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CASE REPORT

Using sustainability science to analyse social–ecological restoration in NE Japan after the great earthquake and tsunami of 2011

K. Takeuchi · T. Elmqvist · M. Hatakeyama · J. Kauffman · N. Turner · D. Zhou

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Abstract In the wake of the catastrophic earthquake and tsunami that devastated part of northeastern Japan in March 2011, proposals for reconstruction and rehabilitation are still subjects of debate. The claim by many climate scientists that large-scale extreme events can be expected in the future, with similar catastrophic effects in coastal areas, suggests the need for long-term planning that aims at building resilience, the ability for socio-ecological systems to withstand and recover quickly from natural disasters, and continue to develop. We hypothesize that ecosystems and socio-economic resilience will provide affected communities with flexible barriers against future disasters and greater protection in the long run than will hard/engineering solutions such as high seawalls aimed at ensuring only physical security. Building social/ecological resilience in the Tohoku region will increase general security and is anticipated also to contribute to an enhanced quality of life now and for generations to come. This paper argues that building resilience in the affected area requires a transformation to sustainable agriculture, forestry and fisheries and we describe how the links between *satoyama* and *satoumi*, traditional rural territorial and coastal landscapes in Japan, can contribute to this revitalization and to strengthening the relationship between local residents and the landscape in the affected communities. Decision makers at local, regional and national levels need to take a holistic approach based on sustainability science to understand the inter-relationships between these landscapes and ecosystems to develop a robust rebuilding plan for the affected communities. Moreover, this paper suggests that building resilient communities in Japan that demonstrate the strategic benefits of *satoyama* and *satoumi* linkages can be a model for building resilient rural and urban communities throughout the world.

Keywords Social–ecological resilience · Great NE Japan earthquake and tsunami · Sanriku Fukko National Park · *Satoyama* and *Satoumi*

Handled by Osamu Saito, UNU-Institute for the Advanced Study of Sustainability (IAS), Japan.

K. Takeuchi
United Nations University (UNU), IR3S, The University of Tokyo, Tokyo, Japan
e-mail: takeuchi@unu.edu

T. Elmqvist
Natural Resource Management, Stockholm Resilience Center, Stockholm University, Stockholm, Sweden
e-mail: thomas.elmqvist@su.se

M. Hatakeyama
Mori wa Umi no Koibito, Kesennuma, Japan
e-mail: info@mori-umi.org

J. Kauffman
IR3S, The University of Tokyo, Tokyo, Japan

J. Kauffman (✉)
Le Cleou, 83670 Fox Amphoux, France
e-mail: kauffman@alum.mit.edu

N. Turner
Institute for Sustainability and Peace, UNU, Tokyo, Japan
e-mail: turner@unu.edu

D. Zhou
Beijing Normal University, Beijing, China
e-mail: zhoudy@bnu.edu.cn

Introduction

Although more than 3 years have passed since the Great East Japan Earthquake and Tsunami devastated the

northeastern coast of Japan and shocked the world by its force and consequences, proposals for reconstruction and rehabilitation are still subjects of debate. Although clean up and recovery efforts began almost immediately after the waters from the great tsunami receded, many of the devastated communities remain barren and social–ecological and economic as well as psychological recovery is likely to take decades.

Agricultural and fishing villages from the Pacific coast of northeastern Japan to the Kanto area especially were affected by the related disasters of the earthquake and tsunami followed by the disastrous handling of damage to the Fukushima Daiichi nuclear power plant. Most of the fishing villages along the coast in the three Tohoku prefectures (Miyage, Fukushima, and Iwate) endured catastrophic damage. Agricultural lands such as paddy fields were flooded by the tsunami. Sea grass beds were lost in Miyako Bay and elsewhere. Land subsidence in many areas altered the topography affecting potential for livelihoods from rice cultivation and other crops and livestock (Asia Air Survey Co. 2013). In the Sanriku area, most of the vegetation in the sand dunes was washed away together with the sandy beaches (Nature Conservation Bureau of Japan 2013). Many of the fishing villages like Kesenumma in Miyagi Prefecture lost their entire shipping fleets and infrastructure.

Beyond the loss of infrastructure and fields, these industries also suffered from radioactive pollution from the Fukushima Daiichi nuclear plant disaster where high waves knocked out emergency generators needed to maintain water circulation for cooling the reactors. And radiation released from the accident—the worst since Chernobyl—continues to be a concern in Japan and globally (Fisher et al. 2013; UNSCEAR 2014). Many uncertainties remain concerning the long-term environmental and socio-economic impacts from the failure of the plant. Of the 470,000 people who were left homeless by the force of the disaster and those who were evacuated from the area contaminated by the damaged Fukushima nuclear power plant, 267,000 remain in temporary housing, according to Kyodo News International (March 2014) including 97,072 evacuees from Fukushima.[1] While the evacuations greatly reduced the levels of exposure to radioactive material, stress on mental and social well-being related to the enormous impact of the earthquake, tsunami and nuclear accident coupled with the fear and stigma related to the perceived risk of exposure to ionizing radiation is severe (United Nations Scientific Committee on the Effects of Radiation (UNSCEAR) 2014:10).

Rebuilding of the area is a government priority and the restoration of agricultural, forestry, and fishery industries has become a vital issue in the Ministry of the Environment (MOEJ) (MOEJ 2012a). Yet, there is a sense of unease and differences of opinion remain on means to ensure long-term security against future natural disasters and what should be the vision for the future of this region (Bird 2013).

