

# A fifty-year production and economic assessment of common property-based management of marine living common resources: A case study for the women divers communities in Jeju, South Korea

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## ABSTRACT

We examined the conditions of successful common property-based management for coastal marine living resources, using a case of historically and anthropologically well established women divers communities on Jeju Island, South Korea, focusing on their decentralized work rules and production records. Due to their tight social network and work rule, the women divers have harvested coastal marine living resources with limited fishing pressure exclusively from their village fishing grounds for over 400 years. However, their harvest patterns have been mostly reactive to market prices, eventually requiring direct governmental regulations such as total allowable catch in some cases. Most recently, the communities have been experiencing multiple challenges: their aging population, water pollution in the coastal zone, competition with cultured products and imported seafood, and expanding barren grounds. These challenges demand a multi-scale/dimensional response if the women divers communities are to keep their village fishing grounds and communities sustainable.

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## 1. Introduction

Coastal and ocean marine living resources are depleting at an alarming rate, due in large part to increasing demand for seafood and poor property management policies [e.g., 1,2]. Common-pool resource (CPR) management—fishing community centered—has been advocated as a way to promote the sustainable management of marine living resources [3–9]. Applications of the CPR-based program to local fisheries have generated positive results for sustainable fishery management [e.g., 10–12]. However, even if the conditions of successful CPR management are met, results of the CPR-based reforms are not always effective [for review, 13,14]. For example, the reform efforts of Cambodia's fisheries, which followed the CPR principles, were not successful in generating functioning local fishing communities, largely attributable to inadequate legal authorities, low accountability of public officials, and equity problems in resource allocation [15]. There is a need for historical research to explain what makes CPR institutions durable over an extended period of time [16]. Further, the US National Oceanic and Atmospheric Administration (NOAA) is currently evaluating a fishery management option employing a

version of common property-based management for the New England Fisheries [17].

We believe it is timely to test the hypothesis of the common property-based management: self-governing institutions promote sustainable yields of living resources. We examined the anthropologically and historically well-established CPR institution of the women divers communities, which have lasted over 400 years in Jeju (Cheju) Island, South Korea, by using previously unexamined records of their production and revenue data for the last 50 years.

Anthropologically, the women divers have developed a distinctive culture, that has been recognized by outsiders for several hundred years. Since the 1960s, their customary rights to fishing have been institutionalized by relevant national laws. However, since the 1970s, their numbers have declined under new local, national, and global challenges. After reviewing their work rules and the governmental restrictions on harvesting marine living resources, we analyzed their production records of multiple marine living resources such as seaweed, shellfish, and sea urchins, and new challenges facing them in reference to CPR management.

We believe that a multi-scale approach is needed to address the current different challenges associated with sustainably maintaining a local CPR institution for marine living resources: from stakeholder meetings for maintaining ecological conditions of their fishing grounds at the local scale to solving the expansion

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of barren grounds, which is presumed to be related to increasing water temperature, for a global scale issue.

## 2. Common property institution for marine living resources

Common property (or common-pool resource, CPR) proponents take the position that a person's motivation to maximize his/her own interest is the most important factor in designing and explaining common pool resource management, while disagreeing about how to divide the community resources. In support of their position, CPR proponents argue that (1) collective action-based management is less costly than dividing common resources, and that self-government is better than government intervention in handling common pool resources; (2) problems of resource overexploitation are a result of the resource's open access to the public, and a clear boundary to limit users' accessibility should be considered; (3) individuality is more important than societal factors in explaining social actions, because conflicts in a society are mainly struggles among self-interested individuals. Incentives for individuals should be considered, as governmental regulation decreases local people's incentive to manage resources; (4) members within a boundary will incur the full opportunity costs of their actions, and any management framework will prohibit free-riders; (5) local people know the conditions of resources better than the central government; (6) external intervention generates unnecessary transaction costs; and (7) there is no significant threat or pressure from the outside [18–24]. Thus, an institution of self-rule is the best way to minimize transaction costs in managing common resources. Table 1 illustrates a summary of the successful CPR management conditions. The practical advantages of the approach are (1) local knowledge of the resources are brought into play, (2) the local fishing community's participation in the decision-making process are ensured, and (3) over-stretched government burdens are lifted, and administrative costs not effectively charged are also lifted [8].

**Table 1**

Conditions for successful CPR management.

(Source: [21], p. 1654, Table 1).

1. Resource system characteristics: small size, well-defined boundaries
2. Group characteristics: small size; clearly defined boundaries; shared norms; past successful experience-social capital; appropriate leadership; interdependence among group members; heterogeneity of endowments, homogeneity of identities and interests
3. Relationship between resource system characteristics and group characteristics: overlap between user group residential location and resource location; high levels of dependence by group members on resource system; fairness in allocation of benefits from common resources
4. Institutional arrangements: simple and easily understandable rules; locally devised access and management rules; ease in enforcement of rules; graduated sanctions; availability of low cost adjudication; accountability of monitors and other officials to users
5. Relationship between resource system and institutional arrangements: matching restrictions on harvests to regeneration of resources
6. External environment:
  - (1) Technology: low cost exclusion technology
  - (2) Government:
    - (a) Central government should not undermine local authority
    - (b) Supportive external sanctioning institutions
    - (c) Appropriate level of external aid to compensate local users for conservation activities
    - (d) Nested levels of appropriation, provision, enforcement, governance

## 3. Women diver communities in Jeju, Korea

### 3.1. Background: geography, oceanographic description of coastal environment around Jeju Island

Jeju Island, located 450 km (280 miles) south of Seoul, capital city of South Korea, and 80 km (50 miles) off the southern tip of the Korean Peninsula, is the largest of South Korea's islands. It consists of one main island and 62 smaller islands, only eight of which are occupied. The main island comprises a total of 1845 km<sup>2</sup> with a 253 km coastline (Fig. 1). As of 2008, the total residential population was estimated as 565,000 (<http://www.jeju.go.kr>).

The Island has a temperate climate with four distinct seasons. Its air temperature ranges from an average of 1 °C in January to 34 °C in August. Jeju Island is mainly affected by the Kuroshio and Yellow Sea warm currents, and is seasonally influenced by various cold water masses such as China Coastal Water, South Coastal Water, and the Yellow Sea cold current. The temperatures of coastal waters range from 13 °C in February to 28 °C in August. Under this influence, both inshore and offshore seas of Jeju Island as well as the East China Sea, become migration routes and/or wintering grounds for warm-water species, resulting in good fishing grounds.

