopoida, Ostracoda, and Diptera (mainly chironomid larvae) appeared to be the main food items. Flexion larvae (10 days old, 11.4 mm in mean total length) always had Cladocera, mainly *Moina* and *Bosmina*, as the dominant component of their gut contents. Subsequently, the main food item of post-flexion larvae (16 days old, 16.3 mm in mean total length) and early juveniles (24 days old, 24.0 mm in mean total length) was variable, differing among individuals. Nonetheless, 31-day-old juveniles of 29.7 mm in mean total length usually had chironomid larvae as the main component of their gut contents. Ploimida (Rotifera: mainly benthic species of *Lecane*) and benthic algae were often numerous in the guts of larvae/juveniles over 16 days old (Yamazaki et al. 2010).

Food selectivity of the fish gradually shifted as they grew. To ascertain the ambient food item concentration, an acrylic cylinder was inserted into the paddy soil and all the enclosed crustaceans both in the water column supernatant and on the water-sediment interface were collected by sucking out the liquid with a pipette. By comparing the taxonomic composition of the gut contents and the corresponding ambient sample, Manly's (1974) selectivity index *b* was calculated. Its confidence interval was usually wide, indicating variability in food selectivity among individuals. Ostracoda were eaten by post-flexion larvae and juveniles, but were always negatively selected throughout the experiment. Cladocera were positively selected by flexion larvae, but less so as the fry grew. Similarly, selectivity for Cyclopoida appeared to decrease as the fish grew, although they were usually selected to a lesser degree than Cladocera, probably because of being better able to escape the fish's feeding suction (Drenner et al. 1978). In contrast, Diptera (mainly chironomid larvae), which were initially selected negatively by post-flexion larvae, became a strongly selected food item as larvae grew into juvenile fish (Yamazaki et al. 2010).

The observed correlation of the ontogenetic development of the fish with food selectivity can be interpreted as follows. Because the flexion larvae were as yet undeveloped in terms of masticatory force and predatory behavior, they naturally selected cladocerans, which have relatively soft cuticle and a low ability to evade fish predation. As they grew, development of pharyngeal teeth (Nakajima 2005) enabled them to masticate ostracods with hard shells. In addition, development of gill rakers (Tomoda 1965) enabled them to filter benthic animals out of the sediment. The fish thus came to select chironomid larvae of a size that was usually larger than cladocerans or ostracods.

Impacts of Fish Predation on Prey

Juvenile freshwater fish are assumed to prey on large cladocerans and copepods selectively and thus to drive zooplankton community succession (Brooks and Dodson 1965). This hypothesis is reasonable according to optimal foraging theory

(Werner and Hall 1974), but quantitative evidence that fish predation is in fact the main driving force of zooplankton succession has rarely been presented (Mehner and Thiel 1999). This is also true for rice paddies, but it appears easier to test this hypothesis in paddies than in ponds or lakes, because typical Japanese paddies can be used directly as experimental enclosures. As was stated above, most rice paddies in Japan sit much higher than the water level of their drainage canal, and therefore most fishes are excluded from the paddies. In addition, land consolidation has resulted in large expenses of paddies that are homogeneous in size and environmental characteristics. Comparison between paddies with and without fish release, therefore, amounts to an enclosure experiment with a control (Ohtsuka et al. 2012; Okuda 2012).

Such an experiment in 2007 detected an impact of fish larvae/juveniles on the succession of prey animals (Yamazaki et al. 2010). Cladocera and Ostracoda showed obvious temporal changes in all plots, becoming more abundant in the plots without fish than in those with fish in the latter half of the experiment (Fig. 10.6). Particularly, six groups of Cladocera (*Bosmina*, *Ceriodaphnia*, *Daphnia*, *Moina*, Chydoridae, and Macrotrichidae) disappeared from the fish-stocked plots but were not particularly rare in the plots without fish. *Ilyocypris*

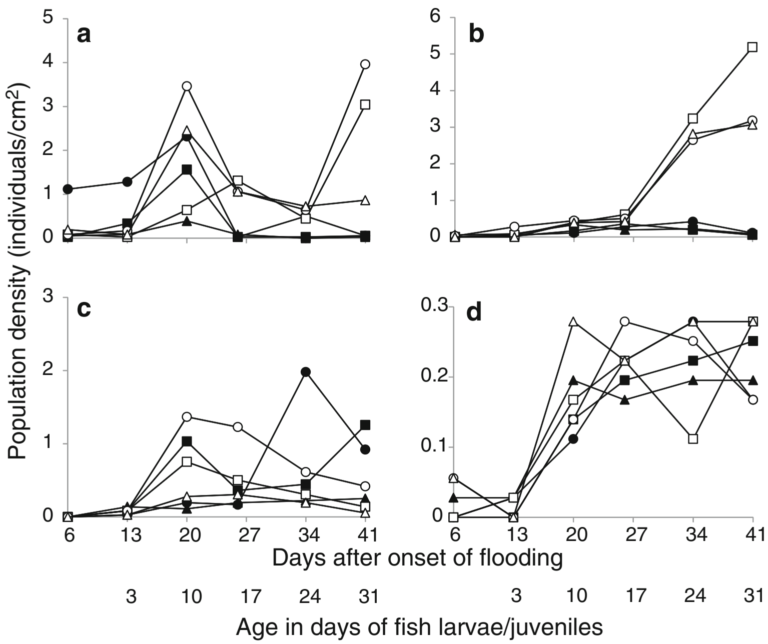

Fig. 10.6 Population densities of representative arthropods in six experimental rice paddy plots. The data are derived from Yamazaki et al. (2010). *Closed and open symbols* denote treatments with and without fish, respectively. *Triangles*, *squares*, and *circles* respectively denote treatments with rice straw plowed under in the previous autumn, plowed under in spring, and controls without rice straw. (a) Cladocera. (b) Ostracoda. (c) Cyclopodia. (d) Diptera

(Ostracoda) was not extirpated, but was significantly less abundant in the fish-stocked plots than in those without fish. The population densities of *Scapholeberis* (Cladocera) and Cyprididae (Ostracoda) were not significantly affected by fish stocking. Cyclopoida tended to increase over time in the fish-stocked plots while they decreased toward the end of experiment in plots without fish (Fig. 10.6). Diptera did not show significant differences between plots with and without fish (Fig. 10.6).

The differences in crustacean assemblage succession between plots with and without fish in this experiment can be interpreted as a consequence of prey selection by the fish. The most highly selected group, the Cladocera, markedly decreased in fish-stocked plots. The single exceptional genus, *Scapholeberis*, usually swims just below the water surface and was probably less easily detected by juvenile fish foraging mainly near the bottom. Ostracoda, particularly *Ilyocypris*, decreased in fish-stocked plots after the fish had grown into post-flexion larvae that can masticate their hard shells. Cyclopoida appeared somewhat less abundant initially in fish-stocked plots than in control plots as a result of flexion larvae positively selecting their naupli as prey, but thereafter differences between plots became undetectable as cyclopoids came to be less selected. Surprisingly, Chironomidae were not reduced in abundance in fish-stocked plots compared to control plots despite the strong selective predation on them by juvenile fish. This may be due to continuous oviposition by adult chilonomids, which are very abundant around the experimental rice paddy (Yamazaki et al. 2010).

Top-Down Cascade Effects of Predation on Microorganisms

Selective predation by fish larvae can alter aquatic communities not only through direct effects on their prey, but also indirect effects on smaller organisms. For instance, large cladocerans such as *Daphnia* are expected to be positively selected by juvenile fish as prey (Mehner and Thiel 1999; Okun et al. 2005). In lakes and ponds, such cladocerans are keystone grazers/predators that regulate the community structure of microorganism (Zöllner et al. 2003; Sarnelle 2005), and they are also strong competitors, suppressing other zooplankton such as smaller crustaceans and rotifers (Brooks and Dodson 1965; Gilbert 1988). If these functional roles of Cladocera are maintained in rice paddies as well, juvenile fish predation will exert a top-down trophic cascade effect on microorganisms there (Carpenter et al. 1985), with indirect positive effects on smaller zooplankton (Gliwicz and Pijanowska 1989). Indeed in a rice-fish system in the Mekong Delta, polyculture of silver barb (*Barbodes gonionotus*), common carp (*C. carpio*), and Nile tilapia (*Oreochromis niloticus*) was associated with a significant decrease in Cladocera and increases in chlorophyll *a* concentration and Euglenophyta (Vromant et al. 2001).

An experiment evaluating the effects of fish introduction on aquatic communities was undertaken (Yamazaki et al. 2010; Nishimura et al. 2011). By stereomicroscopic observation, 29 taxonomic groups (mainly orders) of aquatic organisms of >30 μm in size were quantitatively evaluated. Among the eight most common ones besides arthropods, Euglenophyta (mainly *Euglena* and *Trachelomonas*) and Halteriida (mainly *Halteria*) were significantly more abundant in plots with fish than in those without fish. The interaction between time (date) and presence/absence of fish was significant for Euglenophyta and Prorodontida (mainly *Coleps*): after the fish grew to juveniles, these groups increased in fish-stocked plots, but not in plots without fish (Yamazaki et al. 2010). These protozoa are relatively small in size and can be preyed upon by larger Cladocera such as *Daphnia similis* and *Moina macrocopa* (Burns 1968; Kumar and Hwang 2008), which were dominant in plots without fish. Although *Halteria* is often reported as being less susceptible to Cladocera predation owing to its jumping behavior (Wiackowski et al. 1994; Wickham 1998), some Cladocera species can prey on it effectively (Archbold and Berger 1985). In addition, Cladocera are competitors of Euglenophyta and Halteriida for food. Many Cladocera species can ingest small particles such as bacteria by filtration (Geller and Müller 1981; Brendelberger and Geller 1985), and their range of food size covers organisms ingested by *Euglena* (Epstein and Shiaris 1992) and *Halteria* (Jürgens and Šimek 2000). The suppression of these protozoa by Cladocera is therefore interpreted as intraguild predation (Polis et al. 1989).

Regarding community diversity, the number of taxonomic groups (those of >20 μm in body size) was not significantly different between plots with and without fish. After the fish grew into juveniles, however, the number of taxa particularly of protozoans, markedly decreased in the plot without fish, while there was scarcely any decrease in the fish-stocked plots. Probably this result reflects the alleviation of grazing pressure by, and exploitive competition between, cladocerans which decreased in abundance as a result of selective feeding by the fish larvae/juveniles (Yamazaki et al. 2010).

Smaller phytoplankton became more abundant in plots with fish than without fish. Chlorophyll *a* (chl. *a*) concentration, indicating phytoplankton abundance, was determined for five size fractions: 0.7–2.7, 2.7–15, 15–63, 63–250, and 250–1,000 μm. After the fish grew into juveniles, total chl. *a* became consistently greater in plots with fish (8.9–16.5 μg l^{-1}) than in those without fish (1.1–6.7 μg l^{-1}). Significant effects of fish presence/absence, date, and the interaction fish × date on chl. *a* in the 0.7–2.7 μm fraction, and presence/absence of fish and rice straw application on chl. *a* in the 2.7–15 μm fraction, were detected. The mean chl. *a* concentration of the 0.7–2.7 μm and 2.7–15 μm fractions was significantly greater in plots with fish than without fish. In the three larger fractions, the means were also greater in plots with fish than those without fish, but these differences were not significant (Table 10.2). As for individual taxa of phytoplankton, unicells of *Scenedesmus*, *Kirchneriella*, *Merismopedia*, *Nostoc*, *Monoraphidium*, and *Trachelomonas* and zoospores of Chlorophyceae increased in plots with fish. Except for *Nostoc*, these were mainly found in the <63 μm fraction (Nishimura et al. 2011). Most Cladocera observed in the experimental rice paddy can ingest phytoplankton smaller than 15 μm (Geller and Müller 1981; Kumar and Hwang 2008), and larger cladocerans such as *D. similis* may also be able to consume larger phytoplankton up to 63 μm (Burns 1968). The observed increases in smaller phytoplankton may thus be understood as top-down trophic cascade effect exerted by fish larvae/juveniles (Carpenter et al. 1985).

Table 10.2 Geometric averages of chlorophyll *a* concentrations and HNF and bacterial abundances in experimental rice paddy plots with (+) and without (−) fish

Item	Unit	Average		$\log_{10}$ ratio	*P*
		+	−		
Chlorophyll *a*					
Total	$\mu g\ l^{-1}$	8.89	2.82	0.50	0.055
0.7–2.7 μm	$\mu g\ l^{-1}$	1.03	0.11	1.01	0.004
2.7–15 μm	$\mu g\ l^{-1}$	2.55	0.64	0.60	0.003
15–63 μm	$\mu g\ l^{-1}$	1.34	0.49	0.44	0.056
63–250 μm	$\mu g\ l^{-1}$	0.72	0.33	0.34	0.306
250–1,000 μm	$\mu g\ l^{-1}$	1.82	0.77	0.32	0.407
HNF					
<3 μm	cells μl^{-1}	0.15	0.07	0.36	0.121
≥3 μm	cells μl^{-1}	1.80	0.60	0.48	0.026
Bacteria					
RC 0.2–0.8 μm	cells μl^{-1}	689	615	0.05	0.646
RC 0.8–3 μm	cells μl^{-1}	198	109	0.26	0.139
RC ≥3 μm	cells μl^{-1}	45	13	0.56	0.064
Filaments	cells μl^{-1}	4.63	0.75	0.79	0.027

Data are quoted from Nishimura et al. (2011). Log_{10} ratio is the log-transformed ratio of averages in plots with fish to these in plots without fish. *P* values are given by two-way repeated-measures ANOVA without multiplicity adjustments. For all parameters, averages were always greater in plots with fish in all items, but the differences were often not significant

The cascading effects also reached larger planktonic bacteria and HNF. Fish introduction significantly increased the abundance of filamentous bacteria, resulting in a six times greater density in plots with fish than without fish. HNF in the 3–15 μm fraction were three times more abundant in plots with fish than without fish. In contrast, rod or coccoid bacteria and HNF in the 0.8–3 μm fraction were not significantly different between plots with and without fish (Nishimura et al. 2011; Table 10.2). Absence of Cladocera, major consumers of filaments, in plots with fish may allow such an increase in filamentous bacteria (Pernthaler et al. 2004). By contrast, rod or coccoid bacteria did not significantly decline probably because the increased grazing pressure of protozoans such as ciliates and HNF compensated for the decrease in cladoceran grazing pressure. Increases in filaments relative to total bacteria have been often observed in aquatic systems when predation pressure is temporally increased (Jürgens et al. 1994; Nishimura and Nagata 2007).

Bottom-Up Effects of Juvenile Fish Through Benthic Feeding

By analogy with the littoral areas of lakes, interactions between the water column and sediment are presumably important in rice paddies because of the very shallow water. Any prey shift of juvenile fish from plankton to benthos will reinforce this interaction. For instance, benthivorous fish may increase the phosphorus flux from the sediment to the water column through their excretion and thus enhance phytoplankton growth (LaMarra 1975; Havens 1993; Okun et al. 2005). Bioturbation accompanying benthic feeding may also promote an increase in phytoplankton through resuspension of sedimented algal cells (Roozen et al. 2007) or the release of sediment-bound nutrients (Cline et al. 1994).

In the experiments discussed above, both total chl. *a* and total phosphorus concentration became significantly higher in plots with fish than those without fish after the fish grew to juveniles (Yamazaki et al. 2010; Nishimura et al. 2011; Table 10.2). These differences cannot be explained by a top-down trophic cascade because it changes only the nutrient distribution in the water column. Rather, it can easily be interpreted as a bottom-up effect of fish pumping nutrients from the sediment into the water column through excretion and/or bioturbation. The increase of normally benthic *Nostoc* in the paddy water also indicates an important role of benthivorous fish in resuspension of sedimented algal cells (Roozen et al. 2007).

Comparisons with Some Other Rice-Fish Systems

The results of our study are similar to those of the rice-fish systems in the Mekong Delta studied by Vromant et al. (2001) and Vromant and Chau (2005). Their experiments displayed the effects of concurrent rice-fish systems with the polyculture of silver barb, common carp, and Nile tilapia, on the aquatic ecosystems in rice paddies. At a low rice-seeding rate, the abundance of Euglenophyta and the amount of chlorophyll-*a* increased, while Cladocera/Rotifera ratio decreased in the presence of the fishes. These results also suggest that top-down trophic cascades and bottom-up effects through benthic feeding were exerted by the fish.

Kuwabara (2002) documented a very different effect of fingerlings of common carp on the plankton community; numerical density of most taxonomic groups of plankton was lower, and the number of planktonic taxa was fewer, in the experimental paddy than in the control paddy. As he discussed, this might be attributed to the turbidity caused by fish. Because his observation focused on larger plankton (>0.1 mm), this result may be partly explained by the predation/grazing of omnivorous copepods which did not decline in the presence of fish.

Conclusion

Two means of promoting the use of rice paddies as fish nursery grounds have been practiced around Lake Biwa in recent years. One involves stocking of larvae/juveniles for fish culture, and the other involves the installation of fish passes to enhance natural reproduction. These are both regarded as environmentally friendly practices and, indeed, they have significantly contributed to the recovery of round crucian carp as a fishery resource on account of extremely fast growth and low mortality of the fish in rice paddies. These practices are also supported by the rich social capital of Shiga Prefecture. This is evident, for instance, in the broad consensus about environmental conservation of Lake Biwa, movements to preserve the traditional food culture, and regional cooperative frameworks that enable agreement to establish *Sakana-no-yurikago-suiden* among all the farmers who share a drainage canal. Poor competitors and predators of the fish larvae/juvenile appear to be factors contributing to the unusual success of fish nurseries in rice paddies around Lake Biwa.

The impacts of round crucian carp larvae/juveniles on the aquatic biota in rice paddies are, however, very strong and reach beyond prey organisms to others through indirect effects. Fish predation caused a great decrease in Cladocera, and thus most of the prey and competitors of the latter increased. Fish juveniles also increased the total phosphorus and phytoplankton concentration in the water column through their benthic foraging. Probably, few people would have expected that the enhancement of rice paddy biodiversity through their use as fish nurseries would actually be achieved by an increase in the number of orders of protists present.

It is notable that the fish ladders installed in *Sakana-no-yurikago-suiden* areas appear not to be much used by other fishes than crucian carp and Far Eastern catfish (personal observation). We may conclude, then, that rice paddy fish nurseries are effective for the conservation of round crucian carp, but that is not enough to enhance the total biodiversity of the rice paddy areas around Lake Biwa. A comprehensive program for the conservation/resurgence of the biological community in this rice paddy area is necessary in the future, and the rice paddy fish nursery programs should be repositioned as part of it.

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References

Archbold JHG, Berger J (1985) A qualitative assessment of some metazoan predators of *Halteria grandinella*, a common freshwater ciliate. Hydrobiologia 126:97–102

Bence JR (1988) Indirect effects and biological control of mosquitoes by mosquitofish. J Appl Ecol 25:505–521

Brendelberger H, Geller W (1985) Variability of filter structures in eight *Daphnia* species: mesh sizes and filtering areas. J Plankton Res 7:473–486

Brooks JL, Dodson SI (1965) Predation, body size, and composition of plankton. Science 150:28–35

Burns D (1968) The relationship between body size of filter-feeding Cladocera and the maximum size of particle ingested. Limnol Oceanogr 13:675–678

Carpenter SR, Kitchell JF, Hodgson JR (1985) Cascading trophic interactions and lake productivity. Bioscience 35:634–639

Cline JM, East TL, Threlkeld ST (1994) Fish interactions with the sediment-water interface. Hydrobiologia 275–276:301–311

dela Cruz CR, Lightfoot C, Costa-Pierce BA, Carangal VR, Bimbao MP (eds) (1992) Rice-fish research and development in Asia. ICLARM conference proceedings, vol 24. ICLARM, Manila

Drenner RW, Strickler JR, O'Brien WJ (1978) Capture probability: the role of zooplankter escape in the selective feeding of planktivorous fish. J Fish Res Board Can 35:1370–1373

Epstein SS, Shiaris MP (1992) Size-selective grazing of coastal bacterioplankton by natural assemblages of pigmented flagellates, colorless flagellates, and ciliates. Microb Ecol 23:211–225

Fernando CH (1993) Rice field ecology and fish culture – an overview. Hydrobiologia 259:91–113

Fujioka Y (2006) Nigorobuna (round crucian carp). In: Shiga Prefecture Bioassessment Committee (ed) Wildlife to care about in Shiga Prefecture – Shiga Prefecture red data book. Sunrise Publishing, Shiga, p 468 (in Japanese)

Fujioka Y, Maehata M (2012) Propagation and conservation of fishery resources. In: Kawanabe H, Nishino M, Maehata M (eds) Lake Biwa: interaction between nature and people. Springer, Dordrecht/Heidelberg/New York/London, pp 327–329

Fujiwara K (2010) Morphological development, organogenesis and somatic growth of hatchery-reared nigorobuna *Carassius auratus grandoculis*. Nippon Suisan Gakkaishi 76:894–904 (in Japanese)

Fujiwara K, Usuki T, Ujiie M, Mizutani T (1993) Tennen suiiki deno Nigorobuna shi-chigyo no hatsuiku-dankai-kan no seizan-ritsu no hikaku [Survival rates of *Carassius auratus grandoculis* in a natural habitat: comparisons between developmental stages]. Heisei 4 nendo Shiga-ken Suisan-shiken-jo Jigyo Hokoku [Annual business reports of Shiga Prefectural Fisheries Experiment Station in fiscal 1992], Shiga Prefecture, pp 24–25 (in Japanese)

Fujiwara K, Usuki T, Nemoto M, Kitada S (2011) Early life ecology of nigorobuna *Carassius auratus grandoculis* in reed zone of Lake Biwa and physiological adaptation to the environment. Nippon Suisan Gakkaishi 77:387–401 (in Japanese)

Geller W, Müller H (1981) The filtration apparatus of Cladocera: filter mesh sizes and their ecological implications. Oecologia 49:316–321

Gilbert JJ (1988) Suppression of rotifer populations by *Daphnia*: a review of the evidence, the mechanisms, and the effects on zooplankton community structure. Limnol Oceanogr 33:1286–1303

Gliwicz ZM, Pijanowska J (1989) The role of predation in zooplankton succession. In: Sommer U (ed) Plankton ecology. Succession in plankton communities. Springer, Berlin, pp 253–296

Halwart M, Gupta MV (eds) (2004) Culture of fish in rice fields. WorldFish Center, Penang

Hanafusa Y (2000) Wetlands of Lake Biwa: their history, significance and fate. Lakes Reserv Res Manag 5:1–3

Hata K (2002a) Perspectives for fish protection in Japanese paddy field irrigation systems. Jpn Agric Res Q 36:211–218

Hata K (2002b) Field experiment on the migration of fishes to a paddy field with a small fishway. Jpn Agric Res Q 36:219–225

Havens KE (1993) Response to experimental fish manipulations in a shallow, hypereutrophic lake: the relative importance of benthic nutrient recycling and trophic cascade. Hydrobiologia 254:73–80

Hazama T, Hori A (2012) The "Yurikago Suiden" project: has this effort to revive paddy fields as fish nurseries succeeded? In: Rice Paddy Working Group, Ramsar Network Japan (ed) Report for Ramsar COP11 on good practices for enhancing biodiversity in rice paddy ecosystem in Japan, Korea and other Asian countries. Ministry of the Environment (Japan), Tokyo, b-3-2

Hirai K (1972) Ecological studies on fry and juvenile of fishes at aquatic plant areas in a bay of Lake Biwa. III. Relationship of the food habits to the habitat of nigorobuna (*Carassius carassius grandoculis*) larvae. Jpn J Ecol 22:69–93 (in Japanese)

Hirai T (2007) Diet composition of the endangered giant water bug *Lethocerus deyrolli* (Hemiptera: Belostomatidae) in the rice fields of Japan: which is the most important prey item among frogs, fish, and aquatic insects? Entomol Sci 10:333–336

Hirai T, Hidaka K (2002) Anuran-dependent predation by the giant water bug, *Lethocerus deyrollei* (Hemiptera: Belostomatidae), in rice fields of Japan. Ecol Res 17:655–661

Horikoshi M (2012) Traditional culinary culture of Shiga Prefecture. In: Kawanabe H, Nishino M, Maehata M (eds) Lake Biwa: interaction between nature and people. Springer, Dordrecht/Heidelberg/New York/London, pp 343–347

Hurlbert DH, Mulla MS (1981) Impacts of mosquitofish (*Gambusia affinis*) predation on plankton communities. Hydrobiologia 83:125–151

Ikuta K, Yamaguchi M (2005) The present state of carp fisheries and aquaculture in Japan. Bull Fish Res Agency Suppl 2:55–58

Jinguji H, Thuyet DQ, Uéda T, Watanabe H (2013) Effect of imidacloprid and fipronil pesticide application on *Sympetrum infuscatum* (Libellulidae: Odonata) larvae and adults. Paddy Water Environ 11:277–284

Jürgens K, Šimek K (2000) Functional response and particle size selection of *Halteria* cf. *grandinella*, a common freshwater, oligotrichous ciliate. Aquat Microb Ecol 22:57–68

Jürgens K, Arndt H, Rothhaupt KO (1994) Zooplankton-mediated changes of bacterial community structure. Microb Ecol 27:27–42

Kada Y (2012) Chiji wa nani ga dekiru no ka – "Nihon byou" no chiryou wa chiiki kara (What can a governor do? – Japanese disease becomes cured from a local area). Fubaisha, Nagoya (in Japanese)

Kanao S (2005) Fish fauna and its change on paddy fields and irrigation diches around Lake Biwa. Bull Kansai Org Nat Conserv 27:41–46 (in Japanese)

Kanao S, Ueno S (2005) The first record of the exotic freshwater fish Cobitidae sp. in Shiga Prefecture. Bull Kansai Org Nat Conserv 27:59–63 (in Japanese)

Kanao S, Ohtsuka T, Maehata M, Suzuki N, Sawada H (2009) Effectiveness of rice fields as an initial growth environment of larval and juvenile nigorobuna *Carassius auratus grandoculis*. Nippon Suisan Gakkaishi 75:191–197 (in Japanese)

Kanao S, Maehata M, Sawada H (2010) Biwako syuhen no tanbo wa "sakana no yurikago" – suiden no motsu seitaikei-kinou no hozen saisei ni mukete– [Rice paddies around Lake Biwa are "cradle for fish" – toward the conservation and restoration of the ecosystem function of the paddy fields–]. In: Nakamura K, Kada R (eds) Satoyama fukken – Noto kara no hasshin [Satoyama renaissance]. Soshinsha, Tokyo, pp 69–85 (in Japanese)

Kestemont P (1995) Influence of feed supply, temperature and body size on the growth of goldfish *Carassius auratus* larvae. Aquaculture 136:341–349

Kim S, Yoon J, Park S (2012) Observation of fish movements through artificial fish passes installed in rice paddy fields near a reintroduction site for Oriental Storks *Ciconia boyciana*. Reintroduction 2:51–55

Kinki Regional Agricultural Administration Office (ed) (1959–2011) Shiga-ken Nourin Suisan Toukei Nenpou [Annual statistics on agriculture, forestry, and fisheries in Shiga Prefecture, Japan]. Association of Agriculture and Forestry Statistics of Shiga Prefecture, Otsu (in Japanese)

Kinki Regional Agricultural Administration Office (ed) (2012–2013) Kinki Nourin Suisan Toukei Nenpou [Annual statistics on agriculture, forestry, and fisheries in Kinki region, Japan]. http://www.maff.go.jp/kinki/toukei/toukeikikaku/nenpou/mokuzi_2012.html. Accessed 30 July 2013 (in Japanese)

Kiritani K (2000) Integrated biodiversity management in paddy fields: shift of paradigm from IPM toward IBM. Integr Pest Manag Rev 5:175–183

Kiritani K (ed) (2010) A comprehensive list of organisms associated with paddy ecosystems in Japan. The Institute of Agriculture and Natural Environment, Itojima & Biodiversity Agriculture Support Center, Machida (in Japanese)

Kosugi A (1960) On the food habits of some herons. Misc Rep Yamashina Inst Ornithol Zool 2:89–98 (in Japanese)

Kumar R, Hwang JS (2008) Ontogenetic shifts in the ability of the cladoceran, *Moina macrocopa* Straus and *Ceriodaphnia cornuta* Sars to utilize ciliated protists as food source. Int Rev Hydrobiol 93:284–296

Kuwabara R (2002) Succession of the plankton community and water quality conditions during the wet period in an experimental rice-fish culture plot in paddy fields in Tokamachi, Niigata, Japan. In: Ali A, Rawi CSM, Mansor M, Nakamura R, Ramakrishna S, Mundkur T (eds) Proceedings of the Asian Wetland symposium 2001 "Bringing partnerships into good wetland practices," 27–30 August 2001, Penang, Malaysia. Penerbit Universiti Sains Malaysia, Pulau Pinang, pp 1–15

LaMarra VA (1975) Digestive activities of carp as a major contributor to the nutrient loading of lakes. Verh Int Ver Theor Angew Limnol 19:2461–2468

Laurila S, Piironen J, Holopainen IJ (1987) Notes on egg development and larval and juvenile growth of crucian carp (*Carassius carassius* (L.)). Ann Zool Fenn 24:315–321

Lu J, Li X (2006) Review of rice–fish-farming systems in China – one of the globally important ingenious agricultural heritage systems (GIAHS). Aquaculture 260:106–113

Maehata M (2007) Reproductive ecology of the Far Eastern Catfish, *Silurus asotus* (Siluridae), with a comparison to its two congners in Lake Biwa, Japan. Environ Biol Fish 78:135–146

Maehata M (2013) Why do cyprinid fishes of Lake Biwa swim up to the paddy fields in the rice planting season? Aquabiology 35:208–214 (in Japanese)

Manly BFJ (1974) A model for certain types of selection experiments. Biometrics 30:281–294

Matsui Y (1948) Suiden-yogyo [Rice-fish farming]. Tomi-syoten, Kyoto

Matsuzaki SS, Nishikawa U, Takamura N, Washitani I (2007) Effects of common carp on nutrient dynamics and littoral community composition: roles of excretion and bioturbation. Fundam Appl Limnol 168:27–38

Mehner T, Thiel R (1999) A review of predation impact by 0+ fish on zooplankton in fresh and brackish waters of the temperate Northern Hemisphere. Environ Biol Fish 56:169–181

Mills CA (1982) Factors affecting the survival of dace, *Leuciscus leuciscus* (L.), in the early post-hatching period. J Fish Biol 20:645–655

Mills CA (1991) Reproduction and life history. In: Winfield IJ, Nelson JS (eds) Cyprinid fishes: systematics, biology and exploitation. Chapman & Hall, London/New York, pp 483–508

Mills SL, Soule ME, Doak DF (1993) The keystone-species concept in ecology and conservation. Bioscience 43:219–224

Nakajima T (2005) Tayou na katachi wa donoyouni dekiagaru ka? –koi ka gyorui no intoushi [How do pharyngeal teeth of cyprinid fishes develop into their various forms?]. In: Matsuura K (ed) Sakana no katachi wo kangaeru [Discussions on fish morphology]. Tokai University Press, Hadano, pp 69–113 (in Japanese)

Nemoto M, Matsuo M, Nakaarai T (2013) Heisei 22 nendo touki ni okeru Biwako-hokko deno nigorobuna tousaigyo no shigen-jyoukyou (Stock status of 0+ year juvenile round crucian carp in the North Basin of Lake Biwa in the winter of 2010–2011). Heisei 23 nendo Shiga-ken Suisan Shiken-jo Jigyo Hokoku [Annual business reports of Shiga Prefectural Fisheries Experiment Station in fiscal 2011], p 34 (in Japanese)

Nishimura Y, Nagata T (2007) Alphaproteobacterial dominance in a large mesotrophic lake (Lake Biwa, Japan). Aquat Microb Ecol 48:231–240

Nishimura Y, Ohtsuka T, Yoshiyama K, Nakai D, Shibahara F, Maehata M (2011) Cascading effects of larval crucian carp introduction on phytoplankton and microbial communities in a paddy field: top-down and bottom-up controls. Ecol Res 26:615–626

Nishimura T, Matsushita K, Fujie T (2012a) Determinants of price premium for ecosystem- and environment-friendly rice – a case of *Sakana no Yurikago Suiden Mai* rice from Shiga Prefecture, Japan. Environ Sci 25:204–214 (in Japanese)

Nishimura T, Matsushita K, Fujie T (2012b) Economic conditions for the development of biodiversity-friendly paddy rice agriculture: a case study of rural communities in Shiga Prefecture. J Rural Plan Assoc 31:514–520 (in Japanese)

Ohba S, Miyasaka H, Nakasuji F (2008) The role of amphibian prey in the diet and growth of giant water bug nymphs in Japanese rice fields. Popul Ecol 50:9–16

Ohba S, Izumi Y, Tsumuki H (2012) Effect of loach consumption on the reproduction of giant water bug *Kirkaldya deyrolli*: dietary selection, reproductive performance, and nutritional evaluation. J Insect Conserv 16:829–838

Ohtsuka T (2012) Practices for conserving paddy field biodiversity in the basin of Lake Biwa, a Ramsar wetland. In: Rice Paddy Working Group, Ramsar Network Japan (ed) Report for Ramsar COP11 on good practices for enhancing biodiversity in rice paddy ecosystem in Japan, Korea and other Asian countries. Ministry of the Environment (Japan), Tokyo, b-3-1

Ohtsuka T (2013) What happened in the paddy field which reared *Carassius auratus grandoculis* larvae/fry. Aquabiology 35:215–221 (in Japanese)

Ohtsuka T, Suzuki T (2012) Pioneer studies on some microscopic organisms: an unknown aspect of species diversity in paddy fields. In: Rice Paddy Working Group, Ramsar Network Japan (ed) Report for Ramsar COP11 on good practices for enhancing biodiversity in rice paddy ecosystem in Japan, Korea and other Asian countries. Ministry of the Environment (Japan), Tokyo, b-3-5

Ohtsuka T, Yamazaki M, Nishimura Y (2012) Fish stock visualizes biological interactions of paddy field community – as a basis to clarify the multiple functions. Jpn J Ecol 62:167–177 (in Japanese)

Okuda N (2012) How to assess ecosystem structure and functioning of paddy fields using stable isotopes. Jpn J Ecol 62:207–215 (in Japanese)

Okun N, Lewin W-C, Mehner T (2005) Top-down and bottom-up impacts of juvenile fish in a littoral reed stand. Freshw Biol 50:798–812

Paulovits G, Tatrai I, Matyas K, Korponai J, Kovats N (1998) Role of Prussian carp (*Carassius auratus gibelio* Bloch) in the nutrient cycle of the Kis-Balaton Reservoir. Int Rev Hydrobiol 83(Suppl):467–470

Pernthaler J, Zöllner E, Warnecke F, Jürgens K (2004) Bloom of filamentous bacteria in a mesotrophic lake: identity and potential controlling mechanism. Appl Environ Microbiol 70:6272–6281

Polis GA, Myers CA, Holt RD (1989) The ecology and evolution of intraguild predation: potential competitors that eat each other. Annu Rev Ecol Syst 20:297–330

Richards FJ (1959) A flexible growth function for empirical use. J Exp Bot 10:290–300

Roozen FCJM, Lürling M, Vlek H, Kraan EAJVP, Ibelings BW, Scheffer M (2007) Resuspension of algal cells by benthivorous fish boosts phytoplankton biomass and alters community structure in shallow lakes. Freshw Biol 52:977–987

Sánchez-Bayo F, Goka K (2006) Ecological effects of the insecticide imidacloprid and a pollutant from antidandruff shampoo in experimental rice fields. Environ Toxicol Chem 25:1677–1687

Sarnelle O (2005) *Daphnia* as keystone predators: effects on phytoplankton diversity and grazing resistance. J Plankton Res 27:1229–1238

Takamura K, Yasuno M (1986) Effects of pesticide application on chironomid larvae and ostracods in rice fields. Appl Entomol Zool 21:370–376

Tanaka S (2006) "Sakana-no-Yurikago-Suiden" project [Project for "Restoration of fish breeding mechanism in paddy fields"]. In: Washitani I (ed) Chiiki to kankyo ga yomigaeru suiden saisei [Restoring rice paddy wetland environments and the local sustainable society]. Ienohikari Kyokai, Tokyo, pp 104–124 (in Japanese)

Tomoda Y (1965) Morphological studies on the development of the crucian carp in Lake Biwa. I. Ontogenetic development of nigoro-buna, and some remarks on the differentiation of gengorobuna and nigoro-buna. Bull Osaka Mus Nat Hist 18:3–30 (in Japanese)

Tomoda Y (1978) Biwako to Namazu [Lake Biwa and Catfish]. Chobunsha, Tokyo (in Japanese)

Trexler JC, Tempe RC, Travis J (1994) Size-selective predation of sailfin mollies by two species of heron. Oikos 69:250–258

Tsuruta T, Tada T, Kotera N, Akagawa I, Iguchi K (2009) Effects of predators and herbicides on community structure of benthic invertebrates in paddy. Jpn J Limnol 70:1–11 (in Japanese)

Ueda F (2012) Life in the Jomon and Yayoi periods. In: Kawanabe H, Nishino M, Maehata M (eds) Lake Biwa: interaction between nature and people. Springer, Dordrecht/Heidelberg/New York/London, pp 243–248

Ujiie M, Mizutani T, Fujiwara K, Usuki T (1993) Nigorobuna no chichu oyobi tennen deno seicho (Growth of *Carassius auratus grandoculis* in a pond and a natural habitat). Heisei 4 nendo Shiga-ken suisan-shiken-jo jigyo hokoku [Annual business reports of Shiga Prefectural Fisheries Experiment Station in fiscal 1992], Shiga Prefecture, pp 12–13 (in Japanese)

Vromant N, Chau NTH (2005) Overall effect of rice biomass and fish on the aquatic ecology of experimental rice plot. Agric Ecosyst Environ 111:153–165

Vromant N, Chau NTH, Ollevier F (2001) The effect of rice seeding rate and fish stocking on the floodwater ecology of the rice field in direct-seeded, concurrent rice-fish systems. Hydrobiologia 445:151–164

Werner EE, Hall DJ (1974) Optimal foraging and the size selection of prey by the bluegill sunfish (*Lepomis macrochirus*). Ecology 55:1042–1052

Wiackowski K, Brett MT, Goldman CR (1994) Differential effects of zooplankton species on ciliate community structure. Limnol Oceanogr 39:486–492

Wickham SA (1998) The direct and indirect impact of *Daphnia* and *Cyclops* on a freshwater microbial food web. J Plankton Res 20:739–755

Wismer DA, Christie AE (1987) Temperature relationships of Great Lakes fishes: a data compilation, Great Lakes Fishery Commission special publication 87–3. Great Lakes Fishery Commission, Ann Arbor

Yagi H (1977) Nigorobuna no jinkou shubyou seisan ni kansuru kenkyu. II. Youran-su, shigyo no yuko jiryou oyobi tousai-gyo no shiiku ni tsuite [Studies on nursery of *Carassius auratus grandoculis* in an artificial environment. II. Clutch size, effective prey of larva, and breeding of 0+ juvenile fish]. Bull Shiga Prefect Fish Exp Stat 29:9–15 (in Japanese)

Yamazaki M, Ohtsuka T, Kusuoka Y, Maehata M, Obayashi H, Imai K, Shibahara F, Kimura M (2010) The impact of nigorobuna crucian carp larvae/fry stocking and rice-straw application on the community structure of aquatic organisms in Japanese rice fields. Fish Sci 76:207–217

Zöllner E, Santer B, Boersma M, Hoppe H-G, Jürgens K (2003) Cascading predation effects of *Daphnia* and copepods on microbial food web components. Freshw Biol 48:2174–2193

Chapter 11
Column: Rice-Fish Culture: The Contemporary Significance of a Traditional Practice

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Keywords Agroecosystems • Biodiversity • Fertilizing effect • Food safety • Multifunctionality • Rice-fish system • Rice yield • Rural amenities • Sustainable farming • Weed control

Introduction

Rice-fish farming is a traditional practice since 170 years in Japan. Its exact origin is unknown but the concurrent culture of rice and fish was developed in the early 1840s in the Saku basin, Nagano Prefecture, and subsequently spread to other regions (Tansuigyo-kenkyukai 1984). Fish, mainly the common carp (*Cyprinus carpio*), raised in rice fields were an important source of protein for the farmers as well as a supplementary source of income as a custom-free, salable crop (Fig. 11.1). During World War II, rice-fish farming practices expanded throughout the country, encouraged by subsidies for wartime food production. At the peak of production in 1945, a total of three million carp fry were stocked in 60,000 ha of rice fields and production reached nearly 7,500 t (Kasamura 1950). However, after the war, the widespread use of chemical pesticides and the development of more intensive carp production systems resulted in a rapid decline of carp culture in rice fields (Tansuigyo-kenkyukai 1984; Ikuta and Yamaguchi 2005). Currently large-scale rice-fish operations are found only in a few areas of the country, including the Saku basin (Fig. 11.2). The main species used is the crucian carp (*Carassius* sp.), rather than the common carp.

However, the declining practice of rice-fish farming has recently received renewed interest for its potential as a sustainable agricultural system (Iguchi et al. 2009, 2011). This interest appears to reflect the increasing concerns about the impact of conventional farming practices on biodiversity and ecosystems in agricultural landscapes and growing demands for their conservation and

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Fig. 11.1 Farmers harvesting common carp from a rice field (Photograph in the 1910s–1930s in Saku, Nagano)

Fig. 11.2 Crucian carp schooling in the marginal part of a rice field in Saku, Nagano. The field margin is not planted to rice for the convenience in feeding fish and ditching the field bed during the harvest of fish

restoration. Rice-fish farming has significant potential for addressing these concerns and demands.

In this article, I present a brief review of the potential benefits of rice-fish farming from an environmentally sustainable agriculture perspective. Several authors have considered the potential benefits in the human dimension, including food security, poverty alleviation, and public health (Coche 1967; Fernando 1993; Halwart and Gupta 2004), thus I focused on the benefits of rice-fish farming in the environmental and agroecological dimensions. My main purpose in this article was to emphasize that traditional rice-fish farming has genuine value in modern times.

Environmental and Agroecological Benefits

Biodiversity and Ecosystem Services

Rice-fish farming has an affinity for biodiversity. To avoid harmful effects on fish, the application of pesticides is minimized in rice-fish farming. For example, most rice-fish farmers in Saku do not use insecticides or fungicides, applying herbicides only once prior to the stocking of carp eggs or fry (Iguchi et al. 2011). Rice fields are an alternative habitat for a diverse assemblage of species that originally inhabit wetland environments (Kiritani 2000; Bambaradeniya and Amerasinghe 2003). The reduced pesticide use in rice-fish farming helps to conserve this biodiversity and its resulting ecosystem services, including pest control by useful insects (i.e., integrated biodiversity management; Kiritani 2000).

As a top predator, stocked fish often dramatically reduce the abundance of their prey organisms in the rice field (Yamazaki et al. 2010; Tsuruta et al. 2011; Ohtsuka 2015). For example, Yamazaki et al. (2010) showed in a controlled experiment using a conventional rice field that the stocking of nigorobuna (*C. auratus grandoculis*) larvae depleted large cladoceran zooplankton such as *Bosmina* and *Moina*. A similar result was found in rice-fish fields in Saku, with the abundance and taxonomic richness of large zooplankton being markedly decreased compared with conventional rice-only fields (Y. Koseki, unpublished data). Importantly, this high exploitation does not lead to the impairment of the system's long-term viability or productivity in subsequent years; despite being stocked with fish over a decade or more, the above rice-fish fields in Saku showed a similar abundance and richness of zooplankton relative to the neighboring rice monoculture fields in the early flooding period (Y. Koseki, unpublished data). While completely utilizing its high productivity, rice-fish farming is compatible with the conservation of biodiversity and ecosystems in the rice field.

