Chapter 2
The History and Future of Satoumi Concept

Tetsuo Yanagi

Abstract This chapter introduces the history of the emergence of the concept of Satoumi in Japan and its expansion not only in Japan but also in the world. The natural and sociological mechanisms by which Satoumi enhances biodiversity and productivity in coastal waters will be discussed using empirical verifications, with the discussions on the relationship between Satoumi and Ecosystem-Based Management (EBM), Community-Based Management (CBM), Marine Spatial Planning (MSP), and Integrated Coastal Management (ICM).

Keywords Coastal area · Human intervention · Productivity · Biodiversity · Primary production · Transparency

2.1 The Beginning of the Satoumi Theory

In 1998, in response to a request from the editorial board of the *Journal of Japan Society of Civil Engineers* and the *Journal of Japan Society on Water Environment* to "discuss the future direction of research on coastal seas," I wrote a short essay, claiming that "Since the marine pollution problem has been settled, and many fishers want to have 'rich seas' rather than 'clean seas,' 'Satoumi creation' should be the main direction of future research on coastal waters to realize the Satoyama-like way of life in coastal waters" (Yanagi 1998a, b). Satoyama refers to the forests with high biodiversity and productivity under human interventions. After that, I gave lectures on Satoumi in various parts of Japan as requested, but I received many comments from the participants of the lectures that it is impossible to realize Satoumi unless detailed concepts and methodologies are clarified. In 2006, I wrote a Japanese book entitled *Satoumi Theory*, in which I defined Satoumi as "coastal waters with high

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biodiversity and productivity through appropriate human interventions," and developed a detailed logic (Yanagi 2006).

2.2 Development of the Theory of Satoumi in Japan

After the publication of the *Satoumi Theory*, the creation of Satoumi was included in many of Japan's marine policies, such as the Strategy for an Environmental Nation in the 21st Century in 2007, the Third National Biodiversity Strategy in 2007, and the Basic Plan on Ocean Policy in 2008. The Ministry of the Environment (MOE) of Japan has designated eight coastal areas in Japan as model areas for the creation of Satoumi. At the end of FY2010, MOE prepared the "Satoumi Creation Support Manual" (Ministry of the Environment 2010).

The concept of Satoumi was spreading throughout Japan. However, some ecologists criticized us that biodiversity in Satoyama could be increased by human interventions, while biodiversity in coastal areas could be increased by doing nothing. Based on the results of the field experiments, it was concluded that there are two types of appropriate human interventions in the Satoumi: (1) human interventions to create new habitats for marine organisms and (2) human interventions to prevent marine vegetation such as seaweed beds from reaching its climax (Fig. 2.1). Adaptive management of these human interventions can increase biodiversity and productivity of coastal waters. We also conducted an empirical study on the effects of human resource management on the increase of biodiversity in coastal waters (Yanagi 2009).

From 2009 to 2012, the Japan Science and Technology Agency (JST) provided ca. 90-million-yen research funding for the "Construction of a Social System for the Restoration of the Marine Environment (Satoumi Creation)" project (Principal Investigator: Tetsuo Yanagi). In addition to increasing the scientific knowledge

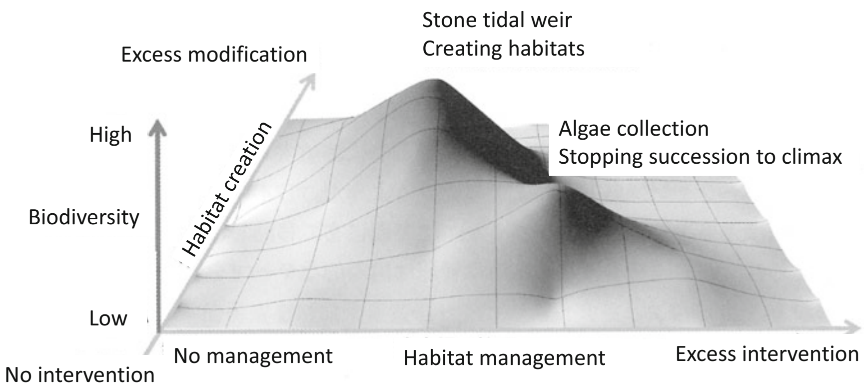


Fig. 2.1 Relationship between human interventions and biodiversity in Satoumi

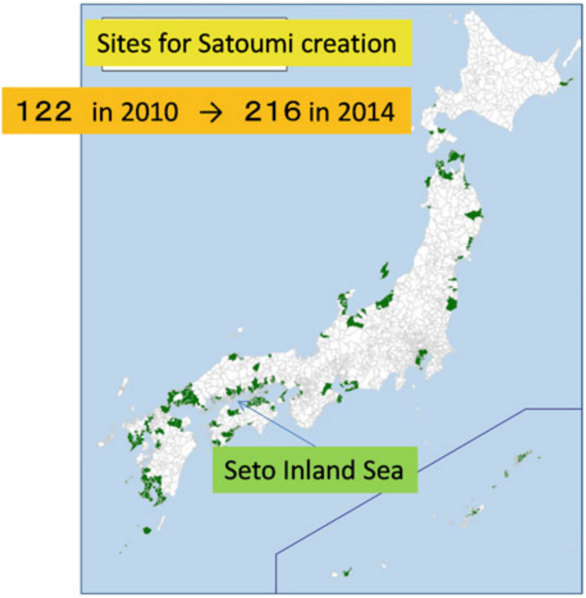


Fig. 2.2 Sites of Satoumi creation in Japan in 2014

necessary for the creation of Satoumi, a series of interviews were conducted on Satoumi-related activities in Japan and around the world. The results of this project and related research were summarized and published in *Satoumi Creation Theory* in Japanese (Yanagi 2010). In April 2012, the NPO Satoumi Creation Research Council was established (Satoumi Creation Research Council 2012).

