Ecosystem Services 37 (2019) 100940

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Community values and traditional knowledge for coastal ecosystem services management in the "satoumi" seascape of Himeshima island, Japan

Shamik Chakraborty[a,*], Alexandros Gasparatos[b]

[a] Faculty of Sustainability Studies, Hosei University, Fujimi, 2-17-1, Chiyoda-ku, 102-8160, Japan
[b] Institute for Future Initiatives (IFI), The University of Tokyo, 7-3-1, Hongo, Bunkyo, 113-8654, Japan

ARTICLE INFO

Keywords:
Traditional and local knowledge (TLK)
Cultural ecosystem services
Social-ecological systems
Fisheries

ABSTRACT

This paper combines primary and secondary data to highlight the history of resource use and ongoing change in a coastal social-ecological system (SES) in Japan. We focus on Himeshima island, whose local community both depends on coastal ecosystem services and has developed over generations resource management practices informed by a rich body of traditional and local knowledge (TLK). By engaging with local resource users through focus group discussions (FGDs), household surveys and expert interviews we identify 14 ecosystem services that contribute manifold to the wellbeing of the local community. While provisioning services are key for the livelihoods of most community members, some of the cultural services related to the traditional food culture and food-sharing practices are a source of pride and cohesion for the local community. However, respondents indicated that several key provisioning and cultural ecosystem services have degraded over time through the combined effects of habitat change/loss and overexploitation. Underlying drivers include demographic, economic and technological change that has eroded TLK practices associated with fisheries management. New economic activities based on shrimp mariculture and tourism seek to revitalize Himeshima, but eventually create important ecosystem services trade-offs that could affect substantially the local community.

1. Introduction

Coastal areas are recognized as coupled social-ecological systems (SES) consisting of human and ecological elements that are tightly interlinked and closely interacting (Berkes et al., 2003; Leslie et al., 2015). Coastal SES provide numerous provisioning services (Potts et al., 2014; Barbier et al., 2011) that contribute significantly to the livelihoods and food security of local communities (McClanahan et al., 2009; Weeratunge et al., 2013). They also provide multiple regulating and cultural ecosystem services that contribute manifold to human wellbeing (MA, 2005 Barbier et al., 2011; Rodrigues et al., 2017; Martin et al., 2016).

Ecosystem-based approaches are needed to manage sustainably coastal and marine resources (Foley et al., 2010; Berkes, 2012). However, multiple values associated with gender/ethnicity (Daw et al., 2011; de la Torre-Castro et al., 2017), the meanings/attachments ascribed to coastal environments (Burley et al., 2007), and cultural factors (Martin et al., 2016; Kearney et al., 2007), can affect how resource management decisions are made in coastal SES. Thus, in order to manage sustainably coastal SES (and their ecosystem services) it is essential to capture and consider the range of cultural interrelationships and "*cultural meanings, values, and identities; knowledge and practice*" that local communities have with coastal SES (Poe et al., 2013: 166), including how traditional and local knowledge (TLK)[1] is deployed.

Understanding the cultural ecosystem services derived from coastal SES can provide important insights about the underlying values and the connection of local communities with seascapes (de Souza et al., 2017; Havas et al., 2016; Ranger et al., 2016; Bryce et al., 2016; Raymond and Kenter, 2016; Orchard-Webb et al., 2016; Kenter, 2016; Pascua et al., 2017; Neumann et al., 2017). However, these underpinning cultural factors and values are often poorly understood (Riveri and Villasante, 2016).

Similarly, TLK practices can offer insights about local ecosystem services use (e.g. Woodward et al., 2012) and inform sustainable management options in SES (Tengö et al., 2014; Hind, 2015; Adams et al., 2014). However, TLK erosion can be an indirect driver of ecosystem change and biodiversity loss not only in SES in rapidly developing areas (e.g. Ruddle and Satria, 2010; Assefa and Hans-Rudolf,

* Corresponding author.
E-mail address: shamik.chakraborty.76@hosei.ac.jp (S. Chakraborty).

[1] TLK systems comprise practices and beliefs that (a) deal with the relationship between living beings and their surrounding environments, (b) are transmitted to the next generation through cultural practices, and (c) evolve through adaptive processes (Berkes, 2004; Folke, 2004).

https://doi.org/10.1016/j.ecoser.2019.100940
Received 18 September 2018; Received in revised form 21 March 2019; Accepted 6 May 2019

2015; Reyes-Garcia et al., 2013; Queiroz et al., 2017), but also in SES in highly developed and ageing societies (e.g. Cetinkaya, 2009; Iniesta-Arandia et al., 2015; Kamiyama et al., 2016; Tattoni et al., 2017; Hernandez-Morcillo et al., 2014).

The 'satoumi' seascapes are typical Japanese coastal SES (SCBD, 2011; Matsuda et al., 2012; Duraiappah et al., 2012). They are characterized by strong human presence (denoted by the prefix "sato" or village) in coastal/marine environments (demoted by the suffix "umi"). Essentially they are multifunctional and biologically rich coastal seascapes in close proximity to human settlements that have been managed through TLK practices over generations for their ecosystem services (Duraiappah et al., 2012; Yanagi, 2010; Berque and Matsuda, 2013; Hashimoto et al., 2015). Satoumi are characterized by "active" conservation measures, compared to the "passive" conservation of protected areas where humans are considered external to the landscape/seascape (Berque and Matsuda, 2013). In this sense, in satoumi seascapes there is a close interaction between local communities and the coastal/marine environment that forges community values and TLK practices in a reinforcing way. However, rural depopulation[2] has affected TLK practices in satoumi seascapes (Takeuchi et al., 2012), which can be particularly problematic for their sustainable management (Cetinkaya, 2009; Cetinkaya, 2012; Duraiappah et al., 2012).

The satoumi concept has been popularized in Japanese environmental policy following the Japan Satoyama-Satoumi Assessment (Duraiappah et al., 2012). Many scholars have pointed that local community perspectives/values (often exemplified through cultural ecosystem services) and TLK practices should be integrated into satoumi management (Yanagi, 2010; Matsuda and Kokubu, 2016). This is largely because fisheries management often depends on informal, traditional and/or community-based rules (Berque and Matsuda, 2013; Yagi, 2011; Lim et al., 1995) (Section 3.1). However the interface between ecosystem services, TLK practices and community values is not yet well-documented for satoumi seascapes.

This paper aims at identifying the ecosystem services provided by satoumi seascapes of Japan, and how they intersect with community values and TLK practices. To achieve this we use a qualitative approach based on primary and secondary data analysis to identify patterns of ecosystem services provision, use and change at Himeshima island (Oita prefecture). Himeshima was chosen as it exhibits unique coastal resource management traditions, mediated through long-held community values and TLK practices, but is also experiencing demographic, socioeconomic and technological changes. These changes have eroded the long-standing TLK practices, affecting some of the deeply-rooted cultural ecosystem services that are a source of pride and cohesion for the local community.

Section 2 describes Himeshima (and its coastal SES), and outlines the data collection and analysis methods. Sections 3.1 draws from historical analysis, secondary data and expert interviews to outline the main historical resource use patterns (and related practices) in the island since the late 19th Century. Sections 3.2–3.4 uses primary data collected through focus group discussions (FGDs) and household surveys to identify the type of ecosystem services derived by the local community (Section 3.2), their location within the seascape (Section 3.3), and the direct and indirect drivers of their change (Section 3.4). Section 3.5 identifies the main policy/practice recommendations and knowledge gaps to enhance the sustainability of satoumi seascapes in Himeshima, and beyond.

2. Methods

2.1. Study area

Himeshima is a small volcanic island at the extreme western part of the Seto Inland Sea. It is situated 6 km from the coast of Kunisaki Peninsula (Fig. 1), and the easiest way to access it is by a 20 minutes ferry ride from the port of Imi. The island is quite small (area = 6.85 km^2; perimeter = 17 km) and is under the administration of Himeshima-mura (Himeshima village). It belongs to the Higashikunisaki district of Oita Prefecture (Kyushu), making it the only island in the prefecture.

Due to its volcanic origin, Himeshima has high geological variability, including obsidian rocks used by ancient inhabitants to make sharp-edged tools for fishing and hunting. The seafloor around was formed about 1.2 million years ago, during a period of high volcanic activity and a massive inflow of lava and volcanic sediments. The island started forming about 300,000 years ago through multiple monogenetic eruptions of Himeshima's volcanoes and seafloor uplift. Initially Himeshima consisted of four separate islands, which later joined through this geological activity.

Despite its small size Himeshima contains various ecosystems and landscape/seascape elements (Figs. S1–S2 and Table S1, Supplementary Electronic Material), which collectively provide multiple ecosystem services (Sections 3.2 and 3.3). Healthy seagrass (*Zostera*) beds are located in the sandy shallow areas, and seaweed/algae (*Undaria*) beds in the deeper and steeper rocky slopes. Gently rolling mudflat coasts are interspersed with rocky shores.

Settlements, upland forests and agricultural areas dominate the interior. The forests in the main mountain (Mt. Yahazu), are characterized by Chinquapin (*Persera thunbergii*) trees, interspersed by wild Japanese cherry trees. Other notable tree varieties include Chinese Hackberry (*Celtis sinensis*), Muku tree (*Aphananthe aspera*), China berry (*Melia azedarach*), Camphor (*Cinnamomum camphora*), and Japanese Mallotus (*Mallotus japonicus*). Deciduous shrubs such as *Ficus erecta* are located in lower forest levels.

Himeshima does not contain any large rivers, lakes or floodplains. Even though the existing water bodies from the Sako dam and two other water reservoirs (Section 3.1) can meet the demands of the small island (Section 3,1), they do not provide suitable conditions for extensive rice cultivation. In fact, Himeshima contains few rice fields (only three in 2015), but many homegardens. Potato was the main staple crop in the past, but currently agricultural activities mainly revolve around vegetable cultivation in homegardens. These homegardens are low-input agricultural systems cultivated by elderly women in small plots adjacent to houses and along the major roads of the island (Section 3.1–3.3).

Himeshima is known for its healthy small-scale fisheries located in the Suo Nada Sea, one of the most productive parts of the Seto Inland Sea (Nagasaki and Chikuni, 1989). The local community has relied historically on near-shore fishing (i.e. within 6–10 km from coast). In 2011 (last available year of data), 164 fisheries cooperative members operated in Himeshima compared to only seven full-time farmers. Currently most fishing is done using larger 5-ton boats (approx. 100 boats), or smaller 1-2-ton boats (47 and 35 respectively) (Japan Fisheries Cooperative Oita, unpublished data) (Section 3.2). The communal fishing area is operated by the Himeshima Fishermen Community, but has undergone substantial changes in the past decades (see below and Section 3.1). However, fisheries have declined drastically since the 1980s (Sections 3.1 and 3.4).

Fisheries are now controlled through the Himeshima Branch[3] of the Oita Prefecture Fisheries Association (OPFA) founded in April 2002.

[2] Rural depopulation in Japan is a composite phenomenon that combines elements of low fertility rates and youth migration to urban areas for education and employment. As a key demographic process, it is a major indirect driver of ecosystem change in Japan (Gu and Subramanian, 2014).

[3] The Himeshima Branch was previously known as the Himeshima mura Gyogyo Kyodo Kumiai (1903–2002).

