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Application of information and communication technology and data sharing management scheme for the coastal fishery using real-time fishery information

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A B S T R A C T

In this paper, we propose an automatic computation and data sharing scheme to support management system in coastal fishery using real-time fishery information through information and communication technology (ICT). In Japan, several species of fisheries commodity have not been specified in Total Allowable Catch policy, causing a lot of confusion on fishery cooperatives and fishermen on how to set the catch limit. To deal with the problem, in the previous study, we developed catchable stock index, a method to estimate a certain extent of resource via the swept area method. However, as the calculation of the index was computed on a GIS software manually, it was very time consuming, costly and unable to give an immediate evaluation of the fishing operation. This study aims to support management system in a coastal fishery through the development of automatic catchable stock index algorithm. In this study, ICT was utilized to obtain and transmit the real-time data sharing of fishery information as well as to distribute the computation results to the fishermen and fishery cooperative. The data used were vessels' trajectories and catch records, which included the start/end time and catch amount of each fishing operation. The catchable stock index was automatically computed in an originally developed cloud computing service. We have conducted the test run of the present method in sea cucumber dredge-net fishery on the coast of Rumoi City, Hokkaido, Japan. Data were collected from the entire vessels in Rumoi (16 vessels) during the 2012 and 2013 fishing seasons. The results were returned to the fishermen via the Internet each day during the fishing season, therefore, fishermen were able to immediately evaluate their catch. The estimated catchable stock index for the 2012 and 2013 seasons was 85.5 tons and 92.3 tons, respectively. By referring to the present system, fishermen voluntarily stopped the 2012 and 2013 fishing season several weeks earlier than their initial schedule to avoid overfishing. Moreover, in the previous study, the spacing of the grid has been decided empirically, but in this study, the adequate grid size could be evaluated due to the fast computation through ratio of the area of a grid cell to the total dredged area. In light of the evidence, the present automatic algorithm provided useful information for supporting the self-management of this coastal fishery.

1. Introduction

Coastal fishery is an important primary industry in Japan. Hokkaido, an island-sized prefecture in northern Japan, is known as the largest producer of fishery as indicated in MAFF report (2010). The report also indicates that about a quarter of Japan's coastal fishery output was produced in Hokkaido. In 1949, Japanese Government established the fishery law to create a fundamental management system and ensure fishery productivity, including to avoid overfishing. The law requires all fishermen to obtain fishing permit from local fishery cooperative association. A local cooperative has an autonomy to determine and self-manage its own set of regulations to be observed by all members, such as restrictions on target species, fishing seasons, catch limit and appropriate fishing method (Akamine, 2005). As a very big prefecture, Hokkaido is divided into several cities, and each city has its own autonomous

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fishery cooperative conducting the self-management system explained above. Such self-management system and community based management have been used traditionally among the fishermen in Japan, including Hokkaido. The fishermen operated with awareness of local and indigenous knowledge for hundreds of years and thus, most fishermen without resistance accepted the modern regulation. Research on several areas in Japan such as in Kyoto prefecture, Okinawa and Iwate prefecture, has shown that this system has been successful in maintaining the ecosystem and fishery resource for several fish species (Makino and Matsuda, 2005; Makino, 2011).

In order to support the self-management system, the Japanese government sets Total Allowable Catch (TAC) to impose the catch quota limit for most species (Makino, 2011). The Fishery cooperatives then decide the quota distribution and access rules by the recommendations of fisheries scientist for the defined TAC species. For the species that have not been specified in TAC policy, fishery cooperatives and fishermen basically perform a self-management by themselves empirically (MAFF, 2010). Consequently, there was a lot of confusion on fishery cooperatives and fishermen on how to set the catch limit (MAFF, 2010; Sano et al., 2011; HRO, 2014). For that reason, there is a need to support the fishery cooperatives and fishermen, who perform self-management, with scientific and numeric system. In particular, such system must be able to systematize, analyze and display the information so that it would be easier for them to perform decision-making and self-management system.

Data sharing in coastal capture fisheries can support the management process and fisheries policy to keep the sustainable fisheries (Halls et al., 2005). Although generally fishery is a competitive structure, a number of fishermen in Japan compete with upholding community based management, especially those who conduct self-management system (Yamamoto, 1995; Valencia and Center, 1998). The way of thinking of community based fishery management is similar to the data sharing system, and we expect to apply data sharing system to support self-management system. Data sharing could be realized optimally by applying Information and Communication Technology (ICT) and real-time framework to support fisheries management (Wada and Hatanaka, 2010; Wada et al., 2008, 2012). Several practical ICT and data sharing applications for coastal management fishery has been conducted in the last few years in Hokkaido. For example, real-time data sharing of fishing vessels' location information by microcomputer known as micro-Cube (Wada et al., 2008) and catch record data sharing in real-time for local fishery management through the scheme of digital diary (Wada et al., 2012).