Ecological Weed Control

Rearing fish in rice fields benefits weed control. The impact of rice-fish farming on weed control has long been known among rice-fish farmers (Tansuigyo-kenkyukai 1984). The benthivorous common carp effectively controls weeds directly by digging them up and indirectly by making the water turbid with bottom sediments, thereby inhibiting photosynthesis (Takahashi et al. 1995). Takahashi et al. (1995) showed that the stocking of 10-cm fish at a density of 10,000 fish per hectare or 15-cm fish at a density of 5,300 fish per hectare completely inhibited the emergence of weeds by 30 days of release. A similar result was also reported by Oba and Suzuki (1995).

Compared with the common carp, the crucian carp, the main species used today are plausible to be less effective for weed control owing to its more omnivorous feeding habit and smaller size. However, the species can still serve as a weed control agent. Tsuruta et al. (2011) found that experimental rice fields in which crucian carp and their domesticated relative, goldfish, were stocked at a density of 33,000 fish per hectare had a substantially lower coverage of duckweed (*Spirodela polyrhiza*, *Lemna aoukikusa*, and *L. gibba*) than rice monoculture fields.

Irrespective of the species used, the rice-fish field has to be necessarily maintained at relatively high water depths (typically 10–20 cm, Kuronuma 1954; Y. Koseki, unpublished data). At such high water depths, hygrophytic species cease to grow and die. Arai and Miyahara (1956) reported that the standing crops of hygrophytes such as *Echinochloa* spp., *Cyperus microiria*, and *Lindernia procumbens* were greatly reduced at a water depth of 10 cm or more. The combined effect of stocked fish and high water depths enables to control weeds with no or minimal use of herbicides.

Nutrient Availability

Rice-fish farming has been shown to increase nutrient (nitrogen and phosphorus) status in soil and water (Yamazaki et al. 2010; Tsuruta et al. 2011; Xie et al. 2011; Ohtsuka 2015). This is, in part, because fish release sediment-fixed nutrients into water by excretion (a fertilizing effect) and perturbing the sediment-water interface (bioturbation). The other potential mechanisms by which nitrogen availability is increased involve reduced NH_3 volatilization, where fish lower pH through the negative effect of their bioturbation activities on algal photosynthesis, thereby increasing the proportion of NH_4^+ that is not susceptible to volatilization (Li et al. 2008). Moreover, when supplementary feed is supplied, unconsumed nitrogen in the fish feed is used by the rice plants (Xie et al. 2011). The increased nutrient availability in rice-fish farming implies that the input of chemical fertilizers can be reduced compared with conventional rice farming.

Rice Yield

A major concern is whether the stocking of fish increases rice yield as a consequence of the effects on rice ecosystems. Several authors have reviewed the available data on rice yield in different rice-fish systems in different countries and shown that growing fish in rice fields generally leads to higher yields (Coche 1967; Lightfoot et al. 1992; Halwart and Gupta 2004). A recent comparative experiment also showed that rice-fish plots had 20 % higher yields than rice monoculture plots (Tsuruta et al. 2011). However, rice-fish farming does not always increase rice yield. For example, the input of excessive amounts of nitrogen in the forms of fish feces and supplementary feed can result in reduced yields, increasing susceptibility to lodging and damage from pests and diseases (Tansuigyo-kenkyukai 1984). Rice-fish farming will increase rice yield only if it does not override the balance of rice ecosystems.

Rice Field Restoration Using Rice-Fish Farming

Traditionally, rice-fish farming has been practiced to increase food production on a limited land area. This conventional value of rice-fish farming or higher productivity is no longer important for farmers, given that high-input monoculture systems have dramatically improved rice productivity. However, rice-fish farming offers great potential as a sustainable agricultural system, lowering agrochemical input, conserving local biodiversity, and enhancing agroecosystem functions (Fig. 11.3). In this environmentally conscious age, the practice of sustainable agriculture is becoming increasingly important. Given its multifunctional potential, much attention should be paid to the rice-fish system and its active application to the conservation and restoration of biodiversity and ecosystems in rice-dominated landscapes in Japan and perhaps in other countries.

Is the application of rice-fish farming to the ecological conservation and restoration of agricultural landscapes a viable option? For an agricultural practice to be viable, it needs to be economically feasible. The economic feasibility of an agricultural practice today largely depends on the marketability of the agricultural commodity. In this sense, rice-fish farming appears to be promising because the organic or semi-organic rice grown with fish will be highly valued by increasingly environmentally and health-oriented consumers. For example, the producer prices of organic (chemical-free) and semi-organic rice (with only selected herbicides used) from the rice-fish fields in Saku are about 80 % and 20 % higher than those of non-organic rice, respectively. Such a premium price of the rice (i.e., high value-added rice) is encouraging for farmers to convert from conventional monoculture farming to the unfamiliar rice-fish farming. Moreover, the harvested fish provide an additional income for farmers. For example, in Saku, the gross income from crucian carp is, on average, 130,000 yen 0.1 ha^{-1} (based on the average yield of 100 kg 0.1 ha^{-1} and price of 1,300 yen kg^{-1}), which yields a net return of 70,000–100,000

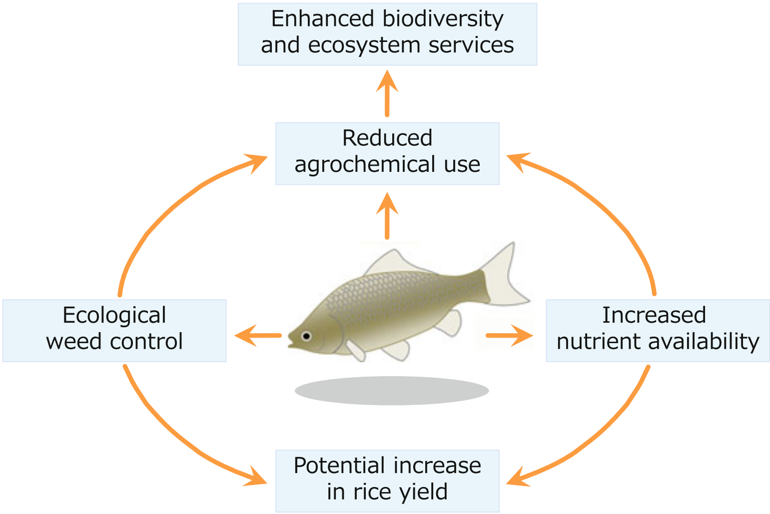

Fig. 11.3 Schematic diagram of the agroecosystem functioning of rice-fish farming system. Concurrent culture of fish with rice leads to reduced use of chemical pesticides, which leads to the conservation and enhancement of local biodiversity and associated ecosystem services (e.g., pest control by useful insects). Stocked fish and relatively high water depths of the rice field provide effective weed control, by which the use of chemical herbicides is reduced. Fish also increase nutrient availability to rice by their excretion and bioturbation activities, thereby contributing to the reduction of the use of synthetic fertilizers. As a result of increased nutrient availability and reduced nutrient competition with weeds, rice-fish farming often results in an increase in rice yield

yen 0.1 ha^{-1} after deducting the production costs (broodfish and supplementary feed). Although these figures would vary across localities, rice-fish farming would benefit farmers economically.

Despite the economic benefits, the extra work required for the fish culture operation may hinder the adoption of the rice-fish practice. The fish culture work, such as feeding and harvesting is often laborious in the conventional, production-oriented rice-fish farming. However, the rice-fish farming practiced for the sake of rice field conservation does not necessarily need to produce high fish yields and thus may not require the same level of fish culture effort as the conventional rice-fish system. For example, supplementary feeding may not be necessary, at least for the growing of juvenile fish (Kikko et al. 2013a, b; Ueshima and Koseki 2013). Such extensive rice-fish practice will greatly reduce the income from fish but still provide economic benefits in terms of the production of high value-added rice and a potential increase in rice yield.

Rice-fish farming can also be socially and economically beneficial for local communities, providing a fresh, local, and seasonal treat of fish and fostering the development of local food culture. In Saku, people enjoy the local dish, sweetened boiled crucian carp. Farmers share the fish and the cuisine with their relatives and friends, creating harmonious social environments. All of these sociocultural activities vitalize the local community. Moreover, the environmentally and biodiversity-preserved agricultural landscapes potentially offer rural tourism resources. For these reasons, environmentally sustainable rice-fish farming can play a vital role in empowering farmers and local communities both socially and economically.

References

Arai M, Miyahara M (1956) Studies on weed control by submergence in rice cultivation: I. Effect of submergence on the structure of weed communities and the quantity of weeds. II. Effect of submergence on the growth and yield of rice plant. Jpn J Crop Sci 24:163–165 (in Japanese with English summary)

Bambaradeniya CNB, Amerasinghe FP (2003) Biodiversity associated with the rice field agroecosystem in Asian countries: a brief review, Working paper 63. International Water Management Institute, Colombo

Coche AG (1967) Fish culture in rice fields. A world-wide synthesis. Hydrobiologia 30:1–44

Fernando CH (1993) Rice field ecology and fish culture – an overview. Hydrobiologia 259:91–113

Halwart M, Gupta MV (eds) (2004) Culture of fish in rice fields. FAO/The WorldFish Center, Rome/Penang

Iguchi K, Tsuruta T, Takahashi D, Sato T (2009) Evaluation of public opinion on rice cultivation with crucian carp through a sensory test of cooked rice. Nippon Suisan Gakkaishi 75:1–5 (in Japanese with English abstract)

Iguchi K, Tsuruta T, Yamaguchi M, Haketa N (2011) Current status of rice-fish culture using crucian carp in the Saku area of Nagano Prefecture. J Fish Tech 4:1–6 (in Japanese with English abstract)

Ikuta K, Yamaguchi M (2005) The present state of carp fisheries and aquaculture in Japan. Bull Fish Res Agency Suppl 2:55–58

Kasamura K (1950) Toden-yori. I [Rice-carp culture. I]. Suisankai 793:50–59 (in Japanese)

Kikko T, Nemoto M, Ban S, Saegusa J, Sawada N, Ishizaki D, Nakahashi T, Teramoto N, Fujioka Y (2013a) Efficient rearing of larvae and juveniles of gengoroubuna *Carassius cuvieri* in paddy fields. Aquacult Sci 61:19–26 (in Japanese with English abstract)

Kikko T, Nemoto M, Ban S, Saegusa J, Sawada N, Ishizaki D, Nakahashi T, Teramoto N, Fujioka Y (2013b) Efficient rearing of larvae and juveniles of honmoroko *Gnathopogon caerulescens* in paddy fields. Aquacult Sci 61:303–308 (in Japanese with English abstract)

Kiritani K (2000) Integrated biodiversity management in paddy fields: shift of paradigm from IPM toward IBM. Integr Pest Manag Rev 5:175–183

Kuronuma K (1954) Carp culture in rice fields as a side work of Japanese farmers. Ministry of Agriculture and Forestry, Government of Japan, Tokyo

Li CF, Cao CG, Wang JP, Zhan M, Yuan WL, Shahrear A (2008) Nitrogen losses from integrated rice-duck and rice-fish ecosystems in southern China. Plant Soil 307:207–217

Lightfoot C, van Dam A, Costa-Pierce BA (1992) What's happening to the rice yields in rice-fish systems? In: dela Cruz CR, Lightfoot C, Costa-Pierce BA, Carangal VR, Bimbao MP (eds) Rice-fish research and development in Asia, ICLARM conference proceedings, vol 24. International Center for Living Aquatic Resources Management, Manila, pp 177–183

Oba S, Suzuki M (1995) Weed control under rice culture on non-agricultural chemicals. I. Weed control in lowland field by the stocking of carp. Tohoku Agric Res 48:57–58 (in Japanese)

Ohtsuka T (2015) Nursery grounds for round crucian carp, *Carassius auratus grandoculis*, in rice paddies around Lake Biwa. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_10

Takahashi S, Abe Y, Furuyama T (1995) Mechanism of weed control by carp in the paddy rice. Rep Chugoku Branch Crop Sci Soc Jpn 36:1–9 (in Japanese with English abstract)
Tansuigyo-kenkyukai [The Freshwater Fish Study Group] (1984) Sakugoi no rekishi [The history of the Saku carp]. Dai'ichi Houki Shuppan, Nagano (in Japanese)
Tsuruta T, Yamaguchi M, Abe S-I, Iguchi K (2011) Effect of fish in rice-fish culture on the rice yield. Fish Sci 77:95–106
Ueshima G, Koseki Y (2013) Juvenile production of the Japanese crucian carp and pond loach without artificial feeding in paddy fields. Bull Nagano Prefect Fish Exp St 14:11–16 (in Japanese)
Xie J, Hu L, Tang J, Wu X, Li N, Yuan Y, Yang H, Zhang J, Luo S, Chen X (2011) Ecological mechanisms underlying the sustainability of the agricultural heritage rice-fish coculture system. Proc Nat Am Soc 108:E1381–E1387
Yamazaki M, Ohtsuka T, Kusuoka Y, Maehata M, Obayashi H, Imai K, Shibahara F, Kimura M (2010) The impact of nigorobuna crucian carp larvae/fry stocking and rice-straw application on the community structure of aquatic organisms in Japanese rice fields. Fish Sci 76:207–217

Chapter 12
Responses of Aquatic Insect, Terrestrial Arthropod, and Plant Biodiversity to the V-Furrow Direct Seeding Management in Rice Fields

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Abstract The aim of this study was to determine the effects of the V-furrow no-till direct seeding (DS) management on diversity patterns of aquatic insects, terrestrial arthropods and plants in rice paddies. In DS fields, rice is sown in well-drained fields, and flooding is performed 1 month later than that in conventional transplanting rice fields. DS fields are then continuously flooded until harvesting, unlike in conventional fields where a midseason drainage is performed during summer. We observed that diversity patterns of the study organisms were affected by the farming systems. DS fields supported abundant and species-rich assemblages of water beetles and water bugs, presumably because of the high compatibility between the flooding period and the reproductive season of the insects, as well as the absence of seedling box-applied insecticide (clothianidin). The DS farming system positively affected several taxonomic groups (terrestrial arthropods such as Collembola and Araneae, and several endangered plant species), while it negatively affected plant species richness. DS farming enhanced the densities of two rice pest species (*Nephotettix cincticeps* and *Lissorhoptrus oryzophilus*). The large differences in the responses of different taxonomic groups to farming systems suggest that a combination of DS and conventional system is preferable to the use of either system alone, for the conservation of aquatic and terrestrial biodiversity in rice agro-ecosystems.

Keywords Rice agroecosystem • Midseason drainage • Community composition • Low-input agriculture • Coleoptera • Heteroptera • Arthropods • Plants

Introduction

Agricultural intensification has been a major driver of biodiversity decline during the past several decades (Krebs et al. 1999; Benton et al. 2003). In Japanese flooded rice (*Oryza sativa* subsp. *japonica*) ecosystems, modern drainage systems have been widely adopted since the 1960s to reduce manual labor and to enhance farming efficiency (Hasegawa and Tabuchi 1995). The conversion of traditional, poorly drained paddy fields into modern, well-drained paddy fields, in conjunction with the overuse of agrochemicals, have caused a decrease in habitat quality for aquatic and terrestrial organisms in rice ecosystems (Fujioka and Lane 1997; Kiritani 2000; Nishihara et al. 2006; Kadoya et al. 2009; Katayama et al. 2011). To minimize the loss of biodiversity while maintaining the required rice production, refuge habitats should be available during times when crops are disturbed and/or alternative, *wildlife-friendly* farming methods that have longer water permanence and lower agrochemical inputs should be used (Washitani 2007; Natuhara 2013).

Direct seeding of rice has recently received attention as an alternative to conventional transplanting systems because it is less labor-intensive, uses less water with high efficiency, and is conducive to mechanization (Pandey et al. 2002; Farooq et al. 2011). In Japan, under a new governmental policy for rice production, large-scale modernized cultivation is being encouraged and farmers are adopting direct seeding to reduce labor and cost of rice production. Direct seeding technology in Japan is highly mechanized. For example, the V-furrow direct-seeding method (hereafter referred to as the DS method) with tractor-mounted mechanical row seeders was developed by Aichi Agricultural Research Center in the early 1990s and is increasingly being used in central Japan (Hamada et al. 2007). The major distinctions of the DS from conventional farming are (1) a delayed and long-lasting irrigation period and (2) the absence of seedling box-applied insecticides. In the DS farming system, rice is sown in well-dry fields and flooding is performed 1 month later than that in conventional fields, where rice is planted earlier. Then, the DS paddies are continuously flooded until harvesting, unlike in conventional rice fields where a midseason drainage is usually performed during summer. Furthermore, systemic seedling box-applied insecticides, which negatively influence aquatic and benthic insects in paddy fields (Sánchez-Bayo and Goka 2006; Jinguji et al. 2013), are not used in the DS method. The different irrigation and pest control practices in DS fields could have profound effects on the biodiversity and associated ecological functions in the system.

In this chapter, we examine the effects of the DS method on the abundance and diversity of aquatic insects, terrestrial arthropod orders, rice pest insects, and plants. The main questions were as follows: (1) Do DS fields support more abundant, species-rich, and diverse communities of animals and plants? and (2) Does the response to farming systems differ among taxonomic groups?

Study Site

The study was performed in commercial rice fields in Suzu City, Ishikawa Prefecture, Japan (37°5′N, 137°3′E). The area is flat lowland and consists mainly of rice fields (Fig. 12.1). There are woodland patches and two irrigation ponds adjacent to the area. After farmland consolidation in 2007, shallow earth ditches were converted to deep concrete-walled ditches, and underground drainage pipes were installed in the paddies. Average paddy plot area expanded from 810 to 3,546 m^2 after the land consolidation. The DS method was first adopted in the study area in 2007. The area cultivated using the DS method has gradually increased and reached 22 % (9.9 ha) of the total rice crop area (45 ha) in 2010.

Four DS and four TP rice fields (each 1,000–4,000 m^2 in size) were haphazardly chosen and sampled between May and September 2010. The TP fields were watered and puddled in mid-May, before the transplantation of rice (variety Koshihikari) seedlings. On the day of transplantation, fertilizer (nitrogen, phosphorus, and potassium) and herbicides (imazosulfuron, pyraclonil, and bromobutide) were applied. In the TP fields, the seedling box-applied insecticide, clothianidin (Delaus-Dantotsu®, Sumitomo Chemical Co. Ltd., Tokyo, Japan) was applied at the rate of 50 g per box. Floodwater was maintained in the TP paddy fields from May to June and was drained off by 7–10 day in early July (i.e., mid-season drainage), to dry the soil (Fig. 12.2). The fields were re-flooded intermittently until late September and then drained before harvest in early October.

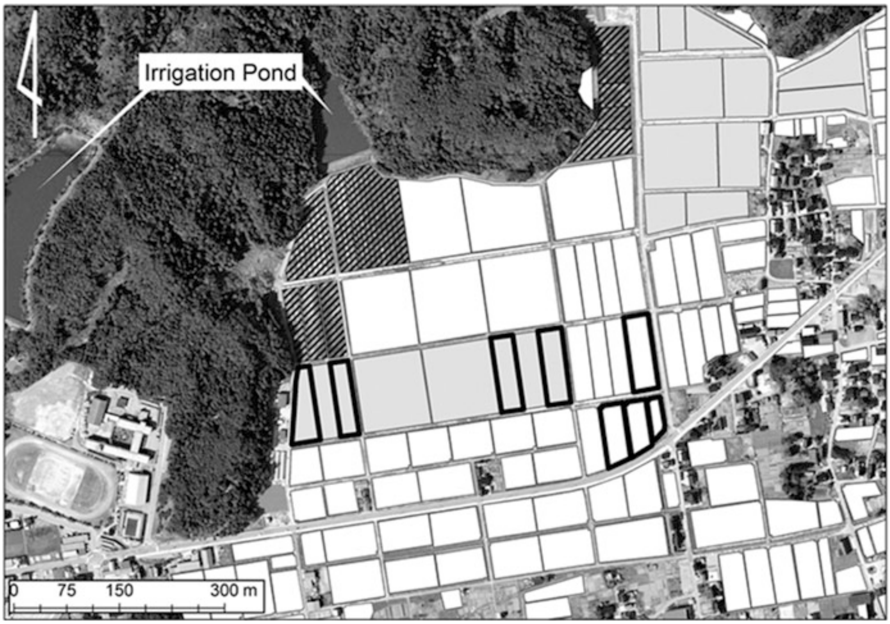
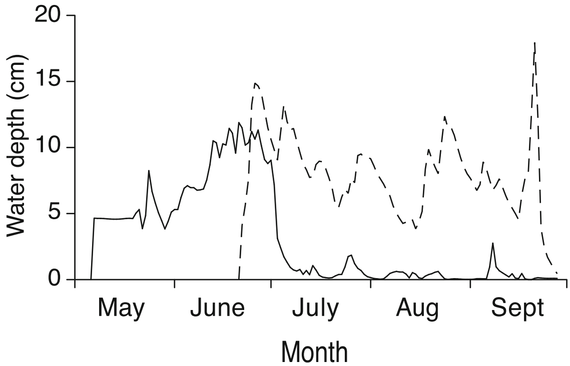


Fig. 12.1 Location of study fields, indicated by *thick lines*. The *grey colored areas* represent direct seeding (DS) rice fields, and the *white colored areas* represent conventional transplanting (TP) rice fields. The *hatched areas* represent soybean fields (This map is based on the orthoimage data published by Geospatial Information Authority of Japan)

Fig. 12.2 Seasonal change in mean water depth in transplanting (*solid line*) and direct seeding (*broken line*) rice paddy fields. Since data were not available for the direct seeding fields in 2010, those collected in 2011 are shown for reference



The agronomic practices for DS rice fields followed the regime described by the Aichi Agricultural Research Center (2007). The fields were plowed and puddled in mid-December 2009, kept flooded throughout the winter, and fully drained in late March 2010. In early May, rice seeds (variety Koshihikari) were sown in V-shaped furrows on dry soil via machinery, and fertilizer was applied. Selective herbicides (cyhalofop-butyl and bentazon) were applied on June 3 and 9, 2010.

Flooding was performed at the two-leaf growth stage (June 20, 2010), and floodwater levels were maintained at a depth of 5–15 cm until early October, without a mid-season drainage.

To reduce damage by mirid bugs, the TP and DS fields were twice treated using insecticides and fungicides: ethofenprox and tricyclazole were applied on August 11, 2010 and dinotefuran and tricyclazole were applied on August 18, 2010. Further details of the agrochemical regimes are described in Watanabe et al. (2013).

Water Beetles and Water Bugs

Many water beetle (Coleoptera) and water bug (Heteroptera) species reproduce in paddy fields in summer (Saijo 2001). In conventional rice fields, the lack of floodwater due to mid-season drainage reduces the number of reproduction sites for aquatic insects, and therefore, has a negative effect on their population sizes (Mukai et al. 2005; Nishihara et al. 2006; Ohba and Goodwyn 2010). Conversely, DS fields are continuously flooded and can serve as insect habitats throughout the summer. Thus, the delayed and long-lasting hydroperiod in DS fields, if it coincides with the reproductive season of the insects, could increase the diversity of water beetles and bugs in conventionally farmed areas. In this section, we examine the effect of the DS method on species diversity and abundance of water beetles and bugs in rice paddy fields.

Methods

Water beetles and water bugs were sampled by sweeping and by quadrat samplers. Because of identification difficulties, Odonata larvae were excluded from the analysis. For sweep sampling, a square-frame dip net (30 cm in width and <1 mm in mesh size) was used once for 50 cm along the bottom of the paddy field. This procedure was replicated 40 times at random along the levee in each field. The quadrat method was performed using a rectangular plastic quadrat (18 cm $\times$ 59 cm, 15 cm high). We placed 20 quadrats along the levee in each field and swept a square-frame dip net (12 cm $\times$ 15 cm and <1 mm in mesh size) through the entire water column and surficial sediments within the quadrat, until no more insects were observed in the quadrat. For both sweeping and quadrat sampling, the captured adult and larval specimens were identified to the species level, enumerated, and then released in the same place where they were captured. Individuals that could not be identified in situ were preserved in 70 % ethanol and taken to the laboratory for further examination. Sweeping and quadrat sampling were conducted 21 and 10 times, respectively, from May to September 2010. When the rice fields were drained, however, sampling was not performed in fields lacking surface water. Thus, the number of sampling events differed among fields, ranging from 7 to 15 times for sweeping and from 2 to 8 times for quadrat sampling.

The differences in total abundance, species richness, and Shannon diversity of aquatic insects were compared between farming systems (DS vs. TP). The data for all dates and all sweep/quadrat samples within each field were summed. The effect of farming systems on insect abundance was analyzed using generalized linear models with negative binomial distribution and log link by using the glm.nb function in the MASS library in R 2.10.1 (R Development Core Team 2009). The logarithm of the number of samples was incorporated into the model as an offset term (i.e., a variable that compulsorily has a regression coefficient of 1) to allow for the difference in the number of surveys (Faraway 2006).

To obtain estimates of species richness for each paddy field, the Chao2 estimator (Colwell and Coddington 1994) was calculated using the software EstimateS version 9.1 (Colwell 2013). The Chao2 index is a nonparametric species richness estimator and is one of the most reliable predictors of total species richness when sampling unit (i.e., one sweep or quadrat) is comparable (Hortal et al. 2006). Wilcoxon's signed-rank tests were used to compare the estimated species richness and Shannon diversity indices between the DS and conventional fields.

Results

A total of 5,141 water beetles and 4,427 water bugs were collected by sweeping, and 1,356 water beetles and 79 water bugs were collected by quadrat sampling. Twelve water beetle species were collected, and the predominant species were *Sternolophus rufipes* (Fabricius), *Enochrus simulans* (Sharp), *Hydroglyphus japonicus* (Sharp), and *Rhantus suturalis* (Macleay). Eight water bug species were collected, and the predominant species were *Sigara* spp. (including *S. septemlineata*, *S. substriata*, and *S. nigroventralis*). Two nationally threatened species *Graphoderus adamsii* (Clark) and *Cybister chinensis* Sharp and two near-threatened species *Cybister brevis* Aube and *Cymatia apparens* (Distant) were collected from the study fields.

Total abundance was significantly higher in the DS than in the conventional TP fields (sweeping: $\chi^2 = 71.73$, df = 1, $P < 0.001$; quadrat: $\chi^2 = 89.64$, df = 1, $P < 0.001$; Fig. 12.3). The same tendency was observed for both water beetles (sweeping: $\chi^2 = 38.04$, df = 1, $P < 0.001$; quadrat: $\chi^2 = 71.08$, df = 1, $P < 0.001$) and water bugs (sweeping: $\chi^2 = 24.22$, df = 1, $P < 0.001$; quadrat: $\chi^2 = 4.60$, df = 1, $P = 0.032$). Overall species richness, estimated using Chao2, was higher in the DS than in the TP fields (sweeping: $Z = 2.165$, $P = 0.030$; quadrat: $Z = 2.165$, $P = 0.030$). The Shannon diversity indices for sweep samples were higher in the TP fields ($Z = 2.165$, $P = 0.030$), while those for quadrat samples were higher in the DS fields ($Z = 2.165$, $P = 0.030$).

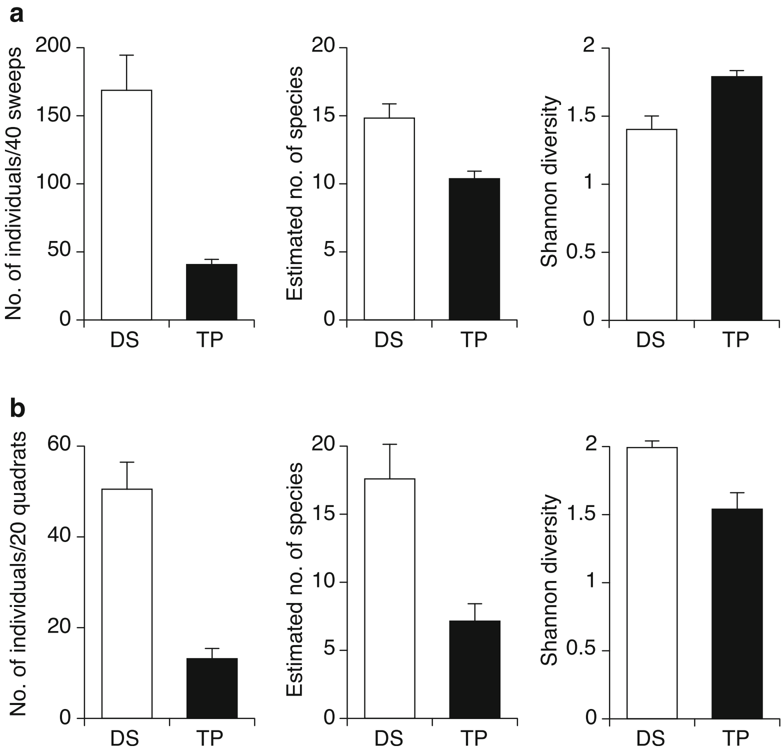


Fig. 12.3 Mean abundance (*left*), species richness (*center*), and Shannon diversity indices (*right*) of aquatic Coleoptera and Heteroptera collected by sweeping (**a**) and by quadrat samplers (**b**) in direct seeded (DS, *white bars*) vs. conventional (TP, *black bars*) fields. Error bars represent standard errors

Discussion

Water beetles and water bugs were more abundant and species richness was more in the DS than in the conventional TP fields. There are at least three explanations for these tendencies. First, the high compatibility between the flooding period and reproductive season of the insects may have enhanced population densities of many species in DS fields. Watanabe et al. (2013) examined seasonal population dynamics of water beetles and bugs in DS and conventional fields, and found that seven species switched breeding habitats from conventional to DS rice fields in late June, and that the number of larvae increased until it peaked from July to August in the DS fields. DS fields can serve as complement breeding habitats for aquatic insects in rice paddies, when most conventional fields are dried by mid-season drainage. Because the area of this study was dominated by conventional farming, the positive effect of DS fields might have been enhanced by the increased immigration of reproductive adults from neighboring TP fields.

A second explanation for the high abundance of predatory water beetles and bugs may be the higher abundance of invertebrate prey associated with DS fields. Many studies on community succession in rice fields show an initial dominance of producers and consumers, followed by a build-up of predator populations (Settle et al. 1996; Suhling et al. 2000; Bambaradeniya et al. 2004; Lawler and Dritz 2005; Leitão et al. 2007; Bloechl et al. 2010). Mid-season drainage and intermittent flooding in conventional fields may reset the community to an earlier successional stage (Lawler 2001). On the other hand, a longer continuous irrigation period in DS fields could support numerous invertebrate prey populations, which could enhance populations of predatory water beetles and bugs in the later successional stage.

Finally, the higher abundance and diversity of aquatic insects in DS fields may be related to the absence of seedling box-applied insecticides. Systemic seedling box-applied insecticides such as neonicotinoid and phenyl-pyrazole influence aquatic insects in paddy fields directly by increasing insect mortality (Jinguji et al. 2013) or indirectly by reducing food availability (Sánchez-Bayo and Goka 2006). In the present study, the application of clothianidin, a neonicotinoid insecticide, might have had direct toxic effects on water beetle and bug populations in TP fields, at least during the early part of the season.

Although our results showed that the Shannon indices for sweep samples were higher in the TP than in the DS fields, the TP fields did not have more species than that in the DS fields, as the Chao2 values were higher in the DS fields. This is because the most predominant species (*Sigara* spp.) had a high frequency of occurrence, which lowered the Shannon index values in the DS fields (Watanabe et al. 2013).

DS farming enhanced species richness and abundance of water beetles and water bugs. Furthermore, from a conservation perspective, DS rice fields may be beneficial for threatened aquatic insects. Three out of four national red list species (*G. adamsii*, *C. chinensis*, and *C. brevis*) were more abundant in the DS than in the conventional fields (Watanabe et al. 2013). These results suggest that DS farming may be an important factor for the conservation and enhancement of aquatic insect assemblages in rice paddy systems.

Terrestrial Arthropods

Previous studies on the terrestrial arthropods in rice fields have focused mainly on agronomic aspects, and rice pests and their natural enemies have been extensively surveyed. Comprehensive studies on the terrestrial biodiversity of rice are relatively scarce (but see Hidaka 1990; Settle et al. 1996; Schoenly et al. 1998, 2010; Bambaradeniya et al. 2004). However, several studies have shown that arthropod groups that are neither pests nor natural enemies, such as chironomids and collembola, can be useful alternative foods for generalist predators when pest prey are less available (Hidaka 1990; Settle et al. 1996). Such trophic linkages among pest, beneficial, and neutral arthropods indicate the importance of comprehensive multitaxa assessments to evaluate the effect of DS farming on rice field biodiversity. In this section, we compare abundance and faunal assemblages of arthropod orders sampled from DS and conventional transplanting (TP) rice fields. Furthermore, the effects of agricultural system on rice pest density were examined.

Methods

Terrestrial arthropods were surveyed biweekly from June to August 2010. In DS fields, sampling was not performed in June because of the delayed germination of rice. Thus, the number of sampling events was 4 and 6 times for DS and TP fields, respectively. Each field was divided into 100 equal-sized subplots. On each sampling occasion, ten subplots were selected at random within each field. To avoid potential edge effects, no subplots within approximately 3 m of the border were used. A square sampling frame (50 cm × 60 cm, 90 cm high) made of transparent PVC sheets was placed at an arbitrary location in each subplot to cover six rice hills. Terrestrial arthropods inside the frame enclosure were sampled using a suction device (Cariño et al. 1979) powered by a hand blower (UB142DRF, Makita Corporation, Aichi, Japan). Suction sampling was performed until no more arthropods were observed in the frame. The sampling required 3–10 min depending on the size of the plants. Samples were preserved in 70 % ethanol and taken to the laboratory for further examination. Once sampled, subplots were not used again in subsequent censuses.

To analyze the effects of agricultural system on densities of arthropod orders and insect pests, generalized linear models were used with negative binomial distribution and log link by using the glm.nb function in the MASS library in R 2.10.1 (R Development Core Team 2009). The data for all dates and all samples within each field were summed. The logarithm of the number of sampling events was incorporated into the model as an offset term to allow for the difference in the number of surveys (Faraway 2006).

We compared the order composition in paddy fields managed under different farming methods with nonmetric multidimensional scaling (NMDS) by using PC-ORD version 6 (McCune and Mefford 2011). The analysis was based on a Bray–Curtis similarity matrix, calculated on log $(x + 1)$-transformed data. The ordination of mean values for each field (i.e., the average of all sampling events) was presented. In addition, we used multiresponse permutation procedures (MRPP) to test whether order composition differed significantly between agricultural systems (DS and TP). MRPP was performed using PC-ORD and Bray–Curtis distance as the distance measure between matrices.

Results

Abundance and Order Composition

A total of 86,286 individuals from 14 orders were collected during the study period (Table 12.1). The most numerous orders were Collembola (63.8 %), Diptera (22.0 %), and Araneae (8.6 %). These three orders together comprised 94.4 % of all individuals.

Densities of all the arthropod assemblage were significantly higher in DS than conventional (TP) fields (Table 12.1). Collembola, Araneae, Heteroptera, Hymenoptera, Coleoptera, and Orthoptera densities were higher in the DS fields, whereas Acari density was higher in the TP fields. There were no differences in the densities of Diptera, Thysanoptera, Lepidoptera, and Ephemeroptera or four other orders between the agricultural systems. The NMDS ordination diagram showed different order assemblages between DS and TP fields (Fig. 12.4). MRPP analyses revealed significant differences in faunal assemblages between the agricultural systems ($A = 0.225$, $P < 0.01$).

Table 12.1 Mean (±SE) densities of terrestrial arthropod orders (a) and major insect pests (b) in rice paddy fields under direct seeding (DS) and conventional transplanting (TP) farming methods

	Farming method	
	DS	TP
All arthropods	2584.1 ± 131.9*	1872.5 ± 271.5
(a) Arthropod orders		
Collembola	1765.5 ± 155.9*	1118.3 ± 215.0
Diptera	456.1 ± 45.0	488.5 ± 49.9
Araneae	225.3 ± 8.4**	157.7 ± 6.4
Heteroptera	101.1 ± 13.7*	66.7 ± 8.6
Acari	5.1 ± 1.0**	24.1 ± 6.0
Hymenoptera	14.9 ± 2.2*	8.9 ± 1.5
Coleoptera	9.9 ± 2.3*	5.0 ± 1.0
Thysanoptera	2.3 ± 0.5	2.3 ± 0.2
Orthoptera	2.3 ± 0.5**	0.3 ± 0.2
Lepidoptera	0.9 ± 0.2	0.5 ± 0.3
Ephemeroptera	0.4 ± 0.4	0.04 ± 0.04
Others[a]	0.5 ± 0.2	0.2 ± 0.1
(b) Insect pest species		
Sogatella furcifera	12.81 ± 3.45	15.29 ± 4.21
Laodelphax striatellus	6.69 ± 1.59	4.96 ± 1.39
Nephotettix cincticeps	2.38 ± 0.51**	0.00 ± 0.00
Oulema oryzae	0.06 ± 0.06	0.25 ± 0.14
Lissorhoptrus oryzophilus	2.06 ± 1.23**	0.00 ± 0.00

Asterisk indicates a significant difference between DS and TP: *$P < 0.05$; **$P < 0.01$
[a]Odonata, Dermaptera, Chilopoda

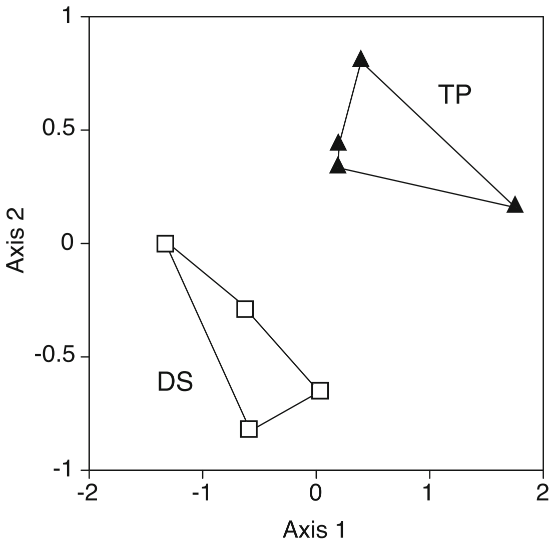


Fig. 12.4 Nonmetric multidimensional scaling (NMDS) plot comparing composition of terrestrial arthropod orders between conventional transplanting (TP, *filled triangles*) and direct seeding (DS, *open squares*) farming methods

Figure 12.5 illustrates seasonal phenology patterns for Collembola, Diptera, and Araneae. In transplanting fields, Diptera populations showed a high peak in late June, and then decreased consistently until mid-August. In the DS fields, Diptera populations gradually decreased from early July to mid-August. The densities of Collembola and Araneae remained low from early June to early July, and then increased until mid-August.

Response of Rice Pests to DS and Conventional Systems

The effect of agricultural system (DS vs. TP) was analyzed for *Sogatella furcifera*, *Laodelphax striatellus* (both Heteroptera: Delphacidae), *Nephotettix cincticeps* (Heteroptera: Cicadellidae), *Oulema oryzae* (Coleoptera: Chrysomelidae), and *Lissorhoptrus oryzophilus* (Coleoptera: Curculionidae). Agricultural systems had no significant effect on densities of two planthopper species (*S. furcifera* and *L. striatellus*) or a chrysomelid (*O. oryzae*) (Table 12.1). Higher population densities of green rice leafhopper (*N. cincticeps*) and rice water weevil (*L. oryzophilus*) were observed in DS fields.

Seasonal changes in the density of five pest species are shown in Fig. 12.6. *S. furcifera* populations had noticeable peaks in late June and late July, which probably coincided with peaks of the immigrant and the first generation, respectively. A similar temporal pattern was observed for the other two planthopper/leafhopper species *L. striatellus* and *N cincticeps*. The population densities of these species increased from early July and peaked in early August, before decreasing until late August. The population density of *N. cincticeps* was consistently higher in DS fields throughout the cropping season. The *O. oryzae* population remained low

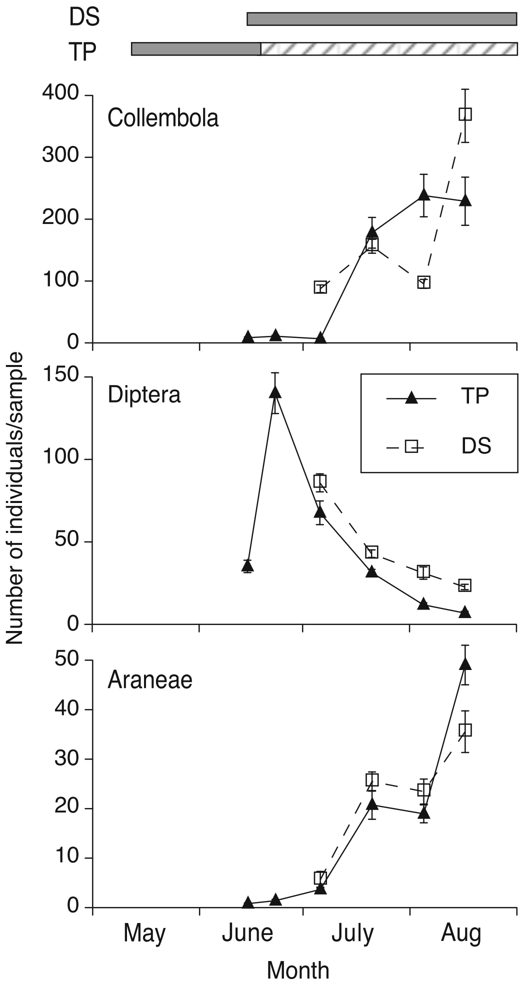


Fig. 12.5 Mean (±standard error) densities of Collembola, Diptera, and Araneae within conventional transplanting (TP, *filled triangles*) and direct seeding (DS, *open squares*) rice paddy fields. Rice fields were flooded and subjected to intermittent irrigation for the period shown with a horizontal gray and hatched bar, respectively

throughout the season in both DS and TP fields. The population densities of *L. oryzophilus* were higher in the DS fields than in the conventional TP fields. The peak population density occurred in early August, which coincided with a peak of the newly emerged adult population.