In response to these movements, the *Journal of the Japanese Society of Fisheries Science* published a special issue entitled "My idea, sense, and approach to Satoumi Part I and Part II" in Volumes 79 (2013) and 80 (2014), in which the author and 12 other experts, including Satoyama experts, summarized and introduced their opinions (Yanagi 2013).

During this period, many people in Japan accepted the concept of Satoumi favorably. According to a questionnaire survey conducted by the Ministry of the Environment on local governments, the number of Satoumi promotion organizations increased from only 122 in 2010 to 214 in 2014 (Fig. 2.2, Ministry of the Environment 2014). They found more Satoumi sites in the southwestern part than the northeastern part in Japan, because the Satoumi concept had been expanded from the Seto Inland Sea (Yanagi 2006). As many kinds of Satoumi creation activities have been performed under different definitions in Japan, Hidaka (2016) introduced a new definition of Satoumi covering diverse activities as "Satoumi is a management structure for the conservation of the environment and resources in the coastal sea by local people and the government, or the coastal areas which are governed by such management structure."

2.3 Development of Satoumi Theory in the World

The Satoumi concept was first introduced to the world at the third conference of the Environmental Management of Enclosed Coastal Seas (EMECS) held in Stockholm, Sweden, in 1997. However, the response was mixed. “You are a servant of fishers! Scientists should explore the natural order without preconceptions. The Satoumi concept of conducting research for fishers is an evil way of science!” Of course, the argument never took off.

However, when I presented my research on Satoumi at the 7th EMECS held in Caen, France, in 2006, the chairperson (Prof. Ozan of Turkey) made the following evaluation at the summary meeting: “Satoumi is a symbiosis between human communities and coastal/marine areas—a more rational vision of co-existence.” The situation in the coastal areas of Europe and the United States changed in the 2000s, and it became clear that the marine environment could not be conserved without appropriate human interventions. After returning from France, I immediately translated *Satoumi Theory* into English and published “Sato-Umi” (Yanagi 2007).

The first International Satoumi Workshop was held at the 8th EMECS in Shanghai in 2008, and since then, the Workshops have been held somewhere in the world every year (Table 2.1). Mainly through this series of international workshops, the Satoumi concept has been spreading around the world (workshop reports are available from the International EMECS Center n.d.).

Several Satoumi-related events were held at the Convention on Biological Diversity (CBD)-COP 10 held in Nagoya, Japan, in October 2010. After the conference, CBD Technical Series 61 “Biological and Cultural Diversity in Coastal Communities—Exploring the Potential of Satoumi in Implementing the Ecosystem Approach in the Japanese Archipelago” was published in 2011. This report explained the contributions of Satoumi activities in various areas in Japan to the increase of biodiversity in coastal areas. It stated that Satoumi is an expression on the CBD

Table 2.1 Locations of the International Satoumi Workshops and meetings

Year	Location
2008	Shanghai in China
2009	Manila in the Philippines
2010	Kanazawa in Japan
2011	Baltimore in the USA
2012	Hawaii in the USA
2013	Marmaris in Turkey
2014	Tokyo in Japan
2015	Da Nang in Vietnam
2016	Saint Petersburg in Russia
2017	Bordeaux in France
2018	Pattaya in Thailand
2019	Saint Lucia, Fiji, and Turkey

ecosystem approach, which is considered the primary framework for action under the CBD.

In 2011 and 2012, the United Nations University conducted the Satoyama-Satoumi Sub-global Assessment in Japan as a continuation of the Millennium Ecosystem Assessment conducted from 2001 to 2005, which evaluated the degradation of ecosystem services at global scales. Its report entitled *Satoyama-Satoumi Ecosystems and Human Well-Being* was published in 2012 (Duraiappah et al. 2012).

In 2012, I published *Japanese Commons in the Coastal Seas*, which was an English translation of *Satoumi Creation Theory* (Yanagi 2012). Also from 2012, as part of the North Pacific Marine Science Organization (PICES) project, the Fisheries Agency of Japan became the sponsor of the "Project for Establishing a Satoumi-type Fishery Management System in the Pacific Rim (2012–2016)." This project aimed to create a fishery management system model based on the concept of Satoumi by setting up model areas in the western, central, and eastern parts of the Pacific Ocean.

2.4 Satoumi and Western Approaches of Coastal Management

It is not easy to establish Satoumi concept as an international term similar to tsunami because the latter clearly refers to the natural phenomenon of "long waves generated by undersea earthquakes." In the case of Satoumi, it involves not only the natural science aspect of "the relationship between human interventions and biodiversity/productivity" but also the humanity aspect of "the relationship between humans and nature" and the social science aspect of "how people manage coastal waters." It is not easy for the people from different societies and cultures to share a common understanding of Satoumi.

For example, Christians believe that "we must preserve nature separately from human beings because God created nature separately from humans" (Fig. 2.3). The desired attitude of humans to nature is expressed by the word "stewardship." People ignore nature in the city, where most human activities are performed. A buffer zone is set up between areas of nature preservation and the city. As a result, under-use occurs in preserved areas and overuse in the city.