While it is clear that safety and security are of paramount importance, the events of 2011 in the Tohoku region demonstrated that disaster mitigation based solely on strengthening of infrastructure and engineering is insufficient in the long term to address a threat of such magnitude. The "once in a thousand years" tsunami left 60 per cent of NE Japan's seawalls in ruins (Bird 2013). To the extent that Japan could be prepared for what was anticipated in terms of potential earthquake and tsunami events in the area, it was prepared. Without the planning drills, exercises, communications, warnings and infrastructure, including evacuation routes and seawalls, the loss of life and damages would have been far greater. But the unpredicted (and unpredictable) triple catastrophe (major earthquake, the largest tsunami in the area in many centuries, and the nuclear power plant accident) overwhelmed the existing infrastructure and coping mechanisms. This suggests the need to rethink how to prepare for such shocks in the future. Holling (1996) differentiates between two contrasting aspects of stability (engineering resilience and ecological resilience) that have very different consequences for evaluating, understanding and managing complexity and change. The definition of engineering resilience focuses on efficiency, constancy and predictability. That of ecological resilience focuses on persistence, change and unpredictability (Holling 1996). Both are important contributors to sustainability.[2]

Climate science predicts more extreme weather events and other environmental disasters that challenge traditional notions of protection based on strength or resistance alone (Dessai et al. 2007; IPCC WGII report 2014). Studies have shown that a plurality of approaches to mitigating the effects of climate change will be necessary and that bottom-up approaches are helpful in coping with uncertainty and surprises (Dessai and van der Shiejs 2007). Conventional hard engineering may provide protection against expected events but as the events of March 11, 2011 showed, the real threats to social–ecological systems lie in the unexpected. A sustainable defence for the future is likely to be one that is based on social–ecological resilience, and provides flexibility in managing systems that can

[1] Statistics provided by the Cabinet Office, Government of Japan. Communication of April 9, 2013, in Japanese.

[2] For examples of engineering approaches to the promotion of sustainable development, see Kauffman and Lee 2013.

absorb and accommodate future elements in whatever form they may take (Holling 1973).

Resilience in this context is understood to mean the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al. 2004; Adger 2000).[3] Looking to the future, a successful strategy to restore the areas impacted by the 2011 earthquake and tsunami will aim at resilience combining traditional macroeconomic stimulus policies with policies aimed at strengthening social–ecological systems that will in turn improve sustainability and self-sufficiency in the production of food, energy, and culture. As noted by Walker et al. (2004), three related attributes of social–ecological systems (SES) determine their future trajectories: resilience, adaptability, and transformability. The manner and extent to which a strategy can be successfully implemented in the affected areas will depend on the adaptability of the social component (the capacity of multiple actors in the affected areas to manage the envisaged transition to a more resilient and sustainable community) and transformability in the landscape, the capacity to create a fundamentally new system in the region (Gunderson and Holling 2002). The challenge in revitalization of the affected areas is to actively strengthen the capacity of ecosystems to support social and economic development in the region (Folke et al. 2004).

Our research suggests that the foundation for this strategy should utilize the twin concepts of *satoyama* and *satoumi,* which centre on the interdependent relationship between humans and the environment they inhabit. *Satoyama* refers to such relationships in the context of agricultural landscapes; *satoumi* refers to similar relationships between the sea and those who live near it and are supported by its biodiversity (Duraiappaah et al. 2012). Both landscapes are defined as dynamic mosaics of managed socio-ecological systems, which produce a bundle of ecosystem services for human well-being (Saito and Shibata 2012, p. 26).

To explore the benefits of this approach to recovery of the Tohoku region, the paper is divided into the following sections:

Section 2 describes the area most affected by the earthquake and tsunami with a particular focus on the fishing village of Kesenumma and the challenges it faces.

In Sect. 3 we consider the concept of socio-ecological resilience and its relevance to the recovery of the Tohoku region. We explore how the concepts of *satoyama* and *satoumi* can contribute to building social–ecological resilience and through the resilience approach strengthen the region's path to sustainable development.

Section 4 examines how sustainability science contributes to this approach through integrated and action-oriented knowledge.

The paper concludes with consideration of the relevance of the approach to building resilience based on local natural capital and human resources to other areas and regions including Japan as a whole and other vulnerable communities around the world.

The Tohoku fishing villages

Solutions for reconstruction in the affected areas will be long and require careful planning and implementation. As the areas affected are greater than expected with each local community experiencing varying degrees of damage, a universal plan for revival and reconstruction is not practicable. Rather, social, environmental and economic needs must be assessed at the local level. However, given that a large percentage of the economy of the affected region was and is dependent on fisheries, there is an urgent need to revitalize the fishery industry in the area's coastal communities (Reconstruction Design Council of Japan 2012). Thus, in the first instance what is called for is (1) a fundamental review of land use in the affected areas, and (2) a vision for future industries that contribute to the socio-economic and environmental well-being of the region.

All that is left of many of those areas and the infrastructure that supported the fisheries industry are piles of rubble. According to government data reported in Globalpost, losses to the fishing industry came to over 14 billion USD through the loss of 319 fishing ports and 22,000 boats. Moreover in 2011, the Tohoku fisheries industry was already in decline, contributing only about two percent of Japan's GDP by about 200,000 active fishermen (down from over a million in the post World War II period (McCury 2012). The area is also affected economically and socially by both an ageing and declining population base (Fukushi 2014).

Kesennuma, a city of 73,000 inhabitants in northeastern Japan was one of the nation's busiest ports for processing tuna [*thynusthynis*], bonito *[euthynnus]*, and Pacific saury [*cololabis saira]*. It is equally famous for its clams and oysters, particularly those raised at the Mizuyama Oyster Farm in Nishimone. Before the 2011 disaster 85 % of the jobs in Kesennuma were fisheries related. On March 11, 2011 the entire industry and one-third of the city were destroyed within 7 min. Within 3 min the city was inundated by the tsunami waves and 3 min later houses, buildings, and boats were strewn like matchsticks. Many were washed out to sea. Fishing ships were flung 100 m

[3] For origins of the term "resilience" and evolution as a widely used concept in many policy arenas, see Folke et al. (2010); McAslan (2010).

and more in toward the city and dumped throughout the town. Fuel tanks of the shipping vessels burst igniting fires that turned the area into an inferno that burned for 4 days. When the waters subsided and the fires died down Kesennuma was left with a devastated and, many thought, ruined port, the coastline stripped of life for a long time (McCury 2012).