Discussion

This study demonstrated that arthropod order compositions in two rice-farming systems were substantially different from each other. Responses to farming method differed among arthropod orders: six orders had higher densities in the DS fields,

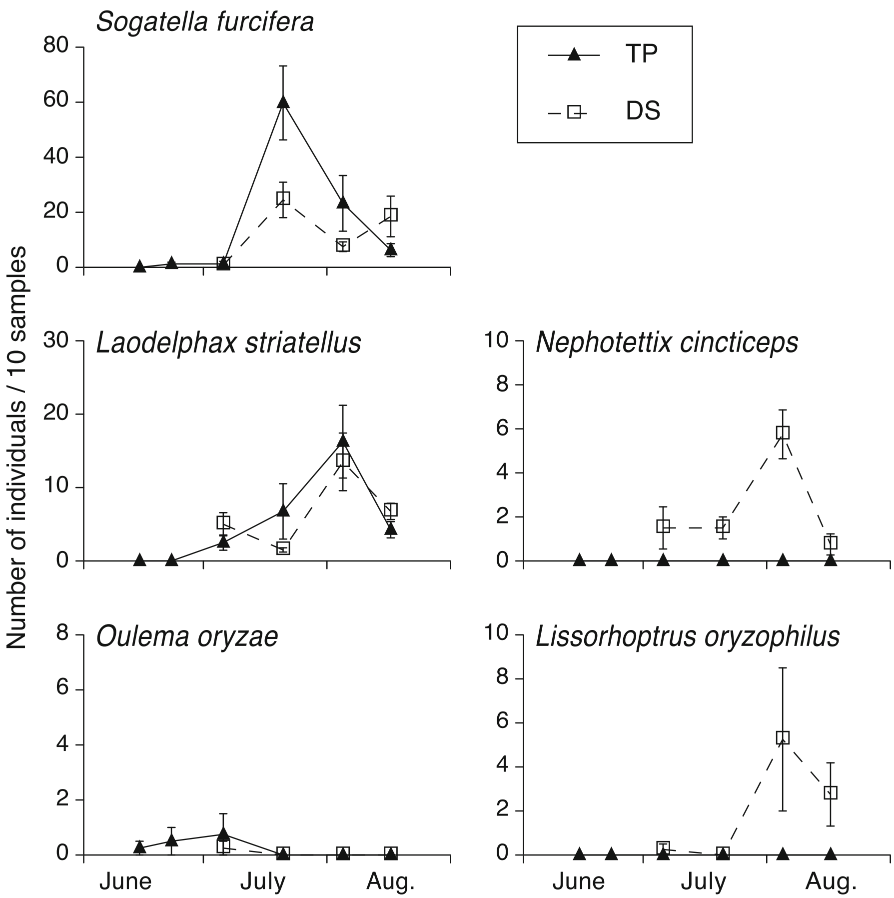


Fig. 12.6 Mean (±standard error) densities of rice pest species (*Sogatella furcifera*, *Laodelphax striatellus*, *Nephotettix cincticeps*, *Oulema oryzae*, and *Lissorhoptrus oryzophilus*) within conventional transplanting (TP, *filled triangles*) and direct seeding (DS, *open squares*) rice paddy fields

one order had a higher density in the TP fields, and four orders were not influenced by farming systems. Agronomic practices such as irrigation practices, pesticide application, land preparation methods, planting density, frequency of fertilization, and weed control may be responsible for differences in order composition.

Seasonal patterns in arthropod communities in TP rice fields were generally similar to those observed in irrigated rice fields in other localities where populations of detritivorous Diptera (mainly Chironomidae) rapidly increased and showed a high peak early in the season, whereas populations of Collembola and Araneae increased later in the season (Hidaka 1990, 1997; Settle et al. 1996; Bambaradeniya et al. 2004; Schoenly et al. 2010). Conversely, in the DS fields, a high peak of Diptera population was not observed and their densities gradually decreased from early July to mid-August. The delayed onset of flooding in the DS fields may be incompatible with the emergence season of dipterous insects, resulting in the low density early in the season.

In terrestrial rice ecosystems, detritivorous prey abundant early in the season enhances populations of carnivorous Araneae, which act as biological control agents against planthoppers and leafhoppers in the late season (Hidaka 1990; Settle et al. 1996). In the DS fields, early entry of dipterous prey from the detritus food web (i.e., detrital infusion, Polis and Strong 1996) was limited compared with transplanting fields. However, Araneae populations were larger in DS fields and were not limited by food resources. Further species level analyses in relation to the spider hunting strategies are needed to evaluate the importance of early detrital infusion on Araneae density in the DS fields.

The effect of farming systems was variable for individual pest species: the abundance of two species (*N. cincticeps* and *L. oryzophilus*) was higher in DS fields, while the abundance of three species (*S. furcifera*, *L. striatellus*, and *O. oryzae*) was not influenced by farming systems. The *L. oryzophilus* population in conventional fields remained low throughout the season, whereas the population in DS fields exhibited a distinct peak at early August. Higher population densities also occurred in clothianidin-untreated transplanting fields (S. Koji, unpublished data), implying that the lack of clothianidin application in DS fields may be a major factor in the differences in the *L. oryzophilus* population densities. *N. cincticeps* was commonly found in DS fields, whereas it was quite rare in TP fields. The reason for the contrasting pattern is unknown, but weed vegetation in DS fields may play a role. Before flooding was performed, the DS field harbored an abundance of grass weeds such as foxtail grass *Alopecurus aequalis*, a preferred host plant of *N. cincticeps*. A high abundance of grass weeds might benefit *N. cincticeps* populations and result in high leafhopper densities in DS fields.

Plants

In Japan, many weed species adapted to traditional paddy environments have become threatened because of agricultural modernization practices such as land improvement intended to dry paddy fields (Watanabe 2011a). In particular, the habitats for most rare species are restricted to traditional paddy fields and surrounding environments, such as irrigation ponds, ditches and artificially constructed wetlands (Hidaka et al. 2006). DS fields, however, can be alternative suitable habitats for these rare species because of their characteristic water management during the rice-growing period and because there is no application of herbicide after irrigation in June. In this section, we evaluate the habitat quality of DS paddies in terms of conservation of rare weeds and plant diversity by comparing DS paddies with transplanting TP paddies.

Methods

The field survey was conducted in four DS paddies and four TP paddies. Quadrats were placed within the paddy interior and on the edge separately because it was expected that the spatial pattern of plant diversity was uneven and that weed growth differed within the paddy. The 1 m × 1 m quadrats of the paddy interior were placed at least 2 m away from the paddy levee, and the 0.5 m × 2 m quadrats of the paddy edge were placed where rice was not planted along the levees. There were 5–10 quadrats in each location type depending on the size of each paddy field. From late August to early September, all species of vascular plants, bryophytes, and algae in the quadrats were identified and percent cover was measured. Each quadrat was treated as a sample unit for statistical analysis.

The average cover per species (%C) was calculated by averaging percent cover of the species across all quadrats for each farming method. The average frequency per species (%F) was also obtained from the percentage of quadrats in which the species was observed. The *t* test with Welch method that does not assume sample homoscedasticity was used to compare the numbers of species between the two farming methods by using R for Windows 2.13. In addition, the composition of habitat types or the Raunkiaer's life forms of plant species were determined and compared between the two farming methods by using Fisher's exact test. The habitat types and the Raunkiaer's life forms followed Numata and Yoshizawa (1978) and Chiba Historical Material Research Foundation (2003). Detrended correspondence analysis (DCA) by using the program PC-ORD was conducted to compare species composition between the two farming methods. Finally, associations of species with either DS or TP fields were evaluated by using IndVal analysis (Dufrêne and Legendre 1997) with PC-ORD. In this analysis, the indicator value based on the relative abundance and occurrence frequency of each species in each habitat type is estimated. IndVal is a symmetric indicator and is at maximum when all individuals of a species are found at a particular type of site. The statistical significance of the IndVal statistics was assessed by using a randomization procedure (9,999 randomizations). Samples from the paddy interior were analyzed by DCA and IndVal analysis.

Results and Discussion

DS Rice Fields as a Habitat for Rare Paddy Weeds

A total of 57 plant species were identified in DS paddies, while 68 species were identified in TP paddies. Of the 84 species observed in this study, 41 species (48.8 %) occurred in paddies under both the farming methods, 16 species (19.0 %) appeared only in DS fields, and 27 species (32.1 %) appeared only in TP fields.

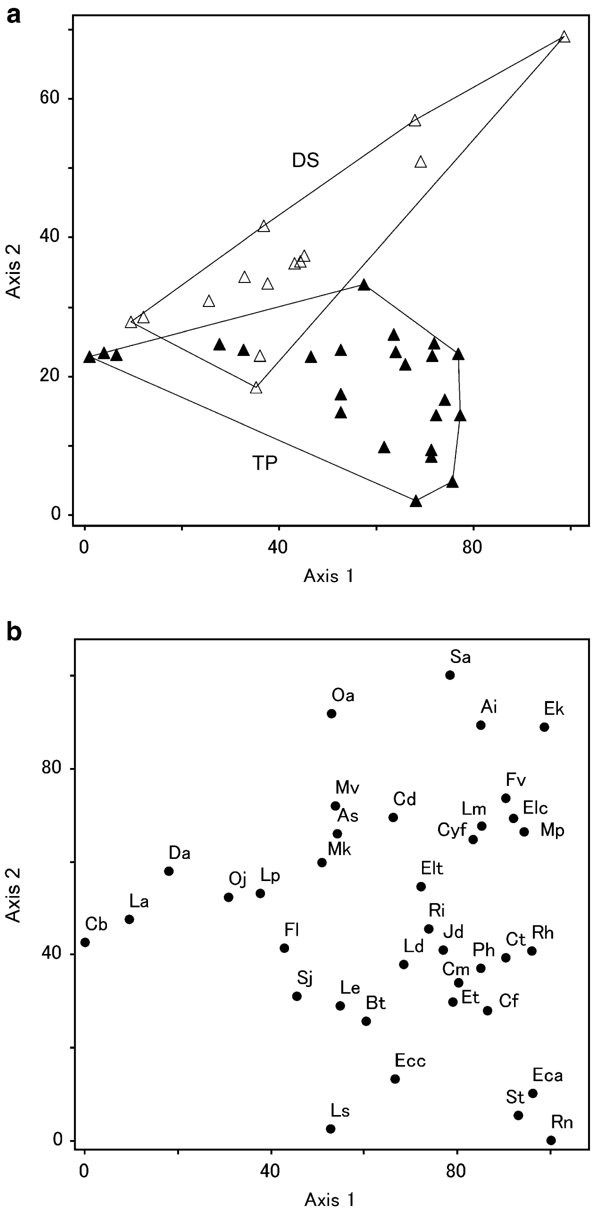
The average number of weed species in DS and TP paddies was 5.69 ± 0.64 ($\pm$SE) and 13.07 ± 0.64 respectively, and DS fields had lower species richness than TP ($t = -8.17$, $df = 103.73$, $P < 0.001$). Lower species richness in DS fields was observed in both field interior and at the edges (field interior: $t = -9.13$, $df = 34.09$, $P < 0.001$; field edge: $t = -6.59$, $df = 52.36$, $P < 0.001$). The average number of species in the interior of DS and TP fields was 2.05 ± 0.65 and 10.00 ± 0.62, respectively, and those at the edge of DS and TP fields were 8.12 ± 0.77 and 15.30 ± 0.77, respectively. Higher weed species richness at the edge of the paddy fields could be attributed to the incursion of terrestrial plants and hygrophytes from adjacent paddy levees.

Seven rare species, which were listed in the national or prefectural red-data book, appeared in the DS and TP paddies. A submerged plant *Ottelia alismoides* occurred exclusively in the DS fields, while a hygrophyte *Deinostema adenocaulum*, an aquatic bryophyte *Ricciocarpus natans*, and an aquatic fern *Ceratopteris thalictroides* appeared only in the TP paddies. Two submerged plant species *Chara braunii* and *Limnophila sessiliflora* were present in fields under both the farming methods. The occurrence frequencies of six rare species (*O. alismoides*, *D. adenocaulum*, *R. natans*, *C. thalictroides*, *C. braunii*, and *L. sessiliflora*) were higher in the paddy interior than at the paddy edge (Data not shown). With the exception of *C. thalictroides*, the appearance frequencies of these rare species were not high in general, and the mean coverage was less than 10 %. Low appearance frequency of these rare species was attributed to the biased spatial distribution of seed banks in the study site.

The DCA ordination diagram showed a clear difference in species composition between farming methods along the first axis (Fig. 12.7). The emergence of weed species that germinate under aerobic conditions (e.g., *Persicaria hydropiper*, *Lindernia dubia*, and *Centipeda minima*) was low in the DS paddies (Table 12.2). In addition, the DS paddies were characterized by aquatic plants such as duckweed *Lemna aoukikusa* and duck lettuce *O. alismoides* and by perennial weeds with tubers such as *Eleocharis kuroguwai*. Comparisons of percentage of Raunkiaer's life forms revealed that DS fields had a smaller proportion of annual species (Th and HH (Th)) and a larger proportion of perennials (G, H, and HH) compared with the TP fields, although the difference was insignificant (Fisher's exact test, $P = 0.085$) (Table 12.3).

In the TP paddies, some rare aquatic plants grew in restricted sites such as hollows in the ground formed by puddling. In contrast, permanent water in the DS fields provided stable habitats for aquatic plants in summer, increased the viability of rare plant populations, and enhanced species diversity at the regional scale. However, it should be noted that some species such as *C. thalictroides* preferred aerobic germination environments produced by the mid-season drainage and intermittent water flow in the TP paddies. Thus, diversity of rice farming methods at the regional level would be preferable for plant species conservation.

Fig. 12.7 Detrended correspondence analysis (DCA) ordination diagrams of the first and second axis for the paddy weed communities. The upper diagram presents the scatterplot of sample score (**a**), and the lower diagram presents the scatterplot of species score (**b**). The analysis targeted only samples from the paddy interior in TP (*filled triangles*) and DS paddies (*open triangles*). The *solid line* envelopes indicate the extent to which samples of each farming system are arranged. The abbreviations of species refer to Table 12.2



Compatibility of Rare Species Conservation with Weed Management

It has been reported that noxious aquatic weeds such as *Schoenoplectus juncoides*, *Monochoria vaginalis*, *Rotala indica* var. *uliginosa*, and *Elatine triandra* can germinate under low oxygen partial pressure conditions and flourish in rice paddies under deep-water management (Arai and Miyahara 1956; Miyahara 1968). In this

Table 12.2 Average coverage (%C) and frequency (%F) of the weed species in direct seeding (DS) and transplanting (TP) paddies

Family	Species	Abb	DS		TP		IndVal
			%C	%F	%C	%F	
Characeae	*Chara braunii*	Cb			9.58	15.8	12.5
Ricciaceae	*Riccia huebeneriana*	Rh			0.04	10.5	8.3
	Ricciocarpus natans	Rn			0.02	5.3	4.2
Pteridaceae	*Ceratopteris thalictroid*	Ct			0.54	42.1	33.3*
Moraceae	*Fatoua villosa*	Fv			0.02	5.3	4.2
Polygonaceae	*Persicaria hydropiper*	Ph			0.56	78.9	62.5*
Cruciferae	*Cardamine flexuosa*	Cf			0.23	52.6	41.7*
Leguminosae	*Aeschynomene indica*	Ai	0.16	5.3	0.10	15.8	5.0
Elatinaceae	*Elatine triandra*	Elt			0.06	15.8	12.5
Lythraceae	*Rotala indica*	Ri			0.13	31.6	25.0*
Onagraceae	*Ludwigia epilobioides*	Le	0.03	5.3	0.40	94.7	70.3*
Umbelliferae	*Oenanthe javanica*	Oj	0.03	5.3			5.3
Labiatae	*Stachys aspera* var. *hispidula*	Sa	0.03	5.3			5.3
Scrophulariaceae	*Deinostema adenocaulum*	Da			0.04	10.5	8.3
	Limnophila sessiliflora	Ls	0.03	5.3	0.02	5.3	2.9
	Lindernia dubia	Ld			0.33	78.9	62.5*
	Lindernia micrantha	Lm	0.03	5.3	0.23	57.9	41.1*
	Lindernia procumbens	Lp	0.24	47.4	0.35	84.2	40.0
	Mazus pumilus	Mp			0.08	15.8	12.5
Compositae	*Bidens tripartita*	Bt			0.02	5.3	4.2
	Centipeda minima	Cm			0.40	94.7	75.0*
	Eclipta thermalis	Et			0.15	36.8	29.2*
Alismataceae	*Sagittaria trifolia*	St			0.02	5.3	4.2
Hydrocharitaceae	*Ottelia alismoides*	Oa	0.05	10.5			10.5
Pontederiaceae	*Monochoria vaginalis*	Mv	0.08	10.5	0.29	42.1	26.2
Juncaceae	*Juncus decipiens*	Jd			0.02	5.3	4.2
Commelinaceae	*Murdannia keisak*	Mk	0.18	36.8	0.35	84.2	43.9
Gramineae	*Agrostis stolonifera*	As	0.03	5.3			5.3
	Echinochloa crus-galli var. *aristata*	Eca			0.33	21.1	16.7
	Echinochloa crus-galli var. *crus-gali*	Ecc			1.40	94.7	75.0*
Lemnaceae	*Lemna aoukikusa*	La	0.84	68.4	1.90	100.0	54.8
Cyperaceae	*Cyperus difformis*	Cd			0.02	5.3	4.2
	Cyperus flaccidus	Cyf			0.10	26.3	20.8
	Eleocharis congesta var. *japonica*	Elc			0.04	10.5	8.3
	Eleocharis kuroguwai	Ek	0.08	15.8			15.8
	Fimbristylis littoralis	Fl			0.02	5.3	4.2
	Schoenoplectus juncoides	Sj	0.05	10.5	0.42	105.3	74.0*

Indicator values (IndVals) are also shown. The table contained only the samples from the paddy interior (DS: $n = 19$, TP: $n = 24$). The abbreviations of species name (Abb) correspond to those shown in Fig. 12.7

*$P < 0.05$

Table 12.3 Number of species and percentage constituent (in parentheses) for each functional type: habitat types (a) and Raunkiaer's life forms (b), within transplanting (TP) and direct seeding (DS) rice paddy fields

	DS		TP	
	N	(%)	N	(%)
(a) Habitat type				
Ruderal	18	(31.6)	18	(26.5)
Wetland	37	(64.9)	48	(70.6)
Others	2	(3.5)	2	(2.9)
(b) Raunkiaer's life form				
G	2	(3.5)	1	(1.5)
H	17	(29.8)	11	(16.2)
HH	5	(8.8)	6	(8.8)
Th	28	(49.1)	45	(66.2)
HH (Th)	4	(7.0)	4	(5.9)
Unclear	1	(1.8)	1	(1.5)
Total	57	(100)	68	(100)

H Hemicryptophyte, *G* Geophyte, *HH* Helophyte and Hydrophyte (perennial), *Th* Therophyte, *HH*(*Th*) Therophytic aquatic plant

study, *M. vaginalis* was observed in DS paddies where floodwater levels were maintained at a depth of approximately 10–15 cm throughout the cropping season. However, *M. vaginalis* biomass was low (data not shown) and no reduction in rice yield was observed in DS paddy fields. The delayed germination of *M. vaginalis* due to the late onset of irrigation (mid-June) in DS paddies could have lowered its biomass and seed production (Kataoka et al. 1979). Furthermore, hard soil surface in DS paddy fields might have impeded root growth of the seedling.

In this study, *E. kuroguwai,* a notorious weed of rice, occurred in DS paddies. Chemical control of *E. kuroguwai* is difficult because of its proliferation by vegetative propagation. Drying and withering of tubers by spring or autumn plowing and crop rotation with crops such as soybean may control *E. kuroguwai* (Shibayama 2001). However, to conserve rare weed species in DS fields, it would be necessary to examine the recoverability of rare aquatic plants after such land drying practices.

An abundance of *Murdannia keisak*, which has a procumbent growth form, was observed in the DS paddies. Excessive overgrowth of the weed could disturb harvest machine operation, but thus far, the population has not seemed to reach a sufficient density as to cause a problem. *M. keisak* is an oviposition substrate for some species of threatened diving beetle (Ichikawa 2002; Watanabe 2011b). To conserve these diving beetles, *M. keisak* should be maintained at an appropriate level in the DS paddies.

Results from this study indicate that the DS farming method does not negatively affect rice weed management. The DS method is less labor-intensive and fits in well with local cropping practices. Expansion of the DS rice cultivation can provide large habitats for rare aquatic plant species and may be important from a conservation perspective. These results indicate that the DS method can be a practical, wildlife-friendly farming option in the region.

Conclusion

Our results show that the use of the DS regime, a method that was originally developed to reduce the cost of labor and other inputs, affected faunal and floral compositions in rice paddy fields. DS farming benefits water beetles and water bugs, terrestrial arthropods such as those of Collembola and Araneae, and several endangered plant species. In contrast, species richness of plants was low in the DS fields. However, since these results are based on an only 1-year observation in eight paddy fields, further studies under different surrounding environments are necessary to address the generality of the conclusion. Furthermore, future studies should explore the role of landscape structure (i.e., landscape composition and configuration), because the abundance and species richness of organisms in many crop systems are associated with surrounding landscape structures, as well as local farming practices (Kleijn et al. 2011; Batáry et al. 2012; Tscharntke et al. 2012; Miyashita et al. 2015). Our findings suggest that a combination of DS and conventional fields is preferable to either field-type alone for the conservation of invertebrates and plants by providing habitats for a variety of species. The next step will be to examine the effects of the DS regime in landscapes with different spatial extent of the DS farming. The combined adoption of DS and conventional regimes can help to sustain abundant, species-rich community assemblages in commercial paddy fields, and reduce the effects on biodiversity in rice agro-ecosystems.

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References

Aichi Agricultural Research Center (2007) Manual of the V-furrow, no-till direct seeding rice. http://www.pref.aichi.jp/nososi/seika/singijutu/singijiyutu74-4-7.pdf. Accessed 22 July 2013 (in Japanese)

Arai M, Miyahara M (1956) Studies on weed control by submergence in rice cultivation. Jpn J Crop Sci 24:163–165 (in Japanese)

Bambaradeniya CNB, Edirisinghe JP, De Silva DN, Gunatilleke CVS, Ranawana KB, Wijekoon S (2004) Biodiversity associated with an irrigated rice agro-ecosystem in Sri Lanka. Biodivers Conserv 13:1715–1753

Batáry P, Holzschuh A, Orci KM, Samu F, Tscharntke T (2012) Responses of plant, insect and spider biodiversity to local and landscape scale management intensity in cereal crops and grasslands. Agric Ecosyst Environ 146:130–136

Benton TG, Vickery JA, Wilson JD (2003) Farmland biodiversity: is habitat heterogeneity the key? Trends Ecol Evol 18:182–188

Bloechl A, Koenemann S, Philippi B, Melber A (2010) Abundance, diversity and succession of aquatic Coleoptera and Heteroptera in a cluster of artificial ponds in the North German Lowlands. Limnologica 40:215–225

Cariño FO, Kenmore PE, Dyck VA (1979) The farmcop suction sampler for hoppers and predators in flooded rice fields. IRRI Newsl 4:21–22
Chiba Historical Material Research Foundation (2003) Natural history of Chiba prefecture, supplementary volume 4: flora of Chiba prefecture. Chiba Prefecture, Chiba (in Japanese)
Colwell RK (2013) EstimateS: statistical estimation of species richness and shared species from samples. Version 9.1. http://purl.oclc.org/estimates. Accessed 22 July 2013
Colwell RK, Coddington JA (1994) Estimating terrestrial biodiversity through extrapolation. Philos Trans R Soc Lond B 345:101–118
Dufrêne M, Legendre P (1997) Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol Monogr 67:345–366
Faraway JJ (2006) Extending the linear model with R. Generalized linear, mixed effects and nonparametric regression models. Chapman and Hall, Boca Raton
Farooq M, Siddique KHM, Rehman H, Aziz T, Lee D, Wahid A (2011) Rice direct seeding: experiences, challenges and opportunities. Soil Tillage Res 111:87–98
Fujioka M, Lane SJ (1997) The impact of changing irrigation practices in rice fields on frog populations of the Kanto Plain, central Japan. Ecol Res 12:101–108
Hamada Y, Nakajima Y, Hayashi M, Shaku I (2007) Development of the V-furrow no-till direct seeding of rice: stabilization of culture by adopting the winter-puddling seedbed preparation. Jpn J Crop Sci 76:508–518 (in Japanese)
Hasegawa S, Tabuchi T (1995) Well facilitated paddy fields in Japan. In: Tabuchi T, Hasegawa S (eds) Paddy fields of the world. Japanese Society of Irrigation, Drainage and Reclamation Engineering, Tokyo, pp 103–124
Hidaka K (1990) The ways for sustainable farming: new ecological direction of neither intensive nor extensive. In: Nakasuji F (ed) Insect pest problems in natural and organic farming systems. Tojusha, Tokyo, pp 10–264 (in Japanese)
Hidaka K (1997) Community structure and regulatory mechanism of pest populations in rice paddies cultivated under intensive, traditionally organic and lower input organic farming in Japan. Biol Agric Hortic 15:35–49
Hidaka K, Mineta T, Enomoto K (2006) Evaluation of the agricultural dependency of endangered RDB wetland plant taxa: an example of habitat records attached to wetland voucher specimens. Jpn J Conserv Ecol 11:124–132 (in Japanese)
Hortal J, Borges PAV, Gaspar C (2006) Evaluating the performance of species richness estimators: sensitivity to sample grain size. J Anim Ecol 75:274–287
Ichikawa N (2002) Factors of decreasing in population size of *Cybister chinensis*. Tameikenoshizen 36:9–15 (in Japanese)
Jinguji H, Thuyet DQ, Uéda T, Watanabe H (2013) Effect of imidacloprid and fipronil pesticide application on *Sympetrum infuscatum* (Libellulidae: Odonata) larvae and adults. Paddy Water Environ 11:277–284
Kadoya T, Suda S, Washitani I (2009) Dragonfly crisis in Japan: a likely consequence of recent agricultural habitat degradation. Biol Conserv 142:1899–1905
Kataoka T, Kojima K, Furuya S (1979) Growth and seed production of *Monochoria vaginalis* Presl. in paddy fields. J Weed Sci Technol 24:86–91 (in Japanese)
Katayama N, Saitoh D, Amano T, Miyashita T (2011) Effects of modern drainage systems on the spatial distribution of loach in rice ecosystems. Aquat Conserv Mar Freshwat Ecosyst 21:146–154
Kiritani K (2000) Integrated biodiversity management in paddy fields: shift of paradigm from IPM toward IBM. Integr Pest Manag Rev 5:175–183
Kleijn D, Rundlöf M, Scheper J, Smith HG, Tscharntke T (2011) Does conservation on farmland contribute to halting the biodiversity decline? Trends Ecol Evol 26:474–481
Krebs JR, Wilson JD, Bradbury RB, Siriwardena GM (1999) The second silent spring? Nature 400:611–612
Lawler SP (2001) Rice fields as temporary wetlands: a review. Isr J Zool 47:513–528
Lawler SP, Dritz DA (2005) Straw and winter flooding benefit mosquitoes and other insects in a rice agroecosystem. Ecol Appl 15:2052–2059

Leitão S, Pinto P, Pereira T, Brito MF (2007) Spatial and temporal variability of macroinvertebrate communities in two farmed Mediterranean rice fields. Aquat Ecol 41:373–386

McCune B, Mefford MJ (2011) PC-ORD. Multivariate analysis of ecological data, version 6. MjM Software, Gleneden Beach

Miyahara M (1968) Effects of cultural practices on the weed community in paddy field. J Weed Sci Technol 7:22–28 (in Japanese)

Miyashita T, Yamanaka M, Tsutsui MH (2015) Distribution and abundance of organisms in paddy-dominated landscapes with implications for wildlife-friendly farming. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_4

Mukai Y, Baba N, Ishii M (2005) The water system of traditional rice paddies as an important habitat of the giant water bug, *Lethocerus deyrollei* (Heteroptera: Belostomatidae). J Insect Conserv 9:121–129

Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecol Eng 56:97–106

Nishihara S, Karube H, Washitani I (2006) Status and conservation of diving beetle inhabiting rice paddies. Jpn J Conserv Ecol 11:143–157 (in Japanese)

Numata M, Yoshizawa N (eds) (1978) Weed flora of Japan illustrated by colour. Zenkoku Noson Kyouku Kyokai, Tokyo (in Japanese)

Ohba S, Goodwyn PJP (2010) Life cycle of the water scorpion, *Laccotrephes japonensis*, in Japanese rice fields and a pond. J Insect Sci 10:45

Pandey S, Mortimer M, Wade L, Tuong TP, Lopez K, Hardy B (2002) Direct seeding: research strategies and opportunities. International Rice Research Institute, Los Banõs

Polis GA, Strong DR (1996) Food web complexity and community dynamics. Am Nat 147:813–846

R Development Core Team (2009) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org. Accessed 22 July 2013

Saijo H (2001) Seasonal prevalence and migration of aquatic insects in paddies and an irrigation pond in Shimane Prefecture. Jpn J Ecol 51:1–11 (in Japanese)

Sánchez-Bayo F, Goka K (2006) Ecological effects of the insecticide imidacloprid and a pollutant from antidandruff shampoo in experimental rice fields. Environ Toxicol Chem 25:1677–1687

Schoenly KG, Justo HD, Barrion AT, Harris MK, Bottrell DG (1998) Analysis of invertebrate biodiversity in a Philippine farmer's irrigated rice field. Environ Entomol 27:1125–1136

Schoenly KG, Cohen JE, Heong KL, Litsinger JA, Barrion AT, Arida GS (2010) Fallowing did not disrupt invertebrate fauna in Philippine low-pesticide irrigated rice fields. J Appl Ecol 47:593–602

Settle WH, Ariawan H, Astuti ET, Cahyana W, Hakim AL, Hindayana D, Lestari AS, Pajarningsih (1996) Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology 77:1975–1988

Shibayama H (2001) Weeds and weed management in rice production in Japan. Weed Biol Manag 1:53–60

Suhling F, Befeld S, Häusler M, Katzur K, Lepkojus S, Mesléard F (2000) Effects of insecticide applications on macroinvertebrate density and biomass in rice-fields in the Rhône-delta, France. Hydrobiologia 431:69–79

Tscharntke T, Tylianakis JM, Rand TA, Didham RK, Fahrig L, Batáry P, Bengtsson J, Clough Y, Crist TO, Dormann CF, Ewers RM, Fründ J, Holt RD, Holzschuh A, Klein AM, Kleijn D, Kremen C, Landis DA, Laurance W, Lindenmayer D, Scherber C, Sodhi N, Steffan-Dewenter I, Thies C, van der Putten WH, Westphal C (2012) Landscape moderation of biodiversity patterns and processes – eight hypotheses. Biol Rev 87:661–685

Washitani I (2007) Restoration of biologically-diverse floodplain wetlands including paddy fields. Global Environ Res 11:135–140

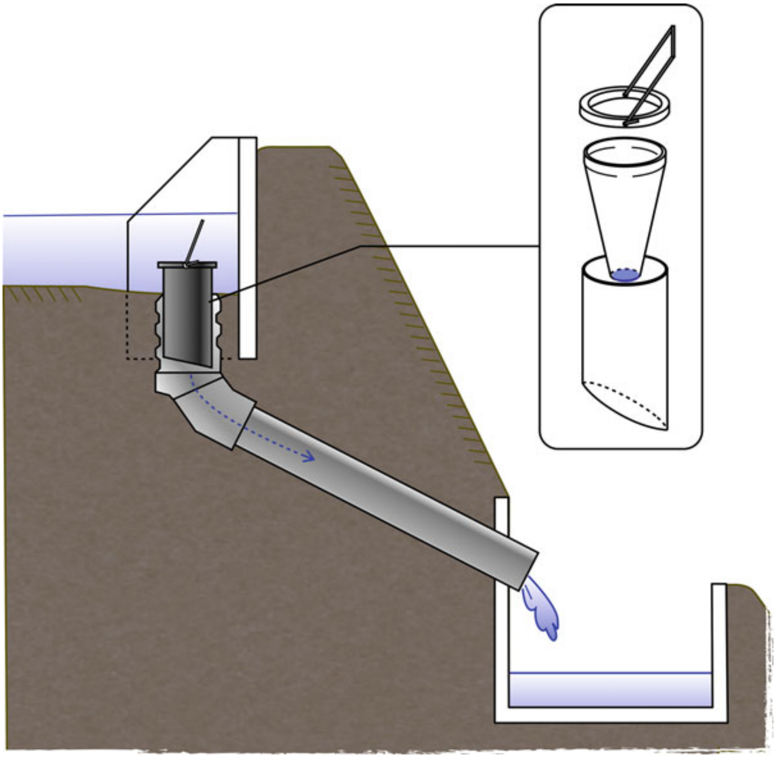
Watanabe H (2011a) Development of lowland weed management and weed succession in Japan. Weed Biol Manag 11:175–189

Watanabe K (2011b) Record of oviposition substrate for *Graphoderus adamsii* under nature. Bull Hoshizaki Green Found 14:59–60 (in Japanese)

Watanabe K, Koji S, Hidaka K, Nakamura K (2013) Abundance, diversity, and seasonal population dynamics of aquatic Coleoptera and Heteroptera in rice fields: effects of direct seeding management. Environ Entomol 42:841–850

Chapter 13
Can Paddy Fields Mitigate Flood Disaster? Possible Use and Technical Aspects of the Paddy Field Dam

Natsuki Yoshikawa



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Abstract To address the recent increase of flood risk, an unconventional measure for flood disaster mitigation using existing paddy fields with enhancement of their function has been recently introduced as an inexpensive and environmentally sustainable means of flood control. This measure is called the *paddy field dam* (PFD), in which rainwater is intentionally and temporarily stored in paddy fields during intense rainfall, by installing runoff control devices at the drainage outlet of paddy field plots. Although the PFD has been proven to have a large flood control function by our in situ investigation and simulation, there are various obstacles to overcome toward wide propagation of this measure. The fact that farmers have no economic incentive to undertake PFD practices is a most serious obstacle to increasing their implementation. In this article, we describe the effects of PFD and review issues that must be resolved before this type of work can be undertaken more widely.

Keywords Paddy field dam • Torrential rains • Runoff control device • Flood damage mitigation • Simulation • Economic incentive

Introduction

It is no exaggeration to state that the history of Japan, with its high annual precipitation and steep topography, has included struggles against flood disasters. *Open levees* or *Kasumi-tei* are a well-known flood control technology from pre-modern times. They are believed to have been invented by Shingen Takeda (1521–1573), a warrior in the Sengoku period. The Kasumi-tei are characterized by multiple discontinuous sub-levees. The levee reduces the risk of large-scale flood damage from a bank breach by mitigating river discharge. This is achieved by releasing part of the flood flow through breaks between the sub-levees, toward the flood control basin inside the levee. In the Meiji era, the introduction of advanced civil engineering technology from Europe changed the flood control concept to one of confining flood flow within the river channel, so that the water flows down to the sea as soon as possible. Instead of earlier discontinuous levees, the mainstays of flood control became a construction of rigid continuous levees, improvement of river alignment, watercourse modification, and use of large-scale structures including dams. This significantly improved the level of flood safety in Japan.

Nonetheless, with an increase in large-scale flood disasters from short-term, intense and localized torrential rains, plus changes of land use and recent agricultural modernization, human suffering and economic losses from physical damage are expected to increase. Although measures such as the enhancement of flood control facilities are continuously being implemented, solving the flood issue using physical structures alone is financially and technologically difficult. We are entering a new phase in which it is necessary to reconsider past and present concepts of flood control. The Ministry of Land, Infrastructure, Transport and Tourism launched the "Future Flood Management Advisory Board" in 2010, which proposes that an entire watershed should be used in flood control measures, rather than relying solely on rivers (Ministry of Land, Infrastructure, Transport and Tourism 2010). The use of paddy fields for preventing inland inundation was also mentioned.

Paddy fields themselves are considered to possess an innate flood mitigation function (Alber 2004; Matsuno 2006; Groenfeldt 2006; Kim et al. 2006; Huang et al. 2006). Various studies at national and regional scale have been carried out to evaluate this function. Shimura (1982) estimated for the first time the floodwater storage capacity of all paddy fields in Japan at 8.1 billion m^3. This greatly exceeds 2.4 billion m^3, which is the total flood detention capacity of flood control dams in Japan. Regional cases have also been investigated, taking into consideration topographical features, for example, terraced paddy fields in sloped areas (Onishi et al. 2004) and paddy fields in low-lying, flat areas (Nakamura et al. 1994; Hiramatsu and Shikasho 2001). Most of these regional case studies concluded that paddy fields are important in increasing the water storage capacity of river basins and reducing river peak flows to some degree, but not to the degree that Shimura estimated. Some studies have found a significant rise in peak runoff with transformation of paddy fields to other land uses, such as upland dry fields or the abandonment of cultivation (Chiba et al. 1997; Masumoto et al. 1997; Wu et al. 2001; Masumoto et al. 2003). To standardize evaluation of the flood-prevention function of paddy fields, Masumoto et al. (2006) proposed a method and index at macro scale, using the relationship between drainage and storage capacity.

These studies have contributed to understanding the flood mitigation role of paddy fields, and suggest that haphazard urbanization and abandonment of paddy cultivation may increase negative impacts on runoff characteristics. However, it seems clear that mere conservation of existing paddy fields will at best maintain the status quo.

To address the recent increase of flood risk, an unconventional measure for flood disaster mitigation using existing paddy fields with enhancement of their function has been recently introduced as an inexpensive and environmentally sustainable means of flood control. This measure is called the *paddy field dam* (PFD), in which rainwater is intentionally and temporarily stored in paddy fields during intense rainfall, by installing runoff control devices at the drainage outlet of paddy field plots. Although paddy fields are not deep (usually surrounded by levees 15–30-cm high), their areal extents are large and so they have ample water storage potential.

In Niigata Prefecture, PFD work has been ongoing since 2002. In this article, we describe the effects of PFD and review issues that must be resolved before this type of work can be undertaken more widely.

Outline of the Paddy Field Dam

A PFD is a means to artificially reduce peak runoff volume from a paddy field area during heavy rain, by enhancing retention of the paddy fields. This is achieved by installing a runoff control device that reduces the cross-sectional area of the drainage outlet of the paddy field. Consequently, a PFD is expected to mitigate flood damage in downstream areas (Figs. 13.1 and 13.2). Since the shape of the drainage outlet and the manner of drainage are not uniform, we have developed several types of runoff control devices suitable for the drainage system adopted by each district (Fig. 13.3). The cost for preparing runoff devices ranges from 60 to 600 yen (from about \$0.6 to \$6) per 1,000 m^2 depending on the materials and types of devices employed.

PFD work began in 2002 in Kamihayashi district of Murakami city (previously known as Kamihayashi Village), Niigata, where residents and farmers were suffering chronic flood damage. We quantitatively evaluated the flood mitigation function of PFDs to demonstrate their effectiveness in mitigating flood damage (Yoshikawa et al. 2009a, b). Based on this verification, Niigata Prefecture has prioritized PFD work as an important measure in *The Future Direction of Agricultural and Rural Community Development in Niigata* (*2011–2016*), with the aim of expanding this work throughout the prefecture (Niigata 2010). The PFD area has been progressively increasing since its 2002 initiation, reaching approximately 9,500 ha in the prefecture during 2012 (Fig. 13.4). Other prefectures are implementing such measures using the Niigata work as a model.

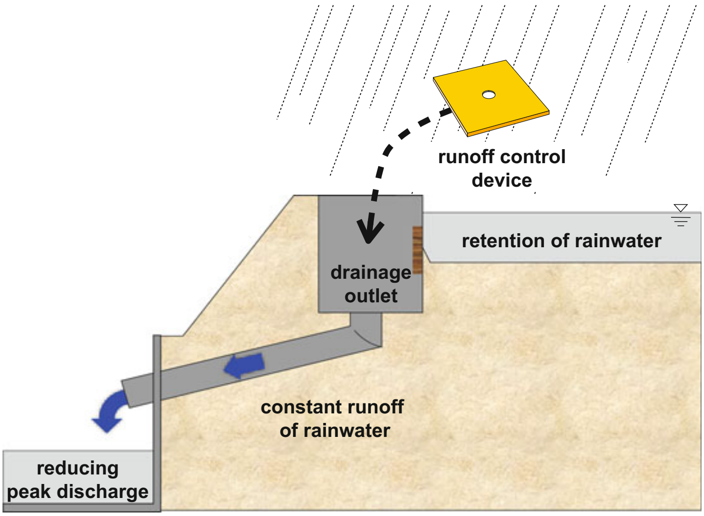

Fig. 13.1 Schematic of paddy field dam

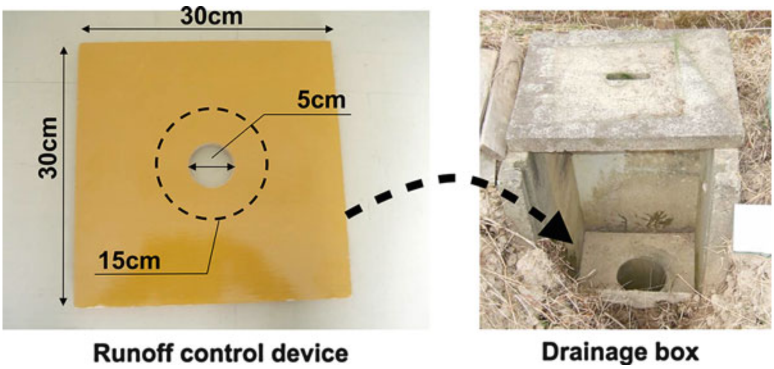

Fig. 13.2 Components of paddy field dam

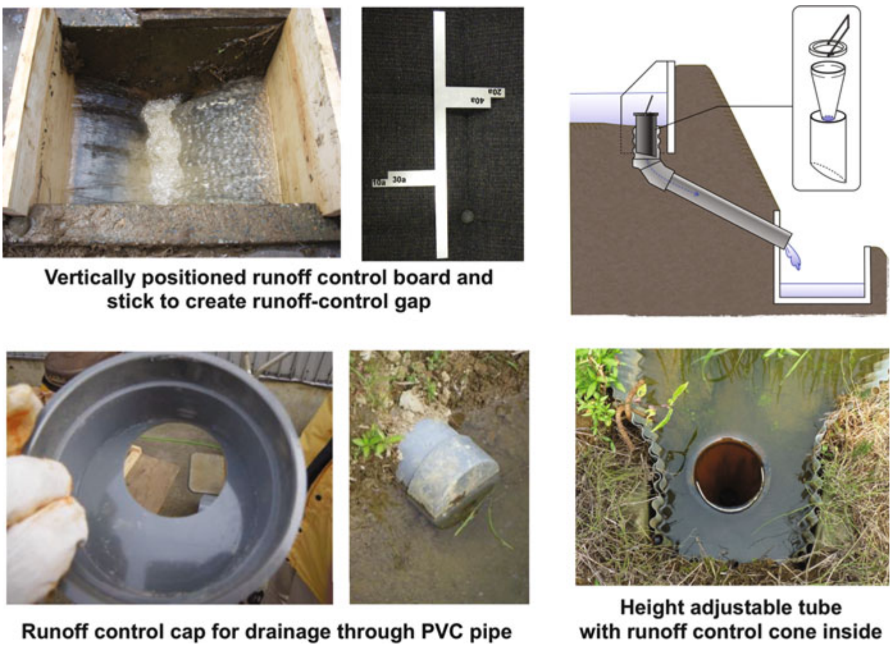

Fig. 13.3 Various types of runoff control devices suitable for drainage systems

Flood Control Effects of PFD

Reduction of Peak Runoff Volume from Paddy Fields

Figure 13.5 shows the PFD effect on reducing peak runoff from paddy fields based on our observation and simulation results. For Kamihayashi district, PFD implementation led to 62, 72, and 75 % reductions of peak runoff from precipitation of 10-year

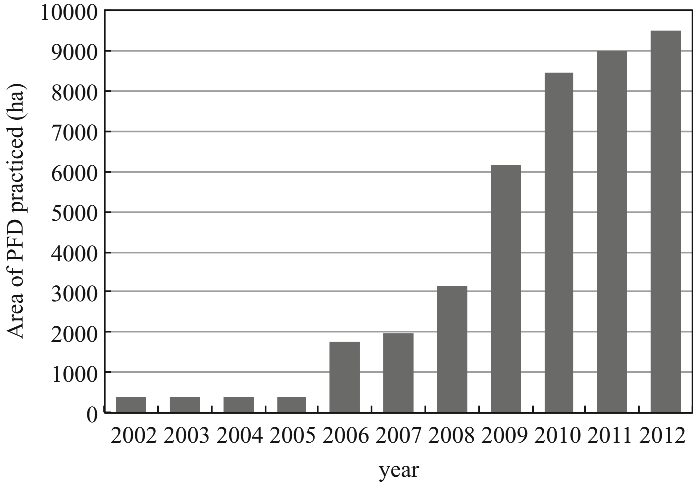

Fig. 13.4 Annual change in area of PFD implementation in Niigata Prefecture

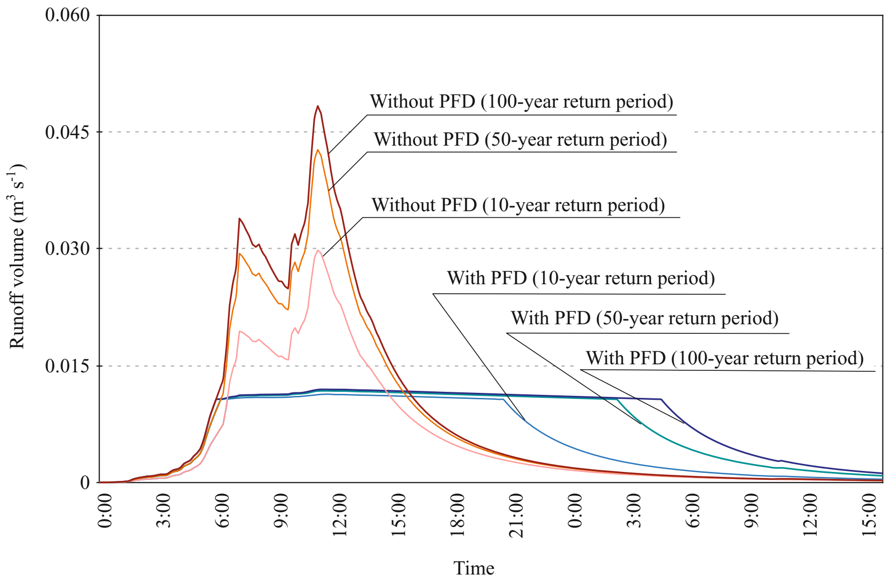

Fig. 13.5 Runoff from paddy fields with and without paddy field dam operation responding to rainfall with 10-year, 50-year and 100-year return periods

(142 mm/day), 50-year (193 mm/day), and 100-year (214 mm/day) return periods, respectively. In the case of conventional drainage, runoff volume fluctuated in conformity with the hyetograph. However, the PFD reduced the range of this fluctuation, smoothed temporal changes of drainage volume from paddy fields, and increased drainage time. This resulted in the mitigation of flood damage in downstream areas.