Asian people generally think that "Gods live everywhere in nature, and humans living in nature must co-exist with gods and nature." Wise-use is the best attitude. People even think that they may be reborn as other animals or even plants in their next lifetime and they must respect every form of lives in the nature (Fig. 2.3).

In terms of environmental management in coastal waters, Westerners have established a framework for coastal management based on various fundamental concepts such as Ecosystem-Based Management (EBM) and Community-Based Management (CBM). Satoumi is a more comprehensive approach to integrate Satoyama, Satochi (the broader land areas with human activities coexisting with

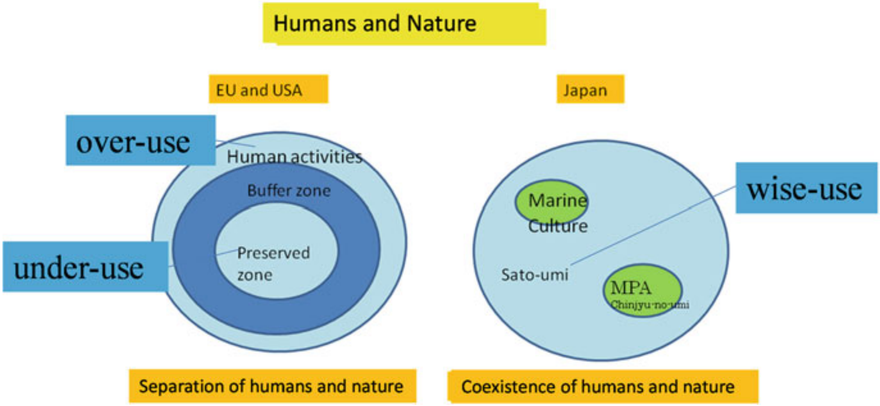


Fig. 2.3 Difference in perceptions of the relationship between human and nature among European and Asian people

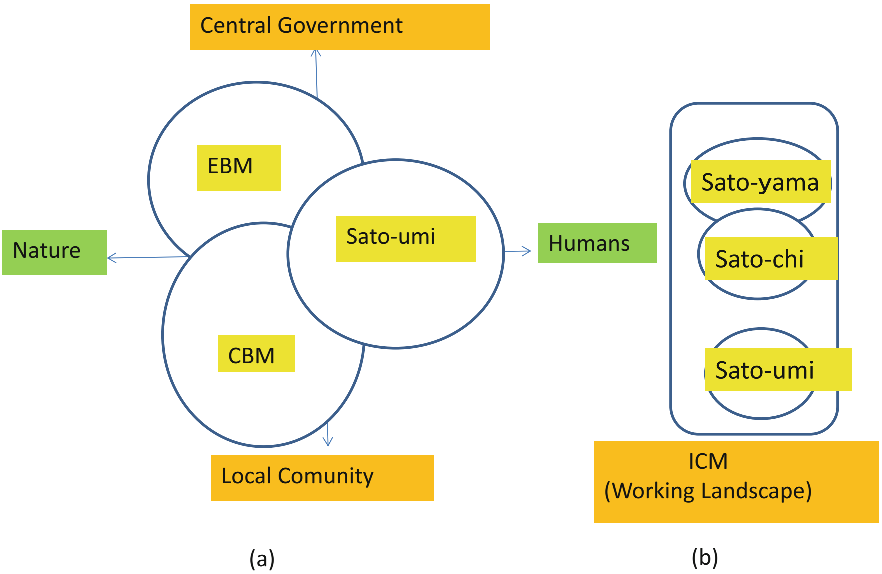


Fig. 2.4 Relationships of Satoumi, EBM, and CBM (**a**) and Satoumi and ICM (**b**)

terrestrial and aquatic nature), and Satoumi through Integrated Coastal Management (ICM) approaches (Fig. 2.4).

In the annual series of the International Satoumi Workshops, similarities and differences of these approaches have been discussed, asking what kind of research would be needed to build a globally valid and acceptable Satoumi concept. In the following sections, I discuss the relationship between Satoumi and EBM, CBM, Marine Spatial Planning (MSP), and ICM, which have been clarified through discussions in the series of international workshops.

2.5 Satoumi and EBM

Water quality parameters such as COD (chemical oxygen demand), TP (total phosphorus), and TN (total nitrogen) have long been used as indicators of coastal zone management in Japan, because environmental policies such as effluent control at land-based sites can manage water quality parameters by making their concentrations conform to standard values. The total allowable catch (TAC) system is used to set the upper limit of catch for each fish species to protect resources.

On the other hand, in Europe and the United States, there has been a strong opinion that it is difficult to conserve the entire ecosystem and its services with such water quality parameters and TACs. The concept of Ecosystem-Based Management (EBM) has been proposed. For example, in the United States, EBM aimed at harmonizing nature conservation with logging, which might lead to the extinction of the owl, was initiated by the federal government under the Clinton administration in 1993, and since then, local collaborative efforts have been developed to optimize complex nature and human systems (Mori 2012).

However, EBM does not have an appropriate index to represent the entire coastal marine ecosystem. In the United States, the coastal ecosystem has been represented by indices such as the Submerged Aquatic Vegetation Index and the Oyster Production Index, which have been used for EBM in the Chesapeake Bay.

