ICT application of real-time monitoring and estimation system for set-net fishery

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***Abstract*—In this paper, we propose an ICT application of real-time monitoring system to estimate the catch amount within set-net. Generally, set-net fishermen do not know the catch amount in advance before arriving to set-net area, in which they tend to unable to perform the fishing operation effectively. It means that the fishermen might suffer a loss of time, gasoline and labor cost, along with extra effort. In order to support the fishermen to avoid such condition, in our previous study, we have presented the real-time monitoring system based on ICT aided echo sounder for the set-net fishing. Besides, the algorithm based on multiple regression analysis (MRA) for estimation of catch amount was proposed so that fishermen could predict the catch amount before they leave the port for harvesting. However, the catch estimation was not sufficiently accurate in practical application. The reason of this is because the daily catch amount varies from some few tons to 250 tons, whereas statistics of ping intensity do not vary so much, thus, it is not easy to build a model of MRA adequately. This study aims to develop a more accurate catch estimation algorithm based on our previous study. The experiment of this study is conducted in Hokkaido and Toyama Prefecture. To transform the catch record appropriately for MRA, Box-Cox transformation (BCT) as pre-processing transformation is applied in this paper. The catch estimation has been done based on fishermen's empirical estimation through a pre-processing transformation and statistical analysis of reflection data in each layer depth. The study showed that the present system could improve the estimation accuracy. In order to measure the differences between catch estimation by the developed algorithm and the real catch record, Relative Absolute Error (RAE) is used in this study. The RAE for Hokkaido experimental site was 1% and in Toyama is 22%, respectively. The results show that the estimation accuracy of the present method is sufficiently adequate for practical application.**

Keywords*—set-net; echo sounder; visualization; catch estimation

I. INTRODUCTION

Set-net fishing (*Teichi-ami*) is one of the major catching methods in Japanese coastal fishery [1] due to its sustainability [2]. Set-net fishing is a simple method to catch fish, as fishermen need to install set-net in a coastal area, back to the port and stand-by for the fish to be trapped. Later, fishermen go to set-net area to harvest the trapped fish. One of the problems of set-net fishing is that fishermen do not know the catch amount in advance, and will be aware of the harvest condition after arriving at set-net area. In case when the catch is very large and fishermen do not prepare for such big amount of catch, they have to go to the port and then come back to set-net area again and do the process twice. It means that the fishermen will suffer a loss of time, gasoline and labor cost, along with extra effort. In order to avoid such condition, real-time monitoring of trapped fish within set-net is needed.

Conventionally, set-net monitoring system has been practiced using a VHF (Very High Frequency) equipment, yet, there are several problems of the VHF equipment [3]. Firstly, it is costly for the fishermen to buy the equipment as well as for the maintenance. The VHF equipment costs more than a hundred thousand dollars, not to mention the cost of replacing some parts of the device, which also requires a lot of money. The second weakness is their large size, which makes the process of installation and its maintenance a difficult task to do. Several fishermen even stated that the maintenance, such as replacing the batteries in the device, requires a lot of effort. Next, the data record from the equipment is printed by thermal printer, which means, the data record remain as a paper based output information. When there is problem with the printer or the ink, the fishermen cannot monitor the set-net properly and might miss some information. In addition, the catch record usually utilized for the future catch prediction, when the record is paper based, the real value reflection intensity is unknown, and the estimation would be very difficult.

To face the stated problems, there is a need to develop a more effective and efficient monitoring system for set-net fishery. In our previous report [3], the authors presented the development of real-time monitoring system based on ICT aided echo sounder for the set-net fishing and conducted an experiment in the coast of Hokkaido, Japan, from November to December 2013. Moreover, the algorithms based on multiple regression analysis (MRA) for estimation of catch amount was proposed so that fishermen could predict the catch amount before they leave the port for harvesting. In the algorithm for the estimation of catch amount, the statistics of ping intensity in several layers of water depths were used for parameters in MRA. Alongside that, several weaknesses were found to be improved for a better catch estimation, i.e. it was not sufficiently accurate in practical application.

This study aims to discuss the development of a more accurate catch estimation algorithm based on our previous

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report [3]. In this study, the authors have developed a better catch estimation algorithm, by applying pre-processing transformation of real catch record, as teacher data for MRA to make the data more statistically normal distribution-like. The newly developed algorithm provided better results of catch estimation in comparison to the real catch.