More than 5000 women divers comprise over 70% of the total fishing population of Jeju Island. In the past, almost all the women living in the coastal areas of the island learned how to skin dive, going out into the coastal waters at a young age, supplementing their family incomes which mainly came from agricultural activities. Major target products are topshell (*Batillus cornutus*), abalone (*Haliotis spp.*), sea cucumber (*Stichopus japonicus*), sea urchin (*Anthocardaris crassispina* and *Hemicentrotus pulcherrimus*), and seaweeds such as gelidium (*Gelidium armansii*), hizikia (*Hizikia fusiforme*), and undaria (*Undaria pinnatifida*).

The women dive to the sea bottom without wearing scuba gear and can hold their breath for up to 2 min, although they wear rubber swimsuits. The typical working water depth is between 4 and 6 m [25]. Most of the women divers work in both agriculture and in catching marine living resources. For example, Kim et al. [25] found that 91.4% of the women divers worked on both agriculture and catching marine resources, while only 8.6% of the women divers worked solely in catching the marine resources in the 1980s.



**Fig. 1.** Location of Jeju (Cheju) Island, Korea.

### 3.2. Evolution of the women divers communities in Jeju, Korea

The community-based, self-ruled organization or *Haenyo* (also known as *Jamssoo*, or *Haenyeo* in Korea, or *Ama* in Japan) began in the early *Chosun* (or *Joseon*) dynasty (1392–1910). At first men and women worked together. However, by the 17th century, only women dove to harvest the seafood. Before the mid 1970s, the women divers most commonly wore cotton swimming trunks and a tank top. After that, they began wearing rubber swimsuits and goggles. In addition, they dive with basket-buoys, which are used to stay afloat and keep their harvest, but they are not allowed to use scuba gear to avoid excess fishing pressure. Hong and Rahn [26] found that in the 1960s the women divers, whose age ranged from 11 to 65 years old, worked 4 h a day with resting intervals of an hour or so in warm weather and also reported that some women divers worked for shortened working hours in cold weather when the water temperature was around 10 °C. Until the 1970s, the women divers worked about 18 days a month from March to September, and eight days a month from October to February. Another study found that women divers from Ozori village worked around 14 days per month during the warm months (March to September), and less than 10 days during the winter months (October to February) [25, p. 232]. However, after the rubber diving swimsuits were adopted, the women divers could work any month in which the weather is good, except the regulated spawning season. Today the women divers work an average of 15 days per month, during 11 months of the year. Their diving trips generally last from 4 to 6 h, although they would be shortened during the winter months [27]. Kim et al. [25] reported that the monthly working hours were 38 h in the mid 1960s, and 75 h in the mid 1980s, reflecting the impacts of increasing application of rubber diving swimsuits.

The fishing right of the women divers to harvest from the coastal fishing grounds was legally recognized in 1952 when the South Korean government enacted the *Fisheries Act*, mandating that the village fishing ground manager should allow for conventionally working women to harvest the marine living resources from the seabed in the area of their village. The Korean government also enacted the *Fisheries Cooperative Law* in 1962, mandating that the women divers join a self-governing fishing village cooperative (*Eochongae*) in every coastal village and would become licensed after having worked more than 60 days in a year in the applied village fishing ground [28]. Before 1962, any woman who wanted to harvest seafood in coastal waters would have to receive approval for her membership into her village's women divers cooperative [28].

The *Fisheries Act* designates the coastal waters near each coastal village as a village fishery ground, which extends from the shoreline to an average water depth of 7 m measured at the lowest ebb tide. As of 2006, there were 127 fishing village cooperatives encompassing 14,451 ha around the island [29]. Each fishing village cooperative on Jeju Island controls its own village fishing ground. For example, in Gosanri village, the 179 member fishing village cooperative controls 285 ha of its coastal waters (total village population: 2870) and most of the members are women divers [30].

Fishing village cooperatives are given exclusive harvest rights by the government to manage a set of confined village fishing grounds. The *Fisheries Act* and the *Fisheries Cooperative Law* establish general frameworks which demand fishing village cooperatives' compliance and the specific management measures are decided by fishing village cooperatives at the local level. The women divers have their own self-ruled voluntary divers cooperative called *Haenyohoe* (or *Jamssoohoe*) within the fishing village cooperative in every coastal village in Jeju. The women divers cooperative reflects their members' common concerns, and

individual activities, to resolve conflicts among themselves, and to encourage resource conservation. Specifically, the divers cooperative decides who can work on the seabed of their fishing village fishing ground, the working time, and distribution of financial revenues among themselves. Thus, the specific working rules differ from one *Haenyohoe* to another [28,31]. The two different cooperatives—fishing village cooperative (*Eochongae*) and women divers cooperative (*Haenyohoe*)—are mutually dependent on each other. The daily harvests are sold through each local village cooperative. The village cooperatives charge handling fees and commissions for the sale. For example, the women divers cooperative in Gosanri village give 2% of their sales revenue to the village cooperative and retain the other 98% [30].

The women divers are allowed to work only in their village fishing ground. If a woman moves to another area, she loses her license. When divers from other regions break into another village's fishing ground, coastal police will expel them after receiving a violation report from the women divers. Between 1975 and 1983, on average, 3.5 cases were reported every year [25]. Disputes among the women divers from neighboring villages tend to be resolved by themselves.