In contrast, Satoumi is currently proposing the following environmental indicators that integrate water quality and ecosystems.

First, we quantitatively identify the transparency and nutrient concentrations that maximize the primary production (mgC/m^2/day) of coastal waters to increase the biological productivity (Fig. 2.5). When the nutrient concentration is too high, red tide occurs in the upper layer, and the transparency decreases. In such a case, the primary production in the upper layer becomes large, but the phytoplankton density in the lower layer decreases because sunlight does not reach the lower layer, and the primary production in the whole water column remains small. If the nutrient concentration is too low and the phytoplankton density in the upper layer is low, the water clarity will be high, but the primary production of the water column will still be small because there are not enough nutrients to support the growth of phytoplankton. In contrast, when appropriate nutrient concentrations are provided, phytoplankton can proliferate in the upper and lower layers. In shallow water, attached diatoms, seagrass, and algae on the seafloor can also photosynthesize, resulting in a maximum primary production in the water column.

It is not easy to clarify the quantitative relationship between transparency and primary production in actual coastal waters. The only such data set in Japan currently available to the author is from the "Interdisciplinary Study on Sustainable Production of Important Fishery Resources and Environmental Conservation in the Seto

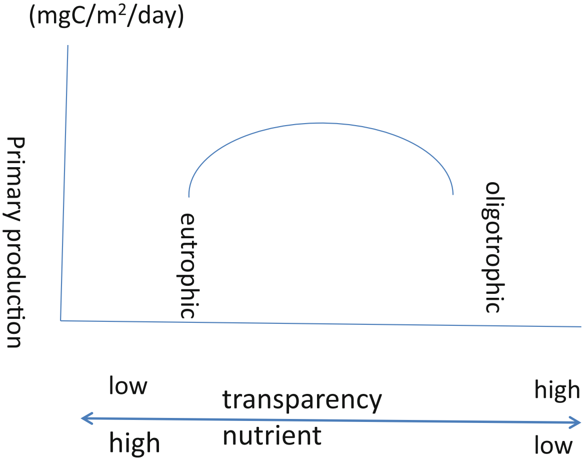


Fig. 2.5 Relationships between transparency (inversely proportional to nutrient concentration) and primary production

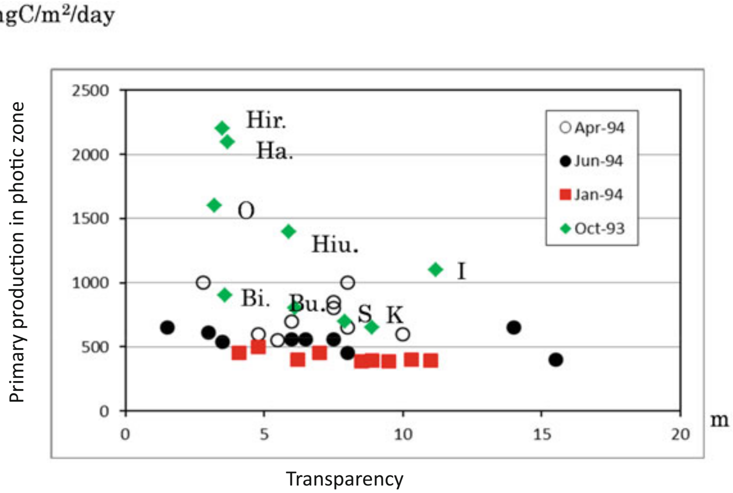


Fig. 2.6 Relationships between transparency and primary production in Seto Inland Sea over four seasons. *Hir* Hiroshima Bay; *Ha* Harima-nada; *O* Osaka Bay; *Hiu* Hiuchi-nada; *I* Iyo-nada; *Bi* Bisan Seto; *S* Suou-nada; *K* Kii Suido; *Bu* Bungo Suido

Inland Sea," a Nissei Foundation special research project conducted in 1992–1995 (Okaichi and Yanagi 1997). Figure 2.6 shows the relationship between primary production and transparency in the Seto Inland Sea over four seasons. This figure is based on transparency data (Hashimoto et al. 1996) and primary production data (Tada 1996; Yanagi 2016). The primary production in the Seto Inland Sea was low in winter, when water temperature was low, and in summer, when stratification had developed and nutrients in the photic zone were depleted. The geographic distribution in Fig. 2.6 shows high production in deep Hiroshima Bay, Osaka Bay, and the

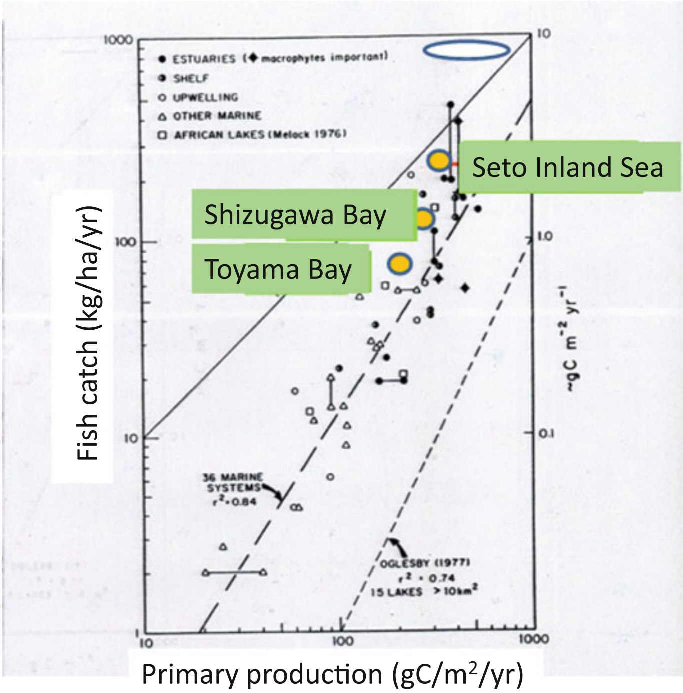


Fig. 2.7 Relationships between primary production and fish catch in various water bodies including the Seto Inland Sea, Shizugawa Bay, and Toyama Bay. (Modified from Nixson 1988)

