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Importance of fishers' knowledge in innovating adaptive co-management in sandeel fisheries

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Abstract: Adaptive co-management has recently been discussed as an efficient approach for managing small-scale fisheries. One type of local ecological knowledge, fishers' knowledge, has been highlighted as a useful way for adapting fishers to a management system of fisheries resources. We present a case study from Japan to demonstrate a practical process of evolving fisheries management systems into adaptive co-management by introducing fishers' knowledge. Fishers recombined elements at hand during fishing procedures for innovation of the system. Their reflections are considered to represent the concept of *bricolage*, as proposed by Lévi-Strauss: i.e., making do with what is at hand. Fishers' bricolages appear to be indispensable for successful implementation of adaptive co-management.

Keywords: *fishers' knowledge, adaptive co-management, sandeel, Ise Bay, bricolage*

1. Introduction

Japanese sandeel (*Ammodytes personatus* Girard) stock is one of the most important resources of two-boat pelagic trawl fisheries in Ise Bay, which opens to the Pacific Ocean in central Honshu, Japan (Fig. 1). At present, about 200 fleets are engaged in this fishery, and the annual amount of sandeel landed in Aichi and Mie prefectures exceeds two billion yen (~265 million USD). From 1950 to 1982, the sandeel stock was managed using a command-and-control method by the local government. However, the abrupt depletion of sandeel stock in Ise Bay in the 1980s drove fishers to regulate the resource (TOMIYAMA *et al.*, 2008). The Fisheries Research Institute of Aichi Prefecture is also currently addressing issues related to local sandeel fisheries. This collaboration may foster progress in the co-management of fisheries resources in Ise Bay (TOMIYAMA *et al.*, 2005).

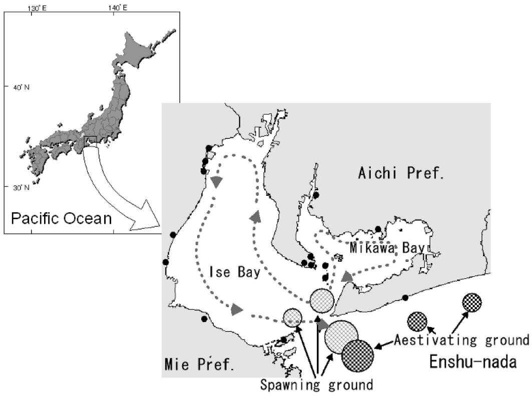

Fig. 1. Schematic view of migration routes of sandeels from spawning grounds to nursery grounds in Ise Bay and Mikawa Bay, as they develop from eggs to adults. Arrows indicate the migration paths of larvae and juveniles. Closed circles indicate the locations of sandeel landing ports around Ise Bay and Mikawa Bay.

Co-management can be defined as a partner-

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ship arrangement in which the community of local resource users (fishers), the government, other stakeholders (boat owners, fish traders, boat builders, business people), and external agents (non-governmental organizations [NGOs], academic and research institutions) share the responsibility and authority for management of the fishery (POMEROY and RIVERA-GUIEB, 2006). Through consultations and negotiations, the partners develop a formal agreement on their respective roles, responsibilities, and rights in management. Co-management covers various partnership arrangements, adjusts the degree of power sharing, and integrates local informal relations, traditions, and customs to centralize government management systems (ARMITAGE *et al.*, 2007; TOWNSEND and SHOTTON, 2008). Co-management of fisheries can be classified into five broad types according to the roles of government in relation to fishers (SEN and NIELSEN, 1996) : instructive, consultative, cooperative, advisory, and informative. Our case involves informative co-management because the local government has delegated fisheries scientists, who provide valuable information on fish resources, to attend meetings of fisher groups that decide upon some fisheries measures; the scientists are then responsible for informing the local government of these decisions.