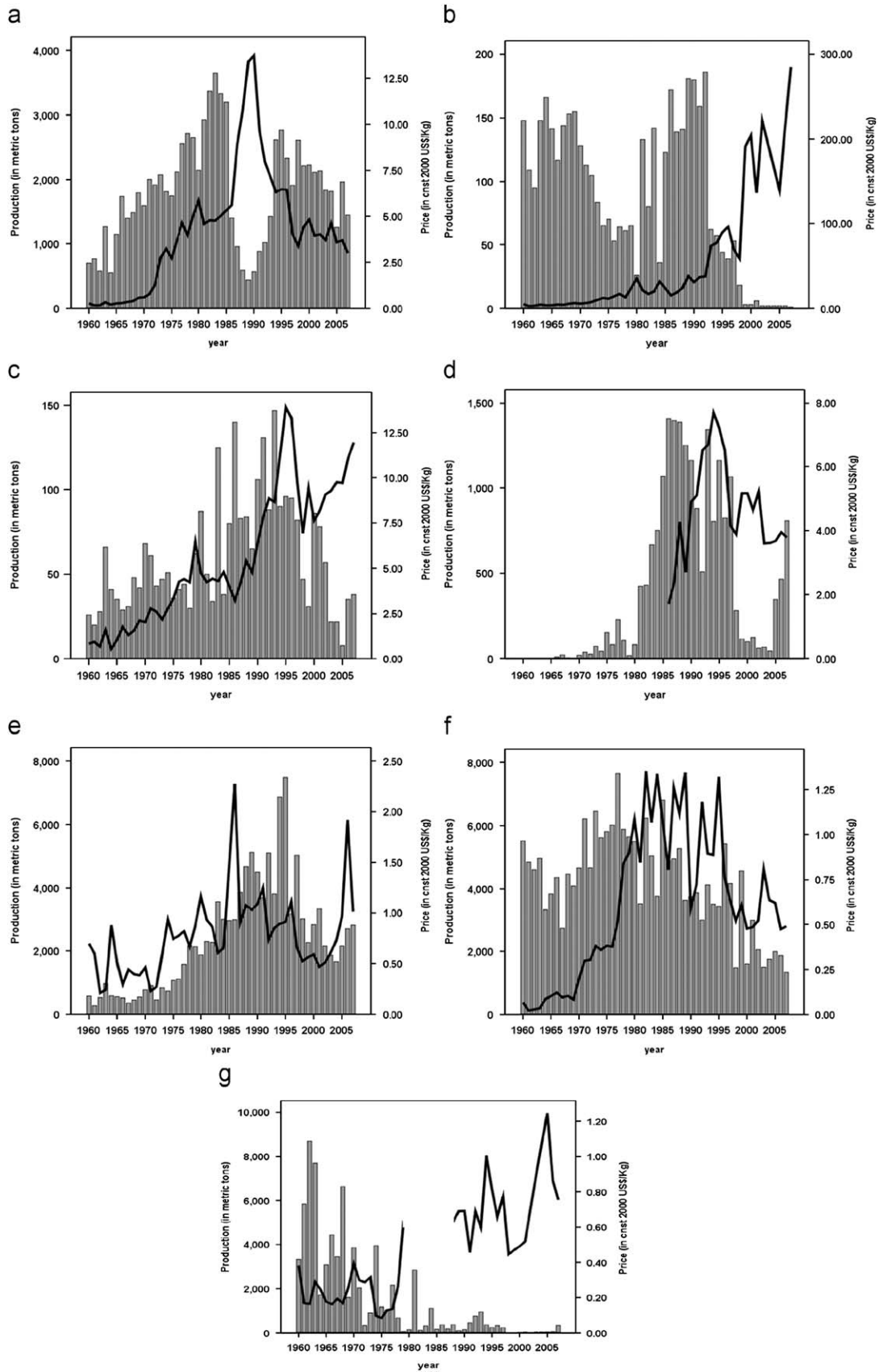
### 3.3. Working patterns of the woman divers

Sharing is an important aspect of *Haenyo* culture. Their self-rule principles reflect tightly connected communities, flexible autonomy, and decentralized decision making through participatory management [32]. The women divers cooperative (*Haenyohoe*) makes decisions related to teamwork in diving operations, cooperation of sales, sharing of a profit, and management of festivals and donations [28]. The organization also provides specific rules and guidelines for the *Haenyo* who move into or out of a village in terms of how and when they can start and stop diving. It has operational rules of diving by season and product and provides regulations of safety, emergency management, and conservation. In addition, any women divers who do not comply with their self-rules are socially and financially punished by the organization. The women divers have developed a set of professional norms built around their desire for an independent lifestyle and the maintenance of close interpersonal relationships. They are not allowed to work alone, and the working days and sale are decided by group, not individually.

In terms of professional rules, obligations, expectations, and authority, the divers cooperatives are almost completely responsible for protecting their members' professional and community interests [28]. For example, the divers cooperatives have been primarily responsible for promoting conservation/environmental protection values, as well as for mediating conflicts with neighboring villages. Such actions are taken according to their cooperative's emphasis on participatory decision making.

The divers cooperative has its own organizational structure—president, vice president, treasurer, general affairs manager, and directors [25,28]. The cooperative controls its members' duty and rights, maintains the fishing ground, keeps entry control, and decides the working period and group activities. In addition, distinctions among individual women divers—*Haenyo*—are made according to three levels of professional skills and experiences: assistant, associate, and senior [25,28].

Ongoing discussions and decision-making over work issues, including diving, prices, and products, safety, and conservation, usually take place in a meeting place, called *bultuk* [28]. Maintaining their seabed as a favorable place for the target seaweeds, including gelidium, hizikia, and undaria, by removing other seaweeds is another important agenda for them. Thus,



**Fig. 2.** Production and price of selected marine resources by the women divers, 1960–2007 (bar graph for production; line graph for price):(a) topshell; (b) abalone; (c) sea cucumber; (d) sea urchin (no production data 1960–65; no price data for 1960–1985); (e) gellidium; (f) hizikia; (g) undaria (no price data for 1980–89).

participation in removing other seaweeds is mandatory among the women divers. Women divers who skip the maintenance work must pay fines to their cooperatives, according to mutually agreed self-rules. The revenue generated from selling their harvested resources, is proportional to each diver's productivity [25].

The decentralized structure of the women divers cooperative provides opportunities for its members to become involved in local issues. In addition to their professional concerns, members use much of their time together in discussing such matters as community festivals and interdependence between women divers and non-diver residents. The social networks and economic interests around the women divers cooperatives have positively affected the quality of life throughout Jeju Island, especially in terms of mutual aid systems that help support families for economic, health, and natural disaster-related emergencies [28]. Kim [32] argues that the women divers cooperatives have established a high level social capital for value of life and norms, authority relations, neighborhood connections, and networking and civic engagement. Better fishery management would come about by utilizing the social capital and social networks within and across fishery stakeholders [33].

#### 3.4. Analysis of marine living resources production and economic assessment

The marine living resources harvested by the women divers have contributed to both individual economic well-being and to the local economy of Jeju Island. For example, marine living resources such as topshell and hizikia, harvested by the women divers, contributed about 83% of the total exports from Jeju Island during the 1970–1980s [25]. Since then, the fishery harvest by them has declined, but, still constituted an average 69% during the 1990s [34]. Nowadays a woman diver makes on average \$150–\$200 per day [35].