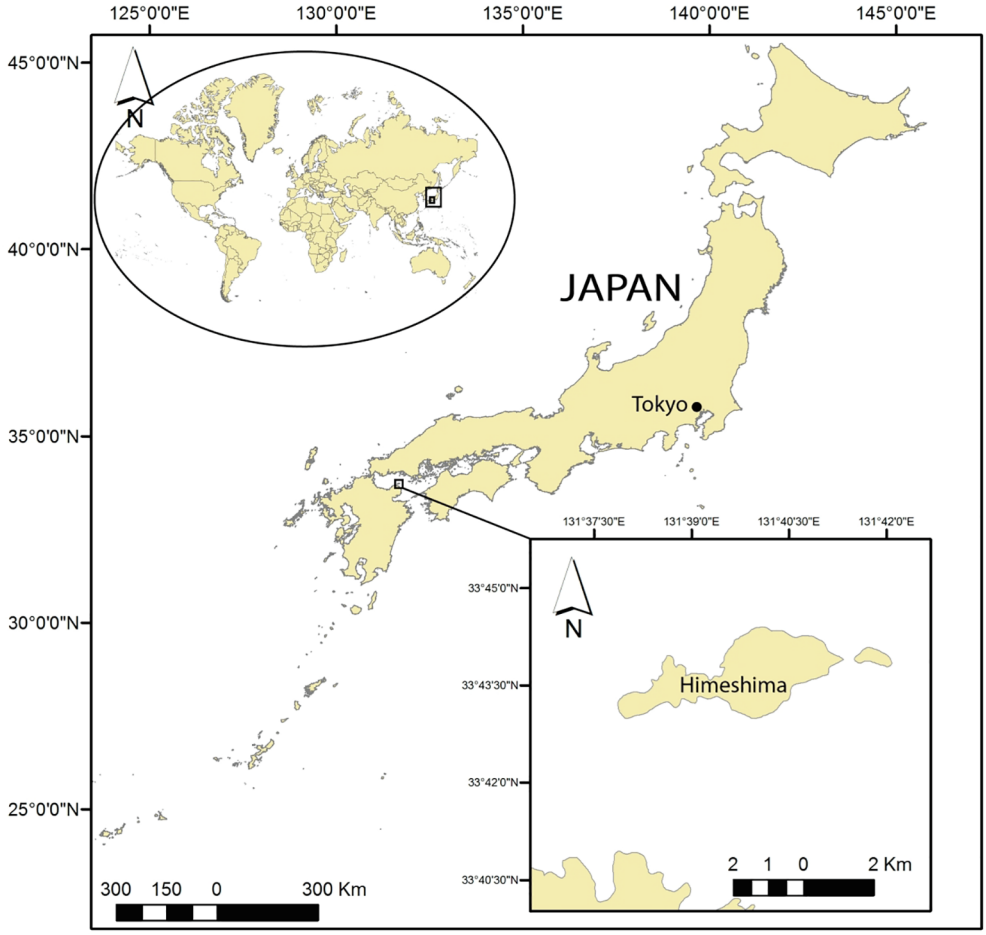


Fig. 1. Location of the study area.

The Himeshima Branch is one of OPFA's 27 constituent branches. Although not frequent, cooperation between branches occurs through meetings between cooperative's chairpersons at the main branch of each fishing zone 2–3 times a year. In most of the cases the Himeshima Branch cannot initiate its own projects, except for deciding which fish to catch from Himeshima' satoumi.

Himeshima has a shrinking and aging population, similar to most rural areas of Japan. In 2015 the total population was 1859, down from 4178 in 1955 (Fig. S3, Supplementary Electronic Material). The fraction of residents over 65 years old has increased from 14.6% in 1980 to 44.8% in 2015, and is predicted to further increase to 59.9% in 2025.

2.2. Data collection and analysis

We synthesise primary and secondary data to elicit the main resource use patterns (Section 3.1), ecosystem services (Sections 3.2 and 3.3) and drivers of ecosystem change (Section 3.4) in Himeshima. Section 3.1 mainly relies on secondary data (see below) and covers resource use patterns from 1870s onwards, including some of the main relevant TLK practices mobilised by the local community. This long-term view is important to put into perspective the current provision of ecosystem services and the drivers of their change in the past decades. Conversely, Sections 3.2 and 3.4 relies on primary data collected in three phases (see below). In particular Section 3.2 identifies the current provision of ecosystem services and their location within the seascape (Section 3.3). Section 3.4 elicits the experiences of resource users about the main direct and indirect drivers of ecosystem change, and covers variable time period depending on the recollection of each respondent (i.e. from around 1960s to current). In this sense the different sections of this paper do not seek to provide an analysis across a unified timeline, but to identify critical issues related to ecosystem services provision and change, and how it intersects with community values and TLK.

Primary data was collected in three phases through focus group discussions (FGDs), household surveys, expert interviews, participant observation and informal discussions with local community members (see Phase 1–3 below). As we focused on both tangible and intangible ecosystem services (see below) we mainly used qualitative data-capturing mechanisms to elicit the experiences, perceptions, values, and TLK practices of the local community (e.g. Lopez and Videira, 2017, 2016; Kenter et al., 2016; Fish et al., 2016a,b; Orchard-Webb et al., 2016; Pert et al., 2015; Guimaraes et al., 2013). Secondary information includes local government statistics, records of fish catches, traditional fisheries rules (*gyogyo kisetsu sadame*), and historical information from archival work, including from old maps (Fig. S4, Supplementary Electronic Material).

Phase 1 entailed expert interviews and informal discussions with Himeshima residents to appreciate the local context and understand better past/current resource use patterns and economic activities. In particular, we conducted 4 semi-structured expert interviews with the head of Himeshima Fishermen Association, the current head of tourism activities, a former member of Oita Fisheries Association, and a member of the shrimp mariculture company. We also arranged informal discussions and meetings with Himeshima residents to (a) explain the research aims, (b) establish trust, (c) understand better the context of the island, (d) identify possible FGD participants, and (e) inform the development of the main data collection instruments.

Phase 2 entailed participatory mapping to identify the type and location of ecosystem services derived from the Himeshima satoumi, and

factors behind their change. In particular we adopted a FGD format to elicit community perceptions (Mukherjee, 2002; Ochieng et al., 2018) through three participatory mapping exercises (Klain and Chan, 2012) involving 6–8 participants each. Participants represented different resource user groups (e.g. commercial fishermen, recreational fishermen, farmers) and included both men and women. For each mapping exercise we printed a map of Himeshima and asked participants to indicate which areas of the island (and its surrounding seascape) they use to derive tangible and intangible ecosystem benefits (i.e. ecosystem services) (see Table S2 Supplementary Electronic Material some examples of questions for intangible services). Tangible benefits mainly included provisioning and some regulating and cultural ecosystem services (e.g. recreation), while intangible benefits included mainly cultural services related to local traditions and social practices that tend to forge social cohesion and a sense of identify. Where needed, we provided examples of different ecosystem services from other satoumi areas, as some participants were not familiar with the concept of ecosystem services. We recorded the responses directly on the maps, and after each session we asked each participant to crosscheck the elicited information, add additional inputs/comments, and clear doubts (Fig. S5, Supplementary Electronic Material).

Phase 3 consisted of in-person household surveys to elicit the importance of different ecosystem services, (as identified through *Phases 1 and 2*), and the factors that influence their use and change over time. We focused mainly on provisioning (e.g. aquatic products, crops, medicinal plants, freshwater) and tangible and intangible cultural services (e.g. aesthetic values, cultural heritage, traditional food culture, recreation and tourism). The survey was semi-structured and contained both fixed-range and open-ended questions. Importance for both tangible and intangible services was elicited through a 4-level scale, which rated the importance as: "very important," "important," "somewhat important," "not important". Respondents also indicated how the provision of these tangible and intangible ecosystem services changed since the respondents started collecting/benefiting from them, and the reasons for this change. This is because respondents had very variable ages and thus the ability to recollect during different periods of the past. Similar to *Phase 2*, respondents indicated on a separate map the main areas that provide these tangible and intangible ecosystem services, and areas associated with bequest values (Table S2, Supplementary Electronic Material)[4].

We used snowball sampling for the household survey (Goodman, 1961) for two main reasons. First we aimed to represent all of the main resource users in the island, rather than obtain a representative sample of the island population. Second, as Himeshima is a relatively "closed" community, it is necessary to "build trust" with the local residents (Atkinson and Flint, 2001). This is especially important for obtaining detailed data from fishermen who cannot be reached easily and/or are not open to outsiders. The FGD participants of *Phase 2* referred the initial survey respondents, and each household respondent subsequently suggested further persons.

We targeted 64 households and interviewed both the main men and women resource harvesters/users, as gender often influences the type of ecosystem services derived from coastal SES, and how (Section 1). We interviewed 59 men and 56 women (eight households contained only men and five only women). Most respondents were relatively elderly in their fifties and sixties (Fig. S6, Supplementary Electronic Material), which represents quite well overall age patterns in the island (Section 3.1). Men were mostly fishermen (39), public servants (8), and private business owners (4) (Table S3, Supplementary Electronic Material). Women were overwhelmingly housewives ($N = 47$) who either help their husbands in fishing activities (e.g. fishing preparation, catch unloading, boat maintenance), homegarden cultivation, or both. Only few women engage in remunerative activities such as owning a business (3) or employment in the service sector (3) (Table S3, Supplementary Electronic Material).

Both men and women respondents were present during the survey, each responding about the type and location of the ecosystem services they use, and how they access these services. Furthermore they reported whether they have noticed any change since they started collecting these services and what the reason of change is. The questions about ecosystem services importance were elicited at the household level, and represented a consensus between the respondents after consultation between them. As our sample contains both older and younger respondents, and different respondents started collecting these services at different stages we left open the recollection timeline about the change questions. This means that responses spanned between the 1960s (for the eldest respondents) to nowadays (see above).

The primary data was collected in Japanese through multiple fieldwork campaigns (January–December 2016) to ensure the representation of all major resource user groups, and especially fishermen that can be busy during certain periods of the year. Following preliminary data analysis we conducted follow up visits in February 2017, August 2017 and February 2019 to recheck data and seek clarifications.

3. Results and discussion

3.1. History of resource use in Himeshima

The secondary information and expert interviews provided rich information that allow us create a timeline of the main activities and changes in Himeshima and the surrounding area since the late 19th Century (Table 1, Fig. 2).

Fishing has traditionally been the main livelihood activity in Himeshima (Section 2.1). Fishing output increased rapidly between the late 1960s and the late 1980s/early 1990s, but then decreased sharply (Fig. S7, Supplementary Electronic Material). As discussed below, fishing activities are regulated through various communal rules and conservation measures that have resulted in an elaborate fisheries management system.

The basis of the fishing rules were articulated in the 1904 guide to communal fishing rules and rights called "Gyogyo kisetsu sadame". This guide includes rules about fishing practices, gear (and places to use them), and periods for capturing different fish. There was no formal documentation of this guide before 1904, but it is believed that these rules were transmitted orally.

Nine traditional fishing techniques were used in Himeshima, with six stopping since the 1980s (Table 2). These traditional techniques relied on small fish catches, and avoided bycatch and fishing gear movement on the sea floor (Table 2). These techniques were complemented over time with gill/drift net fishing, trawling/drag net fishing, octopus pots, and diving with oxygenated tanks to harvest shellfish. Modern fishing technologies such as GPS and sonar were widely introduced in the 1970s. However, some of the modern fishing techniques, have had adverse effects on the coastal environment (Section 3.4). For example, trawling/drag nets destroyed the sea floor (and especially the seagrass and algal beds), and were banned after only three years in the 1960s.

Currently there are very specific fishing rules in the conservation zones, mariculture areas, and communal rights areas around Himeshima (Table 3). In particular, there are very strict fishing and harvesting rules for abalone, turban shells, sea cucumbers in the five conservation zones established in 1977. Fishing and marine harvesting is practically forbidden in the areas allocated for shrimp mariculture (see below), while fishing in communal rights areas is heavily regulated through a permit system.

Other communal rules include the kyugyo-bi (literally meaning rest day from fishing) and the release of juvenile marine creatures. This

[4] Although bequest value is not an ecosystem service per se, it is often a significant motive for the conservation of areas that provide high levels of cultural ecosystem services, especially those that are intangible (Oleson et al., 2015).

Table 1
Major events and processes that have shaped the Himeshima satoumi.