northern part of the Harimanada and low production in the Bungo Suido and Kii Suido, which are close to the open sea.

However, the primary production on the vertical axis of this figure represents the production by suspended phytoplankton in the photic zone and excludes the primary production by attached diatoms, seaweeds, and algae on the seafloor. When light reaches the seafloor, primary production occurs not only in the water column but also on the seafloor. For example, the primary production of Takamatsu Tidal Flat in Kagawa Prefecture reached 1200 mgC m^{-2} day^{-1}, which was greater than the primary production of 600 mgC m^{-2} day^{-1} in the water column at a depth of 20 m in the offshore Bisan Seto (Kadoya 2014). The primary production of seagrass beds was about 4000 mgC m^{-2} day^{-1} (Nishijima, personal communication). If we add the primary production of seafloor-associated diatoms, seagrass, and algae, the distribution of Fig. 2.6, which is skewed to low transparency with high primary production, should be more similar to Fig. 2.5.

For now, Satoumi tentatively proposes using nutrient concentration and transparency as environmental indices to maximize the primary production in the water column (Fig. 2.7).

There is no one-to-one correspondence between the primary production and the catchable amount in fisheries. The higher the primary production, the higher the catch tends to be. However, for the same primary production, the catch differs by more than one digit between stagnant waters such as lakes and tidal-dominated waters such as coastal waters (Nixson 1988). This is because the efficiency of nutrients produced by primary production to be transferred to organisms at higher food levels is greater in coastal waters than in lakes, where horizontal and vertical movements by tidal currents are absent. As a result, the catch per unit of primary production is larger in coastal waters than in lakes.

Let me give a simple example. A comparison of coastal waters and lakes with the same nutrient and organic matter concentrations (including suspended solids) shows that strong currents in coastal waters increase organic matter fluxes (mass transfer per unit time and unit area) and nutrient fluxes to filter-feeding benthic organisms, seaweeds, and algae. On the other hand, weak currents in lakes reduce the fluxes of organic matter and nutrients. As a result, the primary, secondary, and tertiary productivity of coastal waters is higher than that of lakes.

As a result, more fish catch (higher biological productivity) is possible in coastal waters with tidal phenomena. Of course, in windy lakes, there are times when mass fluxes due to blowing currents (wind-induced currents) become large, but the same is true for coastal waters. The continuous flow caused by tidal phenomena rather than the intermittent flow caused by wind forces determines the productivity of coastal waters and lakes.

The differences in the primary production of the Seto Inland Sea, Shizugawa Bay, and Toyama Bay shown in Fig. 2.7 are due to differences in nutrient concentrations and nutrient transport mechanisms shown in Fig. 2.8. In the Seto Inland Sea, phosphorus and nitrogen are supplied from the shore, seabed, and open sea, and the supplied nutrients (dissolved inorganic nutrients) are photosynthesized in the photic layer of approximately 20 m thick to produce organic matter and fed to zooplankton and other organisms. Zooplankton feces and phyto- and zooplankton carcasses (detritus) are decomposed as they sink to be converted to nutrients. The nutrients are then used for photosynthesis again when they are uplifted to the photic layer. Therefore, the concentration of nutrients and the frequencies of nutrients used for photosynthesis per unit time determine the primary production of the area. In the case of the Seto Inland Sea, the basic vertical circulation current is an estuarine circulation current in which riverine water flows toward the open sea in the surface layer and oceanic water flows toward the central part of the Seto Inland Sea in the bottom layer. The tidal velocity and vertical mixing at each strait are large, causing a high rate of upwelling of nutrients from the dark zone into the photic zone, resulting in a large primary production. In contrast, in Shizugawa Bay, where the thickness of the photic zone and the average depth are equal to about 20 m each, the intermittent mid-layer intrusion (ingress of open seawater into the middle layer rather than the upper or lower layers) is the basic component of the vertical circulation current. The nutrient load from the land is not as large as in the Seto Inland Sea, so the total phosphorus and nitrogen concentrations are not as high as in the Seto Inland Sea. The primary production depends on the nutrient concentration itself, in addition to the efficiency of nutrients used for photosynthesis per unit time. In Toyama Bay, the water depth is much greater (about 500 m compared to the photic zone thickness of