The following is a detailed explanation of production and price changes of the marine living resources from 1960 to 2007, mainly based on previously unexamined fishery production and revenue data mainly contained in annual fishery reports by the Jeju provincial government [36], and from the fishery production survey done by the Korean Ministry for Food, Agriculture, Forestry and Fisheries [37]. Additional data were obtained from multiple sources [25,28,29,38]. The revenues originally reported in the local currency—won—are converted into the constant 2000 US dollar using the World Bank currency convertor [39]. We also conducted a discriminant analysis to quantify the influences of rubber swimsuits applications and changing marine environmental quality.

##### 3.4.1. Topshell

The topshell (*Batillus cornutus*) is a settled gastropod thriving in the waters of the southern part of the East Sea (Sea of Japan) and coast of Jeju Island in South Korea, southern coastal waters of Japan, and reef ridden coastal waters of the Yellow Sea of China. It is one of the most economically important marine living resources in Korea.

In 1960, the topshell catch was 702 metric tons (tonnes), and reached a peak of 3648 tonnes in 1983 (Fig. 2a). In 1979, the women divers in Jeju harvested 2650 tonnes, equal to about two-thirds of the national topshell production [25], and most of the harvest was exported to Japan, generating 7.4 million (current) US dollars [25]. The favorable market condition encouraged the women divers to harvest the topshell beyond their sustainable level, and the harvest dropped to 440 tonnes in 1989 (Fig. 2a). The records of production and price for the period of 1960–1984

clearly illustrate a highly correlated relationship between the topshell price and its production until the production peaked in 1984 (Fig. 3).

As a way to recover the topshell production after its production dropped to 440 tonnes in 1989, multiple governmental regulations were imposed by presidential executive orders. Among them, the shell height of harvestable topshell was increased from 5 cm (centi-meter) to 7 cm. Additionally, the local government had worked to recover the topshell population since the mid-1980s by limiting the volume of the topshell catch, through its administrative power. Since 2001 there has been a total allowable catch (TAC) for topshell harvested in the coastal waters of Jeju Island decided by the central government. The topshell TAC was 2186 tonnes for 2001, 2058 tonnes for 2002, and 2148 tonnes for 2003 [40]. The amount of topshell harvested were 2116, 2136, 1830 tonnes for the corresponding years, respectively (Fig. 4). The implementation of the topshell TAC was a direct governmental intervention to maintain a sustainable topshell

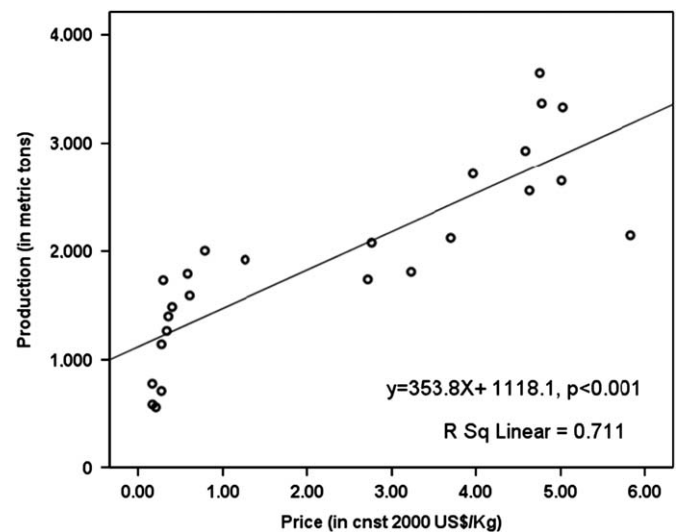


Fig. 3. Topshell price and production, 1960–1984.

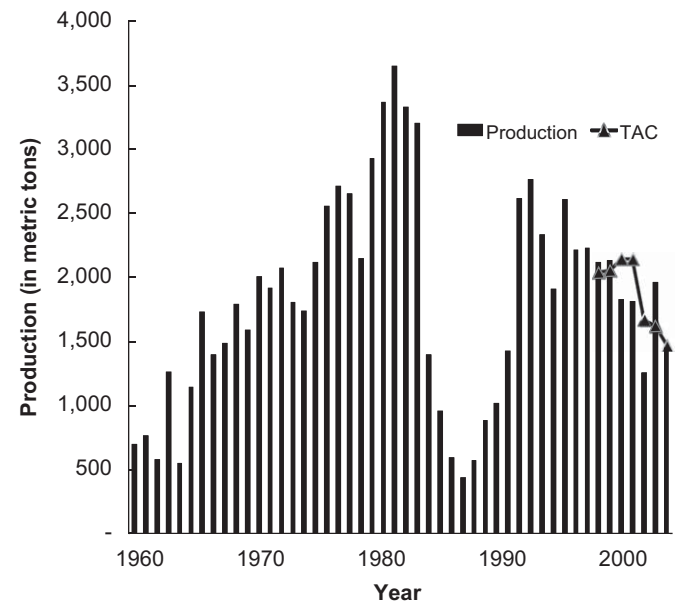


Fig. 4. Topshell production and TAC, 1960–2007.



population for harvest. Further, topshell harvest is now banned during the spawning season from June to August each year.

The annual topshell production has recovered to around 2000 tonnes since 2000 (Fig. 4). Even though their self-rule reduced competition among the women divers, the favorable market price led to an unsustainable level of harvesting by the women divers and forcing government intervention. Due to the governmental regulation that increased the minimum harvestable size of topshell to 7 cm shell height, the mean size of top shell now caught by the women divers is greater than 8 cm, which has increased the sustainable fishery of topshell in Jeju waters.

#### 3.4.2. Abalone

More than 100 tonnes of abalone (*Haliotis spp.*) were harvested by the women divers annually during the 1960 and 1970s. However, presumably due to over-harvesting of abalone, the production decreased to below 2 tonnes after 2000 (Fig. 2b). The decreasing harvest of naturally grown abalone has led to abalone production through aquaculture in other coastal regions of Korea as well as in Jeju Island, and an increasing market share of imported ones from several foreign countries, including China and Japan for a national scale [41]. The local market price of the abalone harvested by the women divers in Jeju has steadily increased, seemingly not impacted by the cultured or imported abalones. The price of abalone produced by the divers, in constant dollars, increased four times from 1998 to 2007 (Fig. 2b). There is a clear consumer preference for naturally grown over cultured abalone, especially for the tourists visiting Jeju Island.

Lately the local government has been working on dispersing juvenile abalone into the coastal waters, rather than spreading out seed abalone into the village fishing ground as a way to increase the effectiveness of recovering abalone population in the coastal marine habitat. Currently, a presidential executive order prohibits the harvesting of abalone from October to December. And only abalone larger than 10 cm diameter can be harvested.