Inundation Mitigation Effect at Basin Scale During Large-Scale Rainfall Event

The only method to verify the effects of PFD at basin scale is direct observation after significant rainfall or computer simulation. Because there is little chance of experiencing a suitable rainfall event of recurrence interval greater than 30 years, we quantified the PFD effect on a basin scale only in the development of a simulation model.

The first opportunity to verify PFD effects for an actual torrential rainfall was from July 27 to July 30, 2011. This event produced total precipitation in excess of 300 mm, even in areas on the plains. PFDs were operating in the following three districts: Shinsai in Nagaoka city (basin area 198 ha; area with PFD 37 ha), Kaibamigawa in Mitsuke (basin area 8,435 ha; area with PFD 854 ha), and Shirone in Niigata (basin area 7,460 ha; area with PFD 2,900 ha).

To verify the PFD effects, we first conducted field surveys to discern actual areas of inundation in the three districts. Then, inundation range and depth in each district were calculated by our simulation model, inputting data of actual PFD implementation rate, precipitation, topography, river and drainage channel arrangements, and so on (Yoshikawa et al. 2011; Miyazu et al. 2012). To check model validity, the calculation results were compared with the actual flood range observed in the field. We then simulated a case with no PFD implementation, and differences of inundation range and depth between the two cases were used to determine the effect of PFD on inundation reduction.

Figure 13.6 shows actual and simulated inundation conditions for Shirone District as an example. Table 13.1 shows that in the Shinsai, Kaibamigawa, and Shirone districts, reductions of inundation area were approximately 30, 15, and 23 %, respectively. Table 13.2 shows that corresponding reductions in flood volume were approximately 33, 19, and 25 %. We defined the “flood control volume” of the PFD as the maximum difference of inundation volume between non-PFD and PFD conditions. This was because we assumed that the reduced flood volume was that retained in the paddy fields by PFDs. Maximum flood adjustment volumes for PFDs were approximately 8×10^3, 81×10^4, and 167×10^4 m^3 in Shinsai, Kaibamigawa, and Shirone districts, respectively. Corresponding volumes were 0.3, 34, and approximately 71 % of the maximum flood control volume (235×10^4 m^3) of the Kariyatagawa flood control pond located near the Kaibamigawa district that was reported to have significantly contributed to reducing river flow during this torrential rain period. This indicates that the total PFD flood adjustment volume of these three districts, 249×10^4 m^3, exceeded the volume of the flood control pond.

Issues Related to the Future Implementation of PFDs

Although the PFD was proven to have a large flood control function, there are various obstacles to overcome toward wide propagation of this measure. The PFD differs from conventional flood control measures because facility development

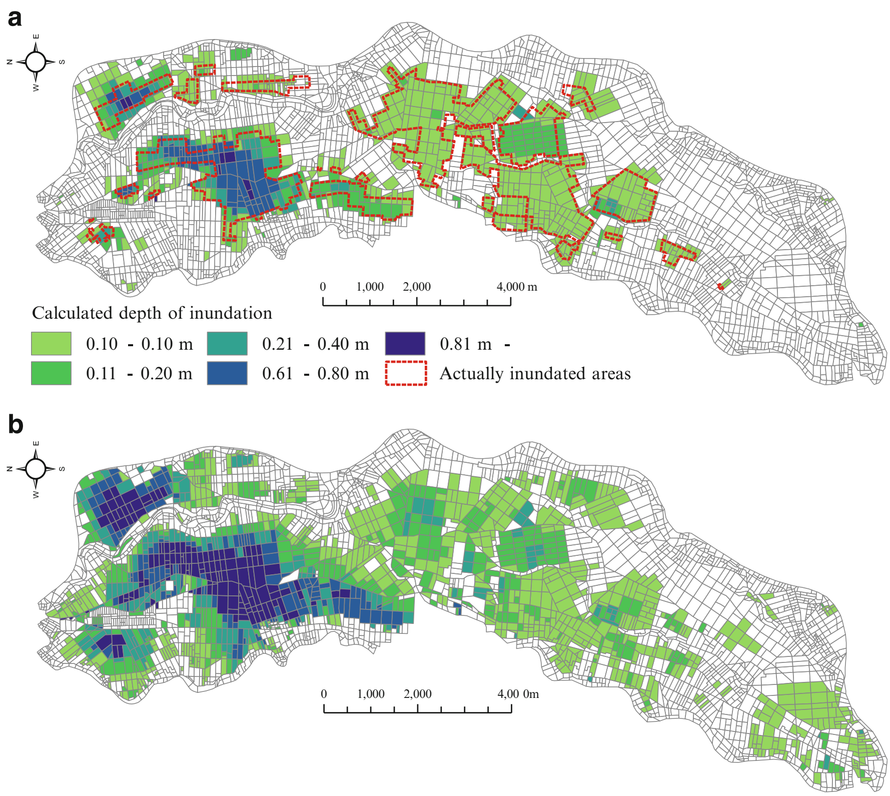

Fig. 13.6 Simulated extent and depth of inundation without PFD implementation versus those with PFD implementation (**a**) Actual and calculated areas of inundation and depth (**b**) Simulated areas of inundation and depth without PFD implementation

Table 13.1 Volume of flood water controlled by PFD relative to that by Kariyatagawa flood control pond

	Inundated area (ha)		
	Without PFD	With PFD (actual installation rate)	Percentage of reduction (%)
Shinsai District	23.7	16.6	30
Kaibami District	1,869	1,589	15
Shirone District	3,490	2,687	23

(device installation) is not the goal. The scale of the PFD effect depends on proper maintenance and operation by farmers and, without their cooperation, the system will not work.

At present, farmers or local public entities have the opportunity but they bear the cost and labor of PFD preparation and functioning. PFDs benefit the public and

Table 13.2 Volume of flood water controlled by PFD relative to that by Kariyatagawa flood control pond

	Flood water volume (m^3)		Percentage of reduction (%)	Flood water control volume (m^3)
	Without PFD	With PFD (actual installation rate)		
Shinsai District	24,000	16,000	33	8,000
Kaibami District	4,263,000	3,448,000	19	815,000
Shirone District	6,712,000	5,047,000	25	1,665,000
Total	11,000,000	8,511,000	23	2,488,000
Kariyatagawa flood control pond	–	–	–	2,350,000

reduce the need for public investment in disaster prevention and environmental conservation by reducing the requirement of large-scale infrastructure development. However, the beneficiaries of these services are mainly residents of areas downstream of districts that undertake the necessary work. In other words, those who do the work do not necessarily benefit. For this reason, farmers have no economic incentive to voluntarily undertake PFD practices. Therefore, for the propagation of PFD as an alternative flood control measure, it is important to establish at an early stage the manner in which costs should be allocated according to benefits received, and the consent and cooperation of farmers should be obtained. However, these aspects have yet been considered in detail.

The fact that farmers have no economic incentive to undertake PFD practice will be an obstacle to increasing its implementation. The consent and cooperation of farmers are essential for preparation and maintenance of functional PFDs. This necessitates conditions that farmers will readily accept, such as the establishment of a system for reducing their economic burden by returning part of the estimated value of the public utility function, and the development of a support system for recovery in case of damage from unexpected rainfall. It has been estimated that the cost of PDF implementation is significantly smaller than the benefit generated by the public utility function by the PFD: the cost is at maximum 2,000 yen per 1,000 m^2 including the maintenance of PFD preparation and functioning and the expected economic value generated by PFD is 11,200 yen per 1,000 m^2 according to our calculation. We consider it appropriate to cover the development cost publicly. Because this results in a situation in which farmers agree to PFD implementation, we believe that such coverage will encourage its propagation.

Another issue regarding the future implementation of PFDs is related to the strategy of selecting PFD sites. The effect of PFDs would of course depend on characteristics of the basin involved, such as topography, land use and drainage systems. Among these, the fraction of paddy field area within a watershed is of highest importance. It is crucial, therefore, to select a suitable site for the PFD before its implementation. Further study is required for developing a simpler method to select suitable PFD sites toward its widespread use as a flood control measure.

PFD as a Flood-Control Measure in a Basin

Because conventional local flood control measures have been largely dependent on development of large-scale infrastructure such as dams and river improvements, paddy fields as flood control facilities have remained undeveloped. However, the PFD facilitates artificial flood control with the desired characteristics by adjustment of design parameters (cross-sectional area of the adjustable outlet of the drainage adjuster board), albeit within a fixed range. In addition, the introduction of maintenance and operational agreements with farmers is expected to lead to the stable functioning of such PFDs. This will enable their flood adjustment function to be integrated into a deliberate scheme of watershed management. In recent years, there has been a need for a system that avoids reliance on dams alone for flood control. PFDs would provide an effective solution in this regard.

Conclusion

The PFD was proven to be effective under the actual torrential rainfall from July 27 to July 30, 2011 in reducing inundation area by approximately 30, 15, and 23 % in the case of Shinsai, Kaibamigawa, and Shirone districts, respectively. The maximum flood adjustment volumes for PFDs were estimated to be approximately 0.8×10^4, 81×10^4, and 167×10^4 m^3. The total flood adjustment volume of these three districts was almost as large as that of Kariyatagawa flood control pond.

Large-scale investments such as construction of flood control dams are difficult owing to budget constraints of national and local governments. Therefore, the PFD is attractive to policy makers nationwide as an inexpensive countermeasure for the recent increase in frequency and magnitude of heavy rainfall events. Indeed, some local governments are exploring the possibility of introducing the PFD in their paddy field areas. The PFD is applicable not only in Japan, but in many Asian monsoon regions with regular flood damage and where paddy fields are the primary means of food production.

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References

Alber D (2004) Multifunctionality, agricultural policy, and environmental policy. Agric Resour Econ Rev 33(1):8–17

Chiba K, Koga K, Baba H (1997) Soil physical properties of uncultivated paddy fields located in semi-wet sloping land and the simulation of their response to heavy rain. Trans Jpn Soc Irrig Drain Rural Eng 65(4):61–70 (in Japanese with English abstract)
Groenfeldt D (2006) Multifunctionality of agricultural water: looking beyond food production and ecosystem services. Irrig Drain 55:73–83
Hiramatsu K, Shikasho S (2001) Flood mitigation function estimates of a flat low-lying agricultural area along the lower reach of the Chikugo River. Sci Bull Fac Agr Kyushu Univ 56(1):1–8 (in Japanese)
Huang CC, Tsai MH, Lin WT, Ho YF, Tan CH (2006) Multifunctionality of paddy fields in Taiwan. Paddy Water Environ 4(4):199–204
Kim TC, Gim US, Kim JS, Kim DS (2006) The multi-functionality of paddy farming in Korea. Paddy Water Environ 4(4):169–179
Masumoto T, Takaki K, Yoshida S, Adachi K (1997) Effects of abandoned paddies in hilly rural areas on runoff. Trans Jpn Soc Irrig Drain Rural Eng 65(3):59–68 (in Japanese with English abstract)
Masumoto T, Nozoe M, Yoshimura A, Matsuda S (2003) A paddy runoff model in hilly rural areas for evaluating runoff change due to abandoned rice cultivation. Trans Jpn Soc Irrig Drain Rural Eng 71(2):35–44 (in Japanese with English abstract)
Masumoto T, Yoshida T, Kubota T (2006) An index for evaluating the flood-prevention function of paddies. Paddy Water Environ 4(4):205–210
Matsuno Y (2006) Prospects for multifunctionality of paddy rice cultivation in Japan and other countries in monsoon Asia. Paddy Water Environ 4(4):189–197
Ministry of Land, Infrastructure, Transport and Tourism (2010) Future Flood Management Advisory Board – Interim guidelines. http://www.mlit.go.jp/river/shinngikai_blog/tisuinoarikata/220927arikata.pdf (in Japanese)
Miyazu S, Yoshikawa N, Abe S, Misaawa S, Yasuda H (2012) Development and application of evaluation model for interior flood damage mitigation effect of a Paddy Field Dam. Trans Jpn Soc Irrig Drain Rural Eng 80(6):479–488 (in Japanese with English abstract)
Nakamura Y, Amezawa E, Terada Y, Sato T (1994) Drainage characteristics and runoff relaxation by paddy fields in the Kokai River downstream basin. J Jpn Soc Irrig Drain Reclam Eng 62 (10):7–12 (in Japanese)
Niigata Prefectural Government (2010) The Future Direction of Agricultural and Rural Community Development in Niigata (2011–2016). http://www.pref.niigata.lg.jp/nochikeikaku/1218045677074.html (in Japanese)
Onishi T, Horino H, Mitsuno T (2004) A case study on storage property of terraced paddy fields. Trans Jpn Soc Irrig Drain Reclam Engin 72(2):53–59 (in Japanese with English abstract)
Shimura H (1982) Evaluation on flood control functions of paddy fields and upland crop farms. J Soc Irrig Drain Reclam Eng 50(1):25–29 (in Japanese)
Wu RS, Sue WR, Chien CB, Chen CH, Channg JS, Lin KM (2001) A simulation model for investigating the effects of rice paddy fields on the runoff system. Math Comput Model 33 (6–7):649–658
Yoshikawa N, Nagao N, Misawa S (2009a) Evaluation of runoff detention function of the paddy field installed with runoff control devices. Trans Jpn Soc Irrig Drain Rural Eng 77(3):263–271 (in Japanese with English abstract)
Yoshikawa N, Nagao N, Misawa S (2009b) Watershed scale evaluation of flood mitigation function of paddy fields installed with runoff control devices. Trans Jpn Soc Irrig Drain Rural Eng 77(3):273–280 (in Japanese with English abstract)
Yoshikawa N, Miyazu S, Misaawa S, Yasuda H (2011) Development of inundation analysis model for low-lying agricultural reservoir. J Jpn Soc Civ Eng Ser B1 (Hydraul Eng) 67(4):I_991–I_996 (in Japanese with English abstract)

Part III
Developing Economic Incentives and Strategies for Sustainable Agriculture

Chapter 14
Sustainable Rice Agriculture by Maintaining the Functional Biodiversity on Ridges

Hidehiro Inagaki, Chieko Saiki, Kazuo Matsuno, and Minoru Ichihara

Abstract The ridges between rice paddy fields, originally constructed for irrigation, also serve as habitats for many organisms, including the rice stink bug *Oebalus pugnax* (the most important insect pest of rice) and natural enemies of the insect pests of rice. Therefore, the ecological management of these ridges is important for pest control and for the conservation of the natural enemies of rice pests. We identified the following ecological management practices for the

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conservation of the natural enemies of rice pests and for the control of rice stink bugs: (1) mowing increases the population of wolf spiders (family Lycosidae), which prey on stink bugs; (2) mowing at a high level effectively controls Poaceae plants, which host rice stink bugs; (3) the use of cover plants on ridges increases or maintains the population of wolf spiders, as well as those of crickets (family Gryllidae), which feed on the seeds of harmful plants. The above ecological management practices should decrease the populations of rice pest insects and serve as laborsaving techniques for sustainable rice agriculture.

Keywords Rice paddy • Ridge • Functional biodiversity • Ecological management • Natural enemy • Wolf spider • Rice stinkbug • Cover plant • Seed predator

Introduction: Conservation of the Functional Biodiversity of Paddy Field Ridges

Farmland ecosystems provide valuable ecosystem services, such as pest control by predators and crop pollination by pollinators, and help support sustainable agriculture (Kremen and Ostfeld 2005; Isaacs et al. 2009). To maintain or enhance ecosystem services in farmlands, the habitats of the arthropods that provide these services must be managed (Landis et al. 2000, 2005; Isaacs et al. 2009; Morandin et al. 2011). In upland fields in Europe and the United States, attempts have been made to enhance pest control and pollination by establishing strips of flowering plants that offer service providers nectar (as a food source) and shelter in the field margins (Landis et al. 2000; Winkler 2005; Morandin et al. 2011). However, little is known about enhancing arthropod-mediated ecosystem services in rice paddy fields.

The importance of biodiversity in Japanese rural areas, including paddy fields, has recently attracted increased attention (Takeuchi et al. 2001). The ridges between paddy fields are not only important for retaining water in paddy fields but also serve as habitats for many plant species (Yamaguchi et al. 1998; Okubo et al. 2005; Otsuka et al. 2006). These ridges may also serve as habitats for many animals. For example, tadpoles live in paddy field water and disperse onto the ridges after metamorphosing into frogs. Firefly and diving beetle larvae live in the water before dispersing and pupating on land. Therefore, many animals that live in paddy fields use these ridges. The ridges may also serve as habitats for rice pest insects. In Japan, rice stink bugs are considered a serious problem to rice cultivation, as they cause pecky rice (Kuwazawa and Nakamura 2006; Higuchi 2010). Certain bugs, including *Cletus punctiger, Eysarcoris aeneus*, *Leptocorisa chinensis*, and *Nezara viridula*, have become important economic pests in Japan (Kiritani 2007). These bugs feed on the Poaceae plants on the ridges, increasing in abundance before dispersing into the paddy fields after the heading of the rice plants (Teramoto 2003; Kuwazawa and Nakamura 2006; Yuasa 2006). Therefore, the control of Poaceae weeds on the ridges is important for the control of rice bugs.

The ridges are also an important habitat for the natural enemies of rice pests. Wolf spiders (family Lycosidae) are among the most important natural enemies of rice pest insects in paddy fields. These spiders spend the winter in dry paddy fields (Inagaki et al. unpublished data), and during spring tilling and irrigation, they escape to the ridges (Kobayashi 1977, Inagaki et al. unpublished data). The spiders then immigrate into paddy fields and ridges in the summer. Therefore, the management of ridges is also important for enhancing the population of wolf spiders. It has been suggested that ridge management is important for maintaining the biodiversity of rice paddies (Kiritani 2000; Fukamachi et al. 2005), but comparatively little attention has been paid to the management of ridges in the context of functional biodiversity as opposed to that of rice cultivation.

In this chapter, we discuss the ecological management of ridges for increasing the functional biodiversity of rice paddy fields.

Mowing Management of Ridges

Increase the Population of Wolf Spiders in Ridges by Mowing

Wolf spiders are an important natural enemy of pests on agricultural land (Riechert and Lockley 1984; Niffeler and Benz 1987) and are predators of planthoppers (family Delphacidae), which are major rice pests in Japan (Ito et al. 1962; Kiritani et al. 1970, 1972; Ishijima et al. 2006). Kobayashi et al. (2011) found a characteristic DNA marker of rice stink bugs, including *Stenotus rubrovittatus* (a serious rice pest), in wolf spiders, suggesting that wolf spiders feed on these stink bugs.

We investigated the effects of vegetation and ridge mowing on the population density of wolf spiders on the ridges. We found a greater number of wolf spiders on ridges harboring the Gramineae species *Imperata cylindrical* and *Echinochloa crus-galli* than on ridges with the Cyperaceae species *Fimbristylis miliacea* and *F. dichotoma* (Inagaki et al. 2009). Although the effects of mowing on wolf spiders have been investigated in grasslands, the effects of mowing on the ridges around paddy fields are unknown (Howell and Pienkowsk 1971; Jensen et al. 1973). We investigated the seasonal changes in the population density of wolf spiders in rice paddy fields under different mowing practices. We found that the number of wolf spiders remained relatively constant from August to September in the paddy fields in which the ridges were not mowed (Fig. 14.1). In contrast, the number of wolf spiders increased considerably after the ridges were mowed. Our results indicate that ridge mowing is effective at increasing the abundance of wolf spiders. Because the abundance of wolf spiders increased over a short period, the increased abundance may have been caused not by reproduction but by the immigration of adults. Further studies should reveal the extent to which wolf spiders migrate around paddy fields.

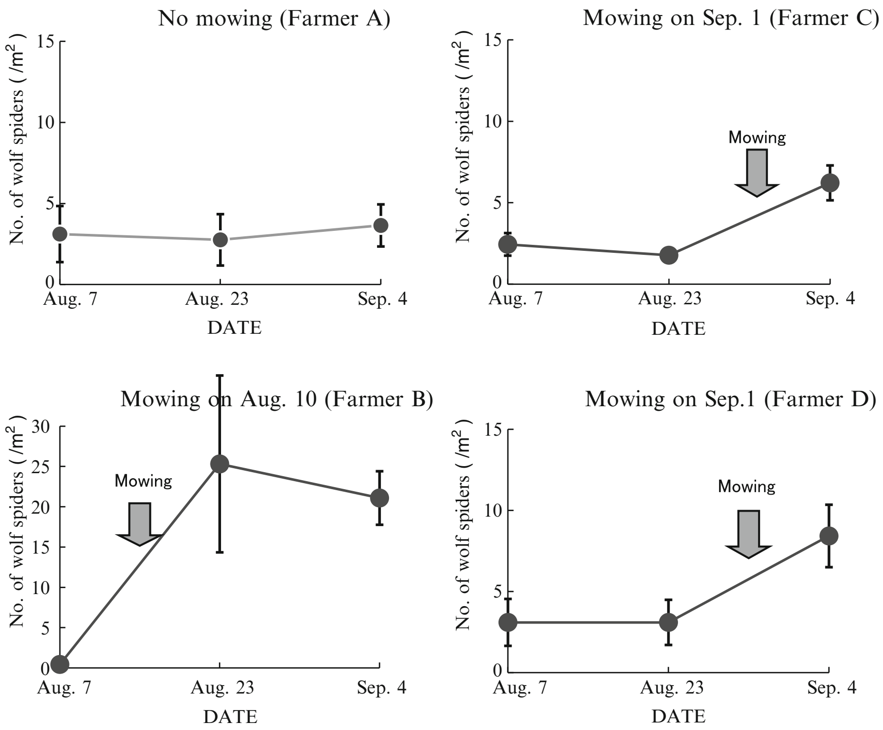

Fig. 14.1 Effects of mowing time on the numbers of wolf spiders in rice paddy fields. Values are the means of ten measurements. The error bars indicate standard errors

Effects of Mowing at a High Level on Controlling the Host Plants of Rice Stink Bugs

Poaceae weeds on rice field ridges are important host plants for rice stink bugs. The control of host plants on the ridges is therefore as important as the control of host plants in the rice paddy itself (Kuwazawa and Nakamura 2006).

Herbicide treatment on the ridges is effective at controlling rice stink bugs because it kills Poaceae plants (Ueno 2004; Niiyama and Itoyama 2006; Takida 2007). However, it is not desirable for all of these plants to be killed because they prevent the destruction of the ridges from erosion (Kusanagi et al. 1994). Therefore, farmers have mainly used mowing to control host plants. However, it is difficult to prevent the growth of Poaceae by mowing alone. If mowing is conducted at an inappropriate point or spaced out over time, the heading of the Poaceae weeds will not be suppressed, and rice stink bugs will appear on the ridge (Teramoto 2003). In addition, mowing can sometimes cause an increase in the number of Poaceae plants. Poaceae are generally tolerant of mowing because their growing point is extremely low (Ito 1993). Furthermore, overfrequent mowing simplifies the flora because of the dominance of species that are adapted to disturbance, such as

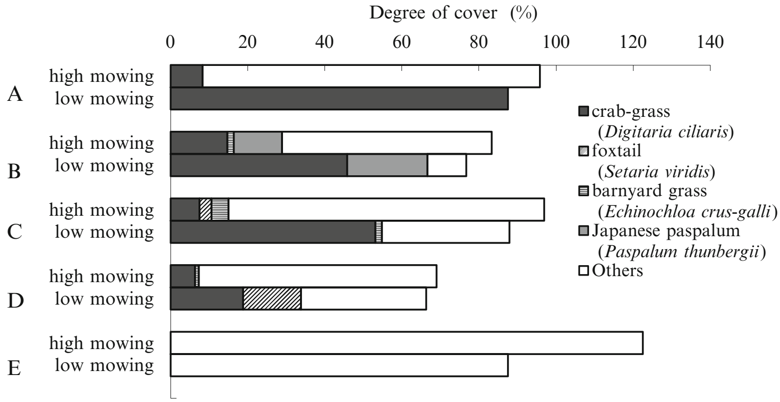

Fig. 14.2 Degree of cover by annual Poaceae plants in high-mown and low-mown plots

lawn grass (Baba et al. 2003). Therefore, excessively increasing the mowing pressure causes an increase in the risk of Poaceae dominance and consequent increase in the rice stink bug numbers. In contrast, decreased mowing pressure may increase the survival rate of other plants, thereby preventing the dominance of Poaceae. Therefore, we tested the effect of mowing at a high level on the dominance of Poaceae.

Our study was conducted in five sites and two test plots grouped based on the differences in mowing heights between ridges. The high-mown plots were cut at a height of 5–10 cm, and the low-mown plots were cut at ground level as a control. The amount of Poaceae plant cover in the high-mown plots was lower than that in the low-mown plots (Fig. 14.2). In conclusion, mowing at a high level is an effective method for decreasing the dominance of Poaceae and controlling rice stink bugs.

Effects of Ground Cover Plants on Pest Control of Paddy Field Ridges

Conservation of Wolf Spiders on Paddy Field Ridges Using Cover Plants

On paddy field ridges in Japan, several species of ground cover plants have recently been introduced to suppress weeds and prevent soil erosion. These species include *Eremochloa ophiuroides* (Poaceae) (Islam and Hirata 2005; Otani et al. 2007; Morandin et al. 2011), *Zoysia japonica* (Poaceae) (Otani et al. 2007; Tomosho 2008; Fushimi and Naganuma 2009; Fushimi and Otani 2010), *Phlox subulata* (Polemoniaceae) (Kawasaki et al. 1997; Kaku et al. 2007; Otani et al. 2007; Tomosho 2008), and *Phyla canescens* (Verbenaceae) (Otani et al. 2007, 2009).

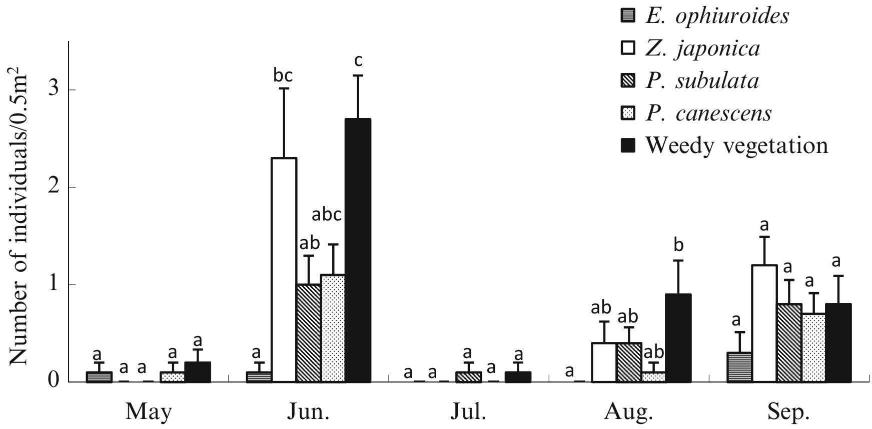

Fig. 14.3 Effects of vegetation type on the abundances of wolf spiders in each month. Data points represent the mean number of individuals per 0.5 m^2. Different letters indicate significant differences within each month, based on Tukey's honestly significant difference test at $P < 0.05$. Vertical bars represent the standard errors of the means of three replications

We evaluated the abilities of these cover plants to serve as habitats for the natural enemies of pest insects.

As shown in Fig. 14.3 (Ichihara et al. 2014), in June, wolf spider abundance was not significantly different between *Z. japonica*, *P. canescens*, and weedy vegetation. In contrast, wolf spider abundance on *E. ophiuroides* was extremely low. During the rest of the year, wolf spider abundance was similar among all of the vegetation types, except for *E. ophiuroides*. Therefore, ridges with *E. ophiuroides* are not suitable habitats for wolf spiders. Although the reason for the low abundance of wolf spiders on *E. ophiuroides* is unknown, possible factors include habitat structure, the presence of predators (Rypstra et al. 2007), and the abundance and composition of prey (Sasaki et al. 1978; Ishijima et al. 2006) on this plant. The effects of these factors on the abundance of wolf spiders should be investigated in future studies.

Conservation of Weed Seed Predators on Paddy Field Ridges Using Cover Plants

Weed control by seed predators has recently attracted increased attention (Westerman et al. 2003, 2005; Evans et al. 2011). Rice stink bugs, one of most serious pests of rice plants, feed on the ears of Poaceae weeds on ridges. Therefore, the control of Poaceae weeds on ridges may be effective for the control of rice stink bugs. Seed predators are expected to have beneficial effects, not only on weed control but also on the control of pest insects. In our study, we found that crickets fed on Poaceae seeds (Ichihara et al. 2012) (Fig. 14.4). Moreover, we conducted

Fig. 14.4 Picture of a cricket feeding on a Poaceae weed shot by an unmanned camera

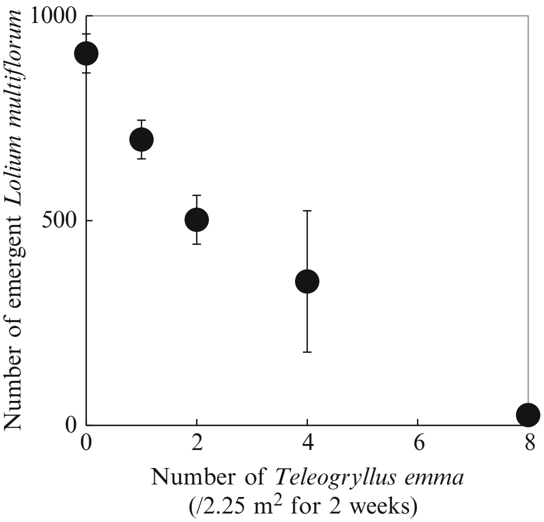

Fig. 14.5 Relationship between the population of the emma field cricket (*Teleogryllus emma*) and the emergence of *Lolium multiflorum*. Vertical bars represent the standard errors of the means of three replications

manipulative experiments in an experimental field. After tillage, 15 enclosures (2.25 m^2) were constructed using 60 cm wide corrugated plates, with 10 cm of the plate situated below the soil surface and 50 cm above. One thousand seeds of Italian ryegrass were sown on the soil surface. Five density treatments of adult emma field crickets (*Teleogryllus emma*) were randomly assigned to the enclosures, with three replications. As the density of *T. emma* increased, the proportion of seedling emergence of Italian ryegrass decreased (Fig. 14.5). The proportion

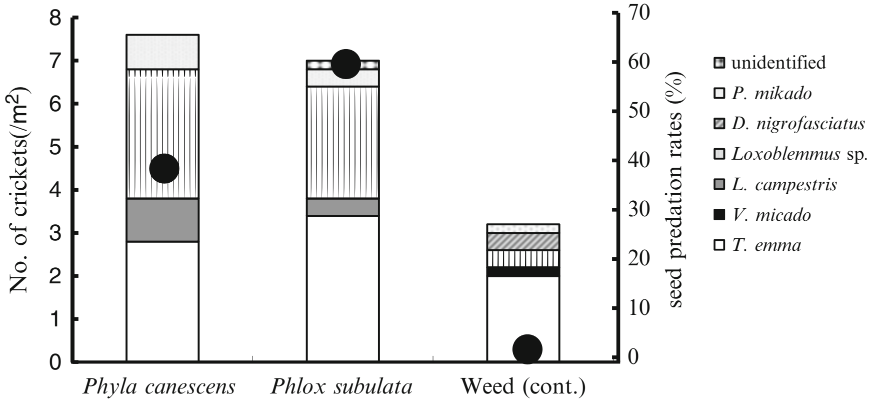

Fig. 14.6 The populations of cricket species and the seed predation rate due to cricket emergence in ground cover plants. Values are the means of five measurements

of emergence of Italian ryegrass in the enclosures without crickets was high, but the proportion of its emergence in the enclosures with two crickets was approximately halved. Furthermore, the proportion of emergence of Italian ryegrass in the enclosures with eight crickets was extremely low. In the enclosures containing crickets, many Italian ryegrass seeds were observed to be consumed by crickets.

In addition, ground cover plants such as *Phyla canescens* and *Phlox subulata* were effective at increasing the population density of crickets such as *T. emma* and *Loxoblemmus* spp., thereby increasing weed seed predation on the ridges and interiors of paddy fields (Fig. 14.6). Cover plants are currently believed to be effective at suppressing weeds. Interestingly, however, the effect of weed suppression was lowered when we prevented the intrusion of crickets (Inagaki et al. unpublished data). From this result, we hypothesized that ground cover plants suppress weeds not only by covering weed plants but also by providing cover for crickets.

Conclusions and Recommendations

The ridges surrounding rice paddy fields are constructed primarily for irrigation. However, these ridges also serve as habitats for many organisms, including rice pest insects, the host weeds of pest insects, and the natural enemies of pest insects. Therefore, the management of these ridges is important for the control of pest insects. The present chapter demonstrated the possibility of pest insect control by the ecological management of rice paddy ridges through the example of the rice stink bug *O. pugnax*, which is the most important insect pest of rice plants.

Recently, farmland ecosystems have been substantially degraded, making the development of ecologically sustainable agriculture a pressing matter (Kleijn et al. 2006). Pest management in paddy fields has previously been conducted primarily in the rice fields. However, it is difficult to increase the functional biodiversity of paddy fields while also maintaining acceptable rice production, as a trade-off often exists between the two factors. Reducing the input of agrochemicals and not tilling in winter have both been indicated as effective in conserving wolf spiders (Hidaka 1993, 1997; Ishijima et al. 2004; Motobayashi et al. 2007). However, these practices may affect rice production. In contrast, ridge management is more straightforward and can be conducted without affecting rice production. Overall, we believe that the ecological management of ridges is effective in increasing the functional biodiversity in and around paddy fields, thereby indirectly controlling pest insects in these fields.

References

Baba T, Sonehara N, Itoh S (2003) Vegetation change by grass cutting control on the paddy field embankment in Obasute area, Nagano Prefecture. J Fac Agr Shinshu Univ 39:23–26 (in Japanese)

Evans DM, Pocock MJO, Brooks J, Memmott J (2011) Seeds in farmland food-webs: resource importance, distribution and the impacts of farm management. Biol Conserv 144:2941–2950

Fukumachi K, Oku H, Miyake A (2005) The relationships between the structure of paddy levees and the plant species diversity in cultural landscapes on the west side of Lake Biwa, Shiga, Japan. Landsc Ecol Eng 1:191–199

Fushimi A, Naganuma K (2009) Ground cover ability of *Zoysia japonica* on a new ridge and introduction of double net planting method. J Agric Sci 64:165–168 (in Japanese)

Fushimi A, Otani I (2010) Vegetation analysis of *Zoysia japonica* Steud. Establishment on a new, rural ridge. Jpn J Grassl Sci 56:126–130 (in Japanese with English summary)

Hidaka K (1993) Farming systems for rice cultivation which promote the regulation of pest populations by natural enemies: planthopper management in traditional, intensive farming and LISA rice cultivation in Japan. FFTC Ext Bull 374:1–15

Hidaka K (1997) Community structure and regulatory mechanism of pest populations in rice paddies cultivated under intensive, traditionally organic and lower input organic farming in Japan. Biol Agric Hortic 15:35–49

Higuchi H (2010) Ecology and management of rice bugs causing pecky rice. Jpn J Appl Entomol Zool 54:171–188 (in Japanese)

Howell JO, Pienkowsk RL (1971) Spider population in alfalfa, with notes on spider prey and effect of harvest. I Econ Eontomol 64:163–168

Ichihara M, Inagaki H, Matsuno K, Saiki C, Yamashita M, Sawada H (2012) Post-dispersal seed predation by *Teleogryllus emma* (Orthoptera: Gryllidae) reduces the seedling emergence of a non-native grass weed, Italian ryegrass (*Lolium multiflorum* Lam.). Weed Biol Manag 12:131–135

Ichihara M, Matsuno K, Inagaki H, Saiki C, Yamaguchi S, Mizumoto S, Yamashita M, Sawada H (2014) Effects of ground cover plants on providers of ecosystem service of pest control in paddy field ridges. Bull Shizuoka Res Inst Agric For 7:29–36

Inagaki H, Matsuno K, Ohishi T, Takahashi T (2009) Effect of mowing ridges on the population density of wolf spiders in rice terraces: a study of the rice terraces of Kurasawa district, Kikugawa, Shizuoka. J Rural Plan 28:267–272 (in Japanese with English summary)

Isaacs R, Tuell J, Fiedler A, Gardiner M, Landis D (2009) Maximizing arthropod-mediated ecosystem services in agricultural landscapes: the role of native plants. Front Ecol Environ 7:196–203

Ishijima C, Motobayashi T, Nakai M, Kunimi Y (2004) Impacts of tillage practices on hoppers and predatory wolf spiders (Araneae: Lycosidae) in rice paddies. Appl Entomol Zool 39:155–162

Ishijima C, Taguchi A, Takagi M, Motobayashi T, Nakai M, Kunimi Y (2006) Observational evidence that the diet of wolf spiders (Araneae: Lycosidae) in paddies temporarily depends on dipterous insects. Appl Entomol Zool 41:195–200

Islam MA, Hirata M (2005) Centipedegrass (*Eremochloa ophiuroides* [Munro] Hack.): growth behavior and multipurpose usages. Grassl Sci 51:183–190

Ito M (1993) Weed science-principles for weed control in Japan. Yokendo Youkendo, Tokyo (in Japanese)

Ito Y, Miyashita K, Sekiguchi K (1962) Studies on the predators of the rice crop insect pests, using the insecticidal check method. Jpn J Ecol 12:1–11

Jensen P, Jacobson GL, Willard DE (1973) Effect of mowing and raking on Colembola. Ecology 54:564–572

Kaku T, Ito M, Ito K (2007) Weed management issues and dynamics during establishment of Phlox (*Phlox subulata* L.) ground cover using geotextile mulch. J Weed Sci Technol 52:57–65 (in Japanese with English summary)

Kawasaki T, Sugiyama E, Kawauchi H, Sato K (1997) Light conditions and weed development on ground covered with vegetation. J Agric Eng Soc Jpn 65:165–170 (in Japanese)

Kiritani K (2000) Integrated biodiversity management in paddy fields: shift of paradigm from IPM toward IBM. Integr Pest Manag Rev 5:175–183

Kiritani K (2007) The impact of global warming and land-use change on the pest status of rice and fruit bugs (Heteroptera) in Japan. Glob Chang Biol 13:1586–1595

Kiritani K, Hokyo N, Sasaba T, Nakasuji F (1970) Studies on population dynamics of the green rice leafhopper, *Nephotettix cincticeps* Uhler: regulatory mechanism of the population density. Res Popul Ecol 12:137–153

Kiritani K, Kawahara S, Sasaba T, Nakasuji F (1972) Quantitative evaluation of predation by spiders on the green rice leafhopper, *Nephotettix cincticeps* Uhler, by a sight-count method. Res Popul Ecol 13:187–200

Kleijn D, Baquero RA, Clough Y, Díaz M, Esteban JD, Fernández F, Gabriel D, Herzog F, Holzschuh A, Jöhl R, Knop E, Kruess A, Marshall EJP, Steffan-Dewenter I, Tscharntke T, Verhulst J, West TM, Yela JL (2006) Mixed biodiversity benefits of agri-environment schemes in five European countries. Ecol Lett 9:243–254

Kobayashi S (1977) Change in population density of spiders in paddy field during winter. Acta Arachnol 27:247–251 (in Japanese)

Kobayashi T, Takada M, Takagi S, Yoshioka A, Washitani I (2011) Spider predation on a mirid pest in Japanese rice fields. Basic Appl Ecol 12:532–539

Kremen C, Ostfeld RS (2005) A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 3:540–548

Kusanagi T, Konnai M, Shibayama H (eds) (1994) Handbook of weed management. Asakura Syoten, Tokyo (in Japanese)

Kuwazawa A, Nakamura H (2006) The relation between the abundance of stink bugs and the occurrence of spotted rice, and the impact of mowing in the ridge between rice fields on stink bugs. Bull Shinshu Univ 4:57–63 (in Japanese)

Landis DA, Wratten SD, Gurr GM (2000) Habitat management to conserve natural enemies of arthropod pests in agriculture. Annu Rev Entomol 45:175–201

Landis DA, Menalled FD, Costamagna AC, Wilkinson TK (2005) Manipulating plant resources to enhance beneficial arthropods in agricultural landscapes. Weed Sci 53:902–908

Morandin L, Long RF, Pease C, Kremen C (2011) Hedgerows enhance beneficial insects on farms in California's Central Valley. Calif Agric 65:197–201

Motobayashi T, Ishijima C, Murakami M, Takagi M, Taguchi A, Hidaka K, Kunimi Y (2007) Effect of spiders on inoculated populations of the migrant skipper *Parnara guttata guttata* Bremer et Grey (Lepidoptera: Hesperiidae) in untilled and tilled paddy fields. App Entomol Zool 42:27–33

Niffeler M, Benz G (1987) Spiders in natural pest control: a review. J Appl Entomol 103:321–339
Niiyama T, Itoyama K (2006) Control of rice leaf bug, *Trigonotylus caelestialium* (Heteroptera: Miridae) by application of herbicide to their source of immigration. Ann Rept Plant Prot North Jpn 57:129–133 (in Japanese)
Okubo S, Kamiyama A, Kitagawa Y, Yamada S, Palijon A, Takeuchi K (2005) Management and micro-scale landform determine the ground flora of secondary woodlands and their verges in the Tama Hills of Tokyo, Japan. Biodivers Conserv 14:2137–2157
Otani I, Watanabe O, Fushimi A (2007) Effect of slope aspects on the growth of ground cover plants and their soil conservation abilities. Bull Natl Agric Res Cent West Reg 6:39–53 (in Japanese with English summary)
Otani I, Watanabe O, Fushimi A (2009) Effect of mulching of plant materials on the growth of ground cover plants and emergence of weeds on ridge slope. J Weed Sci Technol 54:129–138 (in Japanese with English summary)
Otsuka H, Nemoto M, Masuda S (2006) The floristic composition of paddy fields and their ridges under different weed management techniques. J Weed Sci Technol 51:229–238 (in Japanese)
Riechert SE, Lockley T (1984) Spiders as biological control agents. Annu Rev Entomol 29:299–320
Rypstra AL, Schmidt JM, Reif BD, DeVito J, Persons MH (2007) Tradeoffs involved in site selection and foraging in a wolf spider: effects of substrate structure and predation risk. Oikos 116:853–863
Sasaki H, Aoki T, Ozaki K (1978) The Preliminary report on the survivorship curves and life tables of the rice – plant skipper, *Parnara guttata guttata* Bremer et Grey (Lepidoptera, Hesperiidae) in the paddy field. Proc Assoc Plant Protec Shikoku 13:5–9 (in Japanese with English summary)
Takeuchi K, Wahitani I, Tsunekawa A (2001) Satoyama: the traditional rural landscape of Japan. University of Tokyo Press, Tokyo
Takida M (2007) Influence of weeding in the ridge on the premise that basics chemical control of Yamagata Prefecture and control effect of new systematic insecticide, for *Trigonotylus caelestialium* (Kirkaldy). Yamagata Pref Agric Res 39:55–67 (in Japanese)
Teramoto N (2003) Control of rice stink bug complex (Hemiptera) in paddy fields by Gramineous weed control on balks. Bull Shiga Pref Agri Res Center Agri Exp Sta 43:47–70 (in Japanese)
Tomosho T (2008) Ground cover plants. J Rur Plan Assoc 18:320 (in Japanese)
Ueno K (2004) Studies on control of pecky rice bugs in Yamagata Prefecture. Yamagata Pref Agric Res 37:53–78 (in Japanese)
Westerman PR, Wes JS, Kropff MJ, Van D, Werf W (2003) Annual losses of weed seeds due to predation in organic cereal fields. J App Ecol 40:824–836
Westerman PR, Liebman M, Menalled FD, Heggenstaller AH, Hartzler RG, Dixon PM (2005) Are many little hammers effective? Velvetleaf population dynamics in two- and four-year crop rotation systems. Weed Sci 53:82–392
Winkler K (2005) Assessing the risks and benefits of flowering field edges: strategic use of nectar sources to boost biological control. Thesis, Wageningen University
Yamaguchi H, Umemoto S, Maenaka H (1998) Floral composition of the vegetation on ridges of traditional and reconstructed paddies in Sakai city, Japan. J Weed Sci Technol 43:249–257 (in Japanese)
Yuasa K (2006) Relationships between weeds on ridge of paddy fields and incidence of the rice stink bugs and pecky rice. Plant Prot 60:211–214 (in Japanese)

Chapter 15
Assessing the Difficulty of Implementing Wildlife-Friendly Farming Practices by Using the Best–Worst Scaling Approach

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Abstract On Sado Island in central Japan, wildlife-friendly farming is widely practiced, using the crested ibis (*Nipponia nippon*) as an icon. On the basis of farmer preferences, we applied the best–worst scaling (BWS) approach to evaluate the difficulty of implementing seven representative wildlife-friendly farming practices on Sado Island. Typical wildlife-friendly farming practices include reduced inputs of agrochemicals (50 % or 80 % agrochemical reduction), organic (agrochemical-free) cultivation, winter flooding, installation of diversion ditches, installation of fishways, and installation of biotopes (fallow flooding). We conducted a questionnaire survey of 5,010 farmers on Sado Island who distributed rice to Japan Agricultural Cooperatives (JA) at the time of the survey. We employed two approaches to analyze the BWS data: counting analysis and econometric analysis. The results of both analyses showed that organic cultivation was the most difficult of all types of farming practices and that 50 % agrochemical reduction was the least difficult. As expected, the burden of implementing the various farming practices differed. When a farming practice can produce a certain amount of biodiversity with less burden, the practice is considered more efficient. The results of our analysis can be utilized to evaluate each farming practice by quantifying its cost-effectiveness. Our study approach may be an effective assessment tool for disseminating wildlife-friendly farming practices.