Year	Major events	References
1700s	– Salt production and fishing are the first recorded economic activities	Tanaka (1961)
1870s	– Massive deforestation in the uplands of Himeshima. Mt. Yahazu lost entirely its forest cover	Yanagi (2004)
1891	– Formation of the forest association (Shinrin kumiai) to protect forests though command-and-control practices for the ensuing 30 years. Upland areas were planted with Japanese red pine (Akamatsu forests)	Yanagi (2004)
1902	– Enactment of the Fisheries Act, granting fishing rights to fisheries associations and fishing licenses to individuals operating offshore. The fishing rights involved rules for set-net, beach seine fishing, boat seine fishing, aquaculture and capture fisheries	Matiya et al. (2006)
1904	– Documentation of "Gygyo kisetsu sadame", which marked the beginning of the management of the extensive seagrass beds around the island	Yanagi (2004)
1909	– Introduction of round haul nets (locally known as taishibariami) to allow high fish catches (up to 4–5 tons per trip), but the practice was halted after 3 years	Yanagi (2004)
1930s	– Enactment of National Park Law (1931). Seto Inland Sea designated as one of the first three national parks in 1934	Ministry of the Environment Government of Japan (n.d.)
1949	– Himeshima fisheries cooperative was founded following the provisions of the Fisheries Act and National Park Act	Miyazawa (2005)
1950s	– Post-war growth with extensive development of check dams in almost all rivers, concretization of river beds/banks and shores, and road construction. Extensive road development in the island until the early 1980s following the Remote Island Development Act (Rito Fukko Ho)	Duraiappah et al. (2012) Yanagi (2007) Himeshima son shi hen san iinkai (1986)
	– Development of many heavy industries in the Seto Inland Sea, following the new industrial laws. Increased and extensive chemical pollution	
	– Creation of artificial reefs until early 1960s	
1960s	– Substantial changes in fishing practices in Himeshima including use of trawling nets, increase in the allowed days for seagrass cutting, us of digging techniques (called 'kaikogi') with metal-toothed tools to harvest pen shells (*Atrina pectinata*)	Miyazawa (2005)Imai et al. (2006)
	– Massive algal blooms in the 1960s and 1970s have major negative impacts on fisheries in the Seto Inland Sea	
1970s	– Establishment of the Environment Agency to control and reduce water pollution in the Seto Inland Sea (1971). Chemical pollution eventually decreased substantially, but the organic nutrient input remains low	Ministry of the Environment, Government of Japan (n.d.)
	– Notable increases in fish catch through the use of drift nets (for prawns) and set nets (for fishing)	Miyazawa (2005)
1980s	– Expansion of prawn aquaculture on mudflat habitats in the northwest areas of the island. Rapid decrease of fat greenlings possibly due to the degradation of seagrass areas	Miyazawa (2005)
2000s	– Development of Kunisaki Globally Important Agricultural Heritage System (GIAHS)	Tamura et al. (2017)
	– Consolidation of Himeshima Village Fisheries Cooperative to Oita Prefecture Fisheries Association's Himeshima Branch (2002)	JGN (2018)
	– Geopark tourism generates alternative income streams in the island	

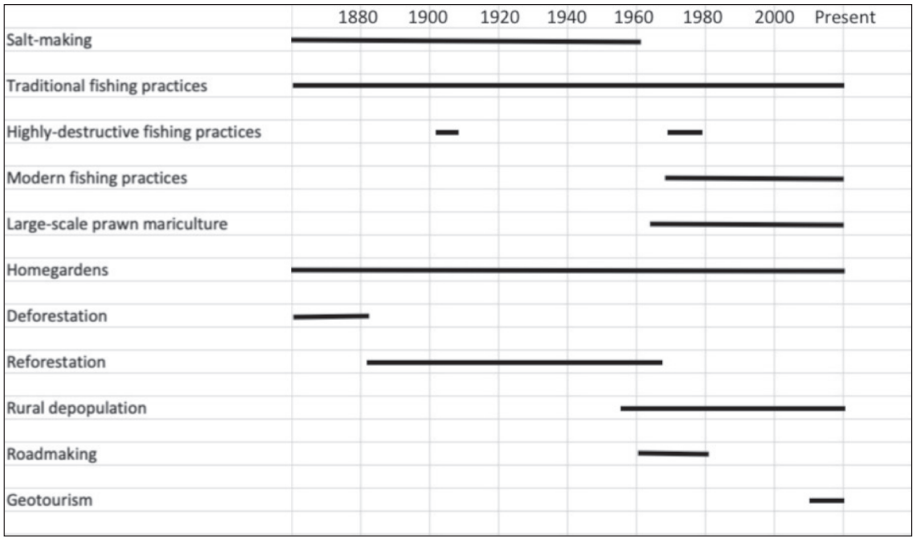


Fig. 2. Different resource use regimes that affected the coastal environments of Himeshima. (Source: Tanaka, 1961; Himeshima son shi hen san iinkai,1986; Miyazawa, 2005; Yiu and Yagi, 2017).

kyugyo-bi has been enforced in 1985 and is observed on the second Saturday of each month. The underlying idea is to reduce the pressure of commercial fishing in the near shore environment around Himeshima by affording fish and other marine creatures some time to grow (Yanagi, 2004). An indirect outcome of the kyugyo-bi has been information exchange about fisheries resource use during this time off fishing. Juvenile marine organisms are released each year (April and July) in different nearshore areas by fishermen on small fishing trawlers. This usually includes juveniles of flounders (41,450), tiger prawns (over 2,000,000), rockfish (10,000), abalone (15,000), and red sea urchins (90,000) (Himeshima Fisheries Association, 2011), but the species (and their numbers) may change (e.g. in 2017, 100 mother octopuses carrying eggs were released). Various agencies bear these costs[5]. Himeshima residents also undertook artificial reef development

[5] For example, in 2017 the total cost was approximately JPY 21.3 million, of which the Fisheries Agency contributed JPY 18.0 million, Himeshima residents covered JPY 0.5 million, the Seto Inland Sea Promotion Project for Flounders JPY 2.2 million and Independent Divers Association JPY 0.5 million.

Table 2
Local fishing and aquaculture practices in Himeshima.

Fishing practice	Main targeted species	Details
Tanagouchi	– Japanese bitterlings – Gnomefish	– Use of fishing rods to catch larger fish but in smaller numbers
Kaketsuri	– Flounders – Fat greenlings	– Use of a cloth or hand net in natural settings rather than bait. Not much fish could be caught as a result
Fukatsuki	– Small sharks – Rays	– Use of fishing rods to catch larger fish but in smaller numbers
Hibi	– Nori seaweeds – Wakame seaweeds	– Use of set bamboo poles to cultivate seaweed in nearshore areas
Oshikiami	– Horse -mackerel – Spotted flatheads – Flounders	– Use of triangular set nets to minimise damage to the coastal seafloor, particularly the seagrass and algae beds
Tegochiami	– Sea Breams – Pike eels – Japanese amberjacks	– Use of gill nets by hand. The need for manual labor reduces boat fish capacity (i.e. small boats operated by 1–2 people) and total fish catch
Kaihori	– Different clam species	– Use of small hand-held tools to harvest clams from the coastal mudflat and rocky shores
Hijikitori	– Hijiki seaweed	– Scrape hijiki seaweeds from coastal rocks and – Collect hijiki seaweeds by going into waters up to the shoulders
Sumoguri	– Abalones – Turban shells – Sea cucumbers	– Dive without oxygenated tanks. This constraints diving time only a few minutes, allowing for the harvest of small amounts of marine species

Source: FGDs and expert interviews.

Table 3
Permitted fishing practices in the coastal and marine areas of Himeshima.

Fishing practices	Main targeted fish species	Conservation area	Communal rights area	Mariculture area
Angling	sea bream, sea perch, cutlass fish,	✓	✓	✗
Long line	fugu, cutlass fish, sea perch	✗	✓	✗
Gill net	cutlass fish, sillago, prawn, flaunder	✗	✓	✗
Octopus pots	octopus	✗	✓	✗
Diving with oxygen tanks	abalone, turban shells, sea cucumber, red sea urchin	✗	✓	✗
Kaihori[1]	Japanese shortnecked clam	✓	✓	✗
Hijikitori[1]	hijiki seaweeds	✗	✓	✗
Tegochiami[1]	sea bream	✗	✓	✗

Note: [1]Refer to Table 2.

(from 1952 to 1982) by submerging old ships, concrete blocks and rocks (Himeshima son shi hen san iinkai, 1986; Yiu and Yagi, 2017).

Prawn mariculture has been, by far, the most significant change in the Himeshima seascape. Small-scale tiger prawn production started in the 1930s, and large-scale production in 1965 following the decline of traditional salt making activities[6]. Large-scale prawn production was facilitated by the (a) desire to diversify the island economy, (b) ready availability of wild tiger prawns around the island, and (c) availability of suitable production areas at low cost in the abandoned salt fields. However, the large-scale prawn mariculture transformed extensively mudflat areas, rocky shores, and seagrass and algal beds, which are some of the most productive coastal areas of the island (Section 3.2).

Currently, there are 15 mariculture ponds in the island covering 383,000 m^2 and employing 30 people (all local). The branded Himeshima prawns have received an One Village One Product (OVOP) award (1981) and two Cultural awards (1986, 1988). However, the industry faces severe risks due to labor shortages (caused by population decline) and disease outbreaks (e.g. acute viremia virus, Vibrio disease, Fusarium fungal infections) that affect both farmed and wild prawn populations around the island.

Land use management followed the concept of uotsukirin (literally meaning forests that support the fisheries) in the 1960s and 1970s. Uotsukirin was an outcome of the extensive forest degradation witnessed in the late 19th century. The then head of the Himeshima post office (Ishitaro Nakajo) believed that if deforestation continued unabated, it would cause the decline of Himeshima's fisheries (Yanagi, 2004). Thus, tree felling was strictly prohibited, in 1892 and pine varieties (*Pinus densiflora*) were planted as protection forests from 1891, which restored the remaining forest and possibly contributed to the high coastal productivity (Yanagi, 2004). However, pine wilt disease decimated Himeshima forests between the late 1960s to the early 2000. Initial measures included cutting and burning the infected trees on the shores, and creating artificial fish spawning grounds. In the 1970s insecticides were used to kill the insects that carry the disease. However, these measures had little success resulting in the severe degradation of the pine forests by the early 1980s. Currently, some pine groves are planted in the Nishi-ura and Inazumi shoreland areas as windbreaks and erosion control measures during heavy storms (Hamada et al., 2018).

As already discussed, agriculture in the island now mainly relates to homegardens (see Section 3.2 for the main agricultural products). Agricultural activities now benefit from abundant freshwater, but that was not always the case. According to the book "Himeshima Son Shi", up until the 1960s freshwater was relatively scarce and was not potable due to its high salinity caused by the porous soil and shallow wells. The rural water supply association was formed in 1961, digging in the same year the first deep well at the Kane area. Freshwater for the Oumi and Inazumi areas was provided through a check dam in the Oumi stream (in 1966) and a new well respectively. In all cases, the drinking water was pumped up to the nearby hills, and was then supplied through gravity to homes and agricultural fields. Increases in living standard and tourism led to the development of the Sako dam in 1978. At

[6] Himeshima Fish Farming Co., Ltd. was actually created in 1960, to pursue the venture of tiger prawn mariculture, but after many changes the Himeshima village became the largest shareholder (80% of the total number of shares) in June 1965. Then it was renamed to its current name (Himeshima Tiger Prawn Farming Co.) and was launched as a tertiary sector system.

present, the Oumi, Sako dam and Futamata ike (a small irrigation pond developed in 1982) remain as the main sources of freshwater in the island (Himeshima son shi hen san iinkai, 1986).

The Oita-Himeshima Geopark is the main touristic attraction on the island. It was established in 2013 as part of the geo-park tourism and conservation initiatives in Japan in the 2000s. The noted geosites within the island include ancient rock and sediment strata from the Pleistocene, undersea monogenetic volcanoes, obsidian rocks, and fossils of ancient megafauna such as Neuman mammoths (*Palaeoloxodon naumanni*).

Finally it is worth mentioning that some new economic activities are now pursued in the island such as kelp cultivation, flower monoculture and solar energy farms. However, these endeavor are relatively new in the island, and have yet to cause significant changes in livelihoods or the broader SES (see also Section 3.4).