#### 3.4.3. Sea cucumber

The sea cucumber (*Stichopus japonicus*) is found on the coast of China, Japan and Korea. The sea cucumber is a cold water species, living within a range of 5–15 °C, and from tidal areas to a depth of 20–30 m (<http://www.fao.org>). Sea cucumber production has been small relative to the other marine resources produced by the women divers in Jeju Island. The annual harvest record shows a threefold increase from the 1960s to the early 1990s, and then a decline after that, presumably due to exploitative catch by the women divers and worsening water quality in the village fishing grounds (Fig. 2c)

However, the market price of sea cucumber has remained favorable, due to the gap between increasing demand and the declining harvest. Like abalone, live sea cucumber caught by the women divers is considered a delicacy by tourists visiting Jeju Island. Lately the local government has been working on spreading out seed sea cucumber into the coastal water, as a way to restore the sea cucumber population to its traditional coastal marine habitat. A presidential executive order prohibits harvesting the sea cucumber during the month of July.

#### 3.4.4. Sea urchin

The major species of sea urchin in the Jeju waters are *Anthocidaris crassispina* and *Hemicentrotus pulcherrimus*. *A. crassispina* is distributed widely in the temperate coasts in Korea, Japan, and southeastern China, while *H. pulcherrimus* is widely found in intertidal and subtidal zones of the temperate and subarctic regions of Japan, northeastern China and Korea [42]. Lee et al. [43] found that the major foods of the sea urchin are benthic

and drifted algae, followed by various animal components (sponges, bryozoans, crustaceans, and various unidentified cap-sulated eggs). *A. crassispina* spawns from May to early July. The spawning of *H. pulcherrimus* occurs in April. People in Korea eat sea urchin roe in multiple forms: raw similar to Japanese *susui*, baked, or fermented using salts.

Like the sea cucumber harvest in Jeju, the sea urchin harvest has shown a sevenfold increase from the mid 1970s to the early 1990s, and a subsequent decrease, returning to the mid 1970s level by 2000 (Fig. 2d). It is not well understood why the sea urchin harvest has increased in the 2000s, from the coastal waters of Jeju Island. So far three main potential explanations are available: (1) whole-scale removal of algae; (2) the alteration of species diversity via feeding preferences and selective removal of algal species; (3) the provision of cleared primary substratum suitable for kelp recruitment [44]. Currently sea urchins are allowed to be harvested year round.

#### 3.4.5. Gelidium

*Gelidium (Gelidium armansii)*, a red seaweed, contains large quantities of mucilage. After picking through diving, the seaweed is washed and spread out on the shore until dried; it is then boiled in water and the mucilaginous solution strained, the filtrate is then hardened by drying in the sun. *Gelidium* contains glose—a gelatinizing agent, producing agar-agar. Like cellulose of vegetables, agar-agar aids the regularity of the bowel movements, and is also used as an adulterant of jams and jellies. In Korea and Japan, it is used in seaweed salads. The Japanese use agar-agar in their traditional jelly cake (called 'yokan', mainly made with red bean paste, agar-agar, and sugar). In Japan, the *gelidium* harvest has been decreasing. *Gelidium* pickers have been aging and their numbers have decreased, due to low market prices for *gelidium*, resulting in increasing dependence on imported *gelidium* from Indonesia, Korea and other countries. The price of domestically harvested *gelidium* is higher than the imported one in Japan, [45].

In the 1960s, the economic importance of *gelidium* was less than that of other seaweeds such as undaria in Jeju Island. However, after exports of *gelidium* to Japan started in the 1980s, its production increased (Fig. 2e). In 1983, the amount of *gelidium* produced by the women divers in Jeju was 3562 tonnes, equal to half of the national production [25]. In the 1990s, the annual production was between 7500 and 3000 tonnes. However, in the 2000s, the production declined below 3000 tonnes. The decreasing trend is attributable to the increasing barren ground (called also 'albinism,' or 'white incrustation'), where seaweed beds have disappeared, and been replaced largely by coralline algae, along the coastal zone of the Jeju Island [29]. The market price has been favorable for *gelidium* lately, mainly due to the increasing demand from Japan. For example, the harvested amount of *gelidium* from Jeju Island for 2005 was 2152 tonnes with the revenue of 2.3 million (current) US dollars. In 2006 the revenue more than doubled to 5.6 million (current) US dollars, after a 25% production increase, and an increased market price of *gelidium*. Although the *gelidium* price dropped for 2007, it was still higher than the 2005 price (Fig. 2e).

Currently, a presidential executive order prohibits the harvest of *gelidium* from November to April. Efforts to keep the seabed favorable for *gelidium* have been made by transplanting young seaweeds to the barren grounds. The success of these efforts is still being evaluated.

#### 3.4.6. Hizikia

*Hizikia (Hizikia fusiformis; tot* in Korea; *hiziki* in Japan) is a brown seaweed, growing from the bottom of the eulittoral to the top of sublittoral zone, around the Korean peninsula, most coasts

of China, and in Japan [46]. Hizikia has been an important seafood for local consumption as an ingredient in soups as well as seaweed salads. Hizikia harvested by the women divers from their fishing grounds represented a significant portion of national production until the widespread adoption of aquaculture technology beginning in the mid 1980s. For example, in 1979, the hizikia production from Jeju Island was 43.6% of national production [25].

Hizikia production increased throughout the 1970s and to the mid 1980s, as processed hizikia became a major exporting item to Japan for industrial use (Fig. 2f). The foreign market demand, followed by a favorable market price, provided incentives for the women divers to harvest more hizikia in Jeju Island. Additionally the favorable market condition has contributed to expansion of hizikia aquaculture in other coastal zones of Korea, especially in the south-west coast of Korea since 1984. The hizikia harvest by the women divers in Jeju Island has been declining since the early 1990s. The major factors explaining this decline are the increasing hizikia production through aquaculture [47], and the increasing volume of cheaply imported hizikia from China. The combined impacts of these two factors have depressed the domestic market price (Fig. 2f). Additionally, habitat quality degradation of their village fishing grounds, including barren areas, have become more significant [29]. Currently a presidential executive order prohibits the harvesting of hizikia from October to January from the Jeju coastal waters.