One of the distinguishing features of the process of evolving to adaptive co-management is the introduction of fishers' knowledge. Fishers' knowledge, which has recently received attention in fisheries studies, is considered one type of local ecological knowledges (e.g., JOHANNES *et al.*, 2000; HAGGAN *et al.*, 2007; RUDDLE, 2007; GARCIA-QUIJANO, 2007; MAMUN, 2010). Such knowledge corresponds to *bricolage,* as proposed by LÉVI-STRAUSS (1962) in his book *La pensée sauvage* (often translated into English as The Savage Mind). *Bricolage*, as described by LÉVI-STRAUSS (1962), means that “there still exists among us an activity that on the technical plane provides a good understanding of what a science we prefer to call 'prior' rather than 'primitive,' could have been on the plane of speculation” (LÉVI-STRAUSS, 1962). Recently, the concept of *bricolage* was introduced into management science to describe the process of making do by applying combinations of the resources at hand to new problems and opportunities (BAKER and NELSON, 2005).

In Japan, some large-scale fisheries are managed by top-down or command-and-control methods such as total allowable catch. But most fisheries conducted in coastal areas of Japan are small scale (MATSUDA *et al.*, 2010). In most cases, successful resource management is conducted by co-management or self-management methods. In this paper, we present several important points concerning the operation of fisheries management (UCHIDA and MAKINO, 2008). In addition, we provide examples of fishers' knowledge being introduced into an adaptive co-management system. We discuss this knowledge introduced into the process as a type of bricolage in management science, i.e., making do with what is at hand (BAKER and NELSON, 2005). It is also very important to analyze development process of sandeel resources co-management system in Ise Bay to clarify what factor contributes to develop the system by applying a newly developed analytical model of knowledge creating process.

2. Sandeel fishery management in Ise Bay

The sandeel stock in Ise Bay experienced declines in the 1970s and 1980s (Fig. 2) (FUNAKOSHI, 1997; TOMIYAMA *et al.*, 2005; TOMIYAMA *et al.*, 2008). Following the collapse of the stock in Ise Bay, a co-management system was implemented in the 1980s.

Autonomous organizations of fishers in Aichi and Mie Prefectures have played a central role in co-managing the sandeel fishery. The history of the shift from command-and-control management to co-management of sandeel fisheries in Ise Bay can be divided into three periods: (1) Sandeel pelagic trawl fisheries were licensed in 1950 by the Aichi and Mie prefectural governments (TOMIYAMA *et al.*, 2005) ; (2) the sandeel stock in Ise Bay and Mikawa Bay collapsed from late 1978 to 1982 because of overexploitation and environmental deterioration (TOMIYAMA, 2009). After this collapse, fishers in Mie and Aichi prefectures and fisheries scientists belonging to the prefectural fisheries research stations of Mie and Aichi

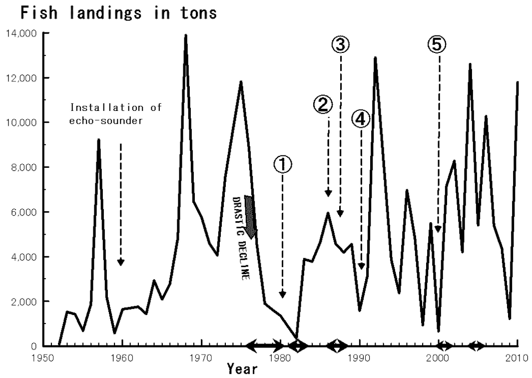

Fig. 2. Annual landing of sandeel in Aichi Prefecture from 1950 to 2004. Black arrows and boxed legends outline the regulatory practices of resource management. Black lines with arrows on the horizontal axis show periods of the large meander of the Kuroshio Current, which causes abnormally low water temperatures in coastal waters along the Pacific coast near Ise Bay and Mikawa Bay. ① Regulation of fishing during the spawning period. ② Regulation of the fishing of large juveniles. ③ Opening day control of the fishing season by the fisheries management simulation model. ④ Establishment of the closing day. ⑤ Adaptive establishment of fisheries refugia

began to discuss regulatory measures in Ise Bay and Mikawa Bay in 1980 based on collaboration between Aichi and Mie prefectures. They decided to apply the first co-management system to sandeel fisheries in 1983. (3) By introducing fishers' knowledge, co-management was innovated into an adaptive co-management in 1990. The main innovations occurred through the following three measures: (a) protection of spawning sandeels, (b) decisions concerning opening day, and (c) decisions concerning the closing day of the sandeel fishery.