Many people in Kesennuma died in the disaster, among them the 93-year-old mother of Shigeatsu Hatakeyama, an oyster farmer and local environmental activist. He is the founder of a popular non-governmental organization called *More wa Umi no Koibito* (literally, "the forest is longing for the sea, the sea is longing for the forest") which is active in planting trees along the Okawa River that runs from the mountains through the city and into the Kesennuma Bay. The aim of the tree planting, which Mr. Hatakeyama has advocated and practiced for more than a quarter century, is to restore the forests to replenish the oyster farms. Along the NE coastline deciduous trees once dominated these forests. But after the Second World War the harder and more construction-worthy Japanese cedar trees replaced the native deciduous trees. By the mid-1960s the cedars lost their value for construction purposes to cheaper imports and the forests above Kesenumma were left untended. Without necessary thinning, the tightly planted cedars prevented sunlight from reaching the forest floor killing off plant life on the ground and robbing it of soil nutrients. Soil in such a forest is dry and runs out easily in heavy rains. When the forests dried out, the runoff carried fewer nutrients to the estuarine areas where the oyster beds were kept and the industry suffered from weaker and polluted stocks. Ultimately, a number of the oyster farmers left as increasing red tides and polluted (red flesh) oysters compromised the industry. Hatakeyama stayed, studied the problem, and realized the important links between the forest, river and coastal estuaries. Based on his analysis of the problem, he set out to recreate the forests of deciduous broad-leafed trees that would eventually lead to the symbiotic revitalization of both areas (Miura 2012).[4]

What Hatakeyama discovered in the 1960s is typical of the disaster stricken area, which contains a range of *satoyama* and *satoumi* regions. With fishers utilizing *satoumi* and also cutting and using the wood from *satoyama* nearby, most local residents are involved in diverse activities in farming, forestry and fishing. In these traditional agriculture and aquaculture areas, small rivers connect *satoyama and satoumi*, and the links between forest–river–sea provide the communities with the bounty of nature. But in recent years, prior to 2011, as forests in upstream areas became denser, the nature of *satoumi* in downstream areas was distorted, and the links between agriculture, forestry, and fisheries disappeared. The satoyama landscape is highly valued because it provides a variety of provisioning and regulating ecosystem services (Takeuchi 2010; Saito and Shibata 2012) as well as diverse cultural services. They have evolved over many years of human co-existence with nature and thus vary significantly depending on the cultural and environmental characteristics of each locality. The Sanriku coastal areas where *satoyama* and *satoumi* are prevalent provide many opportunities to promote the diversity the region offers within the process of post-disaster rebuilding (Box 1). The integration of agriculture and aquaculture in traditional or indigenous cultures to preserve biodiversity in ecosystems for well-being is not unique to this area or to Japan. Linked *satoumi* and *satoyama* landscapes that have evolved over many generations into a mosaic of ecosystems and that embody a symbiotic relationship between ecosystems and humans exist in many parts of the world (Duraiappah and Nakamura 2012). In ancient Hawaii, for example, river drainage basins were managed as integrated systems, fishponds and agriculture were combined, and headwater forests were protected by taboo (Gadgil et al. 1993). Many studies have shown the importance of indigenous or traditional knowledge from a conservation perspective and for preserving and enhancing biodiversity (Ibid. Altieri 2004).

Increasing evidence suggests that ecosystems often do not respond to gradual change in a smooth way (Scheffer et al. 2001). In some cases passing a threshold results in a sudden change. In others, the transition can be more gradual such as those observed by Hatkeyama. Such change can lead to a weakened or "simplified" ecosystem

Box 1 Satoyama and satoumi: definition and characteristics

Satoyama and Satoumi Landscapes

Definition:

Dynamic mosaics of managed socio-ecological systems producing a bundle of ecosystem services for human well-being.

Characteristics:

- *Satoyama* is a mosaic of both terrestrial and aquatic ecosystems comprised of woodlands, plantation, grasslands, farmlands, pasture irrigation ponds and canals, with an emphasis on terrestrial ecosystems.
- *Satoumi* is a mosaic of both terrestrial and aquatic ecosystems comprised of rocky seashore, rocky shore, tidal flats, coral reefs and seaweed/grass beds, with an emphasis on aquatic ecosystems.
- *Satoyama* and *satoumi* landscapes are managed with a mix of traditional knowledge and modern science
- Biodiversity is a key element for the resiliency and functioning of *satoyama* and *satoumi* landscapes

Source Saito and Shibata (2012, p. 26)

[4] For other examples of regime shifts in terrestrial and aquatic environments due to human intervention and in relation to resilience of complex adaptive ecosystems. See Folke et al. 2004.

characterized by unpredictability and surprise in its capacity to generate ecosystem services (Folke et al. 2004)[5]

Rebuilding in the area now provides an opportunity to recreate agriculture, forestry and fisheries links, address the slowly changing variables, and take steps to ensure the biodiversity that plays a significant role in the capacity of ecosystems to renew and reorganize into desired states after disturbance (Elmqvist, et al. 2003). The aim of such efforts is to build long-term social–ecological resilience, and thereby strengthen the economic and ecological foundations of the communities.

In the Tohoku region, economic activities are dependent upon ecosystems and the services they provide. Adger (2000) defines social resilience as the ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change. The triple catastrophe in 2011 put tremendous pressure on local residents to cope with the tragic consequences, to adapt to the effects of those consequences, and to organize to meet the challenges of restoration and revitalization of their communities. Two existing issues make that adaptation particularly difficult in the Tohoku region; namely, the ageing population and a decline in agricultural workers resulting in insufficient manpower (Reconstruction Design Council of Japan 2012). After the disaster, population displacement accelerated this serious situation, which continues to persist and contributes to the persistent psychological impacts of the disaster.

The Basic Guidelines for Reconstruction (ReconstructionAgency 2012) recognize the importance of restoring natural environments affected by the disaster and the National Biodiversity Plan of Japan addresses measures to do so by utilizing ecosystems' capacity to recover, promoting nature restoration, and re-evaluating traditional methods for using and managing the natural environment that have been practiced in Satochi–Satoyama areas (MOEJ 2012a). Providing opportunities for local citizens to participate in social–ecological restoration activities that bring them in touch with the natural environment will also contribute to "healing" not only the ecological impacts but also the psychological and social trauma.[6] Such human–nature interactions can play an important role in fostering resilience in the communities as residents re-connect with the natural environment and contribute to rebuilding it. Through this engagement, they will also learn about and support the restoration of ecosystem services (Tidball 2012).