### 3.4.7. *Undaria*

*Undaria* (*Undaria pinnatifida*; *miyeok* in Korea; *wakame* in Japan), a brown seaweed, grows on rocky shores and bays in the temperate zones of Japan, Korea, and China. It grows best between 5 and 15°C. In recent years it has spread to other continents including the coasts of France, New Zealand and Australia primarily through ship ballast water [46]. *Undaria* has long been a popular seaweed food in Korea and Japan. For example, it is the main ingredient in soybean (miso) soup as well as seaweed salads. Due to developments in food-processing technology, new products of *undaria* are now available in markets including pre-cooked, powdered and dried *undaria* [46].

The importance of *undaria* as a major seafood for Korean people triggered *undaria* aquaculture in the 1960s, relatively earlier than aquaculture for other marine living resources in Korea [48]. Fig. 2g illustrates the impact of *undaria* aquaculture in Korea—a continuously declining harvest since the mid 1960s. The women divers harvested 5837 tonnes of *undaria* in 1961, but less than 50 tonnes in the late 1990s (Fig. 2g).

Recently the market price for *undaria* harvested in Jeju waters has increased, partially due to a distinctive consumer preference for naturally grown over cultured *undaria*, and efforts driven by the local fishing village cooperatives (*Eochongae*) for promoting *undaria* harvested from their village fishing grounds [for example, 49]. However, the *undaria* harvest has not followed the trend of recent price increases, rather only leading to modest increases in the harvest by the women divers (Fig. 2g), presumably because, like other seaweeds produced in Jeju waters, its habitat has been under significant environmental stresses such as worsening water quality and increasing barren grounds.

### 3.4.8. Discriminant analysis

We conducted a discriminant analysis to quantify the influences of diverse factors on the women divers' harvest activities of marine living resources over the past 50 years (1960–2007). The research period is divided into three groups: period 1 (1960–1975), period 2 (1976–1997), and period 3 (1998–2007). Period 1 reflects traditional harvest style. During

this period, the majority of women divers wore cotton swimming trunks with low daily working hours. In period 2, there was an expanded adoption of rubber diving swimsuits—a modern technology—which increased the divers' working hours significantly, resulting in increased per capita production of marine living resources. In period 3, the worsening marine environmental qualities, including lowered water quality, increasing marine debris, and barren grounds, have been identified and extensively monitored, in addition to increasing market share of imported seafood in South Korea. The results of the discriminant analysis clearly illustrate the three different production patterns of marine living resources by the women divers from their village fishing grounds over the last 50 years (Fig. 5 and Table 2). The function 1 ( $x$ -axis) differentiates the production pattern of marine resources for period 3 from the other two periods more clearly than function 2 ( $y$ -axis) (Fig. 5). Tests of dimensionality indicate that both of the dimensions are statistically significant (Table 2a). Dimension 1 has a canonical correlation of 0.907 between the resources productions and the period classification, while the canonical correlation for dimension 2 is a little lower, 0.811. Table 2b indicates that the first discriminant dimension is most strongly influenced by the hizikia production (1.011), followed by abalone (0.780), and gelidium (0.509). For the second dimension, the productions of *undaria* (−0.476), sea urchin (0.473), gelidium (0.466), and topshell (0.406), are almost equally dominating variables. The overall production pattern of the marine living resources shows an increasing trend over the two periods, and a declining trend for period 3. The peak productions of the marine living resources occurred during period 2, except the *undaria* production (Fig. 2g). The *undaria* production, which has suffered from cultured products since the early 1960s, but is now slowly recovering due to newly established consumers' preference for natural grown products, is negatively correlated with the production trend.

### 3.5. Challenges in transition

The exclusive catch rights, afforded the women divers of Jeju, have contributed to the sustainable management of the coastal

Canonical discriminant functions for the production of marine living resources by the women divers

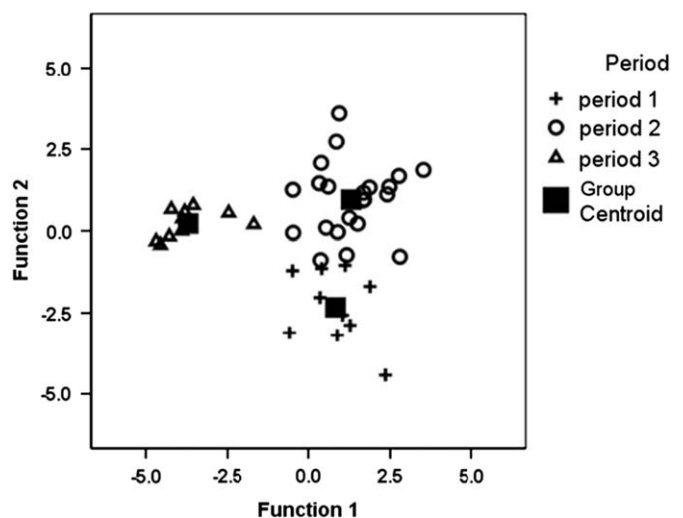


Fig. 5. Production of marine living resources plotted by canonical functions for 1960–2007. Note the strong separation among the three periods. The discriminant analysis, based on the seven marine resources, correctly classifies about 95.2% of the cases.

marine living resources and have kept the local community vibrant. However, the women divers communities are facing a number of complex challenges.

One of the most significant challenges facing these communities is the declining number of women divers. In the 1960s there were up to 23,000 female divers on the island. By the mid 1970s, there were less than 10,000, and now there is around 5000 (Fig. 6). A second challenge is the aging of the women divers' population (Table 3). Due to harsh work, availability of other economic opportunities to the women on Jeju, driven by a broad nation-wide economic development that continues today, the young women of Jeju Island have been taking other inland jobs. There is an almost reversed proportional relationship between the number of registered women divers and the per capita gross domestic product (GDP) (Fig. 6). The economic growth nationwide since the 1960s has provided more economic opportunities for women in Jeju. For example, tangerine cultivation was a major economic factor in leading women divers to abandon the harvesting of seafood in the 1970s [25,50]. The women divers in the 1960s invested their income in educating their children, who became better educated, leading them to not return to their coastal community, but instead to stay in urban areas for the higher incomes that can be earned there.

Many of the women divers are subject to pressure headaches, the effects of diving several meters into the water without taking in air, causing decompression sickness (or Caisson disease). Only after quitting the job, their headaches can be alleviated. For the young generation, diving is too hard, relative to other economic opportunities. Thus, the population of women divers continues to decline and the age of working women divers has gone up, despite diverse government programs such as free medical treatment, due to their historical, anthropological and economical significances to Jeju Island.