3. Fishers' knowledge for innovation of a management system

A collaborative survey between fishers and fisheries scientists is essential for achievement of sustainable co-management based on scientific research design, which is a key factor in a co-management system. The practical tools for the management system have been innovated using fisher's knowledge that is to say *bricolage.*

(a) Protection of spawning sandeels

Fisheries scientists belonging to the prefectural fisheries experimental stations of Aichi and Mie gathered data regarding the migrating area of spawning sandeels using by-catch and echo-sounder information in December. As for fishers' knowledge, fishers have noticed that sandeels spawn earlier when by-catch of sandeel in whitebait trawl fisheries has occurred earlier than in a usual season. Using information on time of the by-catch, we set refugia for spawning sandeel at the mouth of Ise Bay. Moreover, in mid-January, sandeel fishers voluntarily conducted a survey to catch spawners. An open meeting was organized to examine the ovary samples and estimate the timing of sandeel spawning. Related fishers and fisheries scientists belonging to both Mie and Aichi prefectures attended the meeting, during which the parties involved engaged in vigorous discussion and decided on the timing of the opening day for sandeel fisheries in early spring, as discussed below.

(b) Decision concerning opening day

Bongo-nets are plankton sampling gear consisting of two circle rings with a net but no bridle. The lack of a bridle reduces net avoidance by plankton, which are often deterred by the approach of a bridle. Thus, this net is a very effective tool for forecasting the catch of the 0–year-group sandeel before the fishing season (TOMIYAMA, 2007). When the body length (BL) of sandeel reaches 8 to 10 mm, we evaluated the 0–year-group fish stock size using density data from bongo-net catches (frame diameter of 60 cm, net length of 3 m, and mesh size of 0.335 mm).

Under a co-management framework, the opening day for sandeel fishing was set for the day when sandeel larvae reach 35 mm in BL. Therefore, accurate growth predictions were required. The error caused by avoidance of bong-net mouths is not negligible because of the improved swimming ability attained by larvae at 10 to 12 mm in BL. To overcome this problem, the Aichi Fisheries Experimental Station, along with sandeel fishers, needed to