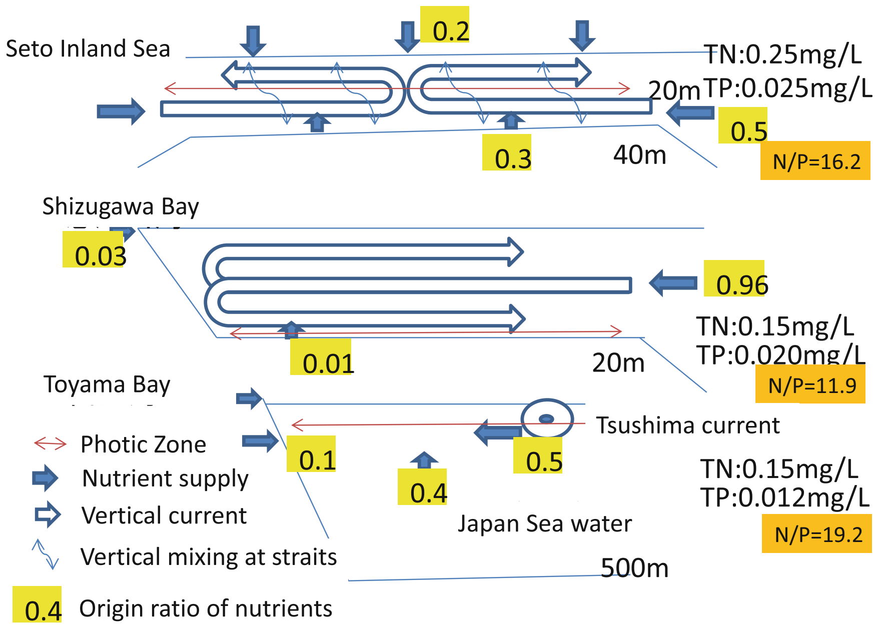


Fig. 2.8 Mechanisms of nutrient transportation in the Seto Inland Sea, Shizugawa Bay, and Toyama Bay, with photic layers of 30 m. TN, TP, and N/P represent amount of nitrogen, phosphate, and their molar ratio

about 20 m), and the rate of nutrients decomposed in the lower layer to return to the photic zone is low, resulting in the lowest primary production among the three areas.

In future, we will study what types of ecosystem structures and tidal flow structures lead to high primary production and high transfer efficiency to deliver nutrients (phosphorus and nitrogen) to large fish at the top of the food chain. We will propose the most appropriate method for "appropriate human interventions" to increase primary production and transfer efficiency in Satoumi. In other words, we are trying to integrate water quality management and EBM and to propose a method for managing coastal waters that will realize "thick, long, and smooth material cycles" (Yanagi 2006).

2.6 Satoumi and CBM

In the past, the central or local government was the major actors leading environmental management of coastal waters. However, such top-down management was often unsuccessful because it was difficult to obtain the cooperation of local communities. Therefore, CBM (Community-Based Management) is important, and

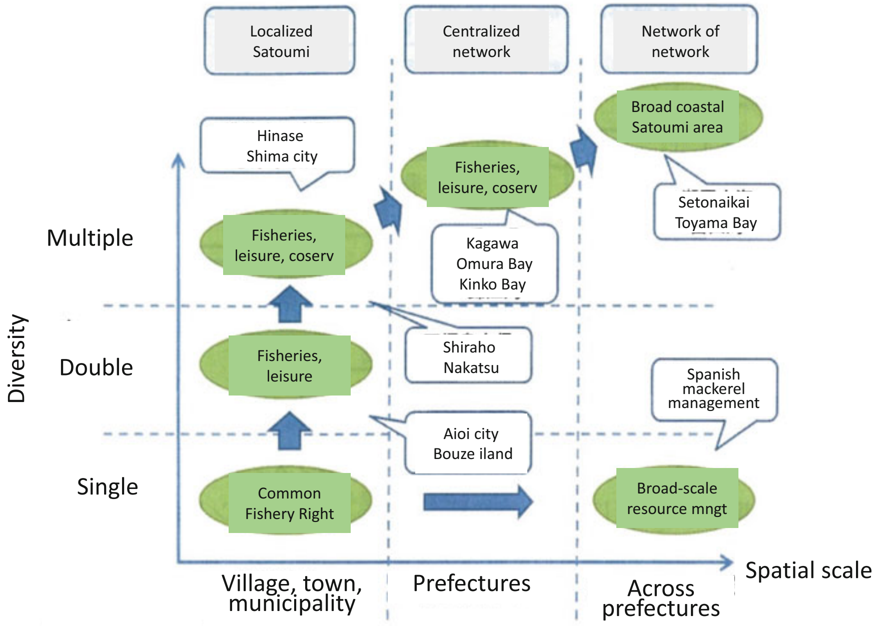


Fig. 2.9 Multilevel council system of Satoumi proposed by Hidaka (2016)

many people are now suggesting that coastal environmental management should be conducted bottom-up by local communities.

However, CBM also has its limitations. For example, sasi (Murai 1998), an excellent community-based natural resource management system in eastern Indonesia, is well followed by the local community, but intruders from other communities frequently violate the rules, poaching the fishery resources protected by the local community (Mosse 2008). To deal with such contradictions is difficult for the CBM alone. It is necessary to set up large-scale monitoring and enforcement systems across communities so that local, regional, and central governments can intervene appropriately to ensure the effectiveness of sasi.

In the Satoumi, a multilevel council system (Fig. 2.9) has been proposed to manage the environment and resources: a small-scale council to conserve the environment and resources of the local waters, a medium-scale council to manage the medium-scale waters, and a large-scale council to work at the national level (Hidaka 2016). The relationship between Marine Protected Area (MPA) and Satoumi is also discussed in these councils.