Keywords Best–worst scaling • Wildlife-friendly farming • Sado Island • Crested ibis • Farmer preferences

Introduction

Paddy fields are an important alternative wetland habitat for a range of aquatic and semi-aquatic wildlife (Lawler 2001; Bang et al. 2012; Miyashita et al. 2015). However, the dramatic decrease in the biodiversity of wetland habitats has shifted considerable focus to wildlife-friendly farming in Japan for conserving or restoring paddy field biodiversity (Natuhara 2013). Since wildlife-friendly farming is costlier and demands more effort, time, and skill and involves a greater risk of decreased yields than conventional farming (Pimentel et al. 2005), there is heavy burden on farmers practicing wildlife-friendly farming. Minimizing this burden is key to further disseminating wildlife-friendly farming practices.

Wildlife-friendly rice farming involves improving habitat quality for wildlife in and around paddy fields (Donald 2004; Natuhara 2013). Such practices include not only the reduced input of pesticides and chemical fertilizers (agrochemicals), but also the implementation of winter flooding, diversion ditches, fishways, and fallow flooding (hereafter termed *biotopes*). Although all these farming practices aim at conserving or restoring farmland biodiversity, the burden of implementing each farming practice may differ. When a farming practice can produce a certain amount of biodiversity with less burden, the practice is considered more efficient. Therefore, it is important to evaluate each farming practice by quantifying its cost-effectiveness, which involves evaluating the burden of implementing each farming practice and its effect on wildlife. Although ecologists have studied the effects of wildlife-friendly farming practices on paddy field biodiversity (Lane and Fujioka 1998; Amano et al. 2011; Usio et al. 2015), the burden of implementing each farming practice has rarely been investigated. Farmers consider the various burdens of implementing such farming practices and decide which farming practice to implement in their paddy fields. As is known, the difficulty experienced by farmers increases as they implement more burdensome practices. Therefore, for farmers, the difficulty of implementing each farming practice is a unidimensional index that reflects the various burdens of implementing each farming practice, and it can be interpreted as disutility (negative utility) as farmers obtain more negative utility from more burdensome farming practices. In this study, we have attempted to quantify the difficulty of implementing each farming practice based on farmer preferences.

On Sado Island in central Japan, wildlife-friendly farming is widely practiced using the crested ibis (*Nipponia nippon*) as an icon (Saito 2015; Usio et al. 2015). The crested ibis has been reintroduced to Sado Island from 2008 (Kato 2015) in an attempt to restore degraded secondary natural environments such as paddy fields and forests and to revitalize depopulated human communities. To improve food availability for the crested ibis and to enhance biodiversity in paddy fields, wildlife-friendly farming has become a common practice on Sado Island. To be approved by the rice certification initiative of Sado City, farmers must apply 50 % or less of the agrochemicals of conventional farming, and implement one of four biodiversity-enhancing practices (Usio et al. 2015). Biodiversity-enhancing practices include the implementation of winter flooding, diversion ditches (locally known by the name *e*), fishways, and biotopes.

We applied the best–worst scaling (hereafter termed *BWS*) approach (Finn and Louviere 1992) to evaluate the difficulty of implementing the wildlife-friendly farming practices used on Sado Island based on farmer preferences. To our knowledge, no study has quantified the difficulty of implementing various wildlife-friendly farming practices.

In the next section, we describe our questionnaire survey, the BWS approach, the design of the choice sets in our survey, and two approaches to analyze the BWS data used in this paper. Subsequently, we present the results of our analyses and discuss the implications of the results. Finally, we summarize the results and explore directions for future research.

Methods

Questionnaire Survey

From August through October 2011, a questionnaire survey was conducted with the farmers on Sado Island (Nakamura et al. 2014). Questionnaires were sent to all 5,010 farmers who distributed rice to Japan Agricultural Cooperatives (JA) at that time. At the time of the study, rice grown under conventional farming could no longer be legally distributed through the JA, and most farmers had reduced agrochemicals by at least 50 % relative to conventional farming. Therefore, we considered 50 % agrochemical reduction farming (compared to the amount of agrochemicals used in conventional farming) to be the base practice.

We attempted to quantify the difficulty of implementing the typical wildlife-friendly farming practices used on Sado Island, which include reduced inputs of agrochemicals (50 % or 80 % agrochemical reduction), organic (agrochemical-free) cultivation, and the aforementioned four types of biodiversity-enhancing practices (winter flooding, installation of diversion ditches, installation of fishways, and installation of biotopes) based on farmer preferences by using the BWS approach explained below.

Best–Worst Scaling Approach

BWS is a method for measuring individual preferences developed by Finn and Louviere (1992). It requires the respondent to choose one alternative that he/she thinks is the best or the most of a particular characteristic (e.g., *preferred*, *important*, *difficult*) and one that is the worst or least of that characteristic from a series of choice sets that contain different combinations of three or more alternatives. BWS is often referred to as *maximum difference scaling* because it assumes that respondents examine every possible pair of alternatives within each choice set and choose the maximally different pair based on an underlying latent scale such as utility, degree of importance, or degree of difficulty (Finn and Louviere 1992; Cohen 2003).

Considerable information can be obtained from the BWS questions (Cohen 2003; Marley and Louviere 2005). Consider a choice set of four alternatives from which a respondent chooses his/her most and least preferred alternatives. If the choice set consists of red, blue, yellow, and green and the respondent prefers red the most and green the least, we can obtain information about 5 of the 6 possible paired comparisons ($4 \times 3/2 = 6$ pairs): red > blue, red > yellow, red > green, blue > green, and yellow > green, where ">" means "is preferred more than." We can determine the location of each alternative on the underlying latent scale by using the extensive information obtained from BWS questions.

BWS is classified into three types—the object case (Case 1), the profile case (Case 2), and the multi-profile case (Case 3)—based on the type of alternative to be evaluated (Flynn 2010). The object case is appropriate when the purpose of the study is to examine the location of each object on an underlying latent scale. We employed the object case in our study because our purpose is to determine the relative difficulty of implementing the seven representative wildlife-friendly farming practices. Therefore, we focus primarily on the object case for our analysis. Refer to Flynn et al. (2007) for more details about profile case BWS and to Louviere et al. (2008) and Scarpa et al. (2011) for more details about multi-profile case BWS.

We employed BWS instead of a rating scale and ranking used for measuring individual preferences in various fields because BWS has certain advantages over these traditional methods (Cohen 2003, 2009; Auger et al. 2007; Lee et al. 2007; Lusk and Briggeman 2009; Flynn 2010). First, it is easier for respondents to complete BWS questions than a rating scale and ranking because the selection process is simple and involves choosing the extremes from among several alternatives. Unlike a rating scale and ranking, respondents are not asked either to rate their preference for each alternative or to rank them in order of preference. The relatively simple BWS questions are thus more suitable for surveys like ours that involve elderly respondents. Moreover, BWS is especially useful in cases involving the evaluation of many alternatives. Incorporating many alternatives in a rating scale and ranking will impose an additional burden on respondents, possibly reducing the reliability of response. In contrast, BWS can handle a relatively larger number of alternatives because respondents are expected to evaluate only several select alternatives out of all alternatives according to the experimental design in each question (Lee et al. 2007; Jaeger et al. 2008; Cohen 2009; Lusk and Briggeman 2009; Mueller and Rungie 2009; Mueller et al. 2009). Second, BWS overcomes the lack of discrimination among alternatives and scale use bias (or response style bias), which potentially exist in a rating scale. BWS is more discriminating since a rating scale allows respondents to equally rate all the alternatives, while BWS requires respondents to make trade-offs among alternatives to choose the maximally different pairs. Scale use bias may exist in a rating scale because respondents with different sociodemographic characteristics or cultural backgrounds may use the scale differently (Lee et al. 2007). In contrast, no bias caused by differences in response style exists in BWS because there is only one way to choose the best and worst alternatives (Auger et al. 2007; Cohen 2009; Lee et al. 2007; Lusk and Briggeman 2009). This implies that BWS is *scale free*. Because of this feature, BWS is more useful in cross-cultural and cross-national comparative studies (Finn and Louviere 1992; Auger et al. 2007; Cohen 2009; Goodman 2009). Finally, BWS is superior to ranking in terms of the extent of information obtained. While BWS tells us both the order and the strength of preference of all alternatives, ranking tells us only the order.

Because of these advantages, BWS has been widely applied in many academic fields. The object case BWS has been employed extensively to investigate consumers' food and beverage preferences (Finn and Louviere 1992; Hein et al. 2008; Jaeger et al. 2008; Louviere and Islam 2008; Lusk and Parker 2009; Casini et al. 2009; Cohen 2009; Goodman 2009; Jaeger and Cardello 2009; Lusk and Briggeman 2009; Mueller and Rungie 2009; Remaud and Lockshin 2009; Yu et al. 2009). In addition, the object case BWS has been used to investigate preferences on other goods and services (Cohen 2003; Chrzan and Golovashkina 2006; Garver 2009) and to examine people's decision making on business (Buckley et al. 2007) and attitudes on social and ethical issues (Auger et al. 2007). Moreover, the object case BWS has been employed in studies on values (Lee et al. 2007, 2008; Bardi et al. 2009) and conflict (Daly et al. 2010) in the psychology field. To the best of our knowledge, this is the first work that applies BWS to quantify the difficulty of implementing wildlife-friendly farming.

Questionnaire Design

The experimental design is used to construct choice sets in order to minimize the number of questions. Balanced incomplete block designs (BIBDs) are used in many empirical studies to ensure that each alternative appears an equal number of times and is equally paired with each of the other alternatives across all choice sets (Auger et al. 2007; Lee et al. 2007). We adopted the BIBD for this study (Table 15.1). We constructed seven choice sets by replacing each number in the BIBD with one of the seven aforementioned wildlife-friendly farming practices, and in this process, the BIBD table was converted to seven choice sets. Each farming practice appeared three times across all choice sets and each pair of farming practices appeared once. Each row corresponds to one choice set. Respondents were presented with all seven choice sets. Figure 15.1 illustrates a choice set. The respondents were required to choose from each choice set the farming practice that they considered the most difficult (best) and the least difficult (worst) to implement. In order to exclude the benefit of implementing each farming practice and evaluate only the difficulty of implementing each farming practice, we asked respondents to consider the amount of effort, time, and skill that each farming practice required and the associated risk of decreased yields, as well as to assume that there were no additional factors such as subsidies, relaxations of production adjustment, or purchasing at higher prices than conventional agriculture. Making these choices may not have been difficult for farmers since they often compare the difficulty of each farming practice, and this survey enabled them to make realistic decisions based on their farming practices.

Table 15.1 Conversion from BIBD to choice sets

BIBD

1	2	6	4
2	1	4	5
3	4	7	3
4	3	2	1
5	7	5	2
6	6	1	7
7	5	3	6

→

Choice sets

1	80 % agrochemical reduction	Installation of fishways	Winter flooding
2	50 % agrochemical reduction	Winter flooding	Installation of diversion ditches
3	Winter flooding	Installation of biotopes	Organic cultivation
4	Organic cultivation	80 % agrochemical reduction	50 % agrochemical reduction
5	Installation of biotopes	Installation of diversion ditches	80 % agrochemical reduction
6	Installation of fishways	50 % agrochemical reduction	Installation of biotopes
7	Installation of diversion ditches	Organic cultivation	Installation of fishways

From each set, please choose the farming practice most difficult to implement and the farming practice least difficult to implement in your paddy field[†].

*Please consider the effort, time, skill, and greater risk of decreased yields.

*Please assume that there are no additional factors such as subsidy, relaxation of production adjustment, or purchasing at a higher price than conventional agriculture.

The farming practice most difficult to implement		The farming practice least difficult to implement
☐	80% agrochemical reduction	☐
☐	Installation of fishways	☐
☐	Winter flooding	☐

[†] Three farming practices were presented in each set.

Fig. 15.1 Example of a choice set

Counting Analysis

Data obtained through BWS questions can be analyzed in a variety of ways. A detailed discussion of the theoretical foundation of each analysis is provided by Marley and Louviere (2005). We employed two approaches to analyze the BWS data: counting analysis and econometric analysis. Counting analysis involves simple calculations and is often used in the analysis of BWS data.

In counting analysis, we count the number of times each alternative was chosen as best and worst. These numbers are referred to as the *total best* and *total worst*, respectively. The *B–W score* for each alternative is calculated by subtracting the *total worst* of each alternative from the *total best* of each alternative. A higher B–W score implies that an alternative is evaluated relatively higher on the underlying latent scale. Marley and Louviere (2005) note that the B–W score is a close approximation of the maximum likelihood estimates of the conditional logit model. As can be observed, analyzing BWS data by the counting analysis method requires no special expertise, and this method is chosen because of its simplicity and ease.

Econometric Analysis

Econometric analysis was conducted for a more rigorous analysis and to check the validity of the counting analysis.

The Maximum difference (maxdiff) model introduced by Finn and Louviere (1992) is a fundamental econometric model for BWS data analysis. This model is a variant or a natural extension of the conventional conditional logit model derived from the random utility model (Thurstone 1927; McFadden 1974). The maxdiff model assumes that respondents examine the difference between every possible pair of alternatives in a choice set based on an underlying latent scale and that from among all possible pairs, they choose the pair that maximizes the difference between two alternatives.

If a choice set has J alternatives, there are $J(J-1)$ possible best–worst pairs a respondent can choose from. In our case, six ($3 \times 2 = 6$) such pairs exist since three of the seven farming practices are included in a choice set ($J = 3$). Let β_i represent the location of the alternative i on the underlying latent scale. Described as follows, $Difference_{ij}$ represents the difference between the locations on the underlying latent scale between alternatives i and j.

$$Difference_{ij} = \beta_i - \beta_j + \varepsilon_{ij} \tag{15.1}$$

where ε_{ij} is an associated error component. The probability that the respondent chooses alternatives i and j as the best and worst of the J alternatives in the choice set is equal to the probability that the difference between alternatives i and j is greater than all other possible (in this case, $6 - 1 = 5$) differences in the choice set. The conditional logit model developed by McFadden (1974) is derived by assuming that ε_{ij} is distributed independently and identically with a type-I extreme value distribution (Gumbel distribution). The probability that a respondent chooses alternatives i and j as the best and worst of the J alternatives in the choice set is described as follows (Lusk and Briggeman 2009):

$$P(i \text{ is chosen as the best and } j \text{ is chosen as the worst}) = \frac{\exp(\beta_i - \beta_j)}{\sum_{k=1}^{J} \sum_{l=1}^{J} \exp(\beta_k - \beta_l) - J} \tag{15.2}$$

In contrast to the conventional conditional logit model where the alternative chosen by the respondent is treated as choice outcome, each pair of alternatives chosen by the respondent as best and worst is treated as a choice outcome in this model. The dependent variable takes the value 1 for the pair of alternatives chosen by the respondent as best and worst and 0 for the remaining pairs of alternatives in the choice set that were not chosen as best and worst. The parameter β_i (in this case, the difficulty of implementing each farming practice) can be estimated by the maximum likelihood method (Train 2009).

Results and Discussions

Data Collection

Responses were obtained from 2,231 farmers, a response rate of 44.5 %. For analysis, we used the data from the 1,355 farmers who answered all seven BWS questions. Of these 1,355 respondents, 1,257 (92.8 %) were male and 97 (7.2 %) were female; 398 (29.4 %) were certified wildlife-friendly farmers and 957 (70.6 %) were uncertified. In terms of age, 17 (1.3 %) respondents were in their 20s–30s, 108 (8.0 %) were in their 40s, 349 (25.9 %) were in their 50s, 538 (39.9 %) were in their 60s, 277 (20.5 %) were in their 70s, and 61 (4.5 %) were in their 80s–90s. Since a significant proportion of the respondents were elderly, the relatively simple BWS questions were considered suitable for our survey.

Results of Counting Analysis

The results of the counting analysis are summarized in Table 15.2. The *total best* and *total worst* data compiled in Table 15.2 show the frequency of farming practices chosen by respondents as the most and least difficult from the set of farming practices. The most frequently chosen farming practice in the *total best* category was organic cultivation (chosen 2,955 times), followed by the installation of fishways (chosen 2,000 times) through to 50 % agrochemical reduction (chosen 127 times). The most frequently chosen farming practice in the *total worst* category was 50 % agrochemical reduction (chosen 3,380 times), followed by winter flooding (chosen 2,425 times) through to the installation of fishways (chosen 311 times). The B–W score presented in Table 15.2 is the difference between the *total best* and the *total worst* categories. The farming practice with the highest B–W score was organic cultivation, followed by the installation of fishways through to 50 % agrochemical reduction. This indicates that the organic cultivation

Table 15.2 Summary of counting analysis

Alternatives	Total best (Most difficult)	Total worst (Least difficult)	B–W score	Ranking
50 % agrochemical reduction	127	3,380	−3,253	7
80 % agrochemical reduction	1,310	653	657	4
Organic cultivation	2,955	466	2,489	1
Winter flooding	531	2,425	−1,894	6
Installation of diversion ditches	1,242	1,751	−509	5
Installation of fishways	2,000	311	1,689	2
Installation of biotopes	1,320	499	821	3

was identified as the most difficult farming practice, while 50 % agrochemical reduction was identified as the least difficult. Among the four types of biodiversity-enhancing practices, winter flooding was chosen as the least difficult, and the installation of fishways was identified as the most difficult. As expected, the burden of implementing each farming practice differed. The ranking of each of these farming practices is consistent with our expectations based on our prior conversations with the farmers.

Results of Econometric Analysis

Table 15.3 shows the estimation results for the maxdiff model (conditional logit model). We included a dummy variable for each farming practice. To estimate the relative difficulty of each farming practice as compared with 50 % agrochemical reduction, the coefficient of 50 % agrochemical reduction was set at zero (therefore, the term was not included in the estimation). All variables were found to be positively significant. The estimated parameter of the organic cultivation was the largest. These results indicate that the organic cultivation was the most difficult farming practice and that the 50 % agrochemical reduction was the least difficult. Among the four types of biodiversity-enhancing farming practices, winter flooding was the least difficult and the installation of fishways was the most difficult. These outcomes are the same as the results derived from the B–W score based on the counting analysis.

The probability that each farming practice is chosen as the most difficult farming practice (i.e., the share of each farming practice) can be calculated using estimated parameters. The probability that farming practice *i* is chosen as the most difficult

Table 15.3 Estimation results for the maxdiff model (conditional logit model)

Parameter	Estimate	*t*-value	*p*-value	ranking	share
50 % agrochemical reduction	0	–	–	7	0.019
80 % agrochemical reduction	2.006	46.95***	0.000	4	0.140
Organic cultivation	2.885	70.96***	0.000	1	0.336
Winter flooding	0.863	22.74***	0.000	6	0.045
Installation of diversion ditches	1.530	37.28***	0.000	5	0.087
Installation of fishways	2.478	58.77***	0.000	2	0.224
Installation of biotopes	2.079	49.49***	0.000	3	0.150
Number of observations	9,485				
AIC	12,279.0				
BIC	12,300.5				
Log likelihood	−12,273.0				

Note: *** $p < 0.01$. AIC and BIC refer to the Akaike information criterion and the Bayesian information criterion, respectively

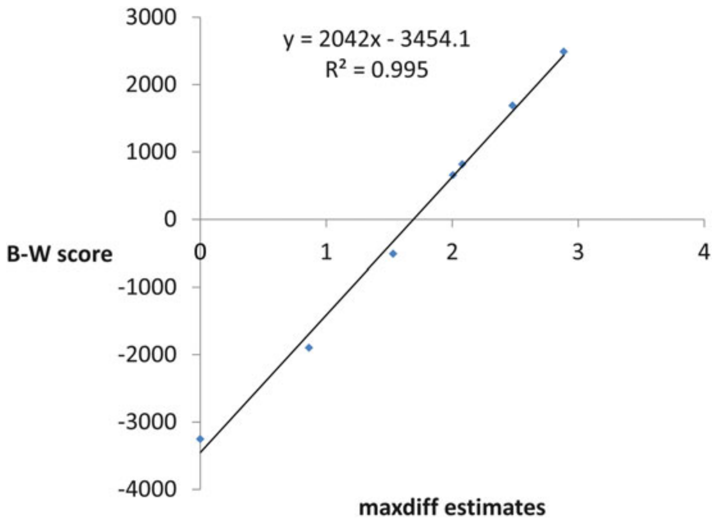

Fig. 15.2 Comparison between counting analysis and econometric analysis

farming practice is calculated by substituting the estimated parameters in the right-hand side of the following conditional logit model:

$$P(i \text{ is chosen as the most difficult}) = \frac{\exp(\beta_i)}{\sum_{j=1}^{7} \exp(\beta_j)} \tag{15.3}$$

It can be observed from the calculated shares that 33.6 % of respondents find organic cultivation to be the most difficult farming practice.

As mentioned earlier, similar results were obtained from the counting analysis and the econometric analysis. Figure 15.2 shows a comparison between the two analyses. A strong linear relationship between the B–W score and the estimates of the maxdiff model can be observed. These results confirm the usefulness and validity of counting analysis as a simplified analytical method.

Conclusions

This study has successfully quantified the difficulty of implementing seven wildlife-friendly farming practices based on farmer preferences by applying the BWS approach. The results of counting analysis and econometric analysis showed that the organic cultivation was the most difficult farming practice and that 50 % agrochemical reduction was the least difficult. As expected, the burden of implementing each farming practice differed. When a farming practice can produce a certain amount of biodiversity with less burden, it is considered more efficient.

The result of our analysis is useful for evaluating each farming practice by quantifying its cost-effectiveness.

The promotion of wildlife-friendly farming practices is important not only in Japan, but also in many other parts of the world in which environmental deterioration is a serious concern. The results of this study make an important contribution to highlighting this issue, and the approach may provide an effective assessment tool for the dissemination of wildlife-friendly farming practices.

Several aspects remain to be addressed in future research. In our econometric analysis, parameters are assumed to be common among all respondents. However, this might be an unreasonable assumption. Since the individual attributes of farmers and farmland conditions vary, perceptions pertaining to farming practices might be heterogeneous. Analyzing the subject by incorporating these differences is an important research task. Moreover, analyzing the differences in the evaluation of each farming practice by certified and uncertified wildlife-friendly farmers is important to derive useful insights that may assist in the further dissemination of wildlife-friendly farming practices.

Conducting a cost-effectiveness analysis is also an important area for future research. The cost-effectiveness of wildlife-friendly farming practices for conserving or restoring farmland biodiversity could be calculated by using the ratio of effectiveness on paddy field biodiversity and difficulty. Moreover, the cost-effectiveness of wildlife-friendly farming practices on rice production can be calculated by using the ratio of the rice yield or consumption quality and difficulty. Data collection on the effectiveness of farming practices is key to any such analysis and could be considered as a subject for future research.

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References

Amano T, Kusumoto Y, Okamura H, Baba YG, Hamasaki K, Tanaka K, Yamamoto S (2011) A macro-scale perspective on within-farm management: how climate and topography alter the effect of farming practices. Ecol Lett 14(12):1263–1272

Auger P, Devinney TM, Louviere JJ (2007) Using best-worst scaling methodology to investigate consumer ethical beliefs across countries. J Bus Ethics 70(3):299–326

Bang H-S, Han M-S, Na Y-E, Kim M-H, Kang K-K, Lee J-T (2012) Biodiversity of inhabitants of animals and vascular plants in Korean paddy field ecosystem. In: Nakano S, Yahara T, Nakashizuka T (eds) The biodiversity observation network in the Asia-Pacific region: toward further development of monitoring. Ecological research monographs. Springer, Tokyo, pp 387–402

Bardi A, Lee JA, Hofmann-Towfigh N, Soutar G (2009) The structure of intra-individual value change. J Pers Soc Psychol 97(5):913–929

Buckley PJ, Devinney TM, Louviere JJ (2007) Do managers behave the way theory suggests? A choice theoretic examination of foreign direct investment location decision making. J Int Bus Stud 38(7):1069–1095

Casini L, Corsi AM, Goodman S (2009) Consumer preferences of wine in Italy applying best-worst scaling. Int J Wine Bus Res 21(1):64–78

Chrzan K, Golovashkina N (2006) An empirical test of six stated importance measures. Int J Mark Res 48(6):717–740

Cohen SH (2003) Maximum difference scaling: improved measures of importance and preference for segmentation. In Sawtooth Software Conference Proceedings, Sawtooth Software, Inc. 530:61–74

Cohen E (2009) Applying best-worst scaling to wine marketing. Int J Wine Bus Res 21(1):8–23

Daly TM, Lee JA, Soutar GN, Rasmi S (2010) Conflict-handling style measurement: a best-worst scaling application. Int J Confl Manag 21(3):281–308

Donald PF (2004) Biodiversity impacts of some agricultural commodity production systems. Conserv Biol 18(1):17–37

Finn A, Louviere JJ (1992) Determining the appropriate response to evidence of public concern: the case of food safety. J Pub Policy Mark 11(1):12–25

Flynn TN (2010) Valuing citizen and patient preferences in health: recent developments in three types of best-worst scaling. Expert Rev Pharmacoecon Outcomes Res 10:259–267

Flynn TN, Louviere JJ, Peters TJ, Coast J (2007) Best-worst scaling: what it can do for health care research and how to do it. J Health Econ 26(1):171–189

Garver MS (2009) A maximum difference scaling application for customer satisfaction researchers. Int J Mark Res 51(4):481–500

Goodman S (2009) An international comparison of retail wine consumer choice. Int J Wine Bus Res 21(1):41–49

Hein KA, Jaeger SR, Carr BT, Delahunty CM (2008) Comparison of five common acceptance and preference methods. Food Qual Prefer 19(7):651–661

Jaeger SR, Cardello AV (2009) Direct and indirect hedonic scaling methods: a comparison of the labeled affective magnitude (LAM) scale and best-worst scaling. Food Qual Prefer 20(3):249–258

Jaeger SR, Jorgensen AS, Aaslyng MD, Bredie WLP (2008) Best-worst scaling: an introduction and initial comparison with monadic rating for preference elicitation with food products. Food Qual Prefer 19(6):579–588

Kato M (2015) Endangered species in Japan: ex situ conservation approaches and reintroduction in the wild. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes. Ecological research monographs, Springer, Tokyo. doi:10.1007/978-4-431-55330-4_6

Lane SJ, Fujioka M (1998) The impact of changes in irrigation practices on the distribution of foraging egrets and herons (Ardeidae) in the rice fields of central Japan. Biol Conserv 83(2):221–230

Lawler SP (2001) Rice fields as temporary wetlands: a review. Israel J Zool 47:513–528

Lee JA, Soutar GN, Louviere JJ (2007) Measuring values using best-worst scaling: the LOV example. Psychol Mark 24(12):1043–1058

Lee JA, Soutar G, Louviere JJ (2008) The best-worst scaling approach: an alternative to Schwartz's Values Survey. J Pers Assess 90(4):335–347

Louviere JJ, Islam T (2008) A comparison of importance weights and willingness-to-pay measures derived from choice-based conjoint, constant sum scales and best–worst scaling. J Bus Res 61 (9):903–911

Louviere JJ, Street D, Burgess L, Wasi N, Islam T, Marley AAJ (2008) Modeling the choices of individual decision-makers by combining efficient choice experiment designs with extra preference information. J Choice Model 1(1):128–163

Lusk JL, Briggeman BC (2009) Food values. Am J Agric Econ 91(1):184–196

Lusk JL, Parker N (2009) Consumer preferences for amount and type of fat in ground beef. J Agric Appl Econ 41(1):75–90

Marley AAJ, Louviere JJ (2005) Some probabilistic models of best, worst, and best-worst choices. J Math Psychol 49(6):464–480

McFadden D (1974) Conditional logit analysis of qualitative choice behavior. In: Zarembka P (ed) Frontiers in econometrics. Academic, New York, pp 105–142
Miyashita T, Yamanaka M, Tsutsui MH (2015) Distribution and abundance of organisms in paddy-dominated landscapes with implications for wildlife-friendly farming. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes. Ecological research monographs, Springer, Tokyo. doi:10.1007/978-4-431-55330-4_4
Mueller S, Rungie C (2009) Is there more information in best-worst choice data? Using the attitude heterogeneity structure to identify consumer segments. Int J Wine Bus Res 21(1):24–40
Mueller S, Francis IL, Lockshin L (2009) Comparison of best-worst and hedonic scaling for the measurement of consumer wine preferences. Aust J Grape Wine Res 15(3):205–215
Nakamura S, Tsuge T, Okubo S, Takeuchi K, Usio N (2014) Exploring factors affecting farmers' implementation of wildlife-friendly farming on Sado Island, Japan. J Resour Ecol 5(4):370–380. doi:10.5814/j.issn.1674-764x.2014.04.013
Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecol Eng 56:97–106
Pimentel D, Hepperly P, Hanson J, Douds D, Seidel R (2005) Environmental, energetic, and economic comparisons of organic and conventional farming systems. Bioscience 55(7):573–582
Remaud H, Lockshin L (2009) Building brand salience for commodity-based wine regions. Int J Wine Bus Res 21(1):79–92
Saito S (2015) In search of biodiversity-oriented farming. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes. Ecological research monographs, Springer, Tokyo. doi:10.1007/978-4-431-55330-4_16
Scarpa R, Notaro S, Louviere JJ, Raffaelli R (2011) Exploring scale effects of best/worst rank ordered choice data to estimate benefits of tourism in alpine grazing commons. Am J Agric Econ 93(3):813–828
Thurstone LL (1927) A law of comparative judgment. Psychol Rev 34(4):273–286
Train KE (2009) Discrete choice methods with simulation, 2nd edn. Cambridge University Press, Cambridge
Usio N, Saito R, Akanuma H, Watanabe R (2015) Effectiveness of wildlife-friendly farming on aquatic macroinvertebrate diversity on Sado Island in Japan. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes. Ecological research monographs, Springer, Tokyo. doi:10.1007/978-4-431-55330-4_7
Yu Y, Sun H, Goodman S, Chen S, Ma H (2009) Chinese choices: a survey of wine consumers in Beijing. Int J Wine Bus Res 21(2):155–168

Chapter 16
Column: In Search of Biodiversity-Oriented Farming

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Keywords Wildlife-friendly farming • Organic farming • Farmer • Crested ibis • Sado Island

On April 22, 2012, a baby crested ibis (*Nipponia nippon*), commonly known as *toki,* was born in the wild for the first time in 36 years in Japan. People who have been working on protecting and raising tokis, and working hard to return them back to their natural habitat—farmers, experts, local groups, island residents—burst with joy that day. Although this was a single passing event, it was a beginning of a never-ending story of Sado Island seeking coexistence with tokis and a range of other wildlife.

Agriculture in Sado Island significantly changed because of the toki. Factors for the extinction of wild tokis included the following: (1) rapid decrease in the number of individuals as a result of overhunting since the Meiji Era; (2) heavy use of pesticides and chemical fertilizers (agrochemicals); and (3) a decrease in food as a result of cementing both sides and the bottom of agricultural irrigation and drainage waterways with concrete as part of modernization of agriculture. The impact of agriculture has been profound.

If agriculture was the culprit for the extinction of the toki, then it should also be possible to revive the toki by changing practices in agriculture. As the ancient Japanese proverbs say, a balanced diet leads to a healthy body, or "you are what you eat." Safe food and living environments guarantee the survival of humans and wildlife species alike.

When I took over a farm 17 years ago, there were hardly any criticisms against heavy use of agrochemicals in Sado. A limited number of farmers were engaged in organic farming because interest in the technique was weak, and consumers who sought organic farm products were sparse. I myself believed in increasing yields through input-intensive farming practices. However, the rising costs for materials, concerns over human health from using agrochemicals, and the presence of

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supporters and consumers outside the island trying to restore the toki in nature prompted me to shift toward wildlife-friendly farming in 2001.

Objectives for the Reintroduction of the Toki in Nature

What does it mean for the toki to be restored to its natural habitat?

1. To keep the promise made to the toki. In 1981, five wild tokis were captured with the intent to artificially breed these animals. The captors must have promised that the toki will be returned to the Sado sky one day.
2. To create a wildlife-rich island environment. The environment of the toki is a rich one, in which many other organisms can thrive. Further, it is an environment that is safe for humans.
3. To create an environment in which tokis can catch their own food rather than expect humans to provide for them as they return to their natural habitat. Such a practice may lead to widespread recognition of the *Sado model* of ecological restoration.
4. To create an ecologically rich island that protects and nurtures wildlife and promotes Sado brand products, especially agricultural products, with the toki as an icon by coexisting with the bird that was once considered harmful.

In the fall of 2000, a non-profit organization (NPO) called *Medaka-no Gakko* [Medaka School] proposed a plan to implement environmentally friendly farming practices to the paddy fields, here at Niibo Village. Having heard of the plan to restore tokis to their natural habitat, Mr. Honma, the village head at that time, agreed to the plan, with the conviction that tokis would one day return to the Sado sky, and asked the farmers to cooperate. Agreeing with Mr. Honma, seven farmers from Niibo Village, Ryotsu City gathered and formed the *Sado Toki-no Tanbo-wo Mamoru Kai* or *Mamoru Kai* for short.

Mamoru Kai's major project was no-till farming, which was gaining public attention at that time, and wildlife-friendly farming, in which wildlife and rice growth are viewed as interrelated, a concept still in its infancy in Japan at that time. Experts in the field of wildlife surveys visited Sado and trained us, while the local government (Sado Municipal Government) provided income insurance to the farmers who implemented wildlife-friendly farming. At the time, this was a groundbreaking effort.

I remember being deeply interested in *no-till farming* more than tokis or other wildlife and could not wait for the spring to arrive any earlier.

Your Troubles Are Not Worth the Effort!

Because it was unrealistic to start without agrochemicals, farming in the first year was started with inputs of reduced agrochemicals, in which herbicide was applied only once. This application produced a satisfactory yield. True agrochemical-free farming was initiated in the second year, followed later by the undertaking of wildlife surveys four times a year, thus, showing a step-wise progression in our plan.

However, producing rice without herbicides was a great challenge. More weeds grew each day right after seedlings were planted (Fig. 16.1), and the rice plants and weeds could not be distinguished from one another by fall. This hindered the cultivation progress, and the curious looks of the neighboring farmers caused me so much stress that I wanted to flee. Ultimately, I had to ask my neighboring women for their help in mowing weeds that I could not mow using an agricultural machine. On the verge of tears, I asked myself several times, "why am I doing this?" Rice yield at the end was only 180 kg/10 ha, which was a dismal result.

As for the wildlife surveys, it must have been as peculiar as my farming, since my colleagues and I spent an entire day for each survey. While no one questioned us, many must have thought, "what good does it do to survey the wildlife?" or "how can those surveys help you earn money?" My colleagues and I, the farmers who engaged in such activities, must have looked like strange folks.

At that time, Sado rice was second only to the famous Uonuma rice in terms of its high price in the market. I remember a visitor to the island who jeered at us, saying, "Sado rice can be sold at a high price, so your troubles are not worth the effort." However, those words may have exactly been the source of energy for the Mamoru Kai.

Fig. 16.1 An organic paddy field covered with plentiful weeds

Turning Disasters into Fortune!

Because of the Great Merger of the Heisei Era in 2004, 1 city, 7 towns, and 2 villages were integrated to form Sado City.

The toki became the iconic bird not only for Niibo Village, but also for the entire Sado Island. The merger was advantageous for the toki, as the entire island has come to take an interest in the bird.

A great disaster struck the farming activities in Sado that year. After the Bon holidays in mid-August, a typhoon struck. The typhoon was also accompanied by a Foehn phenomenon (a weather phenomenon which can lead to significant temperature rises to the lee of high ground). A lack of rain caused serious damage to agriculture by dehydrating the rice, whose ears had just emerged, turning them white. No rice could be sold and Sado rice disappeared from storefronts across the country; Sado rice farmers suffered from very poor sales for the next 2 years. If the area allocated for production adjustment increased based on poor sales, wetlands that produce food for the toki would diminish, greatly hampering the efforts to restore the bird back to nature.

The farmers were hesitant to use the toki as an iconic bird in rice sales through the Japan Agricultural Cooperatives (JA). At that time, our group was the only one selling rice under the brand name *Toki hikari*, which was distributed through JA. Nonetheless, our policy was that we should not be the only ones that would benefit from the use of the name toki. Based on the idea that our efforts with tokis should be an island-wide effort, we chose to coordinate with the local government and JA.

Through concerted efforts among the local government, JA, and the farmers, a Sado City *Toki-to kurasu sato dukuri* rice certification initiative was created to improve rice sales after the typhoon, which continues to this day despite many trials and errors.

A tour in which consumers from the Tokyo Metropolitan area visit and help us with the weeding work also began from fiscal year 2006 (Fig. 16.2). This is an occasion in which consumers gain firsthand experience in understanding where the rice they eat comes from and who produces that rice. At the same time, this activity allows the producers to know who eats the rice they produce. It is a rare and valuable occasion that I look forward to every year.

Learning Something New Every Day, Every Year!

I learn something new every day and every year while conducting rice cultivation practices without the use of pesticides, chemical fertilizers, and by being conscious of the wildlife. This is because I work with nature, which is greatly affected by the weather. Planting the same seedlings does not mean that the same quality or yield of rice will be cultivated. Weeding may be successful 1 year, then not go as expected the

Fig. 16.2 Volunteers from cities on a *weeding tour* help remove weeds at an organic paddy field

next year despite utilizing the same approach, or there may be insect pests 1 year and none the next. Agriculture requires flexibility in accepting both the blessings and threats of nature. However, this is exactly why it is both challenging and enjoyable.

Similar to biodiversity, farming methods are also diverse, including no-till farming, weeding with rice brans, winter flooding, chain-weeding, bamboo-broom weeding, and natural cultivation. Each rice paddy also has a personality and a different compatibility with various farming methods. Farmers must thus conform to diversity to control their farms. Essentially, agriculture is a world of diversity.

Biodiversity-Oriented Farming

While there is *special cultivation* farming with reduced agrochemicals and *organic cultivation* using the JAS (Japanese Agricultural Standards Association)-certified cultivation practice, Sado focuses on *biodiversity* and is developing its own style of agriculture, which we refer to as *biodiversity-oriented farming*.

This is a broad approach that includes special cultivation and organic farming, where safety standards based on wildlife surveys are followed and the philosophy of nurturing wildlife and creating local sceneries are recognized. This is an agricultural operation based on *patriotism for our local community*, where local resources are entirely utilized by the local community, instead of exclusively pursuing individualistic economic values. However, wildlife surveys have become stagnant, and ways of focusing on the wildlife on a daily basis and incorporating these measures into our work at the farm remains a big issue.

The Role of Sado Agriculture

Agriculture is increasingly globalized in this age of intensified competition. Sado aspires to lead biodiversity-oriented farming in an opposite direction, but for how long it can survive under current trends remains to be seen. Even without such a trend, agriculture in Sado faces problems such as lack of willing heirs due to the aging population and an increase in abandoned farmland due to low prices of food crops.