The support of government and non-governmental agencies as well as non-profit and civic organizations will also be necessary to revive existing industries and to promote the development of new green economic initiatives, for example in recreation, environmental education, and tourism can lead to greater economic diversity and provide opportunity for participation of many local residents, including seniors. In the earthquake- and tsunami-affected areas the development of the Sanriku Fukko (reconstruction) National Park and the efforts of the non-profit organization (NPO) *More wa Umi no Kobito* to contribute to revitalization of Kesennuma illustrate opportunities for promoting green community development and community-based ecological restoration.

The Sanriku Fukko National Park

Endowed with a picturesque natural landscape that includes its world-renowned fishing grounds, the Pacific Coastal region of Tohoku District, is also home to many types of parkland, which though severely damaged in the disasters of 2011, offers possibilities for contributing to the economic and ecological revitalization discussed in the preceding paragraph. Many of the distinctive features of the coastline such as cliff faces, remarkably shaped rocks and archipelagos were largely untouched. Yet impacts to ecosystems include severe disturbance to estuarine vegetation such as loss of pines on sandy beaches, reed banks, tidal flats and sand dunes. Today, drawing on the history of park management in the region, the Ministry of the Environment of Japan plans to establish a new "Sanriku Fukko (reconstruction) National Park" that will support the natural environment and traditional lifestyle of the region for future generations. The basic principle underlying creation of the park is the environment ministry's commitment to fostering links between forest, rivers, the sea and *satoyama* (MOEJ 2012b). The proposed new park is based on Rikuchu Kaigan (coastal) National Park (on the Pacific coast of Iwate prefecture). It extends to coastal national parks in Aomori prefecture to the north, and to Fukushima prefecture to the south (Fig. 1).

During the past several decades in Japan, public participation in some city planning efforts has been effectively introduced, bringing both labour and economic benefits to communities that engage local residents in the development of their community. One example is in Kawasaki City where a conservation management plan was drawn up to engage citizens in stewardship activities

[5] The reference includes many examples of regime shifts in ecosystems and addresses conditions that result from human interventions that can make ecosystems more vulnerable to changes that previously could be absorbed.

[6] Tidball (2012) suggests that "when humans, faced with urgent disaster or hazard situations, as individuals and as communities and populations, seek out doses of contact and engagement with nature to further their efforts to summon and demonstrate resilience in the face of a crisis, they exemplify an urgent biophilia." The idea of "biophilia" comes from Wilson's (1984) hypothesis that there is an instinctive urge in humans to affiliate with other living systems.

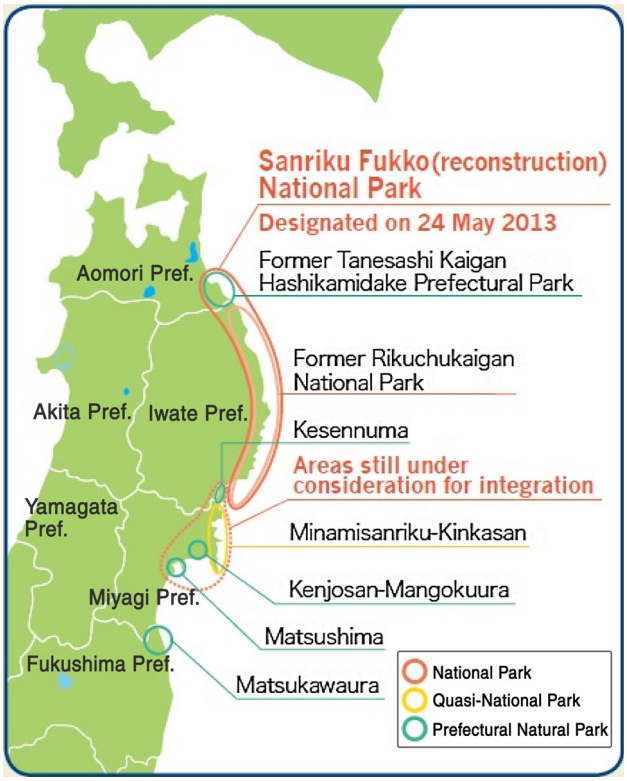

Fig. 1 The Sanriku Fukko (Reconstruction) Park. *Source* provided by Ministry of the Environment of Japan

which saved the community financial resources and provided environmental benefits (Kohsaka et al. 2013). A bottom-up approach that promotes participation of local citizens in rebuilding the Tohoku region, rather than a traditional top-down model can also contribute to the development and maintenance of unique and diverse cultural and ecological characteristics, which are among the goals for the new park. This can also contribute to another of the goals for the reconstruction park, which is to foster a sense of pride and belonging in the region (MOEJ 2012b). Ostrom and Nagendra (2006) demonstrate that when users of natural resources have a role in making local rules, or at least consider those rules to be legitimate (and not merely imposed from the top down) they are frequently willing to enter into robust self management arrangements. The park is bringing together various stakeholders who are proposing the development of recreational amenities including creation of nature trails, kayaking programmes, and other activities that provide opportunities for engagement with the natural environment. NPOs within the park's geography are also working together and with local schools and civic organizations to provide environmental education and hands-on ecological restoration projects such as tree planting and identification and conservation of rare plant and animal species that are intended to contribute to enhancing biodiversity.

The More wa Umi no Koibito example

The area of the disaster-affected Tohoku coastline is a classic example of the integrated forest and sea landscape that represents the use of traditional land and coastal zone management regimes. The work of *Mori wa Umi no Koibito* is illustrative of these practices and sheds light on the potential of traditional practices to contribute both to recovery of the affected area as well as to long-term sustainability of the region.