3.2. Ecosystem services

The FGD respondents during Phase 2 (Section 2.2) identified that currently the local community mainly benefits from 14 ecosystem services from the satoumi, mainly provisioning services related to food and genetic resources, and cultural services. Regulating and supporting ecosystem services were also identified, albeit by far fewer respondents, and usually through anecdotal evidence. These ecosystem services were integrated in the household survey and were asked to all household respondents during Phase 3 (Section 2.2). Table 4 summarizes the main ecosystem services currently derived from the Himeshima SES as elicited through the FGDs and the household survey.

Seafood is the main provisioning service currently derived from the Himeshima satoumi, and includes several varieties of fish, octopus, squid, shellfish, crustaceans, and seaweed collected throughout the year. Fig. S8 in the Supplementary Electronic Material summarises the main species harvested, and the specific periods of the year. Secondary data from the Himeshima Fisheries Association suggest that commercial fish catches can yield annually about JPY 2 million per fisherman (USD 20,000) (Himeshima Fisheries Association, 2011). Wakame (*Undaria pinnatifida*) and Hijiki (*Sargassum fusiforme*) seaweed is collected (mainly by women), with the collection periods strictly confined to few days in February and March due to the dwindling seaweed beds around the island. Men usually collect shellfish such as abalone, turban shells, and top shells are collected mainly through diving, while women collect clams in the near-shore environment with hand tools (see also Section 3.1).

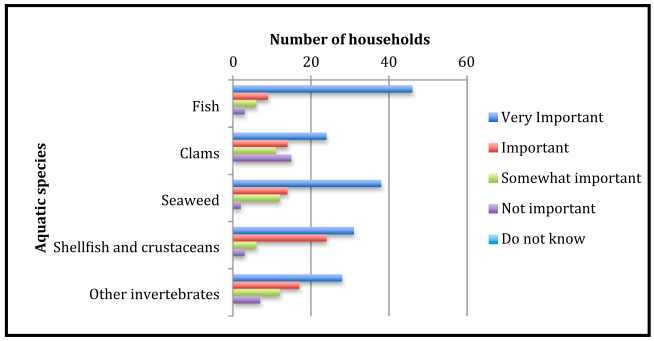


Fig. 3. Importance of different types of aquatic species for each household ($N = 64$).

Generally, while most of the fish, shellfish, and seaweed is sold, a significant amount is shared (see below about the significance of sharing) and consumed within the households. Generally, the most good-looking clams and seaweed are sold and shared, while those are damaged or have imperfections (e.g. attached algae or marine invertebrates) are consumed at home.

Coastal/marine provisioning ecosystem services have differing levels of importance among households (Fig. 3). Most households reported that fish and seaweed are particularly important, but clams were important only for some households (Fig. 3). This is possibly because clam harvesting has declined markedly due to the deterioration of

Table 4
Main ecosystem services identified by local community respondents.

Type	Ecosystem services	Explanations/examples
Provisioning	Food	– Coastal and marine areas provide various types of seafood including fish, shellfish, clams, and seaweed – Homegardens and agricultural areas provide vegetables – Upland forests provide different types of wild plants for food
	Medicinal plants	– Medicinal plants from the low hills (mainly in eastern part of the island) and homegardens
	Genetic resources	– Himeshima tiger prawn bred in the island is a branded type of food (the tiger prawn can be eaten whole, including shells and the head part) – Himeshima kelp grown in warm waters (kelp generally grows in cold waters in N. Japan)
	Freshwater	– Freshwater is collected from water retention tanks located upstream
Cultural	Aesthetic	– Landscape and seascape elements are aesthetically pleasing to residents and visitors, e.g. views of the large expanse of the sea, jagged coastline, Himeshima from low hill (Yahazu dake), sennnindo temple at the coast, migrating chestnut tiger butterflies
	Cultural heritage	– Himeshima is mentioned as a fishing village in Kojiki, one of the oldest Japanese chronicles
	Island art	– Special dances are a central to the Himeshima flounder festival that celebrates the importance of marine resources to local wellbeing – Painting with colors extracted from seagrass (kaiso oshiba)
	Education and knowledge	– Knowledge from the landscapes and seascapes through direct experiences/observations – Knowledge of earth processes and the geological past of the island from geopark sites and geopark based activities
	Recreation and tourism	– Main recreational activities include geosite tours, recreational fishing, hiking, biking, camping and swimming
	Traditional food culture	– Marine resources (e.g. octopus eggs, flathead stomach, fugu liver) are ingredients of unique local dishes that are sometimes used in ceremonies (e.g. marriages are not fulfilled without sea breams in menu) – Sharing local food helps maintains good social relations
	Spiritual and religious	– Numerous small temples are located in the coastal areas of the island – Clams are considered a deity in the Otarashi hachiman temple
Regulating/Supporting	Habitat provision	– Unaltered coastlines, mudflats and seagrass areas provide feeding places, spawning grounds, hiding places for marine species – Upland forest areas provide habitat to plants, birds and insects
	Erosion control and regulation	– Upland forests (especially red pines) prevent soil erosion and have a positive effect on freshwater quality
	Soil formation	– Streams transport soil to the lowlands by eroding rocks and soil

Source: FGDs and expert interviews.

mudflat areas that are prime clam habitats (Section 3.1, 3.3–3.4).

The homegardens and forests provide many other provisioning ecosystem services (Section 2.1). Approximately 20 different types of vegetables and 8 types of wild plants and mushrooms are grown in these homegardens (Table S4, Supplementary Electronic Material). Additionally 12 types of wild plants are obtained from upland forests. Some of these plants have medicinal properties, and are widely used in traditional medicines (Table S4, Supplementary Electronic Material). Similar to seafood, vegetables and wild plants are shared between families and friends, creating social bonds and cohesion. Wild plant gathering has strong links to cultural services, as it is linked to learning opportunities and recreation (see also Schulp et al., 2014).

Provisioning ecosystem services from prawn mariculture are particularly important, and have emerged as a key economic activity that provides about 30 full time jobs (Section 3.1). The actual prawn production fluctuates between 30–200 t annually, depending on the virus and disease outbreaks (personal communication: prawn cultivator, Himeshima Tiger Prawn Co. Ltd, February 2019).

Survey respondents mostly considered the 7 identified cultural ecosystem services as “important” or “very important” for their households (Fig. 4). In particular, most respondents identified the island’s traditional food culture as “very important”. This food culture contains elements associated with diverse ingredients (i.e. from the many different types of seafood and local vegetables mentioned above), unusual ingredients (e.g. octopus eggs, flathead stomach, fugu liver), dishes used for cultural occasions[7], and food sharing. Seafood, vegetable and wild plant sharing is very prevalent as in other coastal parts of Japan (Tatebayashi et al., 2019; Saito et al., 2018; Kamiyama et al., 2016). Overall, 48 households shared seafood (75%) and 51 households shared vegetables grown in their homegardens (80%). Most respondents mentioned that food sharing makes them happy and helps maintain good social relations with neighbors and family members that have moved to other parts of the island. Several respondents also suggested that some of the elements of Himeshima’s unique food culture can contribute to social cohesion.

Fishing and marine resource harvesting is central to Himeshima’s cultural heritage (e.g. the Kojiki, one of the oldest Japanese chronicles, mentions Himeshima as a fishing village). This strong link to the sea gives pride and a sense of identity to many respondents. Furthermore, special dances such as ‘aya odori’ and ‘kitsune odori’ have strong links to the seascape and also forge cultural identity. These dances are central elements of the Himeshima flounder festival that celebrates them as important marine resources for the island’s wellbeing. Recently, painting with colors extracted from seagrass (locally known as ‘kaiso oshiba’) has also become popular.

Other important cultural ecosystem services relate to educational and recreational activities. For example, the island has started attracting tourists to visit its geopark (Section 3.1) and view Chestnut tiger butterflies (*Parantica sita*). Educational values are mainly related to the geopark. However, may respondents perceive their interaction with plants and animals (e.g. during fishing, homegarden cultivation, wild plant collection) as important educational activities (see above). This is viewed as essentially an *individual* undertaking that cannot be ‘taught’ to others, with some respondents even mentioning that such learning experiences could facilitate the better management of the satoumi.

Overall, most respondents had little awareness of regulating and supporting ecosystem services. Most respondents could identify that unaltered coastlines, mudflats and seagrass areas provide important habitat for several marine species for feeding, spawning and hiding. Similarly many respondents identified that the upland forests provide habitat to different species of plants, birds and insects. A few respondents could identify ecosystem services related to erosion control and soil formation, but there is surprisingly low awareness about pollination services despite the prevalence of homegardens.

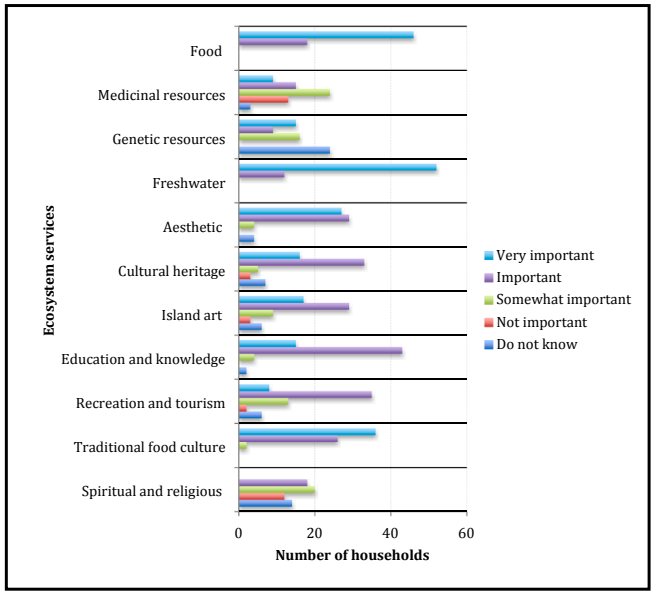


Fig. 4. Importance of different ecosystem services for each household ($N = 64$).

There are strong linkages between ecosystem services, which are often mediated by cultural factors. This is particularly evident for many cultural services such as aesthetic appeal, traditional food culture, and educational values (Table S5, Supplementary Electronic Material). For example, as discussed above Himeshima’s traditional food culture relates directly to food-related provisioning ecosystem services. Furthermore, several respondents linked the vital fish spawning grounds in mudflats, rocky shores, and seagrass beds (a supporting service), with aesthetic and educational values (Section 3.3). Similarly, the secondary pine forests are not only associated with cultural heritage (Section 3.1), but also provide erosion control (a regulating service). This strong linkage between the different ecosystem services alludes to the existence of ecosystem services bundles, as will be discussed in Section 3.3.

Finally, it is worth mentioning that men and women interact differently with the satoumi, and its ecosystem services (Fig. 5). For example, women are more involved in clam harvesting in the nearshore environments (using only hand tools), wild seaweed collection, and are the primary caretakers of homegardens. Men, on the other hand, are more involved in fishing, diving for shellfish, planting secondary pine forests, and creating seagrass beds in degraded areas. Overall substantially more male respondents (39) are involved in fishing compared to female respondents (14). On the other hand 47 female respondents were involved in homegardens, compared to only 12 male.

3.3. Ecosystem service bundles and associated values

The current spatial distribution of these ecosystem services varies substantially as indicated by the FGDs (Phase 2) and household surveys (Phase 3) (Section 2.2). Ecosystem service provision is currently not uniform across Himeshima but is concentrated in some “hotspot areas”, with certain landscape and seascape elements providing specific combinations (or bundles) of ecosystem services (Martin-Lopez et al., 2012; Turner et al., 2014) (Fig. 6).

In particular, most types of ecosystem services are derived from the northern part of Himeshima, which contains relatively unspoiled nearshore seagrass and algal beds, and some of the last remaining mudflats (Fig. 6). In particular these areas provide between 6 and 11 unique ecosystem services (Boxes A, B, D and G in Fig. 6). Apart from

[7] Special seafood dishes such as ‘taimen’ (boiled sea bream and noodles) are used in marriages and other ceremonies.