2.7 Satoumi and MSP

Marine Spatial Planning (MSP) is a process of coordinating the use of marine areas for various purposes (fishing, transportation, recreation, renewable energy including wind and wave power), similar to land use planning. MSP aims to produce the plan and spatial distribution of the use of marine areas to conserve ecosystem services and minimize conflicts among resource uses by mapping the use patterns on hydrographic charts (UNESCO Marine Spatial Planning Programme 2009).

The United Kingdom enacted the Marine and Coastal Access Act in 2009 to coordinate integrated and wholistic uses of coastal waters by MSP through close collaboration between local and central governments. The desired state of coastal waters in the United Kingdom was defined as "clean, healthy, safe, productive and biodiverse." The Marine Management Organization (MMO) was established in 2010 for MSP. Similarly, in Scotland, Marine Scotland was established in 2011 to conduct MSP in its coastal waters.

In the United States, President Obama launched the Interagency Ocean Policy Task Force in 2009 to promote ocean policy, including MSP. In 2008, Massachusetts enacted the Oceans Act, which established the Office of Ocean Energy and Environmental Policy to develop ocean resource management policies and work with NOAA (National Oceanic and Atmospheric Administration) to coordinate existing uses to balance healthy marine ecosystems with active economic activities. Similar efforts are underway in Rhode Island, California, Oregon, and Washington.

In Satoumi, the function of MSP is fulfilled in the multilevel council system described in the previous section, which includes government and researchers as relevant stakeholders (Hidaka 2016).

2.8 Satoumi and ICM

Coastal zone management cannot be done without integration, i.e., Integrated Coastal Management (ICM) must be implemented. In Satoumi, I believe that multifaceted integration processes below are essential.

1. Academic integration: Integration of natural sciences, social sciences, and humanities is necessary. Coastal ocean management cannot be achieved by knowledge of marine physics alone nor by knowledge of natural sciences integrating physics, chemistry, and biology. Coastal zone management can only be successfully achieved by integrating the results of the sciences (natural, social, and humanities), i.e., by successfully conducting interdisciplinary science.
2. Area integration: Coastal zone management cannot succeed by managing only the coastal zone. Water quality supporting the coastal marine environment is related to forests, villages, and rivers influencing coastal waters. Therefore, to maintain good water quality in the coastal zone, environmental management that

integrates the broader spatial scales including forest, village, river, and ocean is necessary.

3. Stakeholder integration: The integration of stakeholders related to different livelihoods and occupations, such as foresters, farmers, urban dwellers, and fishers, is necessary for the success of integrated management in the broader spatial scales.
4. Government integration: It is necessary to integrate the governments of municipalities at the local level, the government of prefectures at the regional level, the central government of the country, and the vertically crosscutting sections such as the divisions of public works, environment, agriculture, forestry, fisheries, economy, and industry within these governmental organizations.

A good example of ICM is the Fushino Catchment Area Committee in Yamaguchi Prefecture. Many local committees from the forest to the coastal sea along the Fushino River cooperate with each other over the conservation of the water environment of the Fushino River and the coastal sea (Seto Inland Sea Research Council 2007).

As a special session after the opening ceremony of the 11th EMECS in 2016, the "ICM and Satoumi" Workshop was held. The general discussion was activated regarding various topics of ICM. The workshop concluded the needs to continue international workshops regarding ICM and Satoumi.

2.9 Toward Clean and Productive Coastal Seas

Year-to-year variations in average transparency and yearly fish catch in the Seto Inland Sea are shown in Fig. 2.10. Transparency decreased until the mid-1980s during the period of rapid economic growth in Japan. In contrast, the fish catch increased until the mid-1980s. Since then, transparency has increased due to the inaction of total phosphate (TP) and total nitrogen (TN) load reduction law, but the fish catch decreased. The relationship between transparency and catch is not one-to-one relationship, because the temporal variability of the catch has a history (hysteresis: the catch does not depend only on the transparency at particular time but is determined by long-term fluctuations in transparency over the past several years). In Fig. 2.10, although the transparency is the same, the catch in the eutrophic period (with decreasing transparency) is higher than the oligotrophic period (with increasing transparency). The reasons for this phenomenon are as follows: (1) anoxic water masses during eutrophication destroyed the benthos ecosystem and reduced the transfer efficiency in the detritus food chain; (2) reclamation conducted in the eutrophic period caused the loss of tidal flats and seaweed beds, which are reproduction sites for fishery resources, and reduced the amount of resources; and (3) jellyfish increased and zooplankton decreased to reduce transfer of nutrients to predators at higher levels of food chain. However, these hypotheses have not yet been quantitatively confirmed.