Speaking at the third International Conference on Sustainability Science in February 2012[7] Makoto Hatakeyama, executive director of Mori wa Umi no Koibito and the son of the organization's founder, described the ways in which small organizations can contribute to revitalization and to building ecosystem and socio-economic resilience through applying traditional practices of *satoyama* and *satoumi* (Hatakeyama 2012). Although the non-profit organization (NPO) was officially founded in 2009, its activities were underway through the voluntary efforts of fishermen organized by Hatakeyama's father in the 1980s to revitalize the polluted waters of Kesennuma Bay by planting broad-leafed deciduous trees upstream on the Okawa River. These activities were initiated in recognition of the interconnection of the two landscapes and the fact that maximizing the number of coniferous trees to expand timber production upstream reduced the forest's traditional ability to provide soil and erosion protection along with nutrients to the sea. Since the initiative began over 30,000 trees have been planted and the Bay was well on the way to recovery before the 2011 earthquake and tsunami. Once the NPO was formed it expanded its activities to include environmental education and attracted large numbers of the public and school children to participate in annual tree-planting events and community activities aimed at expanding understanding of the relationship between the forest, sea, and human activity. It also supports scientifically based conservation projects that are aimed at the protection of wildlife, the use of alternative energy, and support for an agricultural lifestyle. In this way, the organization is not only focused on using traditional system management approaches to protect and build resilience in the local ecosystem, but also to support and promote the cultural attributes and values that are an inherent part of the traditional patterns.

Against this backdrop, the organization was well positioned to support relief efforts following the earthquake and tsunami disasters in 2011. Within less than 10 days after the earthquake, the organization mobilized to facilitate the work of external aid agencies and act as a mediator

[7] Held at Arizona State University, February 20–23, 2012, see www.icss2012.edu.

between them and the Kesennuma City Council. Because of its close ties to the community the organization also was able to facilitate building consensus among local residents for national aid projects. And it immediately moved to restore the organization's aquaculture activities. During the rest of 2011, the organization continued to build on these activities by conducting scientific research of the sea, sponsoring a heavily attended cleaning of the Kuunaki Beach, operating a summer school and survival training class for children in the affected area. The year culminated with a public symposium aimed at increasing public awareness of the *satoyama* and *satoumi* linkages important to the health of the community and coastal ecosystems in general. The next phase of the organization's work focuses on the environmentally friendly reconstruction of Moune Village. This initiative faces many challenges not the least of which include the lingering low motivation of local workers due to depression from loss of capital and work and volunteer "burn-out" (Hatakeyama 2012).

Initial steps have been taken to revitalize the community and the organization has taken the long view to build resilience into the local community by providing opportunities for interactions with nature and education on the *satoyama/satoumi* link, and building support within the community and with various levels of government for new "green" business models. Challenges remain. There is tension between generations in the local population concerning plans for the future and choices concerning the most effective ways to ensure long-term security.[8] In the Miyagi prefecture reconstruction projects called for a concrete seawall as high as 14.7 m (Hatakeyama 2012). The plan also proposed new construction in areas where seawalls did not previously exist and filling exposed areas between land and sea with cement poured into rocky shores and beaches. Many of the proposed new seawalls will be taller, wider, and possibly longer than they were before the tsunami, endangering seaside ecosystems that managed to survive earlier decades of coastal engineering by obliterating tidal flats, dunes and other important habitats and blocking the movement of water, sand and living organisms between land and sea (Bird 2013). And there is also concern that engineering reconstruction plans might disrupt ongoing natural healing as plant communities along the Sendai coast begin to come back and new marshes appear (Ibid). Opponents to this plan, including the Nature Conservation Society of Japan,[9] created a counter-campaign for recovery named "Umi to Ikiru" (Live with the sea) that proposed the abandonment of the seawall project and putting greater emphasis on developing resilience in the natural environment. Studies have shown various ways in which coastal forests and wetlands may reduce tsunami impacts including providing barriers to driftwood and other flotsam, reducing water flow velocity and inundation depth, and amassing wind-blown sand and creating dunes which serve as natural barriers (Latief and Hadi 2007). Ultimately, through a process of public education led by the NPO and public participation, residents of Kesennuma decided unanimously to forego construction of the seawall in their community.

When the NPO first went to work to support recovery in the area one of the earliest challenges they discovered is the mismatch between available resources for aid and need. According to Hatakemaya, most external aid resources are targeting the businesses that need it least—those that could recover without outside assistance, while those receiving the least are exactly the small businesses that are in the greatest need of financial aid to recover (Hatakeyama 2012). Thus, while the outcome is yet to be known, the organization has managed to pinpoint gaps where aid could be most effectively used. In recent meetings with researchers (see footnote 14), local stakeholders and organizers noted that given the history of decline in these industries well before the 2011 earthquake and tsunami, it is important to future planning that their efforts not be aimed solely at restoring what was before, but to introduce new elements that can combine the traditional economic base with new applications—perhaps cultural and social attributes that might lead to new businesses, such as in the area of tourism.

What is particularly significant in the story of the role of Mori wa Umi no Koibito is the importance of a bottom-up approach, one that involves local leadership with strong community ties and a long-term commitment to the community. This in turn has facilitated and helped to ensure the engagement of the local community economically, politically and socially, and helped to raise support at various levels of government for co-management of the resources. As Olsson et al. (2004) showed in examples from Sweden and Canada, a self-organizing process of adaptive co-management and development, which is facilitated by rules and incentives issued by higher levels of governance, has the potential to expand desirable stability domains of a region and make social–ecological systems more robust to change.

The efforts of Mori wa Umi no Koibito focus on traditional systems that connect the forest and the sea, and on providing opportunities for and enhancing interactions

[8] Issues discussed in meetings with stakeholders and local residents in Kesennuma January 22, 2014. Report of meeting sponsored by Sustainability Science Council (SSC) of Japan to Integrated Research for Sustainability Science (IR3S) program, The University of Tokyo. (Unpublished). See also Asahi Shimbun (2014) Editorial: Residents' views should come first in Tohoku reconstruction work. March 11. Online at www.asahi.com/article/views/editorial/AJ201403110035.

[9] www.nacsj.or.jp/english/.

between residents and the natural environment. The aim is to restore ecosystem services that were lost or damaged in the disaster and in the longer term to reduce vulnerability to future natural disasters. Recognizing and applying these principles bodes well for the success of the sustainable reconstruction of the Moune Village and, by example, of other communities in the affected areas.