II. Experimental Sites

In order to develop the catch estimation algorithm, we cooperated with several set-net fishermen for conducting the experiment. The experiments for this study were conducted not only in the coast of Hokkaido as the previous experimental site, but also in several new sites, namely, Toyama, Shizuoka and Mie Prefecture (as shown in Figure 1, within the blue shaded part). Those four sites represent the Japanese coastal area characteristics, as south eastern sea of Hokkaido generally, Shizuoka and Mie is the Pacific Ocean and Toyama is for the Sea of Japan, respectively.

Currently, the only available real catch records are the previous Hokkaido catch records [3] and from Toyama prefecture. The experimental site in Hokkaido is operated from April until December, yet, currently, only a few data is available in this site. The site in Shizuoka operated in the whole year, but we still do not have the real catch records yet. The site in Mie, meanwhile, is not operated. It means we cannot build the model of catch estimation for those experimental site. Therefore, in this paper we only discuss the development of catch estimation algorithm by using the previous Hokkaido records and Toyama. Currently, the remote monitoring system has collected the real catch in Toyama site from April 24th until 18th of July, 2015.

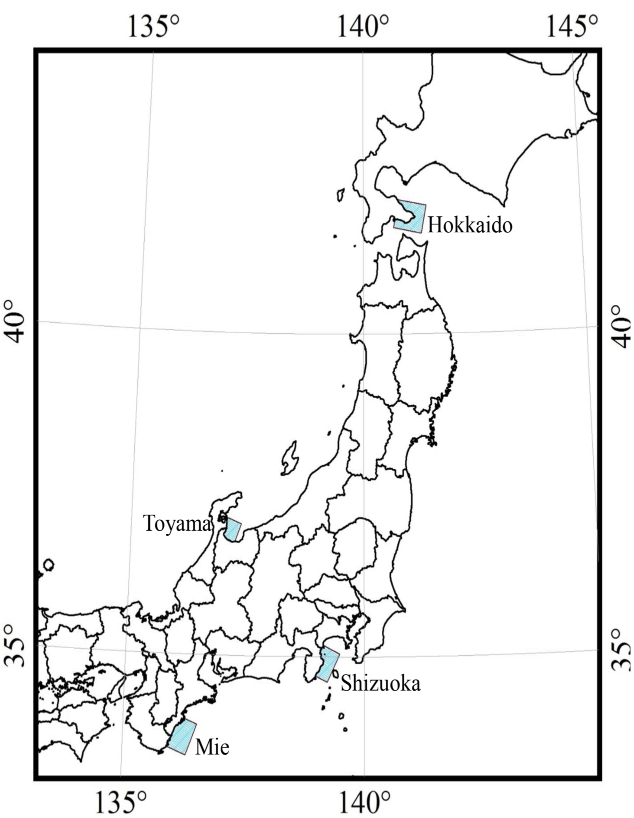

Fig 1. The experimental sites in Hokkaido, Toyama, Shizuoka and Mie Prefecture, which are located within the blue shaded part.

III. Real Time Fishery Information

Fishermen generally do the empirical estimation based on their experience when they were observing the printed-out information from the aforementioned conventional equipment. Since the stronger reflection intensity (ping data) means the more fish trapped in set-net, the fishermen predicted the catch amount by looking to the intensity of the reflection data in the water. The parameters for the catch estimation are extracted by separating the waters into several layers depth. In particular, the ping data series at a selected time and their statistical information, such as average, maximum and minimum ping value, are utilized to extract the characteristics of reflection data. In order to ensure that there is no data lost in the set-net in a certain depth at the same time, the ping value are divided into several overlapping layers depth, i.e. 0 to 10 m, 5 to 15 m, 10 to 20 m, 15 to 25 m until the depth limit (50 to 60 m).

As stated above, in this study, we develop an algorithm based on the previously presented remote fish finder system [3]. The spatial resolution in this study is split into 320 parts. For the case of 80 m water depth, reflection intensity for each spatial resolution of 0.25 m in the direction of depth is possible to be obtained. In the meantime, resolution of reflection intensity is divided into 256 levels. The default setting is to perform data reception and transmission of ultrasonic wave once in six seconds, whereas, the uploading of acquired data is performed once in 120 seconds. In other words, it transmits 20 sets of the acquired data.