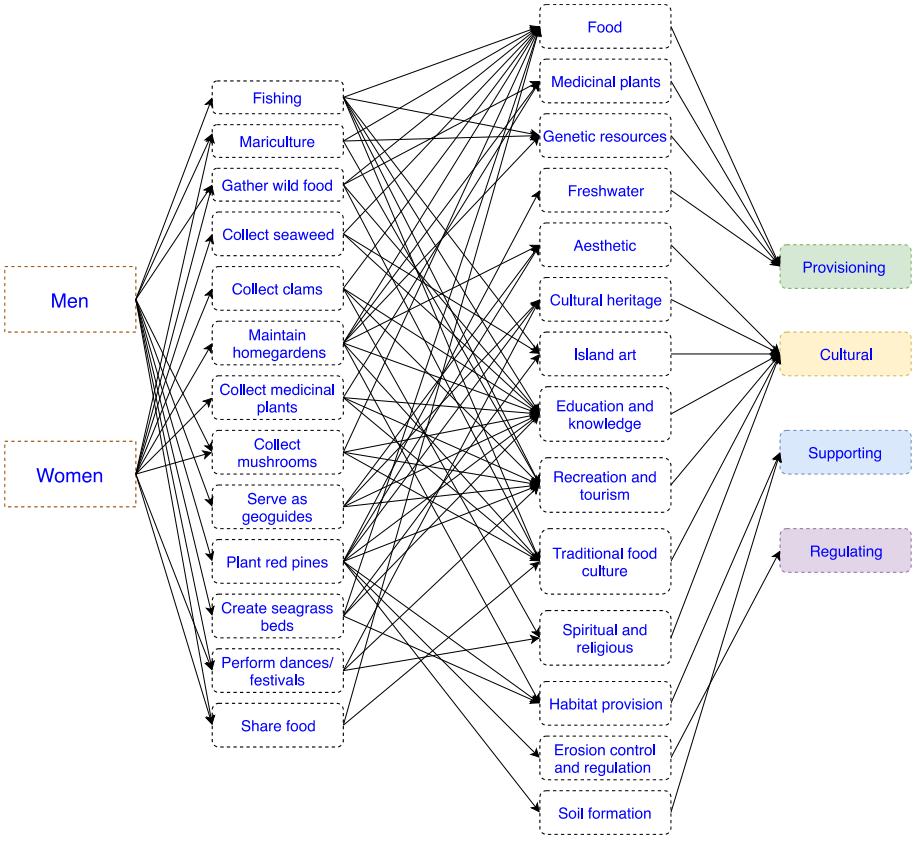
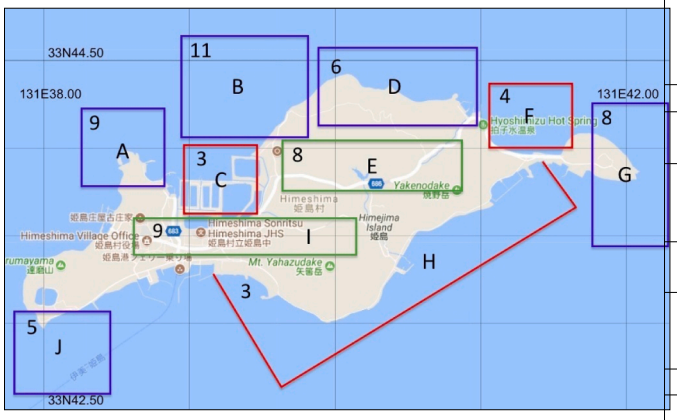


Fig. 5. Human activities related to the identified ecosystem services.



Legend	Ecosystem Service bundles
A	(1) food, (2) genetic resources, (3) aesthetic, (4) education and knowledge, (5) traditional food culture, (6) spiritual and religious, (7) recreation and tourism, (8) habitat provision, (9) erosion control and regulation
B	(1) food, (2) genetic resources, (3) aesthetic, (4) cultural heritage, (5) traditional food culture, (6) spiritual and religious, (7) recreation and tourism, (8) island art, (9) habitat provision, (10) erosion control and regulation , (11) soil formation
C	(1) food, (2) genetic resources, (3) island art
D	(1) food, (2) genetic resources, (3) aesthetic appeal, (4) education and knowledge, (5) traditional food culture, (6) habitat provision
E	(1) food, (2) freshwater, (3) cultural heritage, (4) education and knowledge, (5) traditional food culture, (6) habitat provision, (7) erosion control and regulation (8) soil formation
F	(1) food, (2) genetic resources, (3) spiritual and religious, (4) traditional food culture
G	(1) food, (2) genetic resources, (3) aesthetic, (4) education and knowledge (5) traditional food culture, (6) habitat provision, (7) erosion control and regulation, (8) soil formation
H	(1) food, (2) aesthetic, (3) recreation and tourism
I	(1) food, (2) recreation and tourism, (3) traditional food culture, (4) spiritual and religious, (5) island art, (6) education and knowledge, (7) habitat provision, (8) soil formation, (9) erosion control and regulation
J	(1) food, (2) genetic resources, (3) education and knowledge, (4) traditional food culture, (5) habitat provision

Fig. 6. Ecosystem service bundles of Himeshima island.

many cultural services, these areas also offer important habitat services through nursery and breeding grounds for fish, crustaceans, mollusks, birds, turtles, and marine mammals. Mixed agricultural-woodland landscapes in the interior of the island are associated with the provision of 9 different ecosystem services, mainly related to forest/agriculture provisioning services and cultural services (Boxes E and I in Fig. 6).

On the other hand, coastal areas converted for mariculture and other human uses (e.g. ports, artificial beach) were associated with only 3–4 ecosystem services (Boxes C, F and H in Fig. 6), as both these areas experienced extensive habitat change and loss (Section 3.4). This led to some interesting ecosystem services trade-offs. In particular, the mudflat area in the south (Box H in Fig. 6) was re-developed into an artificial beach and a summer camping site. Although this area now provides some recreational services, this came possibly at the expense of

the various provisioning, supporting and regulating ecosystem services associated with the other mudflat areas of the island (see above).

The fishing grounds further away from the island (not shown in Fig. 6) basically provide only provisioning ecosystem services related to fish and other aquatic species. As already discussed in Sections 3.1 and 3.2 these ecosystem services provide the bulk of the income for most families in the island, but have faced substantial decline in the past decades due to overfishing (Section 3.4).

As discussed above, the richest bundles (in terms of the number of unique ecosystem services) are in unaltered coastlines and upland areas. The bundles in these areas usually contain supporting (mainly habitat), provisioning (mainly food, medicinal plants) and several cultural services (Fig. 6), and are not usually related to monetary benefits, but with materials for subsistence, sharing between the community, and non-use values. It is worth noting that these unaltered coastlines and upland areas tend to have a high bequest value as reported in the FGDs and household surveys. On the other hand, the areas that provide bundles with few ecosystem services, are associated with the provision of readily monetized services such as fish/shrimps for selling and recreation (i.e. the offshore fisheries and areas converted for tourism/mariculture).

3.4. Drivers of ecosystem change

Himeshima has experienced multifaceted changes in the past decades (Section 3.1). Based on the FGDs, household survey, historical analysis and expert interviews we discuss below some of the main direct and indirect drivers of ecosystem change (Japan Satoyama Satoumi Assessment, 2010; MA, 2005; Karki et al., 2018) observed in the Himeshima satoumi.

Habitat change and loss has been the most important direct driver of ecosystem change. Substantial portions of the shoreline have been concretized for road and port development (especially in the southern part of the island), leading to substantial changes in coastal ecosystems. Coastal concretization is a common trend in Japan, as the country has lost more than 1000 km of its natural shorelines and increased its artificial shorelines by about 2500 km between 1978 and 1996 (Government of Japan, 2014). Additionally significant portions of the mudflats and seagrass and algae beds were converted for prawn cultivation. These areas were amongst the most productive in the island in terms of ecosystem services provision (Sections 3.1 and 3.3). The depletion of seagrass/algae beds and mudflats is of great concern among respondents, as these areas are vital habitats for fish and other marine species (Section 3.3). For example, among the interviewed fishermen and clam gatherers, 31 mentioned that the seagrass and algae beds have decreased significantly, 3 that there was no change, and no one that they have increased. Some of the relevant quotes of respondents are included in Box S1 – Habitat change and loss, in the Supplementary Electronic Material.

Concretization has also affected the interior of the island. For example, expert interviews and survey with a local 'wakame' producer suggested that the concretization of the bed/banks of freshwater streams (Table S1, Supplementary Electronic Material) combined with road building could have affected seaweed harvesting in the coastal areas. In particular the stream concretization has affected water flows, which tended to be continuous throughout the year. The construction of the Himeshima Blueline roadway might have blocked water runoff from the foothills of Mt. Yahazu. According to the respondents the combined effect of these phenomena might have contributed to the eventual decline in production of tengusa (*Gelidiaceae*), wakame (*Undaria pinnatifida*), and aosa (*Ulva Linnaeus*) seaweed from the coastal areas next to these streams (which has reached non-harvestable quantities nowadays).

Smaller but still observable habitat change occurs in other inland areas due to the abandonment of agricultural areas, and the development of flower monoculture and solar energy farms (Section 3.1), both of which will have interesting trade-offs. At the same time there is a renewed effort to restore the secondary pine forests through replanting, as a means of providing multiple supporting and regulating ecosystem services (see below and Section 3.1).

Fisheries overexploitation has been the second major direct driver of ecosystem change in the Himeshima satoumi. Fishing output increased rapidly in the 1960s–1970s, peaking in the 1980s, and then decreasing substantially in the early 1990s (Fig. S7, Supplementary Electronic Material). Some of the quotes of respondents about fisheries overexploitation and decline are quite revealing (refer to Box S1 – Overexploitation, Supplementary Electronic Material). Most respondents suggested that this overexploitation has possibly led to the substantial decrease of fish stocks, especially elder respondents involved in the fishing boom of the 1960s and 1970s (Fig. 7). The reasons that contributed to fisheries overexploitation are interlinked and include technology adoption, institutional constraints and loss of TLK (see below).

Other direct, but less prevalent, drivers of ecosystem change include invasive species, disease, pollution and climate change. Several fishermen noted the increasing prevalence of two invasive species, the manta ray and jellyfish. These species predate on small fish and juveniles, and are affecting both fish stock and destroying fishing gear. Pine wilt disease decimated secondary pine forests in the 1960s (Section 3.1), possibly affecting nutrient flows to the coastal areas. Industrial pollution reached its maximum levels in the Seto Inland Sea during the 1970s, possibly affecting marine life, but has now declined substantially

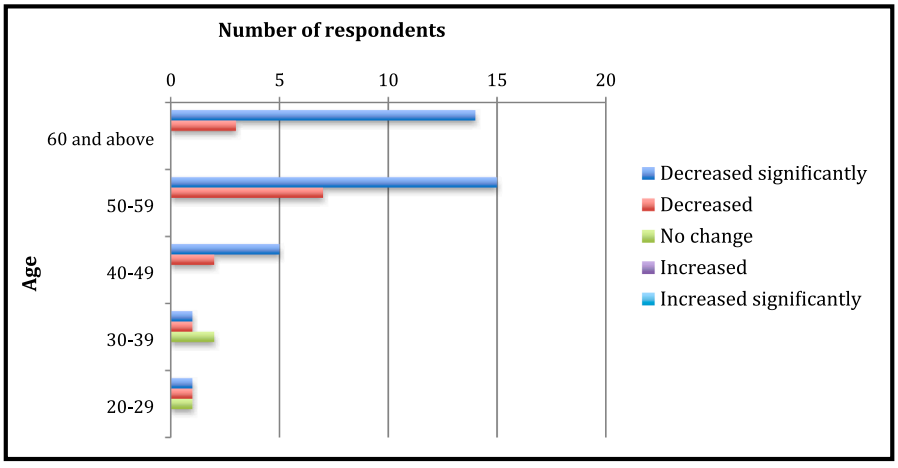


Fig. 7. Change in fish and clam stocks as identified by fishermen and clam gatherers (N = 53).

due to strict national environmental legislation (Section 3.1). Prawn mariculture is reportedly a local source of nutrient pollution, but most likely it occurs at a small scale. Seawater temperature has reportedly increased by about 2 °C (rough estimate of local fishermen), possibly affecting fish movement, prevalence of invasive species, and other important ecosystem processes. However the knowledge and understanding of these processes is not widespread among the local community.