Tidball and Krasny (2008) apply the term "civic ecology" to refer not only to restoration and stewardship practices but also to a theoretical framework for studying the role such practices play in the larger social–ecological system. Civic ecology practices, they maintain, allow individuals to learn through observing and experiencing how their actions impact the biological and physical environment as well as the feedbacks and other interactions among their actions and other ecosystem components (Krasny and Tidball 2009). Experience elsewhere also suggests that civic ecology practices may foster resilience in social–ecological systems through enhancing biological diversity and ecosystem services (Krasny and Tidball 2009; Krasny and Tidball 2012; Chapin et al. 2011).

The work of Mori wa Umi no Koibito based on community involvement and a bottom-up approach is supported by Elinor Ostrom's theory of management of commons, which demonstrates the importance of the involvement of all relevant stakeholders in identifying and maintaining rules for collective responsibility and good management (Ostrom 1990).[10] In reality, this is far from an easy task. Attracting multiple actors to participate in greening activities that will facilitate ecosystem restoration and contribute to building social–ecological resilience in the Tohoku region will require creative and dynamic approaches to management at many levels. Other case studies have shown that restoration of degraded ecosystems built on stakeholder understanding and acceptance is extremely difficult, albeit feasible given sufficient incentives, innovative communication techniques and institutional capacity (Westley et al. 2011). Through community engagement, solid communications and education initiatives, coupled with using the approach to build the economy through support of traditional management of forests and fisheries, the Kesennuma NPO is working toward overcoming barriers to such restoration efforts and providing opportunities for the creation of new green businesses that will contribute to future social–ecological resilience.

[10] Elinore Ostrom (1933–2012) winner of the Sveriges Riksbank Prize in Economics in 2009 created a new theory of the commons which challenged the long-held theory of Garret Hardin known as "The Tragedy of the Commons", which held that the protection of public (common) places required the assignment of property rights or other government regulation. In contrast to Hardin's theory Ostrom found that people can and often do manage efficiently common resources like forests and fisheries independent of government intervention.

Social–ecological restoration

Increased knowledge of how we can strengthen social–ecological resilience is becoming increasingly important in coping with the stresses caused by climate change, other environmental impacts and extreme events such as the Tohoku earthquake and tsunami (Adger et al. 2005).

In the context of the global climate adaptation funds, Elmqvist suggested that when thinking about government support for reconstruction the question that needs to be answered is: "To what extent could these funds be used for restoration to reduce risks and vulnerability and build resilience to climate change, and against future disasters?"[11] This is the question that is being addressed in the context of restoration of NE Japan and with planning for the national park. For example, enhancing *satoyama* and *satoumi* coastal regeneration in Tohoku coupled with strategies to address natural hazards could contribute to restoring lost or damaged ecosystems and help to ensure food security. Increased forest produce from forest restoration and wetland restoration leads to (inter alia) increased fish stocks, revitalization of industries, and socio-economic benefits. The National Biodiversity Plan of Japan recognizes that conservation and restoration of degraded ecosystems and building ecosystem resilience can contribute to multiple benefits in a region from climate change mitigation and adaptation, to combating species loss, and providing the basis for sustainable local industries (MOEJ 2012a, pp 170–175).

In the long-run restoration efforts can be an opportunity to contribute to Japan's Strategy for a Sustainable Society, "Becoming a Leading Environmental Nation Strategy in the 21st Century" (MOEJ 2007; Kamiyama and Iijima 2012). Central to that strategy is the integration of efforts in Japan to create a society that is low carbon, resource circulating, and that is harmonious with nature (MOEJ 2007; Komiyama 2014). Incorporating "resilience-thinking" and enhancing social–ecological resilience in the Tohoku region can contribute to the attainment of those goals for sustainable development at many different scales (Folke et al. 2010; Elmqvist 2013) (Box 2). As Tidball (2012) writes "…the affinity we humans have for the rest of nature, the process of remembering that affinity and the urge to express it through creation of restorative environments, which may also restore or increase ecological functions, may confer resilience across multiple scales" (Tidball 2012:5). This is true not only for the natural environment but also in terms of the built environment, and

[11] T. Elmqvist made the comment during a planning meeting on resilience and recovery in the aftermath of the Great East Japan earthquake and tsunami held at UNU, Tokyo. See, also, Tuvendal and Elmqvist 2012.

Box 2 Elements of "resilience thinking" that contribute to meeting the challenge of sustainable development

Resilience thinking
Enable high rates of framed innovations
Maintain diversity
Maintain modularity
Restore lost ecological functions
Tighten feedback loops
Build social capital—address equity
Build overlap in governance
Create incentives for stewardship of distant ecosystems

Source: Elmqvist, T, M. Fragkias, J. Goodness, B. Güneralp, P. J. Marcotullio, R. I. McDonald, S. Parnell, M. Schewenius, M. Sendstad, K. C. Seto, C. Wilkinson (Editors). 2013. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. A Global Assessment. Springer

with respect to economic, social and political change (Elmqvist et al. 2013). To build resilience in the damaged communities it will be important to integrate socio-economic with ecological efforts (Folke 2006). Adger et al. (2005) point out that resilience of coastal societies is more tightly linked to larger scale processes such as global economic linkages and tourism than in the past. Resilient social–ecological systems, they note, incorporate diverse mechanisms for coping with change and crises including both formal and informal social institutions and robust governance systems at various levels along with means to increase biodiversity and enhance ecosystems.