Despite the adverse conditions and the presence of tokis, I have learned the following lessons:

1. Paddy fields do not just grow rice, but also nurture a diverse range of wildlife.
2. Agriculture is work that connects one person to another, humans and wildlife, and humans and nature, as well as nurtures life and binds several lives together.
3. The scenery involving tokis is Sado's precious treasure, and the unique scenery is maintained by sustaining agriculture (Fig. 16.3).

These are values that cannot be created by economic activities alone, and I am convinced that it is the responsibility of the people on Sado Island to share these values with the world through accounts of the significance of tokis.

Fig. 16.3 The toki (crested ibis; *Nipponia nippon*) as an icon for Sado's Satoyama landscapes

Chapter 17
Sociological Advantages and Challenges of Community Farms in Sustainable Agricultural Practice

Takashi Kuwabara

Abstract According to the previous analyses, larger farms were more likely to practice sustainable agriculture (environmentally friendly farming). In paddy field farming, large community farms have been gaining a share of the farmland area recently and we consider that they are one of the primary pillars of sustainable agriculture. The purpose of this article is to elucidate the advantages and challenges of them in sustainable agricultural practice through three case studies. To achieve this aim, we compared sustainable agricultural practices on two community farms

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and a large household farm in Sado City, Niigata Prefecture, where sustainable agricultural practices have been introduced since 2008 with reintroduction of the Japanese crested ibis (*Nipponia nippon*). Our investigation in this article revealed the following points. One advantage of community farms in the practice of sustainable agriculture for rice farming is the irrigation method of winter flooding. Community farms can utilize pumps (or river water), while household farms tend to utilize rainfall or temporary irrigation pipes. Another one is the ability to quickly convert to sustainable agriculture in respective local communities. At the same time, community farms also face some challenges, which are securing laborers, making landowners (and their children) participate in activities related to cultivation, and establishing a management strategy with little available land for further farmland expansion. The present political measures, *Kankyo hozen gata nougyo tyokusetsu sien taisaku* [Direct Payment for Environmentally Friendly Farming] in which the government have been executing and local measures in which some municipalities have been originally implementing, give support to farmers and local community on overcoming these challenges. However, a perspective of supporting a practice of community farms is not sufficient. We need to consider perspectives on policy making in the future.

Keywords Sustainable agriculture • Paddy field • Community farm • Sado • Japanese crested ibis • Irrigation • Winter flooding • Local community

Introduction

Analyses of data from the Census of Agriculture and Forestry in Japan indicated that farmers with larger farms were more likely to practice sustainable agriculture (environmentally friendly farming) (Noguchi 2002; Kinoshita 2008; Ando 2013). The reasons for this trend are considered that (a) larger farms achieve economies of scale, allowing farmers to cut down additional costs associated with practicing sustainable agriculture and (b) larger farms tend to diversify their management, direct marketing for example, so sustainable agriculture may be selected as a way of farm products branding.

While paddy field farming is traditionally practiced in small farms, there has been a gradual increase in the number of large farms used for practicing paddy field farming in recent years. In particular, community farms have been gaining a share of the paddy field farmland area in some districts (Nishikawa 2013). Community farms, *syuraku-einou*, are organized with individual farmers in a local community (sometimes among some local communities), *syuraku*, aiming for farm-size expansion and/or cooperation on farming (*einou* means *farming*). We consider that community farms are one of the primary pillars of sustainable agriculture. However, we cannot statistically confirm a correlation between community farms and sustainable agricultural practice. In addition, previous studies have not clearly identified the advantages and challenges of community farms in sustainable agricultural practice. It was supposed that small farmers meet sustainable agriculture practice in the past (Goda 1996), but thus view is not appropriate according to the result of the Census of Agriculture and Forestry in Japan above-mentioned.

The purpose of this article is to elucidate these advantages and challenges through plural case studies. To achieve this aim, we evaluated the present conditions and the development process of farming systems in local areas.

This article compares sustainable agricultural practices on two community farms and a large household farm in Sado City, Niigata Prefecture, where sustainable agricultural practices have been utilized since 2008 with the certification initiative and reintroduction of the Japanese crested ibis (*Nipponia nippon*). For this, we reviewed the interviews of farmers from these three farms conducted from 2011 to 2013.

There have been some previous studies regarding sustainable agricultural practices in Sado, including the certification initiative. Otake (2005), Ito (2006), and Tanaka et al. (2008) explained the situation of sustainable agricultural practices before the introduction of the certification initiative. They revealed the conditions of some voluntary organizations aiming for research and promotion of sustainable agricultural techniques, income of farmers, and administrative support systems. Watanabe (2010), as the person in charge, explained the circumstances of introducing the certification initiative. Otake (2010) analyzed the income of farmers who practiced sustainable agriculture based on the certification initiative. Sekijima and Kawaguchi (2009) pointed out a rapid increase in the sustainable agricultural area in Sado after the introduction of the certification initiative. Thus, we can comprehend the conditions before or just after the introduction of the certification initiative from previous studies, but the subsequent conditions have not been clarified. As 2012 was the fifth year of implementing the sustainable agricultural practices and the certification initiative in Sado, the conditions now may have changed.

Generally, in sustainable agriculture (rice farming), working hours increase and the cost of fertilizers and chemicals decrease (sometimes, there may be an increase due to expensive organic fertilizer usage; Yamaki 1993; Ministry of Agriculture, Forestry and Fisheries of Japan 2003). Therefore, these factors influence production costs. On the other hand, the yield usually decreases but sale price increases because of consumers' perception of the conservation of the ecosystem or food safety (price premium). These factors thus influence the gross income. A price premium is often achieved in association with changes of distribution or sales strategy (Kitahara et al. 2001). In order to maintain sustainable agriculture in farm management, the increase of gross income as a result of the price premium must be greater than the decrease resulting from increased production cost and changes in yield. If this condition is not satisfied, interventions such as political support (subsidy) or technical improvements should be implemented (Kai 2000). This article particularly focusses on the yields, available production cost, and sales price.

In addition, a characteristic of sustainable agricultural practices in Sado is winter flooding. Several studies have been conducted on winter flooding, which revealed the effects of water and soil purification and wildlife increasing in paddy fields (Nakamura and Ogura 2012), changes of ecosystem (Nakamura and Ogura 2012; Mineta et al. 2009), rice growth and quality (Ito et al. 2006; Hirauchi et al. 2008), technical genealogy (Makiyama and Tsukamoto 2006), geographic evaluation of potential to practice (Kurita et al. 2006), and appropriate location based on water supply (i.e., irrigation; Yagi et al. 2005). Under the normal situation of a rural society, a rice-farmer does not have the right to use irrigation water during winter, and the ownership of paddy fields is intricate. This article also deals with these issues, which need to be overcome in order to practice winter flooding.

The format of this article is as follows. First, we describe the conditions and characteristics of agriculture in Sado City, especially paddy field farming, through an analysis of the Census of Agriculture and Forestry. In addition, we explain the outline of the certification initiative for sustainable agriculture, which Sado City has utilized since 2008. Second, we grasp a present condition, a developing process, and a sustainable agricultural practice for each of the three farms. Third, we highlight the advantages that community farms possess for sustainable agricultural practice and the challenges of these farms from the standpoint of consensus building in the local community, securing adequate labor, and irrigation compared with household farms. Finally, based on the above, we consider the advantages and challenges of community farms in sustainable agricultural practice and present a political implication.

The Condition of Agriculture in Sado City

Outline of Agriculture in Sado City

Rice farming in paddy field is especially prosperous in Sado, same as Hokuriku district and Niigata Prefecture (Fig. 17.1). The Kuninaka Plain in central Sado is a granary that includes a large area of paddy fields. In old Niibo Village, a part of the

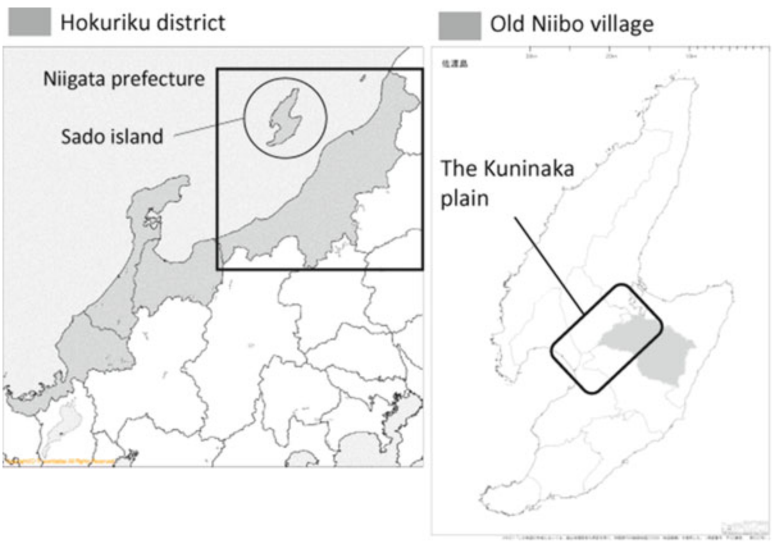

Fig. 17.1 Location of Hokuriku, Niigata, and Sado Island (Source: Retouching a map taken from a following website: http://www.sekaichizu.jp/atlas/japan/prefecture/map_800p/p800_area_hokuriku.html, http://technocco.jp/n_map/0150niigata.html)

Kuninaka Plain, inhabitants have greater interest in the conservation and reintroduction of the Japanese crested ibis and a governmental facility for it locates. In addition, the municipality (the former Niibo Village) has promoted sustainable agricultural practices since 2001, before the municipal merger to Sado City in 2004. Therefore, many farms have been practicing sustainable agriculture longer than farms in other areas of Sado.

According to the Census of Agriculture and Forestry conducted in 2010, there were 5,186 farms that selling agricultural products in Sado and among these farms, 4,134 farms (79.7 %) specialized in rice farming (more than 80 % of the agricultural products sold was rice). This percentage of farms specializing in rice farming greatly exceeds the percentage for the whole country (except for Hokkaido) (52.4 %) but is slightly less than that for Hokuriku and Niigata (both 85.4 %). In Niibo, the percentage of farms specializing in rice farming is 89.7 % (Fig. 17.2a).

Sado has 8,664 ha of farming area, including 7,419 ha (85.6 %) of paddy fields. Similar to the percentage of rice products, the percentage of paddy fields exceeds that in the whole country (71.2 %) but is less than the percentages in Hokuriku (92.3 %) and Niigata (91.3 %). The percentage of rice-cropped paddy fields is greater than 80 % in Hokuriku, Niigata, and Sado (Fig. 17.2b).

Regarding farm size, farms over 3 ha account for 9.5 % of all farms in Sado. This percentage is the same as that of the whole country, but is less than the percentages in Hokuriku (14.4 %) and Niigata (18.7 %). On the other hand, the percentage in Niibo (18.1 %) is similar to the percentages in Hokuriku and Niigata. This trend continues for the percentages of farms over 5 and 10 ha (Fig. 17.2c).

The number of commercial farmers in each commercial household farm is 1.61 in Sado, which exceeds the number in the whole country (1.57), Hokuriku (1.35), and Niigata (1.49). However, when only those farmers aged <65 years are considered, the number drops to 0.47 in Sado, which is less than that in the whole country (0.58) and Niigata (0.51) and similar to the number in Niibo (Fig. 17.2d).

Hokuriku is one of the districts in Japan where community farms play an important role in rice farming. According to the 2010 Census, the percentage of community farms among all farms was 2.8 % in Hokuriku compared with 1.8 % in the whole country. Although the percentage of community farms in Sado is not high (1.4 %), in Niibo, it is higher (2.9 %) than that in Hokuriku (Fig. 17.2e).

For information purposes alone, the percentage of farms practicing sustainable agriculture (data at the municipality level was not available) is higher in Niigata (68.0 %) than in Hokuriku (55.8 %) and the whole country (47.7 %). The percentage of farms specializing in rice farming is 85.1 % in Niigata and 83.3 % in Hokuriku compared with 45.8 % in the whole country. In addition, there is a similar trend among community farms.

Taken together, the above data indicate that rice farming in paddy fields is a main component of agriculture in Sado, similar to the situation in the Hokuriku district and Niigata Prefecture. On the other hand, the percentage of large farms (over 3 ha), the number of commercial farmers aged <65 years, and the percentage of community farms in Sado are less than those in the Hokuriku district or Niigata

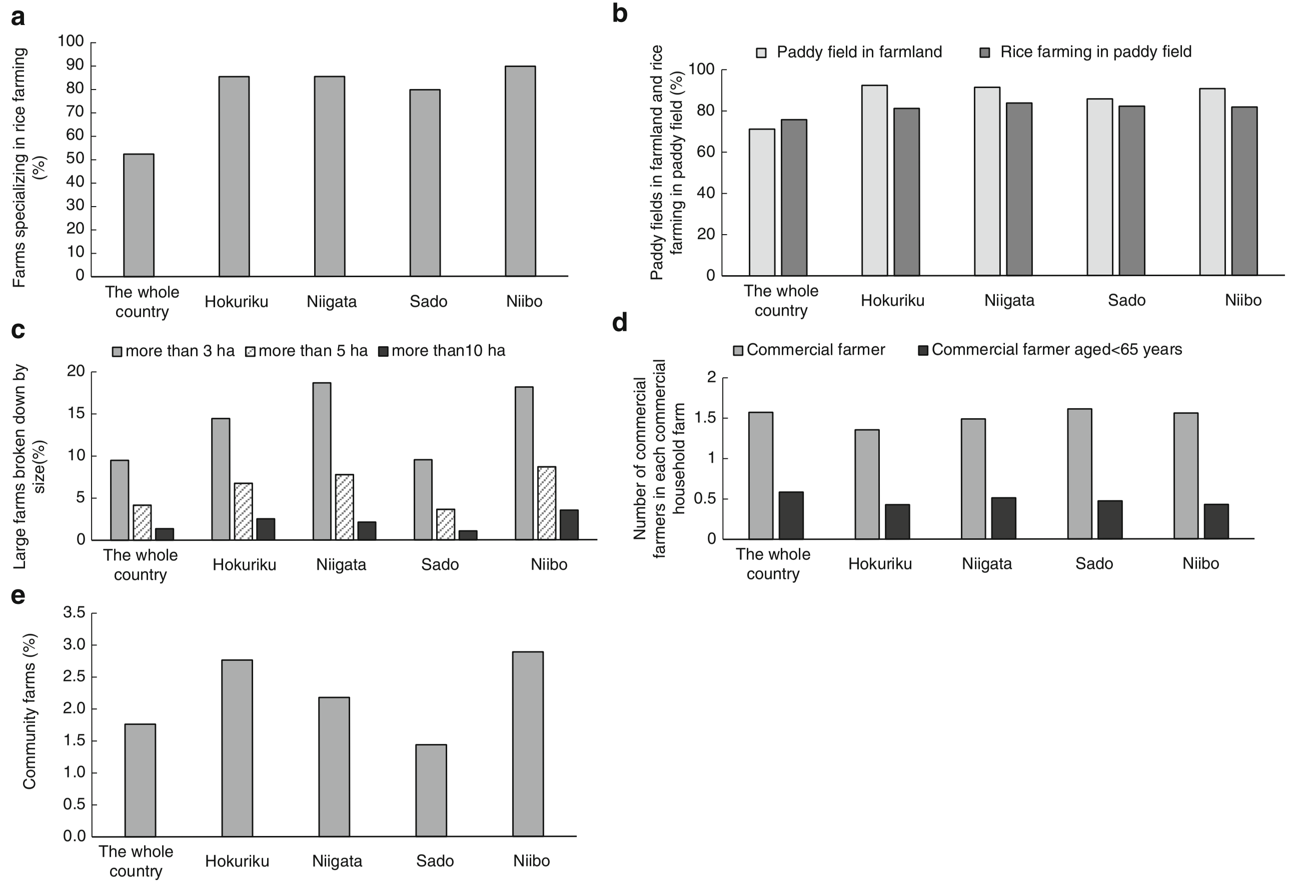

Fig. 17.2 (**a**) Percentages of farms specializing in rice farming in the whole country and stated areas (Source: The Census of Agriculture and Forestry in 2010) (**b**) Percentages of paddy fields in farmland and rice farming in paddy fields in the whole country and stated areas (Source: Ibid.) (**c**) Percentages of large farms broken down by size in the whole country and stated areas (Source: Ibid.) (**d**) Number of commercial farmers in each commercial household farm in the whole country and stated areas (Source: Ibid.) (**e**) Percentages of community farms (Source: Ibid.)

Prefecture. However, these values in old Niibo Village are similar to those in Hokuriku and Niigata. Niibo is an area that has relatively high percentage of large farms and community farms compared with other areas in Sado.

Outline and Achievement of the Certification Initiative for Sustainable Agriculture

Upon reintroduction of the Japanese crested ibis, the Sado Municipal Government has been operating a certification initiative for sustainable agriculture on rice farms since 2008, named *Toki-to kurasu sato dukuri ninsyou seido* [Toki Brand Rice Certification Initiative]. The main requirements of this certification initiative are as follows: (a) introduction of *Ikimono-wo hagukumu nouhou* [Biodiversity-enhancing practices] wherein farmers must utilize at least one method from a list that includes creating *e* [a trench in the paddy field], practicing winter flooding, creating a fish ladder, and creating a biotope; (b) practice of biodiversity research in paddy fields at least once a year; and (c) reduction in agricultural chemical and chemical fertilizer usage by more than 50 % compared with conventional farming methods. The Sado Municipal Government sets a day each summer for biodiversity research and many farmers participate. In addition, requirement (c) became a standard for selling rice through an agricultural cooperative beginning in 2012. Therefore, the most challenging and unique requirement for the certification initiative is (a).

The Sado Municipal Government pays farmers who meet the requirements 1,000–4,000 yen per 0.1 ha.[1] The area of certified land has expanded every year from 427 ha in 2008 to 1,367 ha in 2012, which is approximately 20 % of paddy fields in Sado. Figure 17.3 shows the area of land on which each farming method is practiced. Winter flooding is practiced on the greatest area of land (1,221 ha in 2012).

Farmers usually sell certified rice at a premium of 1,500 yen per 60 kg through an agricultural cooperative. However, farmers are required to sell a part of their crop as uncertified rice in the market. Thus, they receive only a premium of several hundred yen per 60 kg in actuality. Some farmers sell their crop to stores or consumers directly at a higher price.

Before the current practices were implemented, Niibo Village began to promote sustainable agriculture in 2001, which is earlier than other areas in Sado City, with the aim of reintroduction of the Japanese crested ibis. Thus, many farms have been practicing sustainable agriculture in this area for many years. In addition, as mentioned above, there are a relatively large number of large and community farms.

Hence, we selected two community farms and a household farm in the Niibo area. The selected farms have larger farmland area than the average and have been

[1] 1,000 yen on practicing winter flooding, 2,000 yen on creating *e*, and 4,000 yen on creating a fish ladder in 2012 (1 yen = 0.01 US dollars). There is an additional subsidy depending on geographical conditions and the degree of land integration.

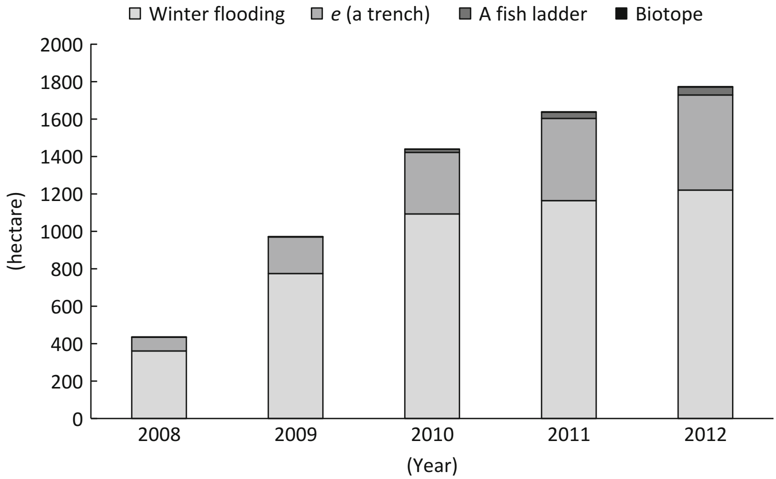

Fig. 17.3 The change in the certification area in each farming method (Source: Sado Municipal Government)

practicing sustainable agriculture since 2001. We here identified the advantages and challenges of community farms in sustainable agricultural practice through three case studies.

Farm Characteristics

Table 17.1 lists the characteristics of the three farms selected for our case studies.

The Nagaune, Syomyoji, and Aoki areas, where the farms are located, are all local communities within the Niibo area. These three areas are adjoined each other. According to the Census of Agriculture and Forestry conducted in 2010, the number of farmers and an average scale of farmland are different among three areas (Table 17.2). In the Nagaune area, most farmers rent their paddy fields to the Nagaune Farming Cooperative (not shown in Table 17.2) so the number of household farms which have paddy fields is less than that in other areas. On the other hand, paddy fields have gentle inclination through three areas.

In these local communities, associations for rural resource management are organized under the subsidy support of *Nouchi mizu kankyo hozen koujo taisaku* [Measures to Conserve and Improve Land, Water and Environment],[2] which the government began in 2007. Associations perform resource management activities one or more times per year. The primary activity is cleaning up irrigation canals and removing weeds at ridges. Existence of such an association is generally an important requirement for the development (expansion of farmland through renting)

[2] This policy was slightly changed as follows: *Nouchi mizu hozen kanri siharai kouhukin* [Payment for Conserving Farmland and Water] in 2011.

Table 17.1 Farm characteristics

	Nagaune Farming Cooperative	Seven System	Saito Farm
Location (in Niibo)	Nagaune	Syomyoji	Aoki
Type of farm	Agricultural producers' cooperative corporation	Limited company (Community farm)	Limited company (Household farm)
Year of organization	1977	1971	–
Year of establishment	1981	1997	1997
Number of members	71	7	–
Farmland for management (hectares)	100.5	32	17.5
Farmland for rice crops (hectares)	85	22	15
Farmland owned (hectares)	0.7	4	3.5
Farmland rented (hectares)	99.8	28	14
Laborers for machine operation (people)	4	3	1
Laborers for crop management (people)	approximately 40	6 or 7	3
Agricultural machines for rice farming	5 set	3 set	1 set

Source: Interview researches conducted by author in 2011 and materials provided by each farm
Organization means voluntary organization, while establishment means conversion into a corporation
All data are for 2010

Table 17.2 Area characteristics

	Nagaune	Syomyoji	Aoki
Whole household farms	27	20	35
Households (including non-farmhouse)	96	69	116
Full-time household farms	13	6	11
Household farms which have full-time farmer aged <60 years	4	1	2
Household farms which have paddy field	8	20	35
Paddy field (hectares)	12.8	28.2	71.5
Average scale of paddy field on each household farms	1.6	1.4	2.0
Inclination of paddy field	Gentle	Gentle	Gentle

Source: The Census of Agriculture and Forestry conducted in 2010

of rice-producing farms, whether household or community. Under these conditions, large farms have developed in each area.

The Nagaune Farming Cooperative was established in 1977 and became an agricultural producers' cooperative corporation in 1981. Farmland consolidation and sharing of agricultural machines were two key factors involved in the formation of the cooperative. The cooperative has approximately 100 ha of farmland for management, and it is the biggest farm in Sado. Almost of all the farmland area is rented by members of the corporation. Among a total of approximately 100 households, there are 71 household farms in the Nagaune area. In general, only four farmers (in their 30s–40s) work in the fields, except during the busy seasons of rice planting and harvesting. In these seasons, the four farmers and some temporary labors (in their 60s) practice mechanical operations in cooperation. In addition, approximately 40 landowners practice cultivation management (irrigation and fertilization) for approximately 2/3 of the farmland. To diversify from rice farming, soybeans are also grown on 11 ha of the cooperative farmland, and tomatoes are grown in a greenhouse.

The Nagaune Farming Cooperative has been practicing sustainable agriculture since 2001, and a typhoon that caused serious crop damage in 2004 was a big opportunity for further conversion from traditional farming. In 2004 and the year after the typhoon, rice harvest and subsequent sale declined in Sado. Therefore, to regain the value of Sado's rice at market, sustainable agriculture was adopted as part of the management strategy.

Seven System was established as a cooperative for use of agricultural machines by 13 household farms in the Syomyoji area in 1971. In 1997, seven farmers established a limited company aiming to preserve and efficiently manage the community's farmland and achieve year-round agricultural work including crop processing (rice cake for example). The cooperative has 32 ha of farmland for management, which represents approximately 50 % of the total Syomyoji area, including 28 ha of rented land. Three farmers (in their 30s–40s) practice mechanical operations and three or four temporary labors (in their 60s) work during the busy season. Soybeans are also grown on 10 ha, and some biotopes are managed in 3 ha of paddy fields.

In addition to the above two farms, we selected the Saito Farm, which is a household farm, for comparison. Saito Farm is a limited company based at a household in the Aoki area. The farm manager quit working at an agricultural cooperative and started farming full-time in 1997. Since inception, the farm has been expanding its farmland area by renting from other farmers in the Aoki area. In 2004, when the typhoon caused serious crop damage, and in 2007, when the price of rice dropped severely throughout Japan, Saito Farm rented an especially large amount of farmland. It employs two laborers (in their 30s–40s) for cultivation management and rice polishing. At present, the scale of management at Saito Farm is continuously expanding, e.g., the farm will introduce another agricultural machine and have two sets of the machine beginning in autumn 2013. Soybeans and some fruits are also cultivated in addition to rice.

Sustainable Agricultural Practices

All three farms practice sustainable agriculture, and most of their rice-cropped paddy fields are certified. Table 17.3 shows the conditions and results of rice farming using sustainable agricultural practices at each farm. The following points are obvious from the table.

Table 17.3 Conditions and results of rice farming using sustainable agricultural practices

		Nagaune Farming Cooperative	Seven System	Saito Farm
50 % reduced chemicals and chemical fertilizers	Cropping (hectares)	66.6	15	10
	Unit yields (kg/0.1 ha)	452	390–420	517
80 % reduced chemicals and chemical fertilizers	Cropping (hectare)	3.3	6	3
	Unit yields (kg/0.1 ha)	269	390–420	480 (Reference value)
No chemicals and chemical fertilizers	Cropping (hectares)	1.4	0.5	1
	Unit yields (kg/10 ha)	347	180–240	450 (Reference value)
Practice of winter flooding (hectares)		85	Unknown	14
Method of supplying water for winter flooding		Pumping up of river water	Unknown	Rainfall

Source: Same as Table 17.1
Results are shown for Koshihikari and Koshiibuki, both of which are ordinary rice species in Sado
Nagaune and Seven System in 2010, Saito Farm in 2008

First, all three farms practice a farming method that involves 50 % less usage of chemical and chemical fertilizer on most of their farmland. On the other hand, very little farmland is maintained with no chemicals or chemical fertilizers. One of the reasons for this situation is that unit yields decline and become less stable with a decline in chemical and chemical fertilizer usage. In addition, farming without chemicals and chemical fertilizers is more time consuming, e.g., removal of weeds without chemicals requires manual labor in the paddy fields. Despite these difficulties, all three farms continue to practice chemical-free farming in order to sell to those consumers who prefer completely safe and reliable rice.

Second, unit yields tend to decline with decreasing use of chemicals and chemical fertilizers. The average unit yield in Sado is approximately 540 kg. However, Table 17.3 shows lower values for every farm and method. To supplement the presented data, Nagaune's unit yields were 449 kg (50 % reduced), 338 kg (80 % reduced), and 213 kg (no chemicals) in 2011. In addition, yields have been unstable since 2008 when sustainable agriculture was started on all farmlands in the Nagaune area under the certification initiative. Besides, Saito Farm unit tended to decrease yields recently. The reasons of the decrease may be due to the increase of weeds and harmful insects preventing rice growing, but it is not clearly verified yet (generally, yields change under the effect of annual climatic change).

Third, the irrigation method of winter flooding differs among the farms or farmland.

Although not shown in Table 17.3, every farm sells a portion of its rice product to consumers or retail stores directly, without shipping to an agricultural

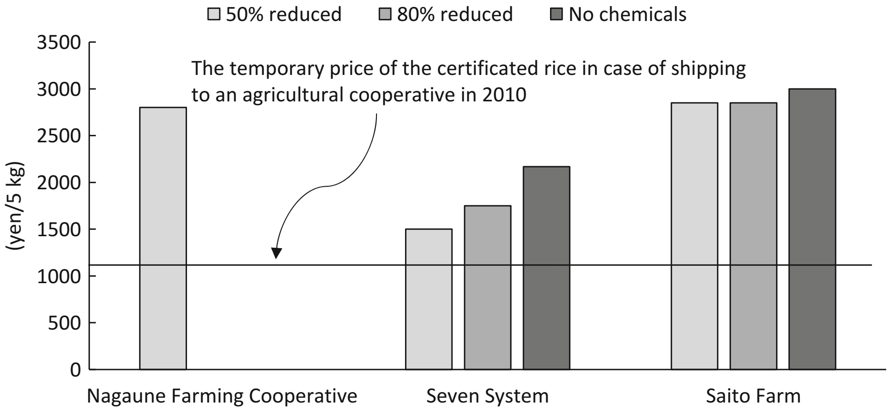

Fig. 17.4 The price of rice sold directly and shipped to an agricultural cooperative (Source: Interview researches and materials provided from each farm)

cooperative. Direct selling returns a higher price, but requires the farmer to package, ship, and settle accounts on his own. Figure 17.4 shows the price of rice when sold directly and shipped to an agricultural cooperative.

The two community farms sell a substantial amount of rice products to retail stores in the Tokyo metropolitan area and Kansai area including Osaka. On the other hand, Saito Farm sells only 4,800 kg, which corresponds to the amount harvested from approximately 1 ha of farmland, to individual consumers in urban areas.

Based on the data presented above, we are able to characterize sustainable agriculture in Sado and the differences between community farms and household farms as follows.

First, sustainable agriculture in Sado is not limited to practices only small farms with a few skilled farmers can adopt. Although farming methods that utilize no chemicals or chemical fertilizers are of the restrictive type, certification does not require such stringent restrictions. Indeed, the farms practice such chemical-free farming on only small portions of their farmland. The requirements for certification set by the Sado Municipal Government are also relatively easy to implement for large farms. Therefore, sustainable agriculture (especially that characterized by winter flooding and 50 % reduced chemical and chemical fertilizer usage) can also become a main farming method for large farms.

Second, despite the successful implementation of sustainable agriculture, unit yields have been declining and unstable on all three farms. Fu (2007) previously identified unit yield decline and instability associated with sustainable agriculture through analyses of data provided by the Ministry of Agriculture, Forestry and Fisheries of Japan for the whole country in 1997, 1999, and 2003. We confirm the same outcome in Sado and speculate that it may be one reason for practicing direct selling at higher prices.

Among the three farms examined here, there are some differences between community and household farms. First, as explained above, the method of irrigation for winter flooding is different among the farms. Second, the two community farms started practicing sustainable agriculture after organization and farmland expansion, while Saito Farm proceeded with both farmland expansion and sustainable agricultural practices at the same time. We will investigate the causes and effects of these differences in the next section.

Causes and Effects of Differences Between Community and Household Farms

Differences in Winter Flooding Practices

Nagaune Farming Cooperative has two concepts and methods of management of winter flooding.[3] First, the practice is used for weed removal on farms where chemical-free farming is practiced. Started in 2001, this practice involves deep flooding with river water. In order to utilize river water, farmland next to a river is selected for such farming. Second, winter flooding is used to enhance biodiversity in paddy fields for facilitating reintroduction of the Japanese crested ibis. Started in 2008, this practice involves flooding to the brim of the paddy fields, like flooding on wheel tracks. A pump is used that is not usually available in winter, and the Sado Municipal Government pays the cost of pumping in winter.

Saito Farm also has same concepts of management of winter flooding but a method of flooding is different (using rainfall). Flooding conditions vary according to the condition of each paddy field (whether it is dry or wet), the weather, and rice growth in the previous year.

In total, there is diversity in winter flooding practices, all of which could be targets of certification and subsidy support (1,000 yen per 0.1 ha) from the municipality. A certification rule permits a practice that involves flooding only on wheel tracks and a period of snow on farmland. Municipality staff checks flooding conditions twice per winter based on this rule. This rule was originally established to ensure the presence of sufficient food for the Japanese crested ibis. It also promotes use of diverse practices that match climate and conditions of each farmland.

In contrast, other areas in which winter flooding is practiced actively, e.g., Osaki City in Miyagi Prefecture and Toyooka City in Hyogo Prefecture, operate under a different rule. Deep flooding (5 cm) is required for 2 consecutive months, except for periods when snow is on the farmland, in order to receive a subsidy in these areas. A similar rule has been adopted for the support system (*Kankyo hozengata nougyo*

[3] In general, the purpose of winter flooding is the creation of wetland environment for various wildlife, such as waterfowl, or improvement of soil environment for weed control.

tyokusetsu sien taisaku [Direct Payment for Environmentally Friendly Farming]), which the government has provided since 2011. Thus, there is a mismatch between practices in Sado and these other areas.[4]

Regarding the method of water supply for winter flooding, Nagaune Farming Cooperative utilizes river water and pumping, while Saito Farm utilizes rainfall. One reason for rainfall utilization is the climate characteristics in Sado. The districts facing the Sea of Japan, including Sado, receive more rainfall or snowfall in winter than other districts.[5] Therefore, it is easy to utilize rainfall for winter flooding. Nagaune Farming Cooperative did not utilize a pump in winter 2011 because of a heavy snowfall. On the other hand, a negative reason for rainfall utilization on Saito Farm is the difficulty of intensive irrigation in winter caused by the wide dispersion of farmlands. When a household farm attempts to expand its farmland, it has to wait for a supply of farmland to become available in the area.[6] Thus, expansion is often dictated by factors other than economic factors, e.g., farms being abandoned because of landowner's aging, therefore rented farmland tends to be dispersed. On Saito Farm, rented farmlands are dispersed to approximately five locations in the Aoki area and the farthest farmland is approximately 4 km away from the farm office.

Conditions in other areas provide supporting evidence of the relative expense of winter flooding for household farms. In the Shinbo area of Osaki City, Miyagi Prefecture, 10 household farms practice winter flooding with organic and chemical-free farming. There is no right to utilize irrigation in winter, and farmlands that are flooded in the winter are dispersed. In addition, irrigation and drainage courses are not separated. If a farm practices winter flooding on a usual irrigation course under these conditions, water floods over other farmland. Therefore, the 10 farms install temporary irrigation pipes every winter. Installation takes a day and removal takes half a day. Thus, winter flooding of sprinkled farmland involves extra costs and difficulties.

In the Koudani area of Toyooka City, Hyogo Prefecture, a community farm (Koudani Farming Cooperative) was established in 2001. It included most farmland in the area and became an agricultural producers' cooperative corporation in 2007. It introduced sustainable agriculture (farming with 75 % reduced chemical and chemical fertilizer usage and winter flooding) beginning in 2004. A characteristic of sustainable practices on this farm is rotation of farmland in winter flooding. A cooperative representative director explained that it is necessary to maintain varied environments in the paddy fields and promote healthy rice growth. He also pointed out that such practices are only possible on community farms in the area.

[4] Indeed, the number of applications and certifications of this system are not much in Sado, according to an interview of staff of the Sado Municipal Government.

[5] According to the Japan Meteorological Agency, the average amount of rainfall in January, February, and December was 368.9 mm in Aikawa, Sado (from 1981 to 2010) compared with an average of 238.0 mm for the whole country.

[6] Or it has to expand to farmland outside the area. Refer to Ando et al. (2013).

As above, the concept and design of the administrative support system resulted in a diversity of winter flooding practices in Sado. In addition, the method of supplying water for winter flooding is different between community and household farms. The former can utilize pumps (or river water) on integrated farmlands, while the latter have to depend on rainfall or installation of temporary irrigation pipes on sprinkled farmlands.

What effects do these differences cause? Although we do not have sufficient information about unit yields of paddy fields on which winter flooding is practiced, some farmers located in Sado often mention a gradual decline in unit yields. Moreover, Saito Farm temporarily abandoned winter flooding in winter 2012. The manager cited the necessity of drying paddy fields once every few years. Thus, in order to minimize the negative impact of winter flooding on rice growth, it may be necessary to control water supply carefully in the winter and rotate farmlands. Community farms have an advantage in this regard because their farmland is intensive; therefore, they can control unit yield decline caused by winter flooding practices more readily than household farms.

Process of Farm Development and Sustainable Agricultural Practice

Nagaune Farming Cooperative and Seven System were established in the 1970s for the purpose of agricultural machine sharing. They had already integrated most of the farmland present in their respective areas and had been practicing sustainable agriculture based on it. For information purposes, Table 17.4 shows the history of Nagaune Farming Cooperative's establishment and development.

Because of the accumulation and consolidation of farmlands, community farms are better equipped to quickly convert all land to sustainable practices. Nagaune Farming Cooperative introduced farming with 50 % reduced chemical and chemical fertilizer usage on all its farmlands in 2008, when Sado City was still promoting farming with 30 % reduced chemical usage for the whole island. On the other hand, although some household farms, such as the manager of Saito Farm, also introduced sustainable agriculture earlier, it is more difficult for them to quickly expand a practice to a whole area because most of the farmlands are dispersed in the area.

Cases from Toyooka City again provide supporting evidence that is instructive.[7] In the Koudani area, mentioned above, inhabitants have been holding study meetings about sustainable agriculture several times a year since 2003. The foundation of these meetings is not only the long-existing neighborhood association but also the community farm (Koudani Farming Cooperative) that was established in 2001. In the Nakanotani area next to Koudani, the community farm (Nakanotani

[7] Toyooka City started a support system for local communities to promote sustainable agricultural practices in 2012. Four local communities were targeted in that year.

Table 17.4 History of Nagaune Farming Cooperative

Year	Topics	Notes
1977	Established farming cooperative	86 household farms participated Accumulated 106 ha of farmland 1,060 thousand yen as capital
1978	Started cooperation for harvesting Started operations of a rice center	
1979	Built a system of whole mechanizing Started an organized exchange of crop	
1981	Acquired a corporate body	10 million yen as capital
1987	Built up a compost center	
1992	Won the prize of Japanese Agriculture	
1997	Introduced a salary instead of a share	
1999	Started cropping soybeans in earnest	
2001	Started sustainable agricultural practices	
2002	Employed full-time workers	
2004	Great decline in harvest caused by a typhoon	
2008	Started direct selling of rice Started farming with 50 % reduced chemical and chemical fertilizer usage on all farmlands	

Source: Interview researches conducted by author in 2011 and materials provided by the farm

Agricultural Producers' Cooperative Corporation) was established in 1988. It acquired a corporate body in 1998 and has been practicing sustainable agriculture with the original standard before Toyooka City started promoting it in earnest in 2003. At present, it cultivates rice on 8.7 ha under the standard set by the municipality and 17 ha under the original standard, which is a slightly stricter. In the Yuruji area next to Koudani, on the opposite side of Nakanotani, farmers began holding meetings for farm organization in 2004 and established the community farm (Yuruji Farming Co. Ltd.) in 2006. It started practicing sustainable agriculture the following year. Although delayed, it currently cultivates more than half of its paddy fields (10 of 16.5 ha) using sustainable agricultural practices (in adherence with the standard set by the municipality).

Thus, is there a possibility that household farms can expand sustainable agricultural practices to the whole area or local communities? Such expansion is difficult at present because a technical system of sustainable agriculture is not sufficiently built, especially for some new practices such as winter flooding. Therefore, traditional farmers are not always eager to change farming methods. The more radical a sustainable agricultural practice, the more difficult the conversion from a traditional farming method is.[8] A household farm that intends to develop its management and

[8] Related to this point, the Sado Municipal Government cleverly permits various conditions of winter flooding practice, mentioned above.

practice sustainable agriculture has to work with landowners to make adjustments to farmland renting and conversion of farming methods at the same time, which often involves transaction costs that are prohibitively high.

Challenges of Community Farms

Community farms also face challenges when implementing sustainable agricultural practices.

The first challenge is securing laborers. Sustainable agriculture practices generally need longer and harder working for weeding and other operations compared with conventional farming. Household farmers may employ laborers, but basically the manager is the main labor force. On the other hand, community farms, especially converted into a corporation, have to secure some laborers from local communities.

Both the Nagaune Farming Cooperative and Seven System have several young laborers (in their 30s–40s) but also temporarily utilize some elderly laborers (in their 60s–70s). The latter have been the main force in the establishment and development of farms; hence, they have great farming skill and consciousness. When they retire, it is not clear whether the farms will be able to secure equally skilled laborers to replace them.[9]

According to the interview to a labor (40s, who also serves as a director) of the Nagaune Farming Cooperative, the younger inhabitants, children of the present landowners, have little interest in and relation to the farms' management and agriculture. An annual income for a full-time worker on these farms is approximately 3–3.5 million yen. The representative directors are worried that this income is not sufficient for young people. It is necessary to earn more profit through adding premium value to products and/or diversifying management in order to pay enough salary to them.

Second, and related to the first challenge discussed above, community farms have to make landowners (and their children) continue to participate rural resource management and cultivation management. Participation often depends somewhat on policy trends, such as support by *Nouchi mizu kankyo hozen koujo taisaku* [Measures to Conserve and Improve Land, Water and Environment]. Thus, operators (who practice cultivation, planting, and harvest) and landowners (who don't practice those works) have to maintain a partnership through support systems and discussion.

Third, there is little scope for the community farms to expand their farmland because they had already integrated most of the farmland in their respective areas.[10]

[9] Refer to a fact that the number of commercial farmers aged <65 years in each household is few in Sado, mentioned at sector 2.

[10] Both the organized farms have no plans to expand its farmland outside the local community (Nagaune and Syomyoji).

For example, Seven System cultivates 32 ha at present, and the representative director projected that 40 ha is the upper limit of cultivation under the present management system.[11] A potential development path for community farms in the future is pursuit of efficiency and diversification of management, rather than farmland expansion. It will ultimately be necessary to harmonize management strategy and sustainable agricultural practices.

Conclusions

Our investigation in this article revealed the following points.

Community farms have two advantages in the practice of sustainable agriculture for rice farming. One is the irrigation method of winter flooding. Community farms can utilize pumps (or river water) easily, while household farms tend to utilize rainfall or temporary irrigation pipes. The degree of farmland integration largely dictates the efficiency of this sustainable practice. Although household farms can also utilize pumps where an irrigation system has been established, this situation is not satisfied every area, e.g., the Shinbo area of Osaki City, Miyagi Prefecture.

Another advantage of community farms is the ability to quickly convert to sustainable agriculture across large areas. Community farms usually have not only large and integrated farmlands but also systems of cultivation. These factors allow for quick conversion to sustainable agriculture. On the other hand, household farms have to gain farmlands and implement sustainable agricultural practices at the same time.

However, community farms also face some challenges when implementing sustainable agricultural practices. For example, they must secure laborers, make landowners (and their children) participate in activities related to cultivation, and establish a management strategy that accounts for the reality that there is little available land for further farmland expansion. These challenges must be considered when developing plans for sustainable agriculture implementation in the future.

In 2013, the government executed *Nouchi mizu hozen kanri shiharai* [Payment for Conserving Farmland and Water] and *Kankyo hozen gata nougyo tyokusetsu sien taisaku* [Direct Payment for Environmentally Friendly Farming].[12] In addition, some municipalities implemented the original measure as the certification initiative in Sado City. These measures provided support to farmers and local communities to help them overcome the challenges. However, a perspective of supporting the practice of community farms is not sufficient. We also need to consider perspectives on policy making in the future.

[11] On the other hand, Saito Farm's manager intends to expand its farmland with a prospect for additional farmland supply in the Aoki area.