The direct drivers of ecosystem change discussed above have been the outcome of several tightly interlinked indirect drivers that work from the local to the regional level (MA, 2005; Karki et al., 2018). These include demographic, economic and technological change, which have collectively influenced the loss of TLK (especially as it relates to fishing practices).

Demographic change mainly manifests through an ageing society and rural depopulation (Section 3.1, Fig. S3, Supplementary Electronic Material), influencing considerably economic activities on the island. Even though fishing remains the main livelihood activity for most community members, its significance has declined (Section 3.1, Fig. S7, Supplementary Electronic Material). Conversely, mariculture and tourism have emerged as important economic activities aiming to revitalize the island economy, and are supported through the development of infrastructure (e.g. port. roads) and an artificial beach (see also Section 3.3).

The overexploitation of fisheries seems to have been the combined outcome of traditional fishing practices loss, technological innovation and unsustainable fishing regulations. In particular, Section 3.1 outlined the gradual decline (and eventual loss) of some traditional fishing practices and the adoption of new fishing practices supported by new technologies. For example, the use of nets with smaller mesh sizes has increased bycatch, including juveniles and smaller fish. Similarly, diving with oxygen tanks increases to 30–40 min the time spent underwater in a single dive, enabling largest shellfish harvests per individual dive. At the same time the extensive use of GPS, sonar and speedier boats has reduced travel times and enhanced fishing accuracy. The combined effects of above have had extremely negative effects on fisheries (see Box S1 – Fishing Technology, Supplementary Electronic Material).

The abandonment of traditional fishing practices and the revisions in the traditional fishing guide towards more marketable fish varieties reflect the loss of TLK (Section 3.1). Several respondents identified these changes as highly unsustainable (see Box S1 – Loss of TLK, Supplementary Electronic Material). However, one important element of the communal fishing guide was never revised. This was the lack of a strong provision to enforce a total allowable catch. Traditionally fishermen have been allowed to harvest as much fish and aquatic products they desired, but due to the extensive manual labour of traditional fishing practices (Table 2), fish catches were limited. However, the extensive use of modern fishing equipment has increased both the possible fishing trips and the amount that can be harvested in each trip. The revision of the communal fishing guide was constantly mentioned as extremely necessary, especially in the current context of fisheries overexploitation (Box S1 – Revision of traditional fishing practices, Supplementary Electronic Material).

3.5. Implication for policy and practice

Our study suggests that Himeshima shares some very important commonalities with other satoumi seascapes. The main commonality is how the combined effects of ageing and rural migration/depopulation affect the management of fisheries and other productive systems such as homegardens (Kamiyama et al., 2016; Watanabe 2012; Duraiappah et al., 2012), often through the loss of TLK. Multiple sources indicated that the main reason for carefully crafting and renewing the communal fishing rights was to ensure the sustained productivity of fishing grounds for future generations. However, as fishermen are ageing and young people leave the island, the overall incentive for managing fisheries sustainably is declining, as seen in many other satoumi areas (Kohsaka et al., 2015; Ara, 2011).

Conversely, the Himeshima satoumi has also some important differences with other islands of the Seto Inland Sea. First, there is no specialization in catching one particular fish species, as fishers catch different species throughout the year (Fig. S8, Supplementary electronic material). Furthermore, the most widely used fishing nets in the Seto Inland Sea, the drag net and bottom trawling net (JFA, n.d.), have been banned in Himeshima (Section 3.1). Second, due to fisheries decline, the island has embarked in other economic activities such as branded prawn culture and geotourism[8] to both diversify and revitalize the island economy (Section 3.1).

The above imply two important and interlinked implications for policy and practice. Even though the insights discussed below are derived through the perceptions and values of Himeshima residents (and are thus highly context-specific), they could possibly be applicable in other coastal contexts of Japan (and beyond) that experience ageing, depopulation and TLK loss.

The first has to do with the emergence of ecosystem services trade-offs due to activities that aim to revitalize the local community and/or diversify its economic base. As discussed in Sections 3.3 and 3.4 areas that provide multiple ecosystem services have been altered to accommodate new economic activities such as tourism and mariculture. Some of these areas have high bequest value and provide very important provisioning (e.g. shellfish, seaweed) and cultural services (e.g. traditional food culture) that are a source of pride and cohesion for the local community. Social cohesion is particularly important for shrinking and ageing communities in coastal areas, as it can enhance their resilience (McElduff et al., 2016; Faulkner et al., 2018; Jurjonas and Seekamp, 2018; Geirsdóttir et al., 2014).

In this sense the policies and practices towards rural revitalization have seen the island environment in a narrow sense (i.e. as a source of revenue), and have not integrated well the local values related to traditions and cohesion derived from the multiple ecosystem services provided by the seascape. In Himeshima (and possibly other similar satoumi areas) it is important to balance these different values that on the one hand aim to revitalize the island through new economic options, and on the other hand seek to maintain a traditional lifestyle based to some degree on ecosystem services. However several studies around the world have shown that balancing such radically different values is particularly challenging in coastal/marine contexts (Arkema et al., 2015; Davies et al., 2018). Multi-stakeholder participatory processes and scenario development would be necessary to further elucidate these trade-offs (e.g. Daw et al., 2015) and design sustainable development pathways (Sandhu et al., 2018).

The second main implication relates to the “tension” between some TLK practices and modern fishing technologies, and their implications for livelihoods and the sustainable management of coastal resources (e.g. CoopeSoliDar, 2017). In, Himeshima this tension is clear-cut, but its outcomes cannot be delineated easily. The loss of some TLK-based (e.g. abandonment of some traditional fishing techniques, re-focus towards marketable species), the retain of some practices (e.g. unlimited allowed catch), and the simultaneous adoption of new fishing technologies, led to increasing economic output from fisheries but also to their overexploitation (Sections 3.1 and 3.4).

This makes clear the need to reconsider some of the fishing practices in Himeshima. This would probably require the balancing of technological options and TLK practices, and the possible revision of some of the existing rules. This would require the combined input of fisheries associations, TLK holders, scientists and other related stakeholders. Even though the combination of these events and practices is unique in Himeshima, it is highly

[8] Himeshima is the only island in the Seto Inland Sea that promotes geotourism, becoming part of the Japanese Geopark Network in September 2013.

likely that similar tensions might materialize in other satoumi seascapes of the Seto Inland Sea (and elsewhere in Japan).

Finally, a very interesting insight emerging from this research is the possibly strong linkage between upland forests and agricultural areas, and the coastal system. Many secondary and primary sources alluded to this linkage but the evidence was mostly anecdotal, and was thus not captured systematically in this research. However, such possible interlinkages suggest an even stronger coupling between the different landscape elements of the Himeshima SES, pointing to the need to adopt integrated management practices to ensure that these linkages are not compromised. They also reinforce to the importance of TLK, as such management practices facilitated to some extent these linkages (e.g. upland reforestation). Further research would be needed to establish and assess these links empirically, and how they are mediated by TLK.

At the broader level the above findings make a stronger case for the current call to integrate better TLK practices and modern scientific knowledge (e.g. Pascual et al., 2017; Díaz et al., 2015 among numerous others), including in coastal and marine contexts (Ban et al., 2017; Thornton and Scheer, 2012).

4. Conclusions

This study combines primary and secondary data to identify the ecosystem services provided by the Himeshima satoumi, and how they intersect with community values and TLK practices. Our results suggest that the local community derives multiple benefits from the satoumi seascape, which play an important role in the rapidly ageing and depopulating island. In particular ecosystem services from fisheries and homegardens are essential for the wellbeing of the local community through many tangible and intangible ecosystem services. Apart from underpinning the local livelihoods, several of these services forge the identity and cohesion of the local community.

However, the satoumi seascape has changed rapidly in the past decades. Some of the main changes relate to habitat loss and overexploitation due to the combined effects of demographic change, technology adoption, and socioeconomic development. Some of these changes are directly linked to interventions that aim to revitalize the island (e.g. tourism, prawn mariculture), the adoption of new technologies in fishing, and the loss of some TLK practices.

This paper highlights the important role that a good understanding of the values, perspectives and TLK of local communities can play in elucidating ecosystem services (and their change) in coastal SES. Such information can inform multi-stakeholder processes for the design of sustainable management practices in coastal SES such as Himeshima affected by ageing, depopulation and loss of TLK practices.

Acknowledgements

We thank Fukashi Ehara and Hitoshi Ono. for their help in planning and carrying out the survey, Kaoru Ichikawa for input on methodology development and advice during fieldwork, Marcin Jarzebski for designing Fig. 1. The authors acknowledge the JSPS-UNU Postdoctoral Fellowship program and JSPS Kaken-hi Grant (15F15784). The authors extend their thanks to the people of Himeshima who took part in the research.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2019.100940.

References

Adams, M.S., Carpenter, J., Housty, J.A., Neasloss, D., Paquet, P.C., Service, C., Walkus, J., Darimont, C.T., 2014. Toward increased engagement between academic and indigenous community partners in ecological research. Ecol. Soc. 19 (3), 5. https://doi.org/10.5751/ES-06569-190305.

Ara, K., 2011. Women's work in a Seto Inland sea fishing village: specializing in fishing after the decline of farming (in Japanese). Minzokubunka 34, 83–97.

Arkema, K.K., Verutes, G.M., Wood, S.A., Clarke-Samuels, C., Rosado, S., Canto, M., Rosenthal, A., Ruckelshaus, M., Guannel, G., Toft, J., Faries, J., Silver, J.M., Griffin, R., Guerry, A.D., 2015. Embedding ecosystem services in coastal planning leads to better outcomes for people and nature. PNAS 112 (24), 7390–7395. https://doi.org/10.1073/pnas.1406483112.

Assefa, E., Hans-Rudolf, B., 2015. Farmers' perception of land degradation and traditional knowledge in southern Ethiopia—resilience and stability. Land Degrad. Dev. 27 (6), 1552–1561. https://doi.org/10.1002/ldr.2364.

Atkinson, R., Flint, J., 2001. Accessing hidden and hard-to-reach populations: snowball research strategies. Social Res. Update 33.

Ban, N.C., Eckert, L., McGreer, M., Frid, A., 2017. Indigenous knowledge as data for modern fishery management: a case study of dungeness crab in Pacific Canada. Ecosyst. Health Sustainability 3 (8). https://doi.org/10.1080/20964129.2017.1379887.

Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C., Silliman, B.R., 2011. The value of estuarine and coastal ecosystem services. Ecol. Monogr. 81 (2), 169–193. https://doi.org/10.1890/10-1510.1.

Berkes, F., Colding, J., Folke, C., 2003. Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press, Cambridge.

Berkes, F., 2004. Rediscovery of traditional ecological knowledge as adaptive management. Ecol. Appl. 10 (5), 1251–1262. http://www.jstor.org/stable/2641280.

Berkes, F., 2012. Implementing ecosystem-based management: evolution or revolution? Fish Fisheries 13, 465–476. https://doi.org/10.1111/j.1467-2979.2011.00452.x.

Berque, J., Matsuda, O., 2013. Coastal biodiversity management in Japanese Satoumi. Marine Policy 39, 191–200. https://doi.org/10.1016/j.marpol.2012.10.013.

Bryce, R., Irvine, K.N., Church, A., Fish, R., Ranger, S., Kenter, J.O., 2016. Subjective well-being indicators for large-scale assessment of cultural ecosystem services. Ecosyst. Serv. 21, 258–269. https://doi.org/10.1016/j.ecoser.2016.07.015.

Burley, D., Jenkins, P., Laska, S., Davis, T., 2007. Place attachment and environmental change in coastal Louisiana. Org. Environ. 20, 347–366. https://doi.org/10.1177/1086026607305739.

Cetinkaya, G., 2009. Challenges for the maintenance of traditional knowledge in the Satoyama and Satoumi ecosystems, Noto Peninsula, Japan. Human Ecol. Rev. 16 (1), 27–40. http://ww.w.humanecologyreview.org/pastissues/her161/cetinkaya.pdf.