The Satoyama Initiative in Japan[12] is aimed at pursuing a healthy (resilient) relationship between people and nature as interdependent systems (see Folke et al. 2010; Armitage et al. 2012). Inherent in the concepts of *satoyama* and *satoumi* is a holistic view of society and nature. Traditional *satoyama* and *satoumi* communities provide not only for biodiversity and sustainable sources of food and energy, they also encourage cultural richness (see Japan Satoyama–Satoumi Assessment 2010; Scherkenbach 2013). Historical communal participation in agriculture and fishing has developed countless traditions, festivals and other community activities. If these ecosystem and cultural services are effectively revived and equitably managed through the park and other institutions in the Tohoku region, they will contribute to the social–ecological restoration of the area (Scherkenbach 2013). Indeed, a sense of collective societal identity could help support the psychological healing of individuals and the community as a whole (see Masten and Obradovio 2008). In turn, these strengths of *satoyama* and *satoumi* communities contribute to attainment of four factors that resilience scholars have identified as critical to fostering resilience: (1) learning to live with change and uncertainty; (2) nurturing biological and cultural diversity; (3) combining different types of knowledge for learning (see Berkes 1993); and (4) creating opportunity for self-organization (Tidball 2012).

In the park experiment, we see evidence of all four of these factors at work in the design and management. The park will utilize vulnerable land for farming and restoring natural marshlands. Revitalization of traditional farming and marshlands will also restore and enhance ecosystem services provided by *satoyama* and *satoumi* landscapes including timber for construction, wood and charcoal for fuel and food, and marine products (Yumoto et al. 2012, 125–154; Ohno et al. 2009). In addition to providing some protection from natural disasters, restored ecosystems also regulate water quality and wildlife habitats, and increase biodiversity, which will contribute to strengthening regional as well as community resilience (Takeuchi and Herath 2010; Elmqvist 2013). Maintaining biodiversity is essential to the production of ecosystem services and maintaining the resilience of ecosystems (Gunderson and Pritchard 2002). Yet, unprecedented rates of biodiversity loss continue to alarm scientists who participated in the UN sponsored Millennium Ecosystem Assessment (MA 2005). In Japan, renewed interest in the potential use of traditional practices for maintaining biodiversity and increasing the resilience of local ecosystems has increased in the wake of the 2011 disaster. The question remains, however, to what extent these practices in for example farming and fisheries, enhance local biodiversity and therefore the supply of ecosystem services for building resilience and contributing to human well-being (Duraiappah and Muñoz 2012).

Revitalization of the communities affected by the 2011 disaster provides unusual opportunity to introduce new policies at national, regional and local levels and to take significant steps in many societal sectors to enhance the use of the rich natural capital in the region, and to promote the economic valuation of biodiversity. As indicated in the national plan itself, the conservation of biodiversity and the sustainable use of its components cannot be achieved only by developing and implementing the National Biodiversity Strategy of Japan (MOEJ 2012b ch.3). Those strategies must be supported by local activities aimed at conserving and utilizing the local natural environment and through innovative management of "new commons" that support it (MOEJ 2012b, Part 2, Chapter 4).

"New commons" are the mosaic of land, water, and climate, and their underlying processes that regulate ecosystem structure and functions to maintain a sustainable supply of common pool resources for human well-being. (Duraiappah et al. 2014) They are different from resources that provide common use. Rather they refer to ecological processes and functions that "transcend" social boundaries, property systems, and political jurisdictions. Characteristic of these

[12] www.satoyama-Initiative.org/about/.

commons is that they be based on existing institutions and supported by broad community involvement, trust and motivation. This in turn requires the direct involvement of many stakeholders, for example, from local municipalities, the private sector, non-profit and non-governmental organizations, potential suppliers, etc. The communication links between and among those institutions must be strengthened to avoid potential mismatches and concomitant unintended consequences. As Duraiappah et al. (2014) have noted, the plurality of values within and across individuals coupled with the spatial scale at which different institutions are organized and at which ecosystem services are produced can create mismatches in the management of "New Commons" which can lead to decline in the services they provide. In the case of the *satoyama* landscapes of Japan these mismatches between, say, the values and goals of modern private property owners and traditional communal rules governing the common pool resources that support the agricultural and other economic and cultural activities have led in some cases to decline in these landscapes and in their underlying ecological services. This is an important consideration in the future development of the Sanriku Fukko National Park. It can serve as a bridging institution between national government and regional authorities in collaboration with local people and users to avoid the potential mismatches and build the kind of partnerships that are necessary to preserve and protect the new commons and contribute to social–ecological restoration.

Sustainability science to support social–ecological restoration

Scientists as well as decision makers are faced with an enormous challenge concerning the questions of how to contribute to the reconstruction of NE Japan. The problems are vast in scope and complex with impacts that touch many aspects of human well-being: social, psychological, environmental and economic. The cause of the devastation is known, yet uncertainties surround the long-term effects of the damage (for example from the Fukushima nuclear power plant failure), and how best to address security and safety issues as well as social and economic concerns for the future are sources of tension and disagreement between generations and between public and private interests (Onishi 2012).[13] Traditional science aimed at understanding of particular phenomena concerning how the universe works tells us much about the causes, history, and consequences of earthquakes, tsunamis, and nuclear energy. But how to (re)build the lost society in a way that renders it more resilient and more sustainable than before requires the integration of knowledge from many spheres including the natural, engineering and social sciences and social–ecological systems analyses, as well as the humanities, psychology and ethics. The orientation of research in sustainability science (and that which makes it more appropriate to the issues at hand) is aimed specifically at action intended to enhance human welfare and well-being (Komiyama and Takeuchi 2006; Wiek et al. 2012; Komiyama and Takeuchi 2011). Human well-being has many constituents including freedom and choice, health, good social relations and security (Duraiappaah et al. 2012, p 458). And these constituents as perceived by people are situation dependent reflecting local geography, culture and ecological circumstances (MEA 2005, p3).

As Ostrom and Nagendra (2006) found in their studies of commons in many rural settings, a single research method used by one academic discipline for complex multi-scale processes does not provide a cumulative understanding of how individuals (and communities) in dynamic, complex, social–ecological settings react to institutional rules and affect ecological systems. Following Ostrom's point, an effective comprehensive approach to problem solving for social–ecological restoration of NE Japan that will support the area's goals for sustainable development requires coordinated use of multiple skills.