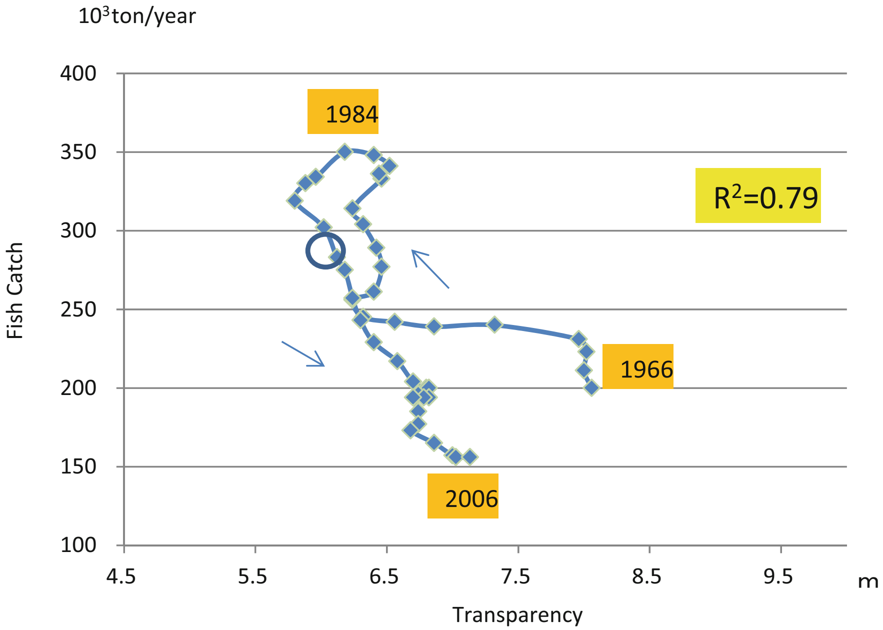
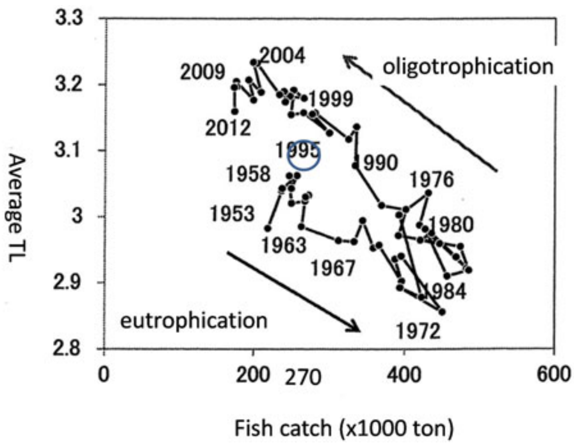


Fig. 2.10 Year-to-year variation of transparency and fish catch in the Seto Inland Sea. Dots show the 5-year running mean. Circle shows the target transparency (6 m) and fish catch (270×10^3 tons year^{-1})

Fig. 2.11 Average trophic level of caught fish and fish catch in the Seto Inland Sea. Circle shows the target fish catch (270×10^3 tons year^{-1}) and TL (3.1)



Not only the fish catch but also the relation between transparency and the trophic level (TL) of caught fish differs during both periods in the Seto Inland Sea as shown in Fig. 2.11. Average TL decreased during the eutrophic period because the catch of plankton-feeding fish such as anchovy (TL = 2.5) increased. On the other hand, average TL has increased during the oligotrophic period because the catch of plankton feeder has decreased and that of higher trophic level fish has relatively increased.

The reason for such difference in TL in both periods can be explained by the difference in the ecosystem structures surrounding caught fishes, which is mainly determined by the relationship between the growth rate of zooplankton and the biomass of phytoplankton (chlorophyll a concentration). The growth rate of zooplankton is saturated at certain phytoplankton biomass concentration (Uye and Shibuno 1992). The excess phytoplankton in the eutrophication period dies and sinks to the bottom layer to cause hypoxia. Hypoxia kills the eggs of zooplankton and decreases the transfer efficiency to the higher trophic levels including fish. On the other hand, most phytoplankton are grazed by zooplankton during the oligotrophic period, and the transfer efficiency to higher trophic levels becomes high.

The Seto Inland Sea Water Quality General Survey conducted by the Ministry of Land, Infrastructure, Transport and Tourism revealed the relationship between transparency and chlorophyll a (chl.a) concentration in the Seto Inland Sea. A chl. a concentration of 4.5 μg L^{-1} corresponded to a transparency of 6 m. We propose that the target transparency for a clean and productive Seto Inland Sea should be 6 m, with the target fish catch of 270×10^3 tons $year^{-1}$ and the target trophic level (TL) of 3.1. The transparency of 6 m corresponded to total phosphate (TP) = 0.028 mg L^{-1} and total nitrogen (TN) = 0.28 mg L^{-1}. The analyses of relationships between TP concentration and TP loads from the land and TN concentration and TN load from the land in the Seto Inland Sea revealed that the TP load of 13 tons day^{-1} and TN load of 260 tons day^{-1} corresponded to a transparency of 6 m. These observations suggest that we must go back to the mid-1980s from the viewpoint of the total load reduction policy; in other words, the policy in the Seto Inland Sea is too advanced now.

In conclusion, we propose a clean and productive Seto Inland Sea with a transparency of 6 m, a fish catch of 270×10^3 tons $year^{-1}$, an average trophic level of caught fish of 3.1, a TP concentration of 0.028 mg L^{-1}, a TN concentration of 0.28 mg L^{-1}, a TP load from land of 13 tons $year^{-1}$ and a TN load from land of 260 tons $year^{-1}$. The target transparency and other parameters such as fish catch, TL, TP and TN concentrations do not correspond one-to-one as shown in Fig. 2.10. Therefore, when we apply these quantitative approaches to other Satoumi areas to create clean and productive coastal seas, we must conduct adaptive management on the basis of continuous environmental monitoring. We also have to rehabilitate tidal flats, sea weeds and sea grass beds, and coral reefs, which are important for fish recruitment and habitat for marine biota. These habitats have continuously decreased in coastal areas in the world. By combining these adaptive activities, we will be able to create a clean and productive Satoumi for sustainable futures.

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