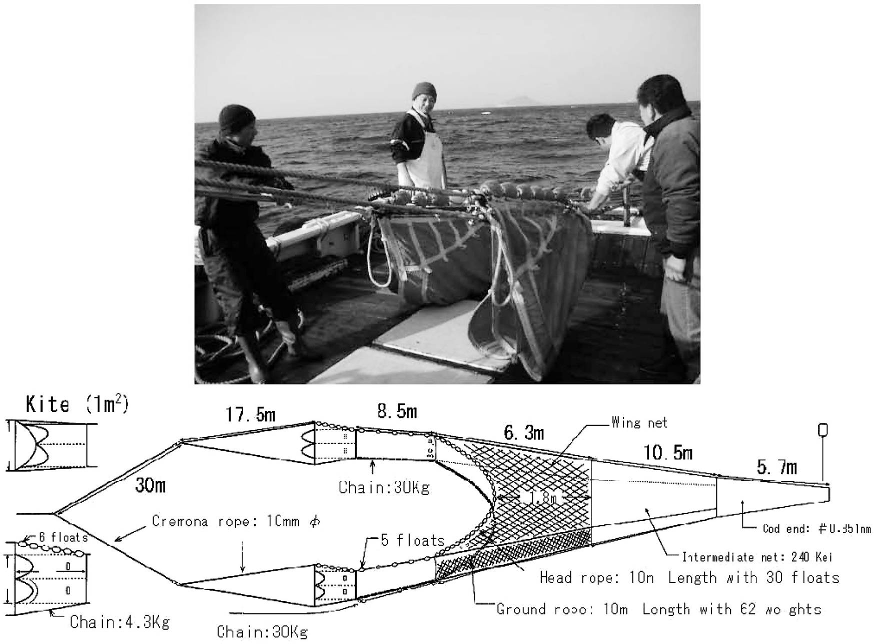

Fig. 3. Photograph showing fishers participating in sandeel larvae sampling using a kite-net (upper panel) and a diagram of the kite-net (lower panel).

develop a new sampling gear that can capture sandeel larvae larger than 10 mm in BL (TOMIYAMA, 2007). At the beginning of gear development, a fisheries scientist of Aichi prefecture requested fishers to transfer their experiences on trawl nets to capture sandeel larvae larger than 10 mm in BL. Mid-water trawl fishers voluntarily made a net set consisting of mesh net tube (mesh size: 1.54 mm) recycled from their mid-water trawl net that had actually used for sandeel fisheries. Thus, this new sampling net was based on fishers' know-how of making trawl net set. The net mouth has a diameter of about 3 m and opened by a canvas kite (Fig. 3) developed by Nichimo Co., Ltd. (TOMIYAMA, 2007). The opening mechanism prompted the name "kite-net." Checking shape of the net deployed in the field at first, fishers took the initiative of experiment. Towing the net near the sea surface from their boat, fishers observed whether the net had wrinkled or not. Then the fishers put down and towed the net in the middle layer, and surveyed cross-section view of the net using their echo-sounder equipped in their boat. Thus, this net innovation represents an example of *bricolage* within co-management. Finally, the kite-net can collect sandeel larvae of a wide size distribution ranging from 10 to 30 mm in BL.

(c) Decision concerning the closing day of the sandeel fishery

Adaptive co-management of sandeel resources requires to protect spawning sandeel throughout successive reproductive seasons during the fishing season. Therefore, many researches pointed out that marine protected areas (MPAs) were necessary for sustainable sandeel fisheries in Ise Bay (TOMIYAMA *et al.*, 2008; TOMIYAMA, 2009; MATSUDA *et al.*, 2010) (Fig. 4). MPAs are defined by the International Union for Conservation of Nature (IUCN, 1994) as "any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment." The present case is applied the MPAs classified as Category IV meaning that they are designated for resource