Cetinkaya, G., 2012. Traditional knowledge and landscape management: evaluation and measurement of traditional knowledge on edible wild plants and mushrooms in the satoyama ecosystems in the Noto Peninsula, Japan. J. Environ. Plann. Manage. 55 (2), 141–160. https://doi.org/10.1080/09640568.2011.586417.

CoopeSoliDar, 2017. Traditional knowledge Use for the Sustainable Management of Marine and Fishing Resources. Samudra Monograph, International Collective in Support of Fishworkers. http://aquaticcommons.org/21176/1/Traditional%20knowledge%20Use_%20COSTA_RICA.pdf.

Davies, T.E., Epstein, G., Aguilera, S.E., Brooks, C.M., Cox, M., Evans, L.S., Maxwell, S.M., Nenadovic, M., Ban, N.C., 2018. Assessing trade-offs in large marine protected areas. PLoS ONE 13 (4), e0195760. https://doi.org/10.1371/journal.pone.0195760.

Daw, T., Brown, K., Rosendo, S., Pomeroy, R., 2011. Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. Environ. Conserv. 34, 370–379. https://doi.org/10.1017/S0376892911000506.

Daw, T., Coulthard, S., Cheung, W.W.L., Brown, K., Abunge, C., Galafassi, D., Peterson, G.D., McClanahan, T.R., Omukoto, J.O., Munyi, L., 2015. Evaluating taboo trade-offs in ecosystems services and human well-being. PNAS 112 (22), 6949–6954. https://doi.org/10.1073/pnas.1414900112.

de la Torre-Castro, M., Fröcklin, S., Börjesson, S., Okupnik, J., Jiddawi, N.S., 2017. Gender analysis for better coastal management: increasing our understanding of socialecological seascapes. Marine Policy 83, 62–74. https://doi.org/10.1016/j.marpol.2017.05.015.

de Souza, L.Q., Rossi, S., Calvet-Mir, L., Ruiz-Mallen, I., Garcia-Betorz, S., Salva-Prat, J., Meireles, A.J.A., 2017. Neglected ecosystem services: highlighting the socio-cultural perception of mangroves in decision-making processes. Ecosyst. Serv. 26, 137–145. https://doi.org/10.1016/j.ecoser.2017.06.013.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., et al., 2015. The IPBES conceptual framework connecting nature and people. Curr. Opin. Environ. Sustainability 14, 1–16. https://doi.org/10.1016/j.cosust.2014.11.002.

Duraiappah, A.K., Nakamura, K., Takeuchi, K., Watanabe, M., Nishi, M. (Eds.), 2012. Satoyama-satoumi Ecosystems and Human Well Being: Socio-ecological Production Landscapes of Japan. United Nations University Press, Tokyo.

Yiu, E., Yagi. N., 2017. Dentouteki na shigen kanri hoho kara kansatsu suru Kunisaki hanto Usa chiiki sekai nogyo isan shitemu ni okeru Himeshima no yakuwari ni kan suru kenkyu chosa. http://www.kunisaki-usa-giahs.com/data/img_data/news/files/(報告書)イヴォーン·ユ–%E3%80%80.pdf.

Government of Japan, 2014. Fifth National Report of Japan to the Convention of Biological Diversity. https://www.cbd.int/doc/world/jp/jp-nr-05-en.pdf.

Faulkner, L., Brown, K., Quinn, T., 2018. Analyzing community resilience as an emergent property of dynamic social-ecological systems. Ecol. Soc. 23 (1), 24. https://doi.org/10.5751/ES-09784-230124.

Fish, R., Church, A., Winter, M., 2016a. Conceptualising cultural ecosystem services: a novel framework for research and critical engagement. Ecosyst. Serv. 21, 208–217. https://doi.org/10.1016/j.ecoser.2016.09.002.

Fish, R., Church, A., Willis, C., Winter, M., Tratalos, J.A., Haines-Young, R., Potschin, M., 2016b. Making space for cultural ecosystem services: Insights from a study of the UK nature improvement initiative. Ecosyst. Serv. 21, 329–343. https://doi.org/10.1016/j.ecoser.2016.09.017.

Foley, M.M., Halpern, B.S., Micheli, F., Armsby, M.H., Caldwell, M.R., et al., 2010. Guiding ecological principles for marine spatial planning. Marine Policy 34 (5),

955–966. https://doi.org/10.1016/j.marpol.2010.02.001.
Folke, C., 2004. Traditional knowledge in social-ecological systems. Ecol. Soc. 9 (3), 7. http://www.ecologyandsociety.org/vol9/iss3/art7/.
Geirsdóttir, G.E., Gísladóttir, G., Jónsdóttir, A., 2014. Coping with storm surges on the Icelandic south coast: a case study of the Stokkseyri village. Ocean Coast. Manag. 94, 44–55. https://doi.org/10.1016/j.ocecoaman.2013.09.013.
Goodman, L.A., 1961. Snowball sampling. Ann. Math. Stat. 32, 148–170. https://doi.org/10.1214/aoms/1177705148.
Gu, H., Subramanian, S.M., 2014. Drivers of Change in Socio-Ecological Production Landscapes: Implications for Better Management. Ecol. Soc. 19 (1), 41. https://doi.org/10.5751/ES-06283-190141.
Guimaraes, M.H., Ballé-Béganton, J., Bailly, D., Newton, A., Boski, T., Dentinho, T., 2013. Transdisciplinary conceptual modeling of a social-ecological system—a case study application in Terceira Island, Azores. . Ecosyst. Serv. 3, e22–e31. https://doi.org/10.1016/j.ecoser.2012.12.007.
Hamada, N., Himeno, Y., Niu, M., Ando, M., Hayashi, T., Yuta, N., 2018. The formation of Nishiura settlement in Himeshima village of Oita Prefecture: the relationship between the formation of settlement or living space and seasonal wind or occupations (In Japanese). Nihon Kenchiku Gakkai Kyushu Shibu Kenkyu Hokoku 57.
Hashimoto, S., Nakamura, S., Saito, O., Kohsaka, R., Kamiyama, C., Tomiyoshi, M., Kishioka, T., 2015. Mapping and characterizing ecosystem services of social–ecological production landscapes: case study of Noto, Japan. Sustainability Sci. 10 (2), 257–273. https://doi.org/10.1007/s11625-014-0285-1.
Havas, J., Saito, O., Hanaki, K., Tanaka, T., 2016. Perceived landscape values in the Ogasawara Islands. Ecosyst. Serv. 18, 130–140. https://doi.org/10.1016/j.ecoser.2016.02.036.
Hernandez-Morcillo, M., Hoberg, J., Oteros-Rozas, E., Plieninger, T., Gomez-Bggethum, E., Reyes-Garcia, V., 2014. Traditional ecological knowledge in Europe: Status quo and insights for environmental policy agenda. Environment 56, 3–16. https://doi.org/10.1080/00139157.2014.861673.
Himeshima Fisheries Association, 2011. Oita ken gyokyo Himeshima shiten no youko. JF Oita Himeshima Shiten (in Japanese). Himeshima gyogyo kyodo kumiai.
Himeshima son shi hen san iinkai, 1986. Himeshima Son Shi (Himeshima Village History) (In Japanese). Saiki Insatsu Kabushiki Kaisha, Oita.
Hind, E.J., 2015. A review of the past, the present, and the future of fishers' knowledge research: a challenge to established fisheries science. ICES J. Mar. Sci. 72 (2), 341–358. https://doi.org/10.1093/icesjms/fsu169.
Imai, I., Yamaguchi, M., Hori, Y., 2006. Eutrophication and occurrences of harmful algal blooms in the Seto Inland Sea, Japan. Plankton Benthos Res. 1 (2), 71–84. https://doi.org/10.3800/pbr.1.71.
Iniesta-Arandia, I., del Amo, D.G., García-Nieto, A.P., Piñeiro, C., Montes, C., Martín-López, B., 2015. Factors influencing local ecological knowledge maintenance in Mediterranean watersheds: insights for environmental policies. Ambio 44 (4), 285–296. https://doi.org/10.1007/s13280-014-0556-1.
JGN (Japanese Geopark Network), 2018. Oita Himeshima Geopark. https://geopark.jp/geopark/oita-himeshima/.
Japan Satoyama Satoumi Assessment, 2010. Satoyama-Satoumi Ecosystems and Human Well-being: Socio-ecological Production Landscapes of Japan – Summary for Decision Makers. United Nations University, Tokyo, Japan.
JFA (Japan Fisheries Agency), n.d. Seto naikai no gyogyo, yoshokugyo. http://www.jfa.maff.go.jp/setouti/tokei/. (Accessed March 5 2019).
Jurjonas, M., Seekamp, E., 2018. Rural coastal community resilience: assessing a framework in eastern North Carolina. Ocean Coast. Manag. 162, 137–150. https://doi.org/10.1016/j.ocecoaman.2017.10.010.
Kamiyama, C., Hashimoto, S., Kohsaka, R., Saito, O., 2016. Non-market food provisioning services via homegardens and communal sharing in satoyama socio-ecological production landscapes on Japan's Noto peninsula. Ecosyst. Serv. 17, 186–196. https://doi.org/10.1016/j.ecoser.2016.01.002.
Karki, M., Sellamuttu, S.S., Okayasu, S., Suzuki, W., Acosta, L., et al., 2018. Summary for Policymakers of the Regional Assessment Report on Biodiversity and Ecosystem Services for Asia and the Pacific. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Bonn.
Kearney, J., Berkes, F., Charles, A., Pinkerton, E., Wiber, M., 2007. The role of participatory governance and community-based management in integrated coastal and ocean management in Canada. Coastal Manage. 35, 79–104. https://doi.org/10.1080/10.1080/08920750600970511.
Kenter, J., 2016. Integrating deliberative monetary valuation, systems modelling and participatory mapping to assess shared values of ecosystem services. Ecosyst. Serv. 21, 291–307. https://doi.org/10.1016/j.ecoser.2016.06.010.
Kenter, J.O., Jobstvogt, N., Watson, V., Irvine, K.N., Christie, M., Bryce, R., 2016. The impact of information, value-deliberation and group-based decision-making on values for ecosystem services: Integrating deliberative monetary valuation and storytelling. Ecosyst. Serv. 21, 270–290. https://doi.org/10.1016/j.ecoser.2016.06.006.
Klain, S.C., Chan, K.M.A., 2012. Navigating coastal values: participatory mapping of ecosystem services for spatial planning. Ecol. Econ. 82, 104–113. https://doi.org/10.1016/j.ecolecon.2012.07.008.
Kohsaka, R., Kawabe, S., Fujihira, Y., Oyamada, K., 2015. Satoumi conservation and sustainability: an empirical exploration through a face-to-face interview survey in a local fishery community in Noto Peninsula. J. Int. Fish. 14, 1–16.
Leslie, H.M., Basurto, X., Nenadovic, M., Sievanen, L., Cavanaugh, K.C., Cota-Nieto, J.J., Erisman, B.E., Finkbeiner, E., Hinojosa-Arango, G., Moreno-Báez, M., et al., 2015. Operationalizing the social-ecological systems framework to assess sustainability. PNAS 112 (19), 5979–5984. https://doi.org/10.1073/pnas.1414640112.
Lim, C.P., Matsuda, Y., Shigemi, Y., 1995. Co-management in marine fisheries: the Japanese experience. Coastal Manage. 23 (3), 195–221. https://doi.org/10.1080/08920759509362266.
Lopez, R., Videira, N., 2017. Modelling feedback processes underpinning management of ecosystem services: the role of participatory systems mapping. Ecosyst. Serv. 28, 28–42. https://doi.org/10.1016/j.ecoser.2017.09.012.
Lopez, R., Videira, N., 2016. A collaborative approach for scoping ecosystem services with stakeholders: the case of Arrabida Natural Park. Environ. Manage. 58 (2), 323–342. https://doi.org/10.1007/s00267-016-0711-5.
MA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, D.C.
Martin-Lopez, B., Iniesta-Arandia, I., García-Llorente, M., Palomo, I., Casado-Arzuaga, I., et al., 2012. Uncovering ecosystem service bundles through social preferences. PLoS ONE 7 (6), e38970. https://doi.org/10.1371/journal.pone.0038970.
Martin, C.L., Momtaz, S., Gaston, T., Moltschaniwskyj, N.A., 2016. A systematic quantitative review of coastal and marine cultural ecosystem services: current status and future research. Marine Policy 74, 25–32. https://doi.org/10.1016/j.marpol.2016.09.004.
Matsuda, H., Makino, M., Tomiyama, M., 2012. Biodiversity and fisheries resource management in the Satoumi. Global Environ. Res. 16, 181–187.
Matsuda, O., Kobuku, H., 2016. Recent coastal environmental management based on new concept of Satoumi which promotes land-ocean interaction: a case study in Japan. Estuarine. Coastal Shelf Sci. 183 (A), 179–186. https://doi.org/10.1016/j.ecss.2016.10.017.
Matiya, G., Wakabayashi, Y., Takenouchi, N., Abe, S., 2006. Coastal resources and management in Japan: an outline of Kaminada fisheries in Futami District of Iyo city, Ehime Prefecture. Ehime Daigaku Nogakubu Kiyou 51, 15–24. https://www.agr.ehime-u.ac.jp/education/img/2018/513.pdf.
McClanahan, T.R., Castilla, J.C., White, A.T., Defeo, O., 2009. Healing small-scale fisheries by facilitating complex socio-ecological systems. Rev. Fish Biol. Fish. 19 (1), 33–37. https://doi.org/10.1007/s11160-008-9088-8.
McElduff, L., Peel, D., Ritchie, H., Lloyd, M.G., 2016. The octagon values model: community resilience and coastal regeneration. Urban Plan. Transp. Res. 4 (1), 1–25. https://doi.org/10.1080/21650020.2015.1124735.
Ministry of the Environment, Government of Japan, n.d. Conservation of the Water Environment (Chapter 1). http://www.env.go.jp/en/water/wq/wemj/history.html. (Accessed March 1 2019).
Ministry of the Environment Government of Japan, n.d. National Park Systems of Japan. https://www.env.go.jp/en/nature/nps/park/doc/files/parksystem.pdf. (Accessed March 1 2019).
Miyazawa, H., 2005. Oita Himeshima no engan gyogyo ni okeru kyodo taikiban gata kanri. Jinbunchiri 57 (6) (In Japanese).
Mukherjee, N., 2002. Participatory Learning and Action: With 100 Field Methods. Concept Publishing Company, New Delhi.
Nagasaki, F., Chikuni, S., 1989. Management of Multispecies Resource and Multi-gear Fisheries Experience in Coastal Waters around Japan. FAO Fisheries Technical paper 305. Food and Agricultural Organization of the United Nations, Rome.
Neumann, B., Ott, K., Kenchington, R., 2017. Strong sustainability in coastal areas: a conceptual interpretation of SDG 14. Sustain. Sci. 12 (6), 1019–1035. https://doi.org/10.1007/s11625-017-0472-y.
Ochieng, N.T., Wilson, K., Derrick, C.J., Mukherjee, N., 2018. The use of focus group discussion methodology: insights from two decades of application in conservation. Methods Ecol. Evol. 9, 20–32. https://doi.org/10.1111/2041-210X.12860.
Oleson, K.L.L., Barnes, M., Brander, L.M., Oliver, T.A., van Beek, I., Zafindrasilivonona, B., van Beukering, P., 2015. Cultural bequest values for ecosystem service flows among indigenous fishers: a discrete choice experiment validated with mixed methods. Ecol. Econ. 114, 104–116. https://doi.org/10.1016/j.ecolecon.2015.02.028.
Orchard-Webb, J., Kenter, J.O., Bryce, R., Church, A., 2016. Deliberative democratic monetary valuation to implement the ecosystem approach. Ecosyst. Serv. 21, 308–318. https://doi.org/10.1016/j.ecoser.2016.09.005.
Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., et al., 2017. Valuing nature's contributions to people: the IPBES approach. Curr. Opin. Environ. Sustainability 26–27, 7–16. https://doi.org/10.1016/j.cosust.2016.12.006.
Pascua, P., McMillen, H., Ticktin, T., Vaughan, M., Winter, K.B., 2017. Beyond services: a process and framework to incorporate cultural, genealogical, place-based, and indigenous relationships in ecosystem service assessments. Ecosyst. Serv. 26, 465–475. https://doi.org/10.1016/j.ecoser.2017.03.012.
Pert, P.L., Hill, R., Maclean, K., Dale, A., Rist, P., et al., 2015. Mapping cultural ecosystem services with rainforest aboriginal peoples: Integrating biocultural diversity, governance and social variation. Ecosyst. Serv. 13, 41–56. https://doi.org/10.1016/j.ecoser.2014.10.012.
Poe, M.R., Norman, N.C., Levin, P.S., 2013. Cultural dimensions of socioecological systems: key connections and guiding principles for conservation in coastal environments. Conserv. Lett. 7 (3) 10.1111/conl.12068.
Potts, T., Burdon, D., Jackson, E., Atkins, J., Saunders, J., Hastings, E., Langmead, O., 2014. Do marine protected areas deliver flows of ecosystem services to support human welfare? Marine Policy 44, 139–148. https://doi.org/10.1016/j.marpol.2013.08.011.
Queiroz, L.S., Rossi, S., Calvet-Mir, L., Ruiz-Mallén, I., García-Betorz, S., Salvà-Prat, J., Meireles, A.J.A., 2017. Neglected ecosystem services: highlighting the socio-cultural perception of mangroves in decision-making processes. Ecosyst. Serv. 26 (A), 137–145. https://doi.org/10.1016/j.ecoser.2017.06.013.
Reyes-Garcia, V., Guèze, M., Luz, A.C., Paneque-Gálvez, J., Macía, M.J., Orta-Martínez, M., Pino, J., Rubio-Campilloe, X., 2013. Evidence of traditional knowledge loss among a contemporary indigenous society. Evol. Human Behav. 34 (4), 249–257. https://doi.org/10.1016/j.evolhumbehav.2013.03.002.
Raymond, C., Kenter, J.O., 2016. Transcendental values and the valuation and management of ecosystem services. Ecosyst. Serv. 21, 241–1157. https://doi.org/10.1016/j.