A. Selection of Ping Data for Parameters

In the previous days, we selected the data of three hours before 6:00 A.M as the time of fishermen went to harvest the catch, i.e. the average ping values of each ten-minute interval from 3:00 up to 6:50 A.M. However, such condition was only limited to Hokkaido during winter, when one go to other place in another season, the condition would be different. Since fishermen sometimes went to set-net for harvesting several hours earlier than 6:00 A.M. and revise versa. We also noted that it is difficult to decide whether 6:00 A.M. is the appropriate time limit to measure the experiment or not. Such kind of situation may cause errors of the selection of parameters data.

To address the problem, there is a need to understand the harvesting habit of set-net fishermen in each place, in difference seasons, for instance, the time of fish harvesting. We then introduced a sensor network platform, called microCube [4], shown in figure 2, to the fishing vessels. The microCube is connected to GPS in fishing vessels in order to collect location data, time information and speed of the vessels in every ten seconds. The microCube starts operating shortly after the vessels' engine is on. Afterward, it will transmit the location data to the database server via email every one minute. The transmission of location location data is enabled due to the availability of SIM card in microCube.

Fig 2. Picture of the microCube that are equipped in the fishing vessels to collect the real-time location and speed data.

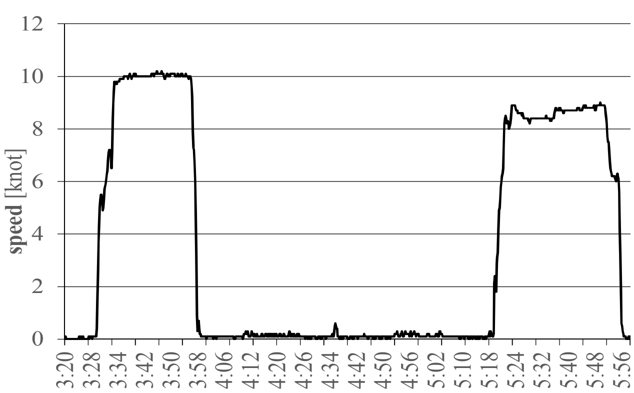

Fig 3. Example of speed of the vessel in Toyama experimental site in May 2015.

During the interview with the fishermen in spring 2015, as soon as they turn the engine on, they will go to set-net to harvest the catch. By introducing the microCube in the fishing vessels, it is possible to detect the trajectory of the vessels and harvesting time automatically. We identify the time boundary for selecting parameters data from the speed of the vessels. First, after the engine has been turned on, the fishermen move toward set-net with the speed that exceeds 8 knots. Several minutes after that, the speed of the vessel will decrease to near zero, which is when the fishermen do the fish harvesting. Continuing on, the ping data of several hours before the fish harvesting is selected as the parameters to estimate the catch. Figure 3 shows the example of speed of the vessel in Toyama experimental site in May 2015. Based on that, we found that the fishermen habitually turn the engine on at around 3:20 A.M., leave it for a 5-minute idle, then get moving to the set-net. Moving in sequence, they arrive in set-net and harvest the catch at around 4:00 A.M. After harvesting the catch, the fishermen go back to the port. The remote monitoring system also indicates that the harvesting time in Toyama was at 4:00 A.M. (Figure 4). With this in mind, the ping data from 0:00 A.M. to 3:50 A.M. is selected as parameters in Toyama.

IV. The Development of Catch Estimation Algorithm

As noted above, the previous report [3], the accuracy of the catch estimation was not sufficiently accurate in practical application. The reason of this is because the daily catch amount varies from some few tons to 250 tons, but statistics of ping intensity do not vary so much and it is not easy to build a model of MRA adequately. In order to address that issue, we applied pre-processing transformation of real catch record, so that the catch record is more appropriate for the teacher data of MRA. In particular, the algorithm of the catch estimation is as follows. Firstly, apply the pre-conditioning of daily catch record via Box-Cox transformation (BCT). Next, the BCT catch record series will be used as teacher data of MRA to build a regression model, and estimate the MRA of BCT estimation based on the regression model. Lastly, we need to return the MRA of BCT estimation to catch unit.