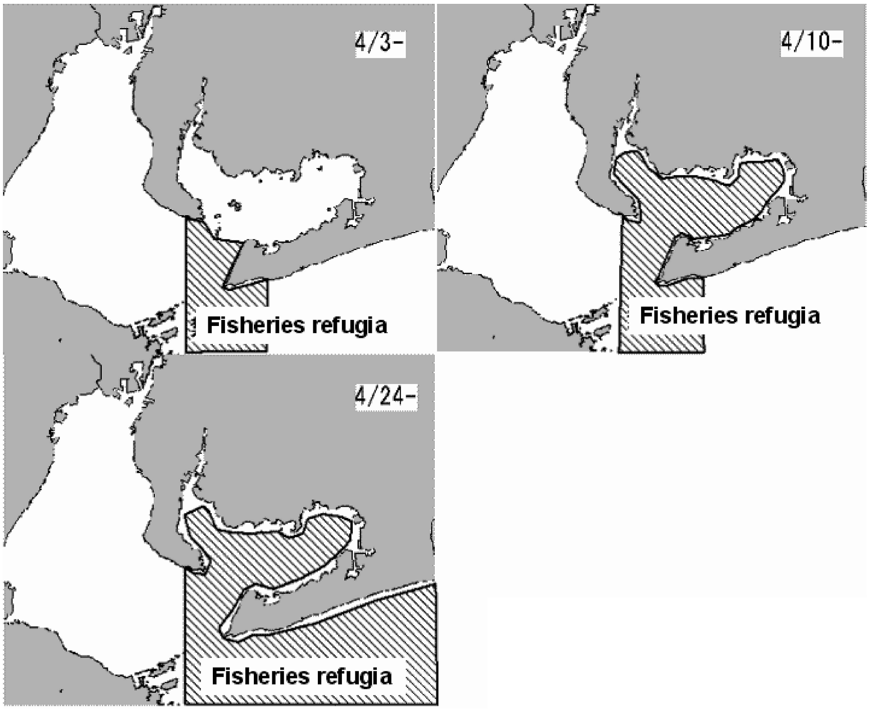

Fig. 4. Fisheries refugia for sandeel in Ise Bay and Mikawa Bay, Japan in 2005. The locations of fisheries refugia were changed weekly based on information regarding the migration routes of spawners detected by fishers.

management (IUCN, 1994). While no fish can be caught within the MPAs throughout the year, it is not practical for sandeel resources whose spawning grounds change during a fishing season (Fig. 4). Another type of protected area is fisheries refugia (PETERSON and PERNETTA, 2006), which are defined as "spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use." Thus, fisheries refugia has been established since 2001 (Fig. 1). Scientists from the fisheries experimental stations in Aichi and Mie prefectures determined fisheries refugia that protected spawning sandeel during the fishing season (TOMIYAMA, 2009) (Fig. 4). The refugia locations are changed according to migration of spawners. These adaptive co-management procedures use diverse information obtained by modern fishing equipments, such as echo-sounders, GPS plotters, fishery radios on fishing boats, and cellular telephones of fishers, all of which also represent examples of *bricolage*. For example, the distribution of sandeel shoals was investigated using echosounders operating at both 50 and 200 kHz. Fishers' knowledge can identify a shoal of sandeel larvae with its shape and appearance on echograms at two different frequencies (TOMIYAMA and YANAGIBASHI, 2004).

As larvae develop into juveniles and eventually adults, sandeels gradually move from the interior to the mouth of Ise Bay, where they enter into aestivation in May-June (Fig. 1) when bottom water temperatures exceed 17℃ (TOMIYAMA and YANAGIBASHI, 2004). Fisheries scientists estimate distribution area of adult larger sandeel from collecting catch data of sandeel by interview or phone to fishers. Based on the estimation, fisheries scientists and a dozen leaders of sandeel fishers discuss and decide area of refugia. The fisheries refugia are regulated by only fishers. Thus, both local

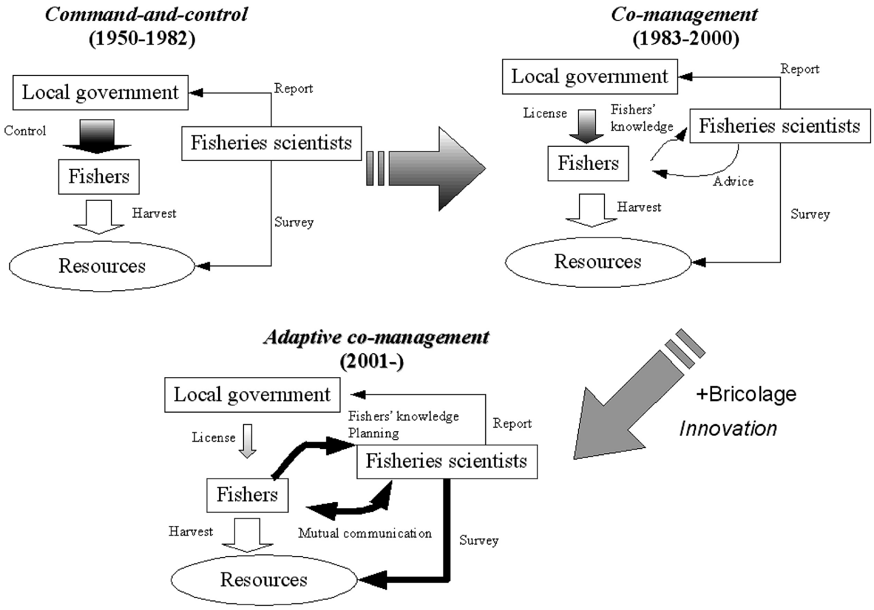

Fig. 5. Conceptual models depicting sandeel management systems ranging from command-and-control to adaptive co-management through co-management.