[12] From 2014, the government will start a new support system rearranging existing measures, including these ones.

Finally, there are several issues that require further investigation. First, technical factors associated with sustainable agricultural practices, especially those that influence unit yields need to be analyzed in detail. Second, farm management, including marketing, needs to be analyzed comprehensively. Third, case studies with different conditions need to be accumulated to allow for political suggestions based on more general analyses.

References

Ando M (2013) Nogyokeieitai no tenkai to kouzou [Development and structure of farms]. In: Ando M (ed) Nihon nougyo no kouzou hendou [Structural change of Japanese agriculture]. Nourin Toukei Kyokai, Tokyo, pp 141–183

Ando M, Yamaura Y, Onaka K (2013) Daikibo keiei no seiritsu jouken [Realization condition of large farms]. Nobunkyo, Tokyo

Fu B (2007) Kankyo hozengata nougyo no seiritsu joken [Economic analysis of sustainable agriculture]. Nourin toukei kyoukai, Tokyo

Goda M (1996) Nihon ni okeru kankyo hozengata nougyo no genjo to sono kanousei [Present condition and potential of sustainable agriculture in Japan]. J Rural Econ 68(2):88–96

Hirauchi H, Ito T, Suzuki K, Uno T (2008) Miyagi ken Izu numa syuhen no touki tansui yuki suiden ni okeru dojo tokusei, suitou no seiiku syuryo oyobi genmai hinshitsu [Soil characteristic, rice growth yields and brown rice quality in organic paddy field with winter flooding practice around Izu pond in Miyagi prefecture]. Abstracts of the meeting, the Society of the Science of Soil and Manure 54, p 129

Ito R (2006) Toki no yaseihukki monndai wo keiki toshita kankyo hozengata nougyo no torikumi [Sustainable agriculture practice triggered by reintroduction of Japanese crested ibis]. Nogyo to Keizai [Agriculture and Economy] 72(1):51–60

Ito T, Kon C, Watanabe H, Mieda M (2006) Miyagi ken Tajiri machi Kabukuri numa syuhen no touki tansui yuki suiden ni okeru dojo tokusei, suitou seiiku oyobi metan housyutsu [Soil characteristic, rice growth, and methane discharge in organic paddy field with winter flooding practice around Kabukuri pond in Tajiri town, Miyagi prefecture]. Abstracts of the meeting, the Society of the Science of Soil and Manure 52, p 121

Kai S (2000) Conflicts and its synthesis between behaviors of profit maximization and environmental safeguard in large-scale farms. Rev Agric Econ 51(1):1–10

Kinoshita Y (2008) Nougyo keiei to nougyo kouzou [Farm management and agricultural structure]. In: Odagiri T (ed) Nihon no nougyo [Japanese agriculture]. Nourin Toukei Kyokai, Tokyo, pp 165–202

Kitahara K, Taniguchi Y, Sato S (2001) Rice marketing strategy and sustainable agriculture under the new distribution system. Jpn J Farm Manage 39(1):95–98

Kurita H, Mineta T, Ishida K, Ashida T (2006) Environmental potentials of winter-flooded rice fields for the wetlands restoration. J Jpn Soc Irrig Drain Reclam Eng 74(8):713–717

Makiyama M, Tsukamoto T (2006) The process of cooperation between winter-flooded rice field and no-tillege rice farming, and foresight of this culture. J Jpn Soc Irrig Drain Reclam Eng 74(8):719–722

Mineta T, Koizumi N, Ishida K (2009) Contribution of winter flooding in multifunctionality of paddy fields: some notes in a case of biota conservation function In Tajiri-Shinpo, Miyagi prefecture. J Rural Plan Assoc 27:335–340

Ministry of Agriculture, Forestry and Fisheries of Japan (2003) Kankyo hozengata nougyo (inasaku) suisinn nouka no keiei bunnseki tyousa houkoku [Research report of management analysis about sustainable rice farming], Ministry of Agriculture, Forestry and Fisheries of Japan

Nakamura T, Ogura H (ed) (2012) Water quality improvement and ecosystem conservation of watershed by the winter-flooded organic farming rice-paddy. Lake Inba-numa Watershed Res Manage 1, pp 1–132

Nishikawa K (2013) Soshiki keieitai no tenkai to chiiki nougyo no kouzou hendou [Development of community farms and structural change of local agriculture]. In: Ando M (ed) Nihon nougyo no kouzou hendou [Structural change of Japanese agriculture]. Nourin Toukei Kyokai, Tokyo, pp 101–140

Noguchi R (2002) Ninaite no kouzou [Structure of agriculture actor]. In: Syogenji S (ed) 21 seiki nihon nougyo no kiso kouzou [Basic structure of Japanese agriculture in the 21st century]. Nourin toukei kyoukai, Tokyo, pp 132–169

Otake N (2005) Sado tou Niibo chiku ni okeru kankyo hozenngata inasaku no dounyu to tenkai heno kadai [Introduction and issues for development of sustainable rice farming at Niibo district in Sado island]. Saitama chiri [Saitama Geography] 29:19–30

Otake N (2010) Problem of paddy field rice cropping by the release of Toki in Sado-city. Stud Environ Symbiosis 3:78–88

Sekijima T, Kawaguchi Y (2009) Restoration scenario and capacity building for the resettlement of the Crested Ibis. Environ Res Q 155:130–138

Tanaka H, Kamioka M, Iwamoto H (2008) The measure and subject of environmentally conscious agriculture of the Toki no Tanbo wo Mamoru Kai of Niigata Sado. J Rural Community Stud 106:57–67

Watanabe R (2010) Toki-to kurasu sato dukuri ninsyo seido kara toki-tono kyouseigata syakai-no jitsugen he [From “toki-to kurasu sato dukuri” certification system to realization of symbiosis society with Japanese crested ibis]. Nouson-to toshi-wo musubu [Connecting rural areas and city] 60(9):36–42

Yagi H, Mineta T, Ashida T, Kurita H (2005) Farmland plot allocation for environmental conservation rice production considering irrigation system: a case study on winter-flooded rice fields. J Rural Plan Assoc 24:67–72

Yamaki T (1993) Jizokuteki inasaku keiei no nouhou to ninaite – Hokuriku chiiki no jirei wo sozai ni [Farming method and pillar of sustainable rice farming – case study in Hokuriku district]. Jpn J Farm Manage 30(4):15–25

Chapter 18
Consumer Preferences and Willingness to Pay for Eco-labeled Rice: A Choice Experiment Approach to Evaluation of Toki-Friendly Rice Consumption

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Abstract Eco-labeling systems to indicate the environmental sustainability of products have been implemented in many countries. In this study I evaluated the characteristics of consumer preference for eco-labeled rice using a hypothetical choice experiment conducted on members of the general public in the Tokyo and

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Osaka metropolitan areas. Subsequently, I used the contingent valuation method (CVM) to analyze consumer evaluations of Toki-friendly rice. In my investigation, the heterogeneity of consumer preference was considered using a latent class model as the consumer choice model. I found consumer heterogeneity and several classes of consumer preference in rice consumption, and it was apparent that some consumers were concerned about agrochemical usage in cultivation, and the biodiversity of paddy fields. This type of consumer might be a promising target for the purchase of eco-labeled rice. The results of this study also suggested that food safety or environmental issues alone were not sufficient to attract consumers. Taste should also be emphasized in the marketing of eco-labeled rice. The CVM analysis indicated that these consumers were more willing to pay for Toki-friendly rice than were general consumers.

Keywords Rice consumption • Latent class logit model • Choice experiment • CVM • Consumer behavior • WTP

Introduction

Environmental issues caused by pollution from industrial activities are longstanding and important social concerns. Eco-labeling systems that indicate the environmental sustainability of products have been implemented in many countries. For example, the Blue Angel label in Germany was introduced in 1978 and is the oldest eco-labeling system in the world. In Japan, guidelines for the eco-labeling of agricultural products were introduced in 1992. Consumer concerns regarding environmental issues are now an important determinant of food consumption.

On Sado Island in central Japan, the reintroduction of the crested ibis (toki; *Nipponia nippon*) was initiated in 2008, and more than 100 birds have been released into the human-dominated landscape (Satoyama). The restoration of suitable habitats for toki is crucial for the success of this ambitious reintroduction project. To restore food items for toki and biodiversity in paddy fields, the Sado Municipal Government established an eco-labeling system using toki as an iconic species. To be approved as Toki-friendly rice, farmers must comply with several prerequisites involving the implementation of wildlife-friendly farming practices (Usio et al. 2015).

However, implementing wildlife-friendly farming is more costly for farmers relative to conventional, modern farming techniques. Therefore, it is important to investigate consumer preferences for eco-labeled rice and to demonstrate price premiums for the Toki-friendly product to incentivize farmers to adopt wildlife-friendly farming practices.

Many studies have investigated consumer behavior toward eco-labeled food (e.g., apples (Blend and Van Ravenswaay 1999; Loureiro et al. 2002), vegetable and fruits (Moon et al. 2002), dairy (Iwamoto 2004; Elbakidze and Nayga 2012), rice (Aizaki 2005; Katada and Tanaka 2008; Ujiie 2010; Yabe and Hayashi 2011), tomatoes (Tsuge 2006), orange juice (Bougherara and Combris 2009), meat products (Lusk et al. 2007; Kehlbacher et al. 2012), salmon (Olesen et al. 2010; Irimajiri et al. 2012), and general foods (Sato and Okamoto 1996; Toma et al. 2012). Gallastegui (2002) undertook a comprehensive literature review. Lagerkvist and Hess (2011) conducted a meta-analysis of the relevant published literature and pointed out that there were few significant differences of willingness to pay for eco-labeled food among several counters in Europe. Most of the studies mentioned above indicated that consumers are willing to pay for attributes associated with environmental conservation.

Although some recent studies (e.g., Bougherara and Combris 2009; Ujiie 2010; Elbakidze and Nayga 2012) used non-hypothetical methodologies, such as an experimental auction or scanner data to record the purchase history of consumers, thus precluding any hypothetical bias, most have used hypothetical methods, such as choice experiments or the contingent valuation method (CVM) to analyze consumer behavior.

Most studies of Japanese consumption of eco-labeled food have considered rice consumption and have indicated that consumers have a positive willingness to pay (WTP) for eco-labeled rice (e.g. Aizaki 2005; Katada and Tanaka 2008; Ujiie 2010; Yabe and Hayashi 2011). In particular, Katada and Tanaka (2008) used the CVM to investigate consumer attitudes toward eco-labeled rice on Sado Island, and revealed that the WTP for eco-labeled rice was 8,093 yen (80 USD) per 10 kg with an additional WTP for toki reintroduction of 2,061 yen/10 kg. These estimated WTPs were quite high, but might have been biased because the respondents were visitors to Toki-no-mori Park, who were likely to be interested in environmental issues, such as toki conservation, and were thus likely to have a greater motivation to support eco-labeled products compared with general consumers.

In this paper, I first describe the characteristics of consumer preferences for eco-labeled rice using a choice experiment on general consumers in the Tokyo and Osaka metropolitan areas. Subsequently, I used the CVM to analyze the consumer evaluations of Toki-friendly rice. In my investigation, the heterogeneity of consumer preference was considered using a latent class model as the consumer choice model.

Survey and Data

A choice experiment was used to investigate consumer choice behavior (cf. Louviere et al. 2000). Respondents were asked to choose one response from a set of alternatives. I presented respondents with several hypothetical rice profiles and asked them to choose the alternative they would most like to purchase (cf. Table 18.1). The attributes and levels of the profiles are presented in Table 18.2. I focused on five rice attributes: area of origin, reduction of agrochemical usage, biodiversity of paddy fields, taste, and price.

To design profiles for the choice experiment, I used an orthogonal array and a shifting method for unlabeled design (Louviere et al. 2000). Ultimately, 49 choice

Table 18.1 An example choice set used in the questionnaire

	Rice 1	Rice 2	Rice 3	Rice 4
Rice producing area	Niigata	Akita	Hokkaido	Akita
Reduction of agrochemical usage	50 %	100 %	100 %	No reduction
Biomass	150 %	200 %	Normal level	300 %
Taste	3rd	3rd	2nd	3rd
Price	2,490 yen	2,240 yen	1,990 yen	2,490 yen
I want to purchase...	□	□	□	□

Source: Author's illustration

Table 18.2 Attributes and levels used in the choice experiment

Attribute	Description	Level
Rice producing area	Area (Prefecture) where rice was produced	Akita (Base), Niigata, Hokkaido
Reduction of agrochemical usage	Percentage reduction of agrochemical usage in rice cultivation compared to the usage in conventional farming	No reduction,
		30 % reduction,
		50 % reduction,
		80 % reduction,
		100 % reduction
Biodiversity of paddy fields	Percentage increase in the abundance of small aquatic animals in wildlife-friendly paddy fields relative to their abundance in conventional paddy fields.	Standard level, 150 %, 200 %, 300 %
Taste of rice	Grading (from 1 to 4) of rice taste, where 1 is worst and 4 is best	1, 2, 3, 4
Price of rice	Price per 5 kg (Japanese yen[a])	1,490 yen, 1,740 yen, 1,990 yen, 2,240 yen, 2,490 yen, 2,740 yen, 2,990 yen

Source: Author's illustration
[a]1 yen = 0.01 US dollars

sets were designed, which were then divided into seven blocks containing seven choice sets. Each block was assigned randomly to a respondent.

The consumer survey was performed in January 2012 by Intage Inc., (Tokyo), which is one of the largest market research companies in Japan. A total of 7,289 consumers, who were married females aged from 20 to 69 years, were randomly selected from a research panel managed by the market research company; 2,630 respondents completed the survey in full. The ratio of responses was 36.1 %. The questioner asked a question to determine general rice consumption, choice experiments of rice, which analyzed in the "Consumer choice model" section of this paper, a question used the CVM in the "Consumer evaluation of Toki-friendly rice and the effect of information" section to evaluate the consumers' WTP for Toki-friendly and collected socio-demographic characteristics of the respondents.

Socio-demographic characteristics are presented in Table 18.3.

Table 18.3 Socio-demographic characteristics of respondents

Number of children	0	41.0 %
	1	31.2 %
	2	23.3 %
	3	3.9 %
	4 or more	0.5 %
Income	<3 million yen	14.9 %
	<4 million yen	15.1 %
	<5 million yen	16.0 %
	<6 million yen	12.8 %
	<7 million yen	9.6 %
	<8 million yen	9.7 %
	<9 million yen	4.7 %
	<10 million yen	6.8 %
	10 million yen or more	10.4 %
Household size	1	1.8 %
	2	37.3 %
	3	29.4 %
	4	22.6 %
	5	5.4 %
	6 or more	2.2 %
Percentage of university or graduate school graduates among total respondents		32.4 %

Source: Author's calculation

Consumer Purchases of Rice in Japan: Descriptive Statistics

Before conducting a detailed analysis, consumer rice purchasing behavior was considered. Table 18.4 shows the frequency of purchase through several rice-purchasing channels. Several channels for rice purchase are available, but that used most frequently was the supermarket, with almost 60 % of respondents purchasing rice at a supermarket during the previous year. Co-ops (consumer cooperative societies) were also frequently used because most had weekly delivery systems. The internet was the third-largest rice-purchasing channel. The importance of this channel cannot be dismissed.

The most frequently purchased package sizes varied among channels (Table 18.5). In supermarkets, drug stores, co-ops, and farmer's markets, 5-kg packages were most commonly purchased. Ten-kilogram packages were popular in discount stores, specialty stores, and through internet shopping. In the case of direct purchases from farmers, packages greater than 30 kg were purchased most often. Therefore, it can be concluded that 5-kg packages were the most popular purchase in rice retail markets.

Table 18.6 shows how customers obtain information about the rice they purchase. Most consumers rely on their own experience and the opinions of family or

Table 18.4 Frequency of purchase by respondents for different rice-purchasing channels

	Twice per month or more (%)	Once per month (%)	Once per 2 months (%)	Once per 3 months (%)	Once per 6 months (%)	Once per year or less (%)	Rate of channel use (%)
Supermarket	7.4	18.6	12.2	8.6	6.2	3.8	56.8
Drug store	0.9	1.6	1.2	1.7	0.7	1.3	7.4
Discount store	0.4	1.6	1.7	1.3	1.2	0.7	6.8
Co-op	4.3	5.0	3.1	2.9	1.6	0.9	17.7
Specialty store	0.8	2.7	1.2	0.8	0.8	0.7	6.9
Farmer's market	0.2	0.6	0.7	0.8	0.7	0.6	3.5
Direct purchase from farmers	0.2	1.4	1.6	2.1	1.4	3.4	10.1
Internet	0.7	2.2	3.5	4.1	3.3	2.2	16.1

Source: Author's calculation

Table 18.5 Most frequently purchased rice package size by respondent

	Less than 2 kg (%)	2 kg (%)	5 kg (%)	10 kg (%)	30 kg or more (%)
Super market	0.7	6.1	61.4	31.3	0.5
Drug store	1.5	2.1	53.8	41.5	1.0
Discount store	0.6	2.2	34.6	60.3	2.2
Co-op	1.1	6.2	82.6	9.7	0.4
Specialty store	1.1	6.0	39.6	46.7	6.6
Farmer's market	3.3	15.2	47.8	19.6	14.1
Direct purchase from farmers	0.8	1.5	12.5	17.7	67.5
Internet	1.7	3.1	26.7	49.4	19.1

Source: Author's calculation

friends when buying rice. In contrast, information from the media such as television, books, or the internet was less often consulted. Thus, primary information is more important for consumers. Additionally, point-of-purchase information was effective in influencing consumer purchasing behavior. This suggests that package design and collaboration with retail shops are extremely important factors for rice marketing. To extend this to internet shopping, display of information on the ordering pages might be important.

Several varieties of eco-labeled rice in Japan are cultivated with the aim of conserving flagship species, such as fukurou (owl), kounotori (Oriental white stork; *Ciconia boyciana*), and toki (see Yabe and Hayashi 2011). Table 18.7

Table 18.6 Frequency of usage of different information sources when choosing rice

	Very often (%)	Often (%)	Rarely (%)	Never (%)
Own experience	42.2	40.5	9.9	7.4
Family or friends	16.0	38.2	26.3	19.5
Internet comments	4.6	16.1	33.1	46.2
Newspaper or books	1.3	11.9	37.4	49.5
TV program	1.2	15.1	36.4	47.2
Web page of provider	3.1	18.0	34.4	44.6
Media advertisement	4.7	21.9	33.1	40.2
Point-of-purchase advertising	9.5	37.8	24.3	28.4
Package advertising	9.4	37.9	25.8	26.9

Source: Author's calculation

Table 18.7 Consumer recognition of eco-labeled rice contributing to the conservation of flagship species in Japan

	Aware of		
	Have purchased (%)	Have not purchased (%)	Unaware of (%)
Fukurou mai (Tochigi)	0.19	1.67	98.14
Toki hikari (Niigata)	0.99	8.78	90.23
Hacchoutonbo mai (Niigata)	0.27	1.44	98.29
Toki to kurasu sato mai (Niigata)	1.10	3.00	95.89
Kari on mai (Miyagi)	0.38	1.98	97.64
Medaka no okome (Yamagata)	0.38	2.40	97.22
Kounotori hagukumu okome (Hyogo)	0.95	7.19	91.86
Kounotori no sato mai (Hyogo)	0.68	7.49	91.83

Source: Author's calculation

shows the consumer perceptions and purchase experiences of rice varieties that contribute to the conservation of these species. Over 90 % of respondents were unaware of these varieties of eco-labeled rice. Therefore, consumer perception of eco-labeled rice is clearly very low.

Consumer Choice Model

It is known that individual consumers have different preferences, but for research purposes economists assume the existence of a *representative consumer* whose behavior can be analyzed. However, recently the heterogeneity of consumer preferences has been recognized as an important factor for understanding consumer behavior. To capture this heterogeneity, many studies have used mixed models, known as random parameter models or multi-level models. In mixed models, the consumer preference parameter is assumed to have a certain distribution (see Train 2012).

A latent class model, which was used in this study, is a multi-level model approach. A latent class multinomial logit model (e.g. Kamakura and Russel 1989; Jain et al. 1994; Greene and Hensher 2003) assumes that the preference parameters of respondents have a discrete distribution.

Consider individual *i*'s indirect utility for rice *j*, which is composed of a deterministic component, V_{ij}, and a stochastic term, e_{ij}. Random utility, U_{ij}, is $U_{ij} = V_{ij} + e_{ij}$.V_{ij}, which is a function of the attributes of the rice *j*;

$$V_{ij} = \beta_i Z_j$$

where B_i is a preference parameter vector and Z_j is an attribute vector of the rice *j*.

When e_{ij} is assumed to be distributed under an i.i.d. type I extreme value distribution, the probability that an individual *i* will choose rice *j* ($P_i(J)$) is:

$$P_i(J) = \frac{\exp(V_{ij})}{\sum_{j \in D} \exp(V_{ij})}$$

where *D* is a choice set (McFadden 1974).

In a latent class model, Θ_i, which is a set of parameters of individual *i*, is supposed to distribute under a discrete probability distribution that has *c* support points and a probability of $\Theta_i = \Theta_c$ is $\pi(\Theta_c)$. Therefore, there are *C* classes in the preference parameter and the parameters of each individual constitute one class.

At this time, $\pi(\Theta_c)$, is a discrete probability, and therefore $\pi(\Theta_c)$ should satisfy the conditions of:

$$\sum_{c=1}^{C} \pi(\Theta_c) = 1$$

and

$$0 \leq \pi(\Theta_c) \leq 1$$

Many studies have assumed that:

$$\pi(\Theta_c) = \frac{e^{\lambda_c}}{\sum_{c=1}^{C} e^{\lambda_c}}$$

where λ_c is a determinant of the distribution, or a hyperparameter.

The probability of observing choice history J of individual i is as follows:

$$P_i(J_i) = \sum_c^C P_i\left(J_i \middle| \Theta_c\right)\pi(\Theta_c)$$

where $P_i\left(J \middle| \Theta_c\right) = \prod_t \left[P_{it}\left(j_{it}\middle|, \Theta_c\right)\right]$, and j_{it} is a choice outcome of individual i at choice opportunity t.

Thus, the log likelihood function lnL is defined as follows:

$$\ln L = \sum_{i=1}^N \ln P_i(J_i) = \sum_{i=1}^N \ln\left[\sum_c^C P_i\left(J_i \middle| \Theta_c\right)\pi(\Theta_c)\right]$$

Clustering for Individuals From the estimated coefficient of the model and individual choice histories, it was possible to estimate the classes to which each individual belongs by Bayesian inference. The posterior probability that individual i belongs to class $\hat{c}_i$ is as follows:

$$\pi_i\left(\hat{c} \middle| J_i\right) = \frac{\pi_{\hat{c}} P_i\left(J_i \middle| \hat{\Theta}_{\hat{c}}\right)}{\sum_{c=1}^3 \pi_c P_i\left(J_i \middle| \hat{\Theta}_c\right)}$$

It can be assumed that an individual's class is that with the largest posterior probability. This approach is a type of clustering method using consumer choice data.

MWTP The estimate of consumers' marginal willingness to pay (MWTP) for a change in one of the choice attributes (A) from one level i) to another level (j), ceteris paribus, (i.e., holding all other parameters constant except the attribute for which the WTP is being calculated) is given by the following equation:

$$\beta_{Ai} + \beta_p p_i = \beta_{Aj} + \beta_p p_j \quad \text{with} \quad p_j = p_i + x$$

where β_{Ai} and β_{Aj} are the coefficient estimates of levels i and j, respectively, for attribute A; β_p is the coefficient estimate of the linear price component; and p_i and p_j are the prices corresponding to levels i and j, respectively. Then,

$$x = \frac{\beta_{Ai} - \beta_{Aj}}{\beta_p}$$

where x is the amount of money consumers are willing to pay to move from level i of attribute A to level j.

Table 18.8 Independent variables of the consumer choice model[a]

Variables	Description
PRICE	Unit price of rice (Japanese yen/5 kg)
NIIGATA	if the rice is grown in Niigata, 1; otherwise, 0
HOKKAIDO	if the rice is grown in Hokkaido, 1; otherwise, 0
RCHEM	Percentage reduction of agrochemical usage relative to conventional farming
ENV	Percentage increase in the abundance of small aquatic animals in wildlife-friendly paddy fields relative to their abundance in conventional paddy fields
TASTE	Taste indicator of rice (4 levels)

Source: Author's calculation
[a]These variables were used in the model as determinants of the consumer utility function

To derive this choice model, I incorporated the independent variables shown in Table 18.8 and set four classes of consumer preference. In addition, I assumed that the coefficients of price in this model were not variable between classes to avoid complexity in explaining the results.

Estimation Results

The consumer choice model was derived using the maximum-likelihood method by an EM algorithm using NLOGIT 4.0. The estimated parameters of the model are given in Table 18.9. All parameters were significant at the $\alpha = 0.01$ level. This indicated that several classes of preferences differed from each other. The estimated probability that a respondent belonged to a particular class is also presented in Table 18.9. In this section, I discuss the characteristics of each class.

Class 1 Almost 8 % of the respondents fit this class of preference. The MWTP for NIIGATA was the highest of all classes. Thus, respondents with this type of preference were very loyal to Niigata rice. Additionally, the MWTP for ENV was high in comparison with classes 3 and 4. This suggests that consumers in class 1 prefer to buy rice cultivated in paddy fields with a rich biomass of small animals.

Class 2 Almost 30 % of respondents fit this class of preference. The MWTP for TASTE and RCHEM were substantially higher than the other classes. The MWTP for ENV was the highest of all classes. Therefore, consumers in this class gave serious consideration to the taste of rice, the reduction of agrochemical usage in rice cultivation, and the biodiversity of the paddy field where the rice was grown. Significantly, respondents who were conscious about food safety or the environment put a premium on the taste of rice.

Class 3 Almost 9 % of respondents fit this class preference. The MWTP for RCHEM and ENV were the lowest of all classes. Consumers in this class were not particularly concerned about the environment or food safety.

Table 18.9 The preference parameters for each class of consumer in the consumer choice model

	Coefficient	sd	t-value	p-value	MWTP (yen/5 kg)
Class 1					
PRICE	−0.0013	0.0000	−114.71	0.0000	–
NIIGATA	3.2855	0.2389	13.75	0.0000	2538.69
HOKKAIDO	−1.7238	0.3488	−4.94	0.0000	−1331.99
RCHEM	0.0066	0.0017	3.89	0.0001	5.12
ENV	0.0034	0.0007	4.65	0.0000	2.65
TASTE	0.6321	0.0748	8.45	0.0000	488.40
Class 2					
PRICE	−0.0013	0.0000	−114.71	0.0000	–
NIIGATA	0.7148	0.0391	18.27	0.0000	552.31
HOKKAIDO	0.3576	0.0422	8.48	0.0000	276.28
RCHEM	0.0260	0.0005	48.50	0.0000	20.08
ENV	0.0049	0.0002	22.59	0.0000	3.82
TASTE	1.3642	0.0224	60.89	0.0000	1054.08
Class 3					
PRICE	−0.0013	0.0000	−114.71	0.0000	–
NIIGATA	−1.2042	0.0798	−15.08	0.0000	−930.51
HOKKAIDO	1.5618	0.0630	24.80	0.0000	1206.77
RCHEM	0.0038	0.0009	4.43	0.0000	2.92
ENV	0.0011	0.0004	2.75	0.0059	0.86
TASTE	0.3951	0.0278	14.21	0.0000	305.32
Class 4					
PRICE	−0.0013	0.0000	−114.71	0.0000	–
NIIGATA	0.2679	0.0225	11.92	0.0000	206.99
HOKKAIDO	−0.4369	0.0258	−16.94	0.0000	−337.58
RCHEM	0.0093	0.0003	33.31	0.0000	7.18
ENV	0.0005	0.0001	4.14	0.0000	0.40
TASTE	0.1834	0.0114	16.05	0.0000	141.70
Probability that an individual has a preference for each class					
Class 1	0.0828	0.0181	4.58	0.0000	–
Class 2	0.3004	0.0189	15.94	0.0000	–
Class 3	0.0934	0.0162	5.75	0.0000	–
Class 4	0.5234	0.0146	35.90	0.0000	–

Source: Author's calculation

Class 4 More than 50 % of the respondents fit this class of preference, and thus class 4 was the largest class. They liked Niigata rice, cared about the reduction of agrochemicals, and were environmentally conscious. However, the absolute values of MWTP are not large. Therefore, consumers in this class had moderate preferences.

Class 2 represents an important class of customers for eco-labeled rice because this class is concerned about food safety and environmental issues to the extent that they place a high premium on rice attributes related to these issues. In addition, it should be emphasized that it is important to inform consumers not only about the reduction of agrochemical use in paddy fields but also about the taste of rice. This class of consumer emphasized the taste of rice, and so this is important for producers to consider if their product is to be attractive. Most providers of eco-labeled rice in Japan have emphasized the food safety and environmental benefits of their products; however, this approach might not be optimum. If providers wish to focus on Class 2 consumers, the above results suggest that they should reconsider emphasizing the taste of their rice.

Consumer Evaluation of Toki-Friendly Rice and the Effect of Information

In the previous section, it was shown that consumers who were willing to pay for environmental attributes, such as the reduction of agrochemical usage and increased paddy field biodiversity, were members of Class 2. In this section, an evaluation of Toki-friendly rice for each class is provided. To estimate the WTP for Toki-friendly rice, I adopted a payment card-style CVM. Following the choice experiment outlined above, respondents answered questions on this contingent valuation. As illustrated in Table 18.10, the WTP was captured as an additional WTP for Toki-friendly rice in comparison with Niigata rice.

Additionally, the influence of information about Toki-friendly rice on consumer evaluation of the product was evaluated. Prior to asking the WTP question for Toki-friendly rice, information about the cultivation method was provided to respondents. The following information was provided:

Table 18.10 Payment card CVM questionnaire

Price of Niigata rice (per 5 kg)	Price of Toki-friendly rice (per 5 kg)	I will purchase Niigata rice	I will purchase Toki-friendly rice
1,980 yen	1,980 yen	☐	☐
	2,040 yen	☐	☐
	2,100 yen	☐	☐
	2,160 yen	☐	☐
	2,220 yen	☐	☐
	2,280 yen	☐	☐
	2,340 yen	☐	☐
	2,400 yen	☐	☐
	2,460 yen	☐	☐
	2,520 yen	☐	☐

Source: Author's illustration

Basic information about Toki-friendly rice:

1. The usage of agrochemicals during the rice cultivation period is less than half that used in conventional farming.
2. In addition, one of the following four biodiversity-enhancing practices is implemented:
   (a) Winter flooding is encouraged to provide foraging habitats for toki.
   (b) A diversion ditch is created along a levee to retain water during the mid-season drainage period to prevent the desiccation of small aquatic animals.
   (c) A fish path is created between a paddy field and the adjacent drainage ditch to facilitate fish migration.
   (d) Fallow flooding (biotope) is implemented adjacent to a cultivated paddy field to provide habitats for wildlife species.

Additional information about Toki-friendly rice:

1. The usage of agrochemicals has been reduced by 30 % or more in all paddy fields on Sado Island.
2. Two yen from the sale of each kilogram of Toki-friendly rice are donated to toki conservation projects.
3. The effectiveness of wildlife-friendly farming on paddy field biodiversity; e.g., "the number of small aquatic animals in wildlife-friendly paddy fields has increased by 1.4 times," "the abundance of tubificids in wildlife-friendly paddy fields has increased by 200 times," "the biomass of small animals in wildlife-friendly paddy fields has increased threefold," and "fish, which are not usually present in conventional paddy fields, survive in wildlife-friendly paddy fields."

This basic information is provided on the actual packaging of Toki-friendly rice. In this way, consumers can access the information immediately when they consider purchasing rice at the market. The additional information was explained to participants in detail, and contains quantitative explanations of the effects of the toki-friendly farming method.

Because the effect of toki-friendly farming on paddy field biodiversity had not been scientifically evaluated at the time of the consumer survey, the information provided above was based on the results of Kounotori-friendly farming in Toyooka City, Hyogo Prefecture. Kounotori-friendly farming was introduced to Toyooka's agriculture (from the 2003 fiscal year) prior to toki-friendly farming being introduced to agriculture in Sado (from the 2008 fiscal year).

I divided respondents into two groups to evaluate the effects of the additional information on consumer WTP for Toki-friendly rice. One group was provided with only basic information and the other was provided with both basic and additional information.

Table 18.11 Estimated additional WTP for Toki-friendly rice in each class

	Estimated value	Std. err.	p-value
WTP			
Class 1	182.8	29.6	0.000
Class 2	180.3	14.8	0.000
Class 3	153.8	28.2	0.000
Class 4	143.5	10.5	0.000
Change in WTP resulting from the provision of additional information			
Class 1	26.4	41.3	0.522
Class 2	−1.2	21.0	0.954
Class 3	23.5	37.6	0.531
Class 4	50.5	14.9	0.001

Source: Author's calculation

The model used to estimate the WTP was as follows:

$$WTP = \beta_1 class1 + \beta_2 class2 + \beta_3 class3 + \beta_4 class4 \\ + \beta_{1a} class1 \cdot AI + \beta_{2a} class2 \cdot AI + \beta_{3a} class3 \cdot AI + \beta_{4a} class4 \cdot AI$$

where class j is a dummy variable that was 1 if the respondent had class j preference, and otherwise was 0. AI is a dummy variable that was 1 if the respondent was provided with the additional information, and otherwise was 0. Beta j and beta j_{a} were parameters of this model. Beta j represents the WTP of the respondents in class j, and beta j_{a} represents the variation in WTP among respondents in class j that could be attributed to the provision of additional information.

These WTP data were collected using payment cards, and therefore an ordinary least-square estimation would be biased. Therefore, interval regression was conducted to estimate the model. The results of the estimation are presented in Table 18.11.

WTP for Toki-Friendly Rice

All classes of consumer had a significantly higher WTP for Toki-friendly rice in comparison with Niigata rice. Toki-friendly rice was more favored than Niigata rice in general. The WTP for Toki-friendly rice for classes 1 and 2 was larger than classes 3 and 4 by almost 30 Japanese yen. Table 18.12, shows the results of a Wald test comparing the WTP between classes. The results indicated that the difference in WTP between class 4, to which more than half of the respondents belonged, and class 2 was significant. This indicates that consumers who were concerned about the reduction of agrochemical usage and paddy field biodiversity were willing to pay more for Toki-friendly rice. Thus, the consumers in class 2 constitute the ideal target market for Toki-friendly rice.

Table 18.12 Results of a Wald test to determine the difference in WTP according to class

Hypothesis	p-value
WTP (class1) = WTP (class2)	0.9396
WTP (class1) = WTP (class3)	0.4792
WTP (class1) = WTP (class4)	0.2115
WTP (class2) = WTP (class3)	0.4067
WTP (class2) = WTP (class4)	0.0424
WTP (class3) = WTP (class4)	0.7324

Source: Author's calculation

Effect of Additional Information

The provision of additional information about Toki-friendly rice significantly increased the WTP of class 4. Therefore, the provision of detailed information regarding wildlife-friendly farming seems to be effective in encouraging more than half of consumers. Although it seems paradoxical that class 2 consumers were unaffected by the provision of additional information, the basic information likely sufficiently motivated such consumers to purchase the product, because these consumers were sensitive to environmental issues. Conversely, to motivate class 4 consumers, the basic information was insufficient and provision of detailed information was necessary.

Conclusion

I analyzed the consumption of eco-labeled rice in Japan using a hypothetical choice experiment for Toki-friendly rice. Additionally, I investigated the WTP for Toki-friendly rice using CVM. I found that consumer heterogeneity and several classes of consumer preference could be defined in rice consumption. I conclude that class 2 (concern regarding agrochemical usage in cultivation, the environment of paddy fields, and the taste of rice) should be considered the most important class for eco-labeled rice consumption. The results suggest that food safety or environmental issues alone are not sufficient to attract class 2 consumers. Rice taste should also be emphasized in the marketing of eco-labeled rice. Class 2 consumers were more willing to pay for Toki-friendly rice than were other classes. Therefore, the consumers in class 2 are potential customers for Toki-friendly rice.

The other classes also indicated a higher WTP for Toki-friendly rice in comparison with Niigata rice. The provision of detailed, quantitative information about wildlife-friendly farming significantly increased the WTP of class 4 consumers, to which most respondents belonged. Therefore, it is crucial to continue scientific monitoring of the effectiveness of wildlife-friendly farming and to provide detailed information to potential consumers. As shown in Table 18.6, many consumers rely on packaging information or information provided at the point-of-purchase when they purchase rice, and thus explanations of the effect of farming on toki must be conveyed with precision and succinctness on the packaging or at the point-of-purchase.

The results indicate that most consumers would be willing to pay for Toki-friendly rice and support conservation efforts on Sado Island by purchasing the rice. However, as discussed in the "Rice consumption in Japan: Descriptive statistics" section, most consumers are unaware of Toki-friendly rice. Thus, Toki-friendly rice must be publicized more widely. The results of this study will improve the understanding of the requirements of potential purchasers and facilitate implementation of social mechanisms to improve environmental quality by encouraging voluntary *donations* by consumers (see Langen 2013); i.e., purchasing goods affiliated with environmental issues.

As Ujiie (2010) and other studies have shown, a preference for eco-labeled food is influenced not only by public or altruistic motivations, such as environmental consciousness, but also by personal or selfish motivations, such as food safety concerns or taste. It is important to recognize how these different motivations influence consumer preferences toward eco-labeled products. This is a potential topic for future analyses.

References

Aizaki H (2005) Choice experiment analysis of consumers' preference for ecologically friendly rice. Agric Inf Res 14(2):85–96 (in Japanese)

Blend JR, Van Ravenswaay EO (1999) Measuring consumer demand for ecolabeled apples. Am J Agric Econ 81(5):1072–1077

Bougherara D, Combris P (2009) Eco-labelled food products: what are consumers paying for? Eur Rev Agric Econ 36(3):321–341

Elbakidze L, Nayga RM (2012) The effects of information on willingness to pay for animal welfare in dairy production: application of nonhypothetical valuation mechanisms. J Dairy Sci 95(3):1099–1107

Gallastegui GI (2002) The use of eco-labels: a review of the literature. Eur Environ 12(6):316–331

Greene WH, Hensher DA (2003) A latent class model for discrete choice analysis: contrasts with mixed logit. Transp Res B 37(8):681–698

Irimajiri M et al (2012) Assessing attitudes toward and public support of the welfare of farm animal. Anim Behav Manag 48(2):66–78

Iwamoto H (2004) Consumers' willingness-to-pay for HACCP and eco labeled milk. Hokkaido J Agric Econ 11(2):48–60 (in Japanese)

Jain DC et al (1994) A random coefficients logit brand choice model applied to panel data. J Bus Econ Stat 12(3):317–329

Kamakura WA, Russel GJ (1989) A probabilistic choice model for market segmentation and elasticity structure. J Mark Res 26(3):379–390

Katada M, Tanaka H (2008) Valuing the low fertilizer and agricultural chemical rice produced in creating a habitat for returning Japanese Ibis. Agric Inf Res 17(1):6–12 (in Japanese)

Kehlbacher A et al (2012) Measuring the consumer benefits of improving farm animal welfare to inform welfare labelling. Food Policy 37(6):627–633

Lagerkvist CJ, Hess S (2011) A meta-analysis of consumer willingness to pay for farm animal welfare. Eur Rev Agric Econ 38(1):55–78

Langen N (2013) Ethics in consumer choice. Springer Fachmedien Wiesbaden, Wiesbaden
Loureiro ML et al (2002) Will consumers pay a premium for eco-labeled apples? J Consum Aff 36:203–219
Louviere JJ et al (2000) Stated choice methods: analysis and applications. Cambridge University Press, Cambridge/New York
Lusk J et al (2007) Public preferences and private choices: effect of altruism and free riding on demand for environmentally certified pork. Environ Resour Econ 36(4):499–521
McFadden D (1974) Conditional logit analysis of qualitative choice behavior. In: Zarembka P (ed) Frontiers in econometrics. Academic, New York, pp 105–142
Moon W et al (2002) Willingness to pay for environmental practices: implications for eco-labeling. Land Econ 78(1):88–102
Olesen I et al (2010) Eliciting consumers' willingness to pay for organic and welfare-labelled salmon in a non-hypothetical choice experiment. Livest Sci 127(2):218–226
Sato S, Okamoto N (1996) Farm animal welfare trend in Japan. Jpn J Livest Manag 32(2):43–52 (in Japanese)
Toma L et al (2012) Consumers and animal welfare. A comparison between European Union countries. Appetite 58(2):597–607
Train K (2012) Discrete choice methods with simulation, 2nd edn. Cambridge University Press, Cambridge/New York
Tsuge T (2006) Estimation of the willingness to pay for the environmentally friendly agricultural products. Doshisha Univ Econ Rev 57(4):263–280 (in Japanese)
Ujiie K (2010) Consideration for the public good and food consumption. J Food Syst Res 17(3):270–275 (in Japanese)
Usio N, Saito R, Akanuma H, Watanabe R (2015) Effectiveness of wildlife-friendly farming on aquatic macroinvertebrate diversity on Sado lsland in Japan. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_7
Yabe M, Hayashi T (2011) Valuation of biodiversity in life brand rice. Sci Bull Faculty Agric Kyushu Univ 66(2):21–32 (in Japanese)

Part IV
Integrating Human Dimensions into Ecological Restoration

Chapter 19
Linking Ecosystem and Socioeconomic Dynamics for the Effective Management of Agricultural Landscapes

Hiroyuki Yokomizo

Abstract Biodiversity in paddy fields and the quality of habitats for aquatic wildlife may directly or indirectly depend on the purchasing behavior of consumers and whether farmers practice wildlife-friendly agriculture. The behavior of farmers and consumers is affected by the status of ecosystems as well as local community social concerns. Thus, it is necessary to consider the status of ecosys-tems and human behavior to properly manage agricultural landscapes and local economies, which result in increases in biodiversity, wildlife-friendly agriculture,

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and wildlife-friendly rice sales. Strategies for achieving these goals include conservation efforts for paddy fields, a subsidization scheme for certified wildlife-friendly rice, and improvement of rice quality. In this study, I developed a coupled ecological and social dynamics model to derive the optimal management strategies for agricultural landscapes. I found that increasing the attractiveness of wildlife-friendly rice was an effective management strategy.

Keywords Biodiversity • Ecosystems • Management • Socioeconomic factors • Social pressure • Social concern • Utility • Wildlife-friendly agriculture

Introduction

Biodiversity in paddy fields and the quality of habitats for aquatic wildlife may directly or indirectly depend on two factors: whether wildlife-friendly (WF) agriculture techniques are used by farmers and the purchasing behavior of consumers. WF agriculture not only enhances biodiversity in agricultural landscapes (Usio et al. 2015), but WF farmers also tend to believe they can obtain additional revenue from WF rice as compared with rice produced using conventional practices (Nakamura et al. 2014). Because farming practices are affected by consumer purchasing behavior, biodiversity indirectly depends on the purchasing behavior of consumers.

Empirical evidence supports the effect that farmers' and consumers' behavior has on the state of biodiversity in paddy fields. According to a study of farmers on Sado Island, Japan, WF farmers had a significantly stronger belief than conventional farmers that WF agriculture enhanced biodiversity (Nakamura et al. 2014). Furthermore, a survey of rice consumers revealed that consumers who purchased certified WF rice tended to believe that WF agriculture enhanced total abundance in paddy fields, even though rice quality was also a purchasing consideration (Ujiie 2015).