Sustainability science is a field defined by the problems it addresses, rather than by the tools of the disciplines it employs (Kates et al. 2001). Its aim is to improve society's attempts to achieve sustainable development, to sustain the life support systems of the planet, and to reduce poverty (PNAS 2007; Kates 2011). Although still in a developmental stage, sustainability science has matured in the last decade and has the potential to provide the framework necessary to address the complex issues of social–ecological restoration by integrating various streams of knowledge, including traditional indigenous sources, and ensuring robust stakeholder participation (Kajikawa et al. 2014). The application of sustainability science in this context is what Wiek et al. 2012, p22) have identified as "transformational research" whose aim is to generate widely applicable solution options.

Yoshikawa's circulating model of sustainability science (Fig. 2) is apt in the present context and well suited to research that is needed on the restoration of ecological and social systems in the Tohoku region. It takes account of the need for flexibility in the design and execution of research that is carried out in frequent communication with social actors who in turn are affected by their participation in the research and supports consistent collaboration between scientists and actors across societal sectors. This approach

[13] These issues were discussed with stakeholders and representatives of three non-profit organizations in Miyagi Prefecture January 22, 2014. "Experts Meeting on enhancing resilience and local sustainabilty for the great east Japan earthquake disaster-affected areas" report, on file at IR3S Program, The University of Tokyo.

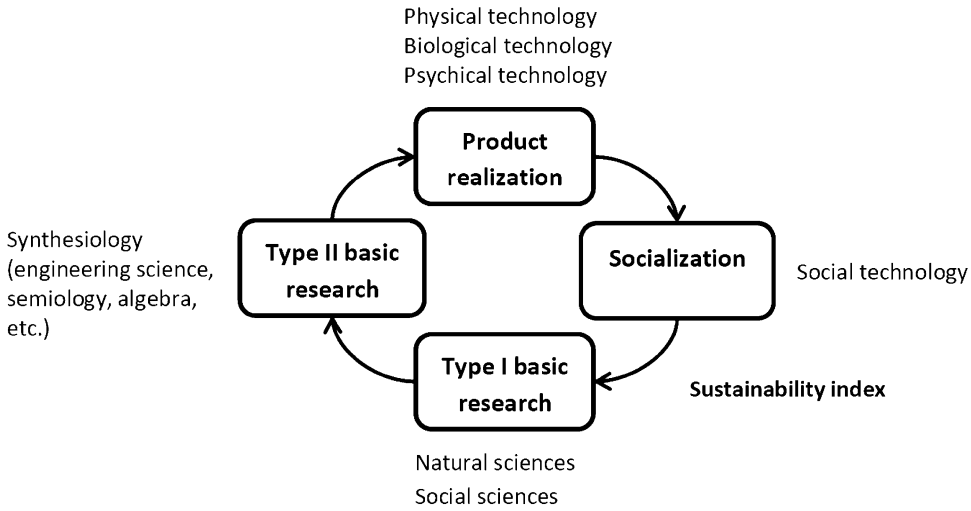

Fig. 2 A circulating model of sustainability science that supports consistent and ongoing collaboration between scientists and society in the conduct of research. Source: Yoshikawa (2011)

provides opportunity to test and measure the effects and impacts of actions taken in the light of increasing scientific knowledge and thus to make corrections over time. To work with communities at various levels sustainability scientists themselves must recognize the need for improved communications skills and strive to work with others to develop them (van der Leeuw et al. 2012). Developing these skills can provide the researcher with enhanced ability to partner with policy makers and implementers in defining research questions identifying data requirements, jointly conducting research and developing solution options that are implementable and contribute to building social–ecological resilience in the affected communities.

Conclusion

The post-disaster reconstruction process in the Tohoku region presents a unique opportunity for Japan to build more sustainable and resilient communities. The hope is that it will lead the way for Japan's long-term shift towards a low-carbon, resource-recycling economy, and a more sustainable society that functions in harmony with nature (MOEJ 2012b, p173). This paper has explored the potential for a strategy to restore social–ecological resilience to the affected areas that will contribute to the revitalization of the affected communities in multiple ways and put them on a path to sustainable development. The twin concepts of *satoyama* and *satoumi,* which are integrated systems in the Tohoku coastal region, provide a basis upon which such a strategy may be modelled. Restoration of these traditional landscapes involves local leadership that can engage community residents and promote shared stewardship of the rich and diverse natural resources of the area. Participation in restoring natural systems and nurturing of the region's biological and cultural diversity will also contribute to psychological healing and recovery from loss of traditional and familiar surroundings. Research has shown that community-based natural resource management contributes to enhancing resilience by conferring social and ecological benefits to individuals, their community and to the environment, and to reducing vulnerability (Tidball and Krasny 2013; Svendsen 2013).

Diversity is fundamental to resilient socio-economic systems. Strengthening local traditions and providing opportunities for all ages to participate in the creation of strategies that support the revitalization of *satoyama* and *satoumi* areas will facilitate socio-economic diversity as well as biodiversity.

The reconstruction of the areas devastated by the 2011 great East Japan earthquake and tsunami presents multiple opportunities to demonstrate the potential for creating sustainable rural and urban communities elsewhere in Japan and throughout the world (see Elmqvist et al. 2013). Efforts are underway to apply the Sanriku Fukku (restoration) National Park as a fulcrum for management and nurturing of socio-ecological resilience in the region. By working across many levels of governance, engaging communities in restoration activities and through environmental education and education for sustainable development (ESD) implementers of plans for the park in collaboration with sustainability scientists have the opportunity to develop a model for restoration of social–ecological systems.

What happened in NE Japan was unexpected. Engineering solutions and preparedness proved valuable but insufficient. Restoration must involve enhancing the capacity of social–ecological systems in the region to adapt to uncertainty and surprise. Today, nearly a quarter of the world's population live within 100 kilometres of a coast

and that is likely to rise to 50 % by 2030. (Adger et al. 2005).[14] Scientists warn that global environmental change will lead to more such events increasing in both frequency and intensity (McLean and Tsyban 2014). The restoration of NE Japan is thus poised to serve as a model for building social–ecological resilience in the face of such events in whatever form they may take and wherever they may occur.

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[14] See also http://sedac.ciesin.columbia.ed/es/papers/Coastal_Zone_Pop_Method.pdf

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