governments of Aichi and Mie prefectures don't take responsibility for control of fisheries in the refugia. On the other hand, they allocate adequate fisheries scientists of both prefectures to establish the refugia and monitor sandeel resources, and support financially research activities. These scientists of Aichi and Mie prefectures announce fishers remained stock of sandeel estimated from daily landing data.

To determine the onset of aestivation, fisheries scientists use a "karatsuri" rake at the sandeel aestivation grounds in May-June. This rake was developed based on fishing gear used to catch burrowing flatfish in the sand and is applied to quantify the number of remaining spawners burrowing in the sand in the summer. This gear is a modification of Tanda and Okamoto's (1992) rake. Developed using fishers' input and modified from the actual fishing gear used to catch burrowing flatfish (TOMIYAMA and YANAGIBASHI, 2004), the karatsuri rake represents another example of *bricolage*.

4. Innovation of the management system

In many cases, resource depletion motivates fishers to begin fishery management, in what is called "the depletion crisis model" (BERKES and TURNER, 2006). For the sandeel stock in Ise Bay, co-management began when depletion became apparent around 1980. Also in the case of entrepreneurial firm, innovations often occur under shortage of human or financial resources (BAKER and NELSON, 2005). The several innovations based on *bricolage* mentioned above were introduced to the management system, which developed into adaptive co-management from the previous co-management system (Fig. 5). When the parties involved discussed the management of sandeel stock, knowledge of fishers played an important role in the "adaptive" aspect of the approach (BERKES, 2007, 2009). Local ecological knowledge (OLSSON and FOLKE, 2001; GADHAV *et al.*, 2003; MAMUN, 2010), traditional ecological knowledge (INGLIS, 1993; RUDDLE, 2007), and fishers' knowledge (JOHANNES *et al.*, 2000; STEAD *et al.*, 2006; GARCIA-QUIJANO, 2007; HAGGAN *et al.*, 2007; HILBORN, 2008) have been treated as important factors in resource management. In contrast to other types of local ecological knowledge, the sandeel fishers' knowledge is not a traditional

Table 1. Shortages in scientific knowledge, application of *bricolages*, and components of fishers' knowledge

	Shortage in scientific knowledge	*Bricolages* by fishers' knowledge
Improvement of larval sampler	Usual sampling gear could neither catch larger larvae nor be operated by small boat.	Fishers ameliorate wing net with a net mouth larger than usual sampling net from pelagic trawl net for halfbeak (*sayori*).
Development of karaturi-rake	No gear were available to capture sandeel burrowing in sand during aestivation.	Fishers' knowlegde on fishing gear for capturing flatfish hints to develop a new sampling gear, karatsuti-rake, to catch sandee burrowing in sand.
Setting fisheries refugia for conservation of spawners in the next year	Little was known about the migrating path.	Survey by fishers revealed the migrating path of sandeel school using echosounders equipped in the boats and fisheries radio.

but rather an on-site or practical knowledge. Table 1 presents three cases of *bricolage* in which fishers' knowledge was used to overcome a shortage in scientific knowledge. These three cases of *bricolage* correspond to BAKER and Ne lson's definition of *bricolage* (BAKER and NELSON, 2005), i.e., "making do by applying combinations of the resources at hand to new problems and opportunities."