One of the target species that need to be managed immediately in Hokkaido is, the spiky sea cucumber (*Apostichopus armata*). Recently, the spiky sea cucumber is considered as one of the most important commodity for Hokkaido (MAFF, 2010; HRO, 2014), and is currently the most valuable traded sea cucumber in the world (Akamine, 2008; Purcell, 2010). As reported by Hokkaido Gov. (2013), the Hokkaido sea cucumber trade has brought 114 million USD in 2011. Hokkaido sea cucumber is very popular in Asian market, especially China and Hongkong, and the popularity is even referred as the black spiky diamond (MAFF, 2010). The Hokkaido sea cucumber catch has significantly increased from approximately 1000 tons in 1990s to 2600 tons in 2011. The catch increase was due to the rapid economic growth of China in early 2000s, which resulting high increase in demand and price (Choo, 2008; Shibuya and Kasai, 2011; Akaike, 2012). Despite of being popular and expensive, there are many ecologically unknown facts about the Hokkaido spiky sea cucumber, yet, has been categorized as "in danger of extinction" animal that need to be managed (MAFF, 2010; HRO, 2014).

The Hokkaido sea cucumber has not been specified in TAC policy, and the Hokkaido fishermen are included in those who are confused in determining the catch limit. In case of sea cucumber catching, the Hokkaido fishermen began to change the competitive structure into a data sharing system due to their concern for overfishing (Wada et al., 2011; Sano et al., 2011). To illustrate, the fishermen in Rumoi City, Hokkaido, have set several data sharing rules in order to maintain the sea cucumber resource. Based on the interview with Rumoi fishermen in 2010, the decision making process of the fishery system was done conventionally, namely by having a meeting once every week or every other week before and during the catch season in order to set the catch limit. During the meeting, the fishermen discussed and then decided the fishing season and catch quota limit of each fishermen. The regulations are such as, setting the fishing season from July 1st until August 30th each year, and each fishing vessel is allowed to catch the sea cucumber up to 5 tons. However, they admitted that they set the rule randomly and they are not sure whether the 5 tons rule should be maintained, reduced or increased. Therefore, this paper looked at the implementation of ICT and data sharing to systematize, analyze, and display the information to support fisheries management in the Rumoi City, Hokkaido, Japan.

To deal with the stated problem, fishery cooperative and fishermen need a support system that is able to estimate the sea cucumber population instantaneously. In our previous research (Sano et al., 2011), we presented a method to estimate a certain extent of resource of Hokkaido sea cucumber, namely the catchable stock index. The catchable stock index is calculated by using trajectory data from fishing vessels and catch information based on the swept area method (Gunderson, 1993) combined with ArcGIS (ESRI). The catchable stock index successfully meets the needs of fishery cooperative and fishermen. Alongside that, we find several weaknesses that need to be improved to conduct a better self-management, i.e. the calculation process was very time-consuming and it required high cost and energy due to the manual calculation. Therefore, the objectives of this study are: (i) to develop an extra method to address the weakness of our previous research (Sano et al., 2011); (ii) to discuss its application for supporting self-management system in the actual fishery of sea cucumber in Rumoi City, Hokkaido; and (iii) to investigate the validity of catchable stock index by examining range of grid sizes. In this study, we have developed an automatic algorithm for assessing the catchable stock index using real-time data sharing instead of the manual operation of ArcGIS. We also enabled the system to automatically share the computation results to fishery cooperative and fishermen through the Internet. This study systematizes information to support a better self-management of a coastal fishery resource at the local level (Rumoi City).

2. Materials and methods

2.1. Study area

The study area was located in Rumoi City, a coastal city in the western part of Hokkaido (as shown in Fig. 1, within the shaded part). Rumoi City is known as one of the major sea cucumber catching regions in Hokkaido (MAFF, 2010; Sano et al., 2011; HRO, 2014). Currently, there are 16 dredge-net fishing vessels in Rumoi City, and all of them perform self-management system of using towed dredge nets for sea cucumber catching. This research was conducted in cooperation with all of the sea cucumber fishermen in the city for 2012 and 2013 fishing season.