Currently the local Jeju provincial government is trying to sustain the number of women divers by transforming their communities into tourist attractions. Since 1994 the national and provincial governments have invested 1.75 billion won (equal to 1.5 million US\$) for tourism development, through building tourist condominiums, docking facilities, recreational fishing, and street lights. For example, fishermen in Gosanri village run 35 recreational fishing boats weighing 3–5 tons and accommodating 8–12 people. These boats have two permits, one for recreation, and the other for commercial fishing. However, the problem of out-migration continues, even starting before there was significant marine resource depletion of the village fishing

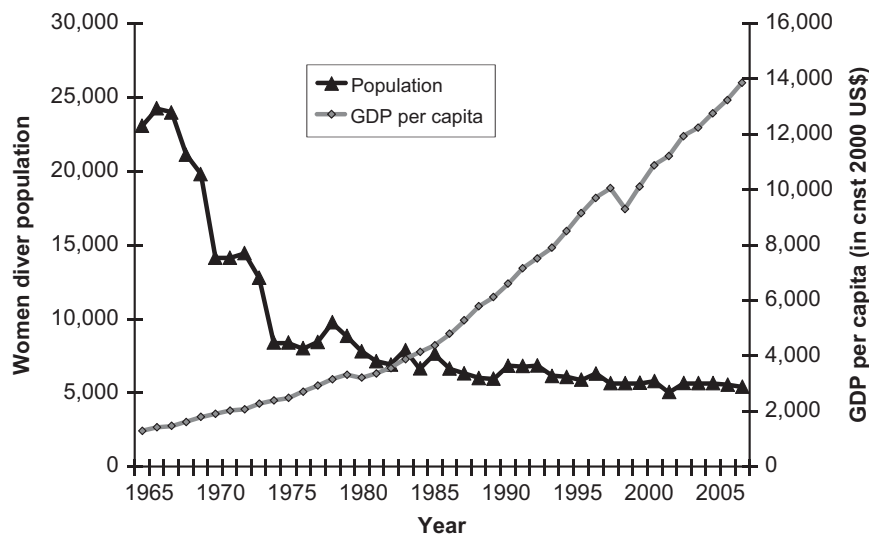
**Table 2**

Dimension	Canonical correlation	Chi-square	df	p
(a) Tests of discriminant dimensions for the production by the women divers				
1	0.907	100.953	14	$P < 0.01$
2	0.811	38.592	6	$p < 0.01$
(b) Standardized canonical discriminant coefficients for the production by the women divers				
Marine resources	Dimension			
	1	2		
Topshell	0.271	0.406		
Abalone	0.780	-0.146		
Sea cucumber	0.065	0.034		
Sea urchin	0.109	0.473		
Gelidium	0.509	0.466		
Hizikia	1.011	0.037		
Undaria	0.391	-0.476		

**Table 3**

Number of Haenyo and age distribution, 1970–2006.  
 Source: for 1970, 80,90,05,06: Jeju Samdamuseum, <http://english.jejusamda.com>; for 2002, [50], Table 3.

Year	Total number	Age distribution			
		Under 30	30–49	50–59	Over 60
1970	14,143 (100.0%)	4425 (31.3)	7760 (54.9)	1310 (9.3)	648 (4.6)
1980	7804 (100.0%)	782 (10.0)	4788 (61.4)	1698 (21.8)	536 (6.9)
1990	6470 (100.0%)	271 (4.2)	2894 (44.8)	2370 (36.6)	935 (14.4)
1995	5886 (100.0%)	20 (0.3)	1843 (31.3)	2247 (38.2)	1776 (30.2)
2002	5659 (100.0%)	2 (0.0)	969 (17.1)	1722 (30.4)	2966 (52.4)
2005	5545 (100.0%)	0 (0.0)	718 (12.9)	1512 (27.3)	3315 (59.8)
2006	5406 (100.0%)	0 (0.0)	518 (9.6)	1331 (24.6)	3557 (65.8)



**Fig. 6.** The women diver population and the GDP per capita of Korea, 1965–2006.



ground [30]. Kim and others [25] argued that the out-migration is largely driven by the two factors: (1) Jeju's main industries transforming from agriculture and fishery to manufacturing and service industries along with the nationwide economic development, and (2) the increased education level among women as more female students attend institutions of higher education.

Another challenge comes from a worsening of the marine ecosystem quality of the village fishing grounds of Jeju Island. Due to increasing human residential population and increasing aquaculture facilities along the shore line, direct inflows of nutrient-rich wastewater and cooling waters from power plants and other facilities, into the coastal zone have caused eutrophic conditions and fish-kills in the coastal zone. Currently, only 62% of wastewater is treated in sewage treatment facilities in Jeju [51]. Additionally, excessive inflows of nutrients, through submarine groundwater discharges are found as another cause of benthic eutrophication problems in the coast of this permeable volcanic island [52].

Further, the barren grounds in which seaweed beds have disappeared, has been expanding. Lee et al. [53] reported that about 20% of the village fishing grounds in Jeju were defined as barren grounds in 1999 (2931 ha out of 14,790 ha). By 2008, the barren ground had expanded to 31% or 4541 ha [54]. Seaweeds are important food sources for the marine living resources including topshells as well as important harvestable marine resources for human consumption. Without proper management in containing the barren grounds, any sustainable production of the living resources will be difficult.

Since the mid 1980s, the fishing pressure by the women divers has declined significantly by over 40%, due to the rapidly declining population of women divers, even after considering the impact of the increased working hours of the women divers by adopting the rubber swimsuits. The CPR proponents argue that mutually agreed self-rules among community members keep fishing pressures at a sustainable level [10–12]. However the reduced fishing pressure in the coastal waters in Jeju Island has occurred because of the decreasing diver population. Further, even though the fishing pressures by the women divers in coastal waters in Jeju Island reduced since the mid 1980s, the overall and per capita productions of the marine living resources by the women divers have declined throughout the 2000s, presumably due to the worsening habitat quality of the coastal waters in Jeju Island. Thus, we believe it is more important to develop programs to improve marine habitat quality of the village fishing grounds than limiting potential impacts of fishing pressure triggered by the women divers.

#### 4. Discussion/conclusion

The women divers of Jeju Island have inherited and shared their core values and interests for over 400 years. Their exclusive rights to fish the nearby coastal waters is both recognized and protected by legal and administrative institutions, designed to provide a framework for sustainable management of coastal marine living resources as well as keeping the local community vibrant.