To understand the success of co-management of sandeel resources and apply it to another fishery, it is very interesting to clarify the process of co-management development in which the stakeholders play roles. Considering the roles of fishers and fisheries scientists, we can apply an analyzing model to the process (Fig. 6). We use here SECI model developed by NONAKA and TAKEUCHI (1995) who analyzed how the knowledge creating process works with tacit and explicit knowledge in an organization, especially enterprises. They classified four stages (Socialization, Externalization, Combination and Internalization) in knowledge creating process. At first, socialization process focuses on tacit to tacit knowledge linking. Tacit knowledge goes beyond the boundary and new knowledge is created by using the process of interactions, observing, discussing, analyzing, spending time together or living in same environment. The socialization is also known as converting new knowledge through shared experiences. Externalization process focuses on tacit to explicit knowledge linking. It

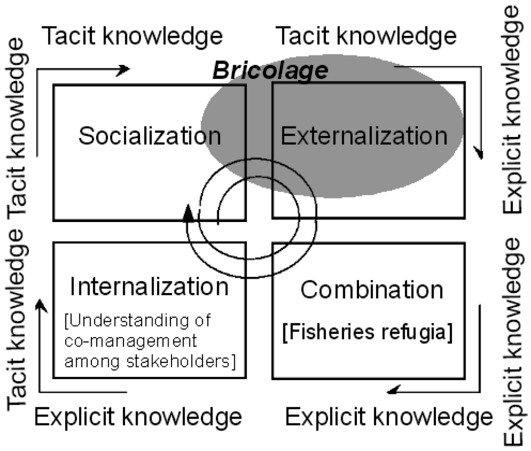

Fig. 6. Applying the creating model, SECI model, proposed by Nonaka and Takeuchi (1995) to adaptive co-management of sandeel resources. Dark area shows a rauge of bricolage.

helps in creating new knowledge as tacit knowledge comes out of its boundary and became collective group knowledge. Combination is a process where knowledge transforms from explicit knowledge to explicit knowledge. By internalization, explicit knowledge is created using tacit knowledge and is shared across the organization. When this tacit knowledge is read or practiced by individuals then it broadens the learning spiral of knowledge creation. Organization tries to innovate or learn when this new knowledge is shared in Socialization process. According to the SECI model, fishers knowledge and management measures are defined as tacit and explicit knowledge, respectively, under four conversion phases: Socialization, Externalization, Combination and Internalization (Fig. 6).

We apply this model to the case of sandeel's stock management. In Socialization phase, tacit knowledge common among all fisher is integrated under initiatives of fishers' leaders. So, the tacit (fishers') knowledge is shared by the fishers' group. Fishers' *bricolage* is effective in Externalization phase, in cooperation with fisheries scientists. In this phase, tacit (fishers') knowledge is converted into explicit knowledge, such as management measures. Furthermore, the measures are easily gained consensus-building among fishers because it contains tacit knowledge in itself. In Combination phase, explicit knowledge of equipments for co-management such as kite-net, karatsuri raker are combined to deciside opening and closing days of sandeel fishery and fishery refugia for protection of spawning sandeel. In Internalization phase, fishers participating monitoring of sandeel's stock, their understanding will spiral upward. This analysis suggests that *bricolage* is a key to start creation of co-management of sandeel resources. Therefore, it is very important for fisheries scientists, who are charged in explicit knowledge, to contact closely fishers for developing co-management of fish resources.

Most of coastal fisheries in Japan are small scale (MATSUDA *et al.*, 2010). Resource management methods for small-scale fisheries should be distinct from those used in industrial fisheries, e.g., individual quota or individual transferable quota methods. As shown here, the introduction of fishers' knowledge into coastal fisheries can be very effective. By adopting *bricolages* based on fishers' knowledge, expensive research equipment is not needed to establish an effective resource management system because fishing boats can be used as research vessels and fishing gear can serve as sampling gear. Our practices highlight the potential for co-management of small-scale fisheries using the concept of *bricolage* and participation by related fishers not only in Ise Bay but also in other areas. In addition, intrduction of fisheries refugia acceptable for fishers is very effective for co-management.

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