ecoser.2016.07.018.
Ranger, S., Kenter, J., Bryce, R., Cumming, G., Dapling, T., Lawes, E., Richardson, P., 2016. Forming shared values in conservation management: an interpretive-deliberative- democratic approach to including community voices. Ecosyst. Serv. 21 (B), 344–357. https://doi.org/10.1016/j.ecoser.2016.09.016.
Riveri, S., Villasante, S., 2016. What are the research priorities for marine ecosystem services? Marine Policy 66, 104–113. https://doi.org/10.1016/j.marpol.2016.01.020.
Rodrigues, J.G., Conides, A., Rodriguez, S.R., Raicevich, S., Pita, P., et al., 2017. Marine and coastal cultural ecosystem services: knowledge gaps and research priorities. One Ecosystem 2, e12290. https://doi.org/10.3897/oneeco.2.e12290.
Ruddle, K., Satria, A. (Eds.), 2010. Managing Coastal and Inland Waters: Pre-existing Aquatic Management Systems in Southeast Asia. Springer, Dordrecht.
Saito, O., Kamiyama, C., Hashimoto, S., 2018. Non-market food provision and sharing in Japan's socio-ecological production landscapes. Sustainability 10 (1), 213. https://doi.org/10.3390/su10010213.
Sandhu, H., Clarke, B., Baring, R., Anderson, S., Fisk, C., et al., 2018. Scenario planning including ecosystem services for a coastal region in South Australia. Ecosyst. Serv. 31 (A), 194–207. https://doi.org/10.1016/j.ecoser.2018.04.006.
SCBD (Secretariat of the Convention of Biological Diversity), 2011. Biological and Cultural Diversity in Coastal Communities, Technical Series No. 61. United Nations University Institute of Advanced Studies Operating Unit Ishikawa/Kanazawa, editors. Montreal: Secretariat of the Convention on Biological Diversity.
Schulp, C.L.E., Thuiller, W., Verburg, P.H., 2014. Wild food in Europe: a synthesis of knowledge and data of terrestrial wild food as an ecosystem service. Ecol. Econ. 105, 292–305. https://doi.org/10.1016/j.ecolecon.2014.0 6.018.
Takeuchi, K., Brown, R.D., Washitani, I., Tsunekawa, A., Yokohari, M., 2012. Satoyama: The Traditional Rural Landscape of Japan. Springer, Dordrecht.
Tamura, Y., Sugimoto, R., Kasai, A., Yokoyama, H., Yamashita, Y., 2017. Ryuiki ken ni okeru nourin suisanngyo to chiiki fukko: Sekai nogyo isan Kunisaki hanto Usa chiiki no mori-kawa-sato-umi. Nihon Suisan Gakkai Shi 83 (6). https://doi.org/10.2331/suisan.WA2458-10.
Tanaka, Y., 1961. Himeshima to gyogyo (In Japanese). Suisan Taimsu Sha, Himeshima.
Tatebayashi, K., Kamiyama, C., Matsui, T., Saito, O., Machimura, T., 2019. Sustain. Sci. 14 (2), 469–486. https://doi.org/10.1007/s11625-018-0580-3.
Tattoni, C., Ianni, E., de Geneletti, D., Zatelli, P., Ciolli, M., 2017. Landscape changes, traditional ecological knowledge and future scenarios in the Alps: a holistic ecological approach. Sci. Total Environ. 579, 27–36. https://doi.org/10.1016/j.scitotenv.2016.11.075.
Tengö, M., Brondizio, E.S., Elmqvist, T., Malmer, P., Spierenburg, M., 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. Ambio 43 (5), 579–591. https://doi.org/10.1007/s13280-014-0501-3.
Thornton, T.F., Scheer, A.M., 2012. Collaborative engagement of local and traditional knowledge and science in marine environments: a review. Ecol. Soc. 17 (3), 8. https://doi.org/10.5751/ES-04714-170308.
Turner, K., Odgaard, M.V., Bøcher, P.K., Dalgaard, T., Svenning, J.C., 2014. Bundling ecosystem services in Denmark: Trade-offs and synergies in a cultural landscape. Landscape Urban Plann. 125, 89–104. https://doi.org/10.5751/ES-04714-170308.
Watanabe, M., 2012. A pathway for a nature-harmonious society. Global Environ. Res. 16, 221–229.
Weeratunge, N., Bene, C., Siriwardane, R., Charles, A., Johnson, D., Allison, E.H., Nayak, P.K., Badjeck, M.C., 2013. Small-scale fisheries through the wellbeing lens. Fish Fish. 15 (2), 255–279. https://doi.org/10.1111/faf.12016.
Woodward, E., Jackson, S., Finn, M., McTaggert, P.M., 2012. Utilising indigenous seasonal knowledge to understand aquatic resource use and inform water resource management in northern Australia. Ecol. Manage. Restor. 13 (1). https://doi.org/10.1111/j.1442-8903.2011.00622.x.
Yagi, N., 2011. Satoumi and institutional characteristics of Japanese coastal fishery management. United Nations University Institute of Advanced Studies Operating Unit Ishikawa, Kanazawa, Biological and Cultural Diversity in Coastal Communities, Technical Series No. 61. Secretariat of the Convention on Biological Diversity, Montreal.
Yanagi, T., 2010. Japanese Commons in the Coastal Seas: How the Satoumi Concept Harmonizes Human Activities in Coastal Seas with High Productivity and Diversity. Springer, Tokyo.
Yanagi, T., 2004. Himeshima no Gyogyou Shigen Kanri (in Japanese). Eng. Sci. Rep. 26 (2), 215–217. https://catalog.lib.kyushu-u.ac.jp/opac_download_md/16728/p215.pdf.
Yanagi, T., 2007. Sato-Umi- A New Concept for Coastal Sea Management. TERRAPUB, Tokyo.