However, their CPR self-rules seemingly contribute to limiting competition among themselves by controlling membership and enforcement against intruders from other communities. Takahashi et al. also found it in the Japanese *ama* [3]. Even though the women divers have worked together to improve the habitats for their target seaweeds and have banned the use of scuba diving equipment, their production records show that short-term economic gains play a more significant role than long-term efforts to conserve and protect their marine living resources.

When the market price is good, they tend to harvest more of the marine resources than is sustainable, and government intervention is needed. For example, the continued exploitation of topshell from the Jeju waters resulted in a harvest collapse in the mid 1980s, and now a TAC policy is in place to regulate the women divers' topshell catch. Local market prices of the marine living resources have been influenced by market prices in importing countries, mainly in Japan, and are also impacted by cheap imports into Korea, mainly from China. Furthermore, their local harvest of the major marine living resources also reflects the foreign/global market demands of these seafoods over time.

Second, there has been limited opportunity for the women divers to understand their village fishing grounds from a scientific perspective. Integrating scientific findings into managerial decisions of the coastal ecosystem is vital for a sustainable marine ecosystem [55]. However, the women divers follow the trends of market prices for the marine living resources under mutually agreed working rules among themselves in harvesting the marine living resources. Jeju National University has developed a one-year education program for the women divers to provide scientific information surrounding the village fishing ground, and other information on health issues, human impacts on coastal zone, managerial issues including marketing, and on their own unique cultural heritage as an outreach effort in 2007. Nineteen women divers completed the program in 2008.

Third, more lucrative and socially prestigious jobs have been available for women in Jeju, following nation-wide economic development, resulting in significant out-migration of the women from diving work. Further, more educated women than their mothers, who were divers, prefer other economic opportunities than the labor-intensive marine work. Without external threats such as intruding divers from outside communities, the common property institution of the women divers' community has been shrinking, because the economic return of the diving work cannot compete with other economic opportunities. Although tourism has been considered as a supplementary effort to keep the divers communities viable, limited successes have been reported [30]. Thus, sustained recruitment should be a factor in considering the common property approach.

Fourth, the production of abalone and seaweeds has been declining, attributable to multiple factors. The increasing market share of imported or cultured abalone and seaweeds decreased the market price of the resources, pushing the divers to focus on non-cultivable resources such as topshell for higher economic return on their efforts. The other factor is the declining habitat quality of the coastal zone due to increasing eutrophication and an increase in the area of the barren grounds.

Finally, the effects of changing fishery technology is seen in two ways: (1) introduction of the rubber swimsuits, and (2) increasing market share of seafood cultured in other regions or imported from foreign countries. The expanding use of rubber swimsuits has allowed the divers to work both more hours per day and work more days per year, catching more marine resources, resulting in higher per capita topshell harvest than before the 1980s, which would have threatened a sustainable marine resource production if the governmental regulations were not in place.

The women divers communities in Jeju, Korea, clearly show multiple problems on difference scales (Table 4), as Berkes [56] argues for management of marine commons. The marine living resources management by the women divers communities provides a case for multiple boundary rule for successful CPR management. There is a clear boundary of village fishing ground and policing work against intruders have been done by the women divers with additional policing service by governments. However, the current boundary rule cannot solve the problems

**Table 4**  
Different scales of challenges for sustainable institution of Haenyo.

Scale	Managerial issues
Local	Worsening coastal water quality Increasing marine debris Increased working hours
National	More economic opportunities for women Relatively slowed growth of financial revenue from selling fishery products, compared with other economic sectors Expanding aquaculture in other region
Global	Expanding barren ground Cheap importing fishery products Market prices of fishery products in importing nations

associated with declining water quality, attributable to coastal development and increasing aquaculture facilities, requiring a different scale of boundary to keep the estuarine environment safe against multiple sources of pollution. Further, the women divers' communities illustrate the importance of relative economic gains. Economic gains coming from the marine living resources have failed to be compatible to other economic opportunities. Even though most of the successful CPR management conditions (Table 1) have been met, the women divers communities have been unsuccessful in recruiting young divers, even without external threats or internal conflicts among members. These communities appear to be unsustainable if the present conditions persist.

Viable fishing communities are an important component of fishery management [7,9]. Multiple strategies should be developed to make the women divers communities sustainable. On the local scale, the women divers, first, should be more keenly aware of the ecological limits of their seafood harvests. Second, analysis of water quality and stock assessment of the marine living resources for the village fishing ground should be conducted periodically as basic scientific information and for increasing awareness of ecological conditions of the fishing grounds. Third, a stakeholder committee, composed of representatives of local government, fishing village cooperative, *haenyo*, commercial fishermen, recreational fishermen, residents, coastal marine scientists and aquaculture facility managers, should be created to manage the overall coastal habitat quality. The goals of the proposed stakeholder committee are twofold: (1) it will be a mechanism where scientific information of physical and biological conditions of each village fishing ground is shared and managerial issues would be discussed among the stakeholders for increased commonly shared understanding on coastal habitat quality and management issues, and (2) it will reduce conflicts among themselves over economic issues related to coastal habitat utilization. Adding a component of co-management—stakeholder committee—increases the quality of common property institutions in managing marine living resources [6].

On the national scale, the women divers should increase their income by diversifying the economic activities within their village fishing ground in order to generate an income compatible with women's jobs off the island. Then, young women would be more likely to join the traditional women divers' community. An example would be their increasing activities in hosting visiting tourists for recreational fishing and other leisure businesses for additional financial gains from their fishing grounds.

On the global scale, the increasing area of the barren grounds has generated additional challenges in maintaining habitat quality, and free trade of seafood has eroded local control over the marine living resources. Expansion of the barren grounds is presumed to be related to increasing water temperature, due to

global warming and to reductions in water quality [53]. Additional studies are needed to determine the specific causes of these barren grounds and to find remedies.

After examining the work rules of the women divers communities in Jeju Island, and their production and revenue records of coastal marine living resources, we found that due to their tight social network and work rule, the women divers have harvested coastal marine living resources with limited fishing pressure exclusively from their village fishing grounds for over 400 years. However, their harvest patterns have been mostly reactive to market prices, eventually requiring direct governmental regulations such as total allowable catch in some cases. Most recently, the communities have been experiencing multiple challenges: their aging population, water pollution in the coastal zone, competition with cultured products and imported seafood, and expanding barren grounds. We believe that these challenges demand a multi-scale/dimensional response and active involvements of multiple stakeholders in keeping coastal habitat quality if the women divers communities are to keep their village fishing grounds and communities sustainable.

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