The behavior of farmers and consumers is also affected by other people's behavior. Compared with conventional farmers, WF farmers are more likely to associate with other WF farmers, and to be aware of the expectations of consumers and the local government (Nakamura et al. 2014). Likewise, the purchasing behavior of rice consumers is likely to be affected by other consumers, such as their family and acquaintances (Ujiie 2015). Hence, consumers of WF rice may lead other rice consumers to purchase WF rice rather than rice produced using conventional practices.

Although working cooperatively with the environment incurs economic costs, the cooperative tendency is determined not only by economic factors, but also by psychological factors. Experiments have shown that people cooperate to protect the environment when the people around them cooperate, and those who do not cooperate sufficiently are punished (Fehr and Gächter 2000; Fischbacher et al. 2001; Pillutla and Chen 1999). In addition, when informed about environmental problems, the level of peoples environmental cooperation was shown to be higher than when they were not informed (Milinski et al. 2006).

The status of ecosystems and human behavior influence each other, and coupled ecological and social dynamics studies have provided useful insights for effective environmental and renewable resource management (Coutts et al. 2013; Figueiredo and Pereira 2011; Furuzono et al. 2013; Iwasa et al. 2007, 2010; Satake et al. 2007; Satake and Iwasa 2006; Suzuki and Iwasa 2009a, b). For example, Iwasa et al. (2007) studied farmers' choices between two agriculture methods: an environmentally friendly option (reduced phosphorus release from the farmland, but more costly) or an economic option (lower costs, but greater phosphorus release). Surprisingly, the environmentally friendly option, which minimized nutrient discharge through technological advances to mitigate pollution levels, may ultimately result in increased pollution because people may lose their willingness to cooperate once a low pollution level is achieved (Iwasa et al. 2007). It is only possible to appreciate this paradoxical situation by considering ecological and social dynamics.

Another consideration when devising conservation plans for local environments is the importance of revitalizing the local economy. Hence, optimal strategies need to be created to meet both criteria.

In this study, I developed a model that aims to simultaneously increase the biodiversity in a paddy field agricultural system, the proportion of WF farmers, and the sales of WF rice to achieve an economically sustainable local society. Strategies to reach these goals included conservation efforts in paddy fields, a subsidy scheme for certified WF rice, and increasing the attractiveness of WF rice for consumers.

Model

Ecological and Socioeconomic Dynamics

The state of ecosystems and the behavior of farmers and consumers interact with each other. The conceptual framework model (see Fig. 19.1) depicts the state of the ecosystem, represented by the total abundance in the paddy field. Farmers have two options: conducting WF farming or conventional farming. Consumers of rice have two options: purchasing or not purchasing WF rice. The model is based on four

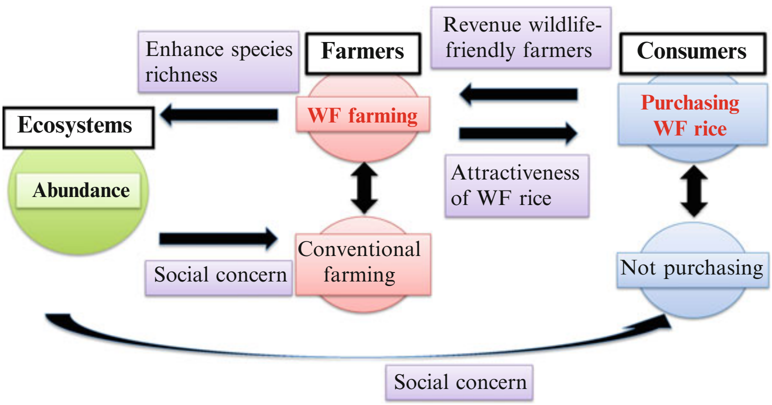

Fig. 19.1 The theoretical links between ecosystem and human dynamics

assumptions: (1) WF farming enhances total abundance in agricultural landscapes; (2) farmers' and consumers' behavior is affected by social concerns for the status of ecosystems; (3) the purchasing behavior of consumers also depends on the attractiveness of WF rice, which is related to the eating quality of the rice and the marketing strategy; and (4) farmers tend to apply WF farming when WF is economically beneficial. Its expected outcome was that the number of WF farmers should increase with the number of consumers who purchase WF rice.

Abundance and Social Concern

I assumed that the total abundance in an agricultural landscape, Z, is proportional to the fraction of WF farmers, X_C (cooperators) in a focal region. Social concern, Q, monotonically decreases as the total abundance increases in agricultural landscapes. I also assumed that farmers and consumers have the same degree of social concern, Q. Abundance in an agricultural landscape and social concern at time t, $Z(t)$, and $Q(t)$, respectively, are expressed by the following equations:

$$Z(t) = aX_C(t) + b, \tag{19.1}$$

$$Q(t) = -kZ(t) + h, \tag{19.2}$$

where a, b, k, and h are constants.

Dynamics of People's Behavior

The following equations were applied to measure the dynamics of farmers' and consumers' behavior: those who cooperate and those who do not.

If Y_C is the fraction of consumers who choose the WF option (cooperators), then $X_N(=1–X_C)$ and $Y_N(=1–Y_C)$ are the fraction of farmers and consumers who choose the economical option (non-cooperators), respectively. Farmers and consumers are likely to choose the option with higher utility.

Utility of Farmers

The utility values of cooperators and non-cooperators among farmers, U_{X_C} and U_{X_N}, respectively, are calculated below.

$$U_{X_C} = \lambda_X - c_{X_C} + dY_C \tag{19.3}$$

$$U_{X_N} = \lambda_X - \gamma_X(1 + \xi_X X_C)Q \tag{19.4}$$

The basic level of utility is λ_X and c_{X_C} is the additional cost of WF farming as compared with conventional farming. The additional revenue from conducting WF farming, Y_C, increases with the number of consumers of WF rice, and d is the increase in the benefit of WF farming per Y_C. I assumed that sales of WF rice and conventional rice in a focal region are non-competitive, meaning that sales of conventional rice in a focal region is fixed and an increase in consumers of WF rice does not decrease the utility of conventional farmers. Hence, total sales of rice in a focal region increases with the consumption of WF rice. The equation $\gamma_X(1+\xi_X X_C)$ Q indicates social pressure on farmers, where γ_X is the basic level of social pressure, $(1+\xi_X X_C)$ indicates the conformist tendency, which increases as more farmers conduct WF farming, and Q indicates social concern for the status of the ecosystem, which increases when total abundance in the paddy environment decreases (see Eq. 19.2).

Utility of Consumers

The utility values of cooperators and non-cooperators among consumers are denoted by U_{Y_C} and U_{Y_N}, respectively, and are calculated as follows.

$$U_{Y_C} = \lambda_Y - c_{Y_C} \tag{19.5}$$

$$U_{Y_N} = \lambda_Y - \gamma_Y(1 + \xi_Y Y_C)Q \tag{19.6}$$

The basic level of utility is λ_Y, and c_{Y_C} is the additional cost of purchasing WF rice compared with conventional rice (WF rice is usually more expensive than conventional rice). The term $\gamma_Y(1+\xi_Y Y_C)Q$ indicates the social pressure on consumers, where γ_Y is the basic level of social pressure, and $(1+\xi_Y Y_C)$ indicates the conformist tendency, which increases as more consumers purchase WF rice.

Individual Decision-Making for Farmers and Consumers

Although farmers and consumers are more likely to choose an option with higher utility, I adopted a probabilistic choice model (McFadden 1981) because they choose an option probabilistically by comparing the utility. The transition probabilities are presented as follows.

$$Pr[X_N \rightarrow X_C] = \frac{q}{1 + e^{-\beta\left(U_{X_C} - U_{X_N}\right)}} \tag{19.7}$$

$$Pr[X_C \rightarrow X_N] = \frac{q}{1 + e^{-\beta\left(U_{X_N} - U_{X_C}\right)}} \tag{19.8}$$

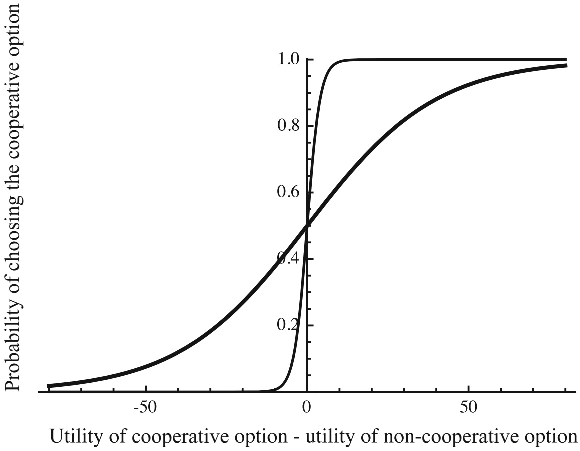

Fig. 19.2 Probability of choosing the cooperative option for farmers, $Pr[X_N \rightarrow X_C]$, or consumers, $Pr[Y_N \rightarrow Y_C]$. The probability increases with the difference between the utility of the cooperative versus non-cooperative option. The larger the value of β, the higher the probability of choosing the option with higher utility. *Bold line*: $\beta = 0.05$ and *thin line*: $\beta = 0.5$

$$Pr[Y_N \rightarrow Y_C] = \frac{q}{1 + e^{-\beta\left(U_{Y_C} - U_{Y_N}\right)}} \tag{19.9}$$

$$Pr[Y_C \rightarrow Y_N] = \frac{q}{1 + e^{-\beta\left(U_{Y_N} - U_{Y_C}\right)}} \tag{19.10}$$

Farmers and consumers with a conservative attitude, q, are reluctant to change their option immediately, even if the utility of the alternative is very high, and β indicates the sensitivity of the transition probability to the difference in utility between the two options. The dynamics in Eqs. 19.7, 19.8, 19.9, and 19.10 are called logit dynamics, and are commonly adopted to describe changes in people's behavior (Hofbauer and Sigmund 2003). Figure 19.2 shows the probability of farmers or consumers choosing the cooperative option, $Pr[X_N \rightarrow X_C]$ or $Pr[Y_N \rightarrow Y_C]$. When β is infinitely large, farmers and consumers choose the option with higher utility with a probability of 1. Conversely, when β is infinitely small, farmers and consumers choose their options randomly. The following equations show the fraction of cooperators at time $t + 1$:

$$\begin{aligned} X_C(t+1) = X_C(t) &+ \frac{q}{1 + e^{-\beta\left(U_{X_C} - U_{X_N}\right)}}(1 - X_C(t)) \\ &- \frac{q}{1 + e^{-\beta\left(U_{X_N} - U_{X_C}\right)}} X_C(t), \end{aligned} \tag{19.11}$$

$$\begin{aligned} Y_C(t+1) = Y_C(t) &+ \frac{q}{1 + e^{-\beta\left(U_{Y_C} - U_{Y_N}\right)}}(1 - Y_C(t)) \\ &- \frac{q}{1 + e^{-\beta\left(U_{Y_N} - U_{Y_C}\right)}} Y_C(t). \end{aligned} \tag{19.12}$$

It is not necessary that the values of q in Eqs. 19.11 and 19.12 be the same, but they were assumed to be the same in this study.

Management Strategy

With the aim of environmental conservation and revitalization of the local economy, the management objectives were set to increase (1) total abundance in the paddy field, (2) fraction of WF farmers, and (3) sales quantity of WF rice. To determine the degree of variable manipulation to achieve these management objectives, I performed a qualitative analysis.

Direct Conservation of the Paddy Environment, *e*

Other efforts to conserve the paddy environment, unrelated to WF farming, such as the construction of a biotope, increase the abundance of aquatic species. I assumed that the increase in abundance was proportional to the level of conservation effort, as follows:

$$Z(t) = aX_C(t) + b + f_e e(t), \tag{19.13}$$

where $e(t)$ is conservation effort level in time t, and f_e is an efficiency coefficient. I also assumed that abundance does not depend on the conservation effort invested in the past.

Subsidy for WF Farming, *s*

Provision of a subsidy for WF farming increases the utility of WF farmers, U_{X_C}, by $f_s s(t)$. The subsidy compensates for the additional costs with WF farming, c_{X_C}, and the utility of WF farming becomes:

$$U_{X_C} = \lambda_X - c_{X_C} + dY_C + f_s s(t), \tag{19.14}$$

where f_s is the increase in utility when the unit of $s(t)$ increases.

Increase in Attractiveness of WF Rice, *v*

Attractiveness of WF rice, v, increases the utility of consumers of WF rice as follows:

$$U_{Y_C} = \lambda_Y - c_{Y_C} + f_v v, \tag{19.15}$$

where f_v is the increase in utility when the unit of v increases. The attractiveness of WF rice can be enhanced by improving the quality of rice or by advertising.

Results and Discussion

Effect of Conservation Effort

According to the model, total abundance increased with the level of conservation effort, but the fractions of WF farmers and consumers of WF rice decreased with the level of conservation effort (Fig. 19.3). These trends arose because conservation efforts enhanced abundance in the paddy environment, but environmental concern decreased as abundance recovered (see Eq. 19.2), and social pressure on farmers and consumers to cooperate also declined. Thus, investing in paddy conservation alone was not a sustainable strategy to increase abundance as well as the fraction of WF farmers and WF rice consumers.

Effect of a Subsidy for WF Farmers

Provision of a subsidy for WF farmers increased the fraction of WF farmers (Fig. 19.4), which, in turn, enhanced total abundance in the paddy environment. However, the fraction of consumers of WF rice decreased as social concern declined. Thus, a subsidy alone cannot increase the abundance and fraction of cooperative farmers and consumers.

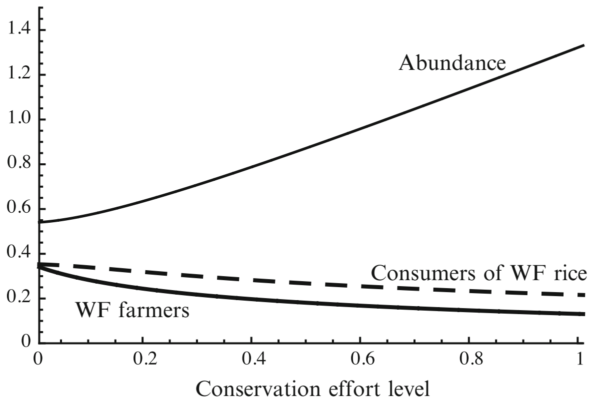

Fig. 19.3 Effect of conservation effort on abundance and the fractions of cooperative farmers and consumers. The graph shows abundance and fractions of cooperative farmers and consumers at $t = 100$. Parameter values are: $\lambda_X = 3$, $c_{X_C} = 80$, $c_{X_N} = 20$, $d = 0.1$, $\gamma_X = 10$, $\xi_X = 5$, $f_e = 1$, $\lambda_Y = 2$, $c_{Y_C} = 60$, $c_{Y_N} = 20$, $\gamma_Y = 2$, $\xi_Y = 20$, $a = 1$, $b = 0.2$, $k = 0.5$, $h = 2$, $q = 1$, $\beta = 0.05$, $X(0) = 0.3$, $Y(0) = 0.3$

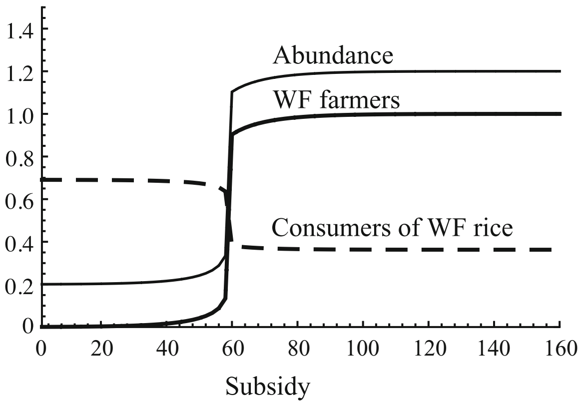

Fig. 19.4 Effect of subsidy on abundance and fractions of cooperative farmers and consumers. The graph shows abundance and fractions of cooperative farmers and consumers at equilibrium states $t = 100$. Parameter values are: $\lambda_X = 3, c_{X_C} = 130, c_{X_N} = 20, d = 0.1, \gamma_X = 10, \xi_X = 10, f_s = 1, \lambda_Y = 2, c_{Y_C} = 60, c_{Y_N} = 40, \gamma_Y = 2, \xi_Y = 10, a = 1, b = 0.2, k = 0.5, h = 2, q = 1, \beta = 0.08, X(0) = 0.3, Y(0) = 0.3$

Effect of Increasing the Attractiveness of WF Rice

Total abundance and the fractions of WF farmers and WF rice consumers increased as attractiveness of WF rice increased (Fig. 19.5). As the utility of WF rice consumers increased with WF rice attractiveness, the fraction of consumers of WF rice grew, which, in turn, increased the revenue of WF farmers. As a result, the fraction of WF farmers increased and total abundance in the paddy environment is enhanced.

Although retaining WF rice attractiveness at a high level requires effort, the effect of the improvement in rice quality, or recognition of WF rice, lasts a long time. Management strategies that increase the attractiveness of WF rice show promise for enhancing biodiversity and revitalizing the local economy.

Future Directions

I used a simple mathematical model to derive qualitative results that suggested effective management strategies for the conservation of local paddy environments and revitalization of the local economy. Additional ecological and sociological studies are required, however, to further develop this research.

First, I assumed that total abundance simply depends on the current fraction of WF farmers. Field research to elucidate the details of the relationship between the fraction of WF farmers and abundance is required because the relationship is likely to be complex and involve other factors.

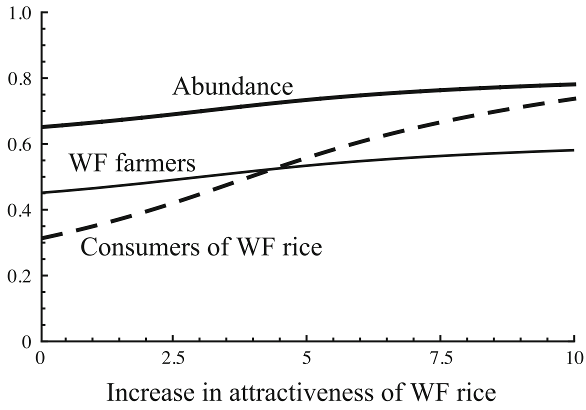

Fig. 19.5 Effect of the attractiveness of wildlife-friendly rice on abundance and fractions of cooperative farmers and consumers. The graph shows abundance and fractions of cooperative farmers and consumers at $t = 100$. Parameter values are: $\lambda_X = 3$, $c_{X_C} = 80$, $c_{X_N} = 20$, $d = 5$, $\gamma_X = 10$, $\xi_X = 5$, $f_v = 1$, $\lambda_Y = 2$, $c_{Y_C} = 60$, $c_{Y_N} = 20$, $\gamma_Y = 2$, $\xi_Y = 20$, $a = 1$, $b = 0.2$, $k = 0.5$, $h = 2$, $q = 1$, $\beta = 0.05$, $X(0) = 0.3$, $Y(0) = 0.3$

Second, we need to identify what ecosystem traits affect the behavior of farmers and consumers. Although I used total abundance to reflect the state of the ecosystem, the number of species could have greater effects on human behavior.

Third, I did not consider that an increase in abundance, as a result of WF farming, enhances attractiveness of WF rice. In this model, fractions of WF farmers and consumers of WF rice decreased with abundance because social concern decreased with abundance. However, consumers may be attracted by WF rice when WF farming enhances abundance. Another possible assumption to consider in future research is that attractiveness of WF rice increases with abundance, which may clarify the importance of advertising the benefits of WF farming.

Finally, we need to further clarify which factors affect the utility values of WF farmers and consumers, and revise Eqs. 19.3, 19.4, 19.5, 19.6, 19.14, and 19.15 accordingly. We also need to estimate parameter values, such as the attractiveness of WF rice, v, and conformist tendency (γ_X, ξ_X, γ_Y, or ξ_Y). Attractiveness can be estimated by examining the relationship between rice quality and WF rice sales. Conformist tendency is estimated by how WF farmers and consumers of WF rice increase with the fraction of cooperators.

In addition to ecosystem conservation efforts, subsidizing WF farmers, and increasing the attractiveness of WF rice, other management strategies exist. One is to strengthen the conformist tendency (increasing γ_X, ξ_X, γ_Y, or ξ_Y) by increasing communication among local community members, and developing community closeness through group work or local festivals (Suzuki and Iwasa 2009a). Expanding community interactions among WF rice consumers could be key to effective management of paddy ecosystems.

Management incurs economic costs, so it is important to consider the cost effectiveness of management strategies. As the conservation of local environments and revitalization of local economies are not necessarily equally important, multi-criteria decision analysis (e.g., Drechsler 2004; Kangas et al. 2010; Runge et al. 2011) could aid effective management of agricultural landscapes.

Conclusion

Coupling ecosystem and human dynamics is critical when attempting to restore local environments and revitalize local economies. According to the model presented here, providing a subsidy or conservation effort to increase abundance is not sufficient to achieve both goals. Rather, enhancing the attractiveness of WF rice was the most effective management strategy. We need to develop effective management strategies for paddy agricultural systems that are sustainable long term. The collaboration between natural scientists and social scientists is crucial for attaining this goal.

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References

Coutts SR, Yokomizo H, Buckley YM (2013) The behavior of multiple independent managers and ecological traits interact to determine prevalence of weeds. Ecol Appl 23:523–536

Drechsler M (2004) Model-based conservation decision aiding in the presence of goal conflicts and uncertainty. Biodivers Conserv 13:141–164

Fehr E, Gächter S (2000) Cooperation and punishment in public goods experiments. Am Econ Rev 90:980–994

Figueiredo J, Pereira HM (2011) Regime shifts in a socio-ecological model of farmland abandonment. Landsc Ecol 26:737–749

Fischbacher U, Gächter S, Fehr E (2001) Are people conditionally cooperative? Evidence from a public goods experiment. Econ Lett 71:397–404

Furuzono Y, Yamakawa T, Ohnishi S, Kaneko T (2013) Combined effects of social pressure from the inside and outside of fishing communities promote cooperation for stock management. Ecol Res. 28:845–854

Hofbauer J, Sigmund K (2003) Evolutionary game dynamics. Bull Am Math Soc 40:479–519

Iwasa Y, Uchida T, Yokomizo H (2007) Nonlinear behavior of the socio-economic dynamics for lake eutrophication control. Ecol Econ 63:219–229

Iwasa Y, Suzuki-Ohno Y, Yokomizo H (2010) Paradox of nutrient removal in coupled socioeconomic and ecological dynamics for lake water pollution. Theor Ecol 3:113–122

Kangas AS, Horne P, Leskinen P (2010) Measuring the value of information in multicriteria decisionmaking. For Sci 56:558–566

McFadden D (1981) Econometric models of probabilistic choice. In: Manski C, McFadden D (eds) Structural analysis of discrete data. MIT, Cambridge, pp 198–272

Milinski M, Semmann D, Krambeck HJ, Marotzke J (2006) Stabilizing the Earth's climate is not a losing game: supporting evidence from public goods experiments. Proc Natl Acad Sci U S A 103:3994–3998

Nakamura S, Tsuge T, Okubo S, Takeuchi K, Usio N (2014) Exploring factors affecting farmers' implementation of wildlife-friendly farming on Sado Island, Japan. J Resour Ecol 5(4):370–380. doi:10.5814/j.issn.1674-764x.2014.04.013

Pillutla MM, Chen XP (1999) Social norms and cooperation in social dilemmas: the effects of context and feedback. Org Behav Human Dec Proc 78:81–103

Runge MC, Converse SJ, Lyons JE (2011) Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. Biol Conserv 144:1214–1223

Satake A, Iwasa Y (2006) Coupled ecological and social dynamics in a forested landscape: the deviation of individual decisions from the social optimum. Ecol Res 21:370–379

Satake A, Leslie HM, Iwasa Y, Levin SA (2007) Coupled ecological-social dynamics in a forested landscape: spatial interactions and information flow. J Theor Biol 246:695–707

Suzuki Y, Iwasa Y (2009a) The coupled dynamics of human socio-economic choice and lake water system: the interaction of two sources of nonlinearity. Ecol Res 24:479–489

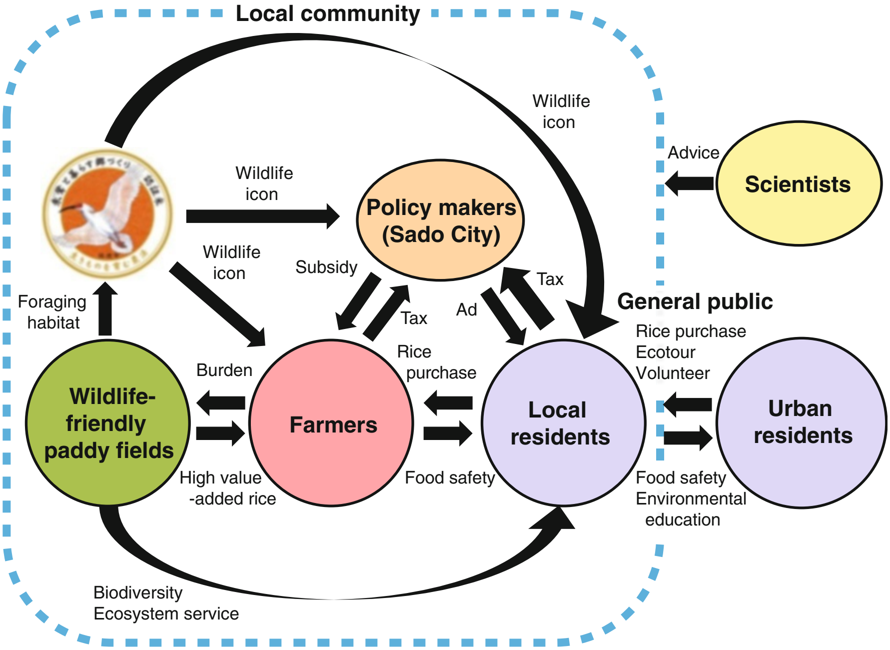
Suzuki Y, Iwasa Y (2009b) Conflict between groups of players in coupled socio-economic and ecological dynamics. Ecol Econ 68:1106–1115

Ujiie K (2015) Consumer preferences and willingness to pay for eco-labeled rice: a choice experiment approach to evaluation of toki-friendly rice consumption. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_18

Usio N, Saito R, Akanuma H, Watanabe R (2015) Effectiveness of wildlife-friendly farming on aquatic macroinvertebrate diversity on Sado Island in Japan. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_7

Chapter 20
Synthesis

Nisikawa Usio and Tadashi Miyashita



Abstract In this book, the authors have addressed ecological, socioeconomic, political, and practical factors pertaining to social-ecological restoration of paddy-

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dominated landscapes. It is evident that both social and ecosystem dimensions of ecological restoration play fundamental roles in restoration success. In the concluding chapter, we synthesize key lessons and offer some reflections on how the field of social-ecological restoration of farmland can be developed in the future.

Keywords Agricultural landscape • Rice paddy field • Ecological restoration • Evaluation • Restoration success • Social-ecological systems • Interdisciplinary

In this book, the authors have addressed ecological, socioeconomic, political, and practical aspects of social-ecological restoration of paddy-dominated landscapes. It is evident that both social and ecosystem dimensions of ecological restoration play fundamental roles in the success of restoration. How can we measure the success of social-ecological restoration of these landscapes? There are three key components that should be considered for measuring restoration success:

1. *Paddy fields*, including the associated infrastructures such as ditches and levees, are the target ecosystems for social-ecological restoration. To measure the ecosystem dimensions of restoration success, the effectiveness of environmentally friendly farming on paddy field biodiversity, ecosystem services, and environmental hazards should be evaluated.
2. *Farmers* are the practitioners of restoration. To measure the socioeconomic dimensions of restoration success, costs and benefits of implementing environmentally friendly farming practices should be considered. Costs include the burden of implementing environmentally friendly farming practices, while the benefits include subsidies from local or national governments and return from ecosystem services.
3. *General public*, such as local and urban residents, play central roles in determining the success and sustainability of restoration. To measure the overall outcome of restoration success, the value of various ecosystem services should be considered.

In addition, policy makers, such as local and national governments, and scientists play important roles as supporters of social-ecological restoration (see the cover figure for the case on Sado Island).

Although none of the studies in this book have measured each component thoroughly, we have provided case studies of each. In this concluding chapter, we will not attempt to summarize the insights from individual chapters, as we believe the work presented speaks for itself. Instead, we consider insights that arise from the work as a whole and offer some reflections on how the field of social-ecological restoration of farmland can be developed in the future.

Key Lessons

Key science and policy lessons are summarized as follows (Fig. 20.1).

- Rice paddy fields have multiple functions, beyond simply producing rice, such as biodiversity conservation, groundwater recharge, flood control,

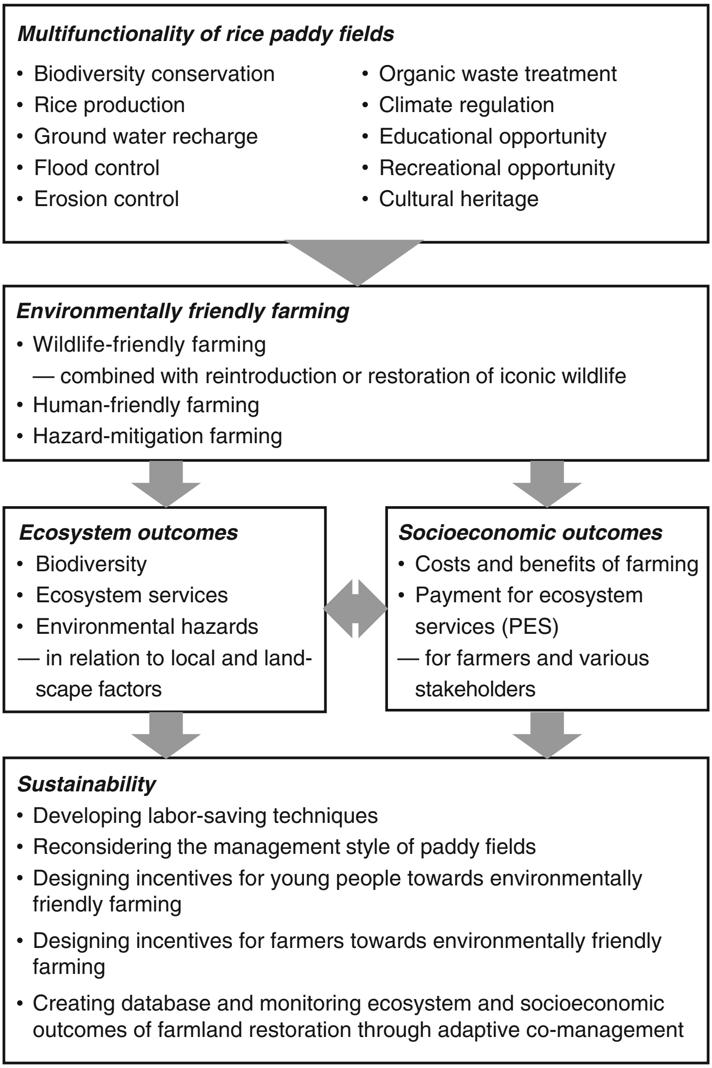

Fig. 20.1 A schematic diagram of the key components of social-ecological restoration in paddy-dominated landscapes

erosion control, organic waste treatment, climate regulation, and provision of recreational opportunities (*Multifunctionality of rice paddy fields*). To restore paddy-dominated landscapes, attention should be paid to restoring multifunctionality of the rice paddy fields, including the associated infrastructures such as ditches and levees. For this purpose, interdisciplinary studies or collaborations among various fields of natural and social sciences are essential to unravel tradeoffs and synergies among restoration practices and the mechanisms behind them.

- *Biodiversity conservation* is among the major functions provided by paddy fields. In Japan, to meet increasing demands for food, most floodplain wetlands have been converted into paddy fields, farm ponds, and ditches. Such agro-ecosystems are inhabited by unique fauna and flora that are rarely or no longer found in natural wetland habitats (Natuhara 2013). However, biodiversity of paddy fields is being threatened by bi-directional threats: farmland abandonment and agricultural intensification (Uematsu et al. 2010). Although direct evidence is rare, farmland abandonment has resulted in loss of disturbance-susceptible organisms, which, in turn, facilitates invasion by nonnative species. In contrast, agricultural intensification has led to the use of strong agrochemicals, farmland consolidation, and introduction of large machinery, which, in turn, has resulted in management style changes over time. Such agricultural intensification is important for enhancing provisional services from paddy fields. However, the concept of *integrated biodiversity management* is important, not only to conserve unique aquatic wildlife but also to enhance natural enemies of insect pests, thereby facilitating reduced inputs of insecticides (Kiritani 2000). In addition, paddy field biodiversity is a reliable indicator of food safety, as many consumers are concerned about the impact of toxic agrochemicals.
- *Environmentally friendly farming* is a sound means of restoring degraded farmland and to revitalize depopulated and aging rural communities. To evaluate the effectiveness of environmentally friendly farming, both ecosystem and socioeconomic outcomes should be monitored.
- *Wildlife-friendly farming* is a form of environmentally friendly farming that focuses on enhancement of paddy field biodiversity. In Japan, some wildlife-friendly farming practices are implemented in conjunction with restoration projects of charismatic wildlife, such as the crested ibis (*Nipponia nippon*), Oriental white stork (*Ciconia boyciana*), and nigorobuna (*Carrasius auratus grandoculis*). Such species reintroduction or restoration projects not only aim to restore locally exterminated wildlife species *per se* and species interactions but also attempt to restore biodiversity in intensified or abandoned paddy fields in rural areas. In addition, iconic wildlife species serve as eco-labels for high value-added rice produced from wildlife-friendly farming or play central roles in ecotourism, thereby contributing substantially to the local and regional economies in depopulated and aging rural communities.
- Evaluation of the effectiveness of environmentally friendly farming on *ecosystem outcomes* is best performed giving consideration to biodiversity, ecosystem services, and environmental hazards. Examples include the abundance, taxonomic richness, and taxonomic composition of indicator groups, rice yield and grain quality, emission rates of methane, concentrations of toxic agrochemicals in water and soil, and water retention capacity. Using multiple ecosystem attributes, comparative studies may be performed between environmentally friendly rice paddies and conventional rice paddies, assuming a sufficient number of replicates to enable statistical analyses. Because the effectiveness of environmentally friendly farming may change according to physicochemical factors and surrounding land use practices, natural experiments are best performed by incorporating

local and landscape environmental heterogeneity. Using experimental paddy fields or with cooperation from farmers, controlled manipulation experiments may also be possible. Without baseline data, however, identifying quantitative goals to measure restoration success may not be practical, given the fluctuating nature of biodiversity and ecosystem functioning. Instead, ecosystem restoration goals may be better set by incorporating fluctuating ranges of ecosystem variables. For this purpose, rigorous studies should be performed to elucidate spatial and temporal variability of ecosystem attributes by considering local and landscape factors. A major challenge is to predict future fluctuation of ecosystem attributes in the face of climatic and other environmental changes.

- When evaluating the effectiveness of environmentally friendly farming on *socioeconomic outcomes*, costs and benefits of implementing such practices and payment for ecosystem services (PES) should be quantified. Calculating PES for a range of stakeholders may allow quantitative evaluation of the socioeconomic outcomes of environmentally friendly farming. For this purpose, both questionnaire and experimental approaches are recommended. An experiment can be performed by employing a workshop approach, in which the participants' attitudes are assessed by the before-after design or by dividing them into several groups assigned to different treatments (e.g., Christie et al. 2006). With a rigorous evaluation study, currency-based goals for environmentally friendly farming can be pursued. In some regions (e.g., Sado Island), farmer-oriented biomonitoring is conducted as a part of the rice certification initiative to assess the effectiveness of wildlife-friendly farming. At present, however, the data from farmer-oriented biomonitoring often lack scientific integrity, as farmers lack knowledge about species identification or sufficient training. However, region-wide biomonitoring plays significant educational and cultural roles, in that it provides an opportunity for farmers to learn about rich wildlife in and around paddy fields, and to mingle and collaborate with other farmers. Such educational and cultural benefits should also be measured to evaluate the socioeconomic attributes associated with restoration success.
- *Sustainability* of farming is a challenging task in depopulated and aging rural communities. To make farming sustainable, several issues need to be considered. First, given the burden of implementing environmentally friendly farming, labor-saving farming techniques that also enhance biodiversity, rice production, and other ecosystem services should be developed and employed. Second, where depopulation and aging are of major concern, management styles of paddy fields may be changed from individual- to community-based farming; i.e., when conditions allow, community-based farming may be considered as a management option. Third, incentives for farming should be designed specifically for young people. For this purpose, agricultural policies or initiatives in rural areas should be scrutinized to make farming life attractive for young people, and relevant information should be transmitted through the Internet, social networking services, journals, television, or newspapers. Fourth, incentives for environmentally friendly farming should be designed for farmers. Subsidies play

an important role in providing these incentives. However, a subsidy alone is insufficient to sustain environmentally friendly farming. To make farming sustainable, paddy field restoration needs to be continuously supported by the general public. For this purpose, rice marketing strategies may play a vital role in designing long-term incentives for farmers. Fifth, long-term monitoring of the ecosystem and socioeconomic outcomes of paddy field restoration should be performed, and the effectiveness of environmentally friendly farming should be communicated to the general public. To track changes in the ecosystem and socioeconomic attributes over time, developing a database for biodiversity, ecosystem services, and public attitudes in the form of geographical information systems (GIS) would be useful. If the expected outcome is not achieved, we should explore both ecosystem and socioeconomic factors. This could, in turn, provide feedback as to how and where we should act accordingly. It should also be remembered that, in the face of global warming and other environmental changes, the criteria of restoration success may change with time. In these contexts, establishing a sustainable monitoring and feedback system that involves scientists, policy makers, farmers, and local residents is essential for adaptive co-management.

Perspectives

Several issues need to be considered further. As pointed out from the models of cropland and permanent pasture, tradeoffs exist between agricultural yield and biodiversity value (Green et al. 2005). This is also true for various environmentally friendly rice farming practices. However, most evaluation studies of environmentally friendly rice farming focus on a single outcome (e.g., biodiversity) and have not considered the overall costs and benefits of ecosystem and socioeconomic outcomes. For example, implementing mid-season drainage may mitigate methane emission by improving soil conditions of paddy fields, from anaerobic to aerobic soil conditions, and harden the soil pan to facilitate the use of large machinery for rice harvest. In contrast, such a practice may have detrimental effects on paddy field biodiversity by disrupting amphibian metamorphosis and insect emergence. Economic analyses may be needed to evaluate the overall costs and benefits of restoration outcomes (e.g., Pejchar and Mooney 2009). By identifying multiple consequences of environmentally friendly farming practices on ecosystem and socioeconomic outcomes, a compromise may be considered to maximize social-ecological benefits. Alternatively, if a compromise cannot be found, a zoning approach, in which different farming practices are implemented in differential paddy fields or regions, according to the aims of the project, may be practical. When conservation of biodiversity or ecosystem functioning is the major goal of a project, one way would be to specify high biodiversity or ecosystem functioning areas and designate such areas as *prioritized wildlife-friendly farming areas*, while designating other areas as *intensive farming areas*. These approaches are consistent with the concepts of land sharing and land sparing (Fischer et al. 2008, 2014).

As we have already seen, degeneration of the primary industry, such as agriculture, is of major concern in Japan. To improve this situation, the *Rokuji sangyouka—chisan chishou hou* or Sixth Industrialization—Local Production and Local Consumption Act of agriculture, forestry, and fishery was enacted in 2010 by the Ministry of Agriculture, Forestry and Fisheries of Japan (Ministry of Agriculture, Forestry and Fisheries of Japan 2010). The Sixth Industrialization—Local Production and Local Consumption Act was named after multiplying ($1 \times 2 \times 3 = 6$) and integrating the primary, secondary, and tertiary industries to revitalize degenerating agriculture, forestry, and fishery under the concept of local (or regional) production and local (or regional) consumption. As wildlife-friendly rice flour is gaining increasing attention as a health food, collaboration between farming and processing industries may benefit both industry sectors. Furthermore, guiding consumers from cities to environmentally friendly farms as a part of ecotourism may benefit both farmers and consumers. As Saito (2015) introduced, farmers' burden of implementing wildlife-friendly farming practices is relaxed through voluntary weeding by participants, and feedback against agricultural products can be obtained through direct communication with them. Many consumers are concerned about food safety issues, so such ecotourism may also benefit consumers by providing them an opportunity to know the producer in person and how and to what extent elaboration is made to cultivate agricultural products. Although we have not discussed in depth the *sixth industrialization* in this book, such a concept is important in sustainable environmentally friendly farming.

In recent years, the possibility of globalization of agriculture through signing the Trans-Pacific Strategic Economic Partnership Agreement (TPP) is frequently picked up by mass media. Many farmers and scientists warn that, once Japan has signed the TPP, domestic agriculture will collapse and various health and socio-economic problems will arise. After signing the TPP, importation of economical agricultural products from overseas countries is expected to increase following the reduction or removal of tariffs, but competing with the price of such agricultural products is impractical for many Japanese farmers. Consequently, cultivation areas of rice paddy fields in Japan may drop dramatically, which will result in the reduction of habitats for wetland-dependent organisms. In addition, liberalization of agricultural trade is expected to relax the amount of agrochemicals applied during the cultivation process and facilitate applications of additional agrochemicals during transportation, thereby contributing to the health problems and loss of biodiversity associated with the use of excess agrochemicals. However, we believe that producing safe and high-quality agricultural products from environmentally friendly farming would contribute to a competitive international agriculture market, and developing such strategy has a promising future in the face of agricultural globalization. Nevertheless, in some areas, agricultural intensification is best promoted to enhance ecosystem services of rice paddy fields, so additional labor-saving techniques would need to be developed for the sake of restoring multifunctionality of paddy fields.

References

Christie M, Hanley N, Warren J, Murphy K, Wright R, Hyde T (2006) Valuing the diversity of biodiversity. Ecol Econ 58:304–317

Fischer J, Brosi B, Daily GC, Ehrlich PR, Goldman R, Goldstein J, Lindenmayer DB, Manning AD, Mooney HA, Pejchar L, Ranganathan J, Tallis H (2008) Should agricultural policies encourage land sparing or wildlife-friendly farming? Front Ecol Environ 6:382–387

Fischer J, Abson DJ, Butsic V, Chappell MJ, Ekroos J, Hanspach J, Kuemmerle T, Smith HG, von Wehrden H (2014) Land sparing versus land sharing: moving forward. Conserv Lett 7:149–157

Green RE, Cornell SJ, Scharlemann JPW, Balmford A (2005) Farming and the fate of wild nature. Science 307:550–555

Kiritani K (2000) Integrated biodiversity management in paddy fields: shift of paradigm from IPM toward IBM. Int Pest Manag Rev 5:175–183

Ministry of Agriculture, Forestry and Fisheries of Japan (2010) Sixth Industrialization—Local Production and Local Consumption Act. Available at: http://www.maff.go.jp/j/shokusan/sanki/6jika/houritu/. Accessed 3 Sept 2014 (in Japanese)

Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecol Eng 56:97–106

Pejchar L, Mooney HA (2009) Invasive species, ecosystem services and human well-being. Trends Ecol Evol 24:497–504

Saito S (2015) In search of biodiversity-oriented farming. In: Usio N, Miyashita T (eds) Social-ecological restoration in paddy-dominated landscapes, Ecological research monographs. Springer, Tokyo. doi:10.1007/978-4-431-55330-4_16

Uematsu Y, Koga T, Mitsuhashi H, Ushimaru A (2010) Abandonment and intensified use of agricultural land decrease habitats of rare herbs in semi-natural grasslands. Agric Ecosyst Environ 135:304–309

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