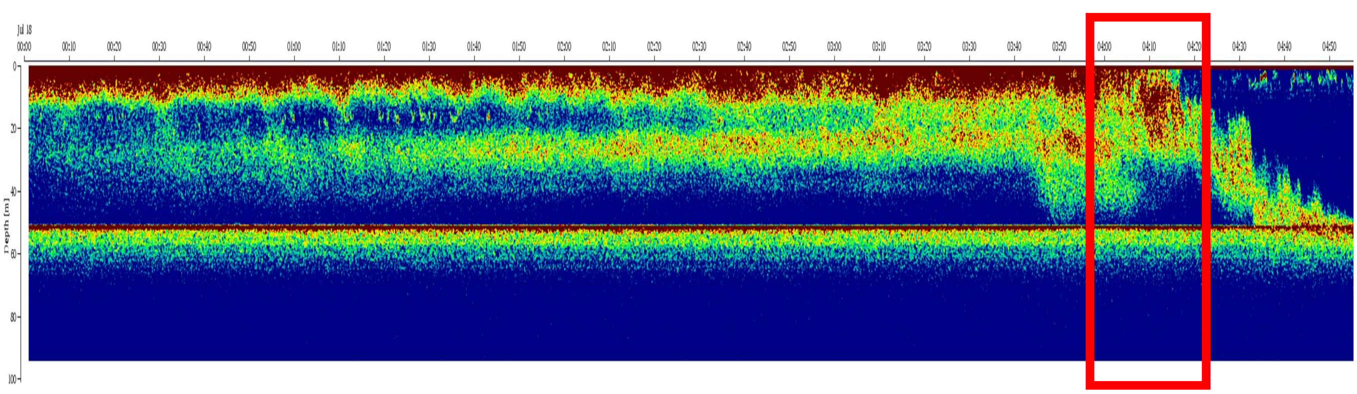

Fig 4. The Toyama Ping data series (0:00 A.M. to 3:50 A.M.) that is selected for parameters on 18th of July, 2015. The fish harvesting activity was done by the fishermen at 4:00 A.M is indicated by red rectangular frame. The longitudinal direction shows water depth, whereas lateral direction is time.

A. Box-Cox Transform (BCT)

In this study, we applied BCT as the pre-processing transformation to stabilize the variance of daily catch record, or in other word, to make the catch record statistically more normal distribution-like. The formulation of BCT can be written as follows,

$$z_n = \begin{cases} \left(y_n^{\lambda} - 1\right) \big/ \lambda, & \lambda \neq 0 \\ \log(y_n), & \lambda = 0 \end{cases} \quad (1)$$

where y_n are series of catch record and z_n are those transformation by BCT. While λ indicates a parameter determined by maximizing the density of function z_n.

B. MRA Model for Catch Estimation

As mentioned above, the catch amount within the set-net could be predicted by a linear MRA based on fishermen's empirical estimation. In our previous report [3], we directly estimated the catch record (y_n) via MRA. Yet, in this study, we use BCT series (z_n) as the dependent variable of MRA. On the other hand the selected data in different layers of water depth were used as independent variables. In this study, MRA is determined by (2),

$$z = c_0 + \sum_{i=1}^{m} c_i x_i , \quad (2)$$

where z indicates the MRA of BCT estimation, c_0 is the intercept and c_i specifies coefficient in the i-th layer depth. While m identifies number of layer depth and x_i is the statistics of ping data in the i-th layer depth. After calculating MRA of BCT estimation, we need to return the value to catch unit via reverse BCT transform in (1).

C. Catch Estimation Using Hokkaido Catch Record

The data in our previous Hokkaido report is used in this study, and in this section we will discuss the development of catch estimation algorithm using the present method compared to the previous method. First, the real catch record (y_n) in Hokkaido is transformed to z_n, shown in dash gray line in Figure 5. Then, z_n is estimated by MRA using λ = 0.10295 and the result is shown in the thick line in Figure 5. Various examinations of MRA have been done using combination of layers in depth and statistics of sounder values. An appropriate result was obtained by using the maximum value of the entire overlapped layer depth (0 to 10 m, 5 to 15, 10 to 20, 15 to 25,..., 40 to 50 m) and the minimum value of sea bottom (45 to 55 m and 50 to 60 m). In this case, R^2 of the MRA was 0.97. Figure 6 shows the comparison between catch record, the catch estimation using previous method and the present method. Although the MRA of BCT estimation do not fit the BCT catch record, when the results are converted into the same unit of catch by reverse transformation, they match almost perfectly with the catch records, as shown in the black thick line in Figure 6. In order to measure the differences between catch estimation by the developed algorithm and the real catch record, Relative Absolute Error (RAE) is used in this study. The RAE of the previous method is 40%, yet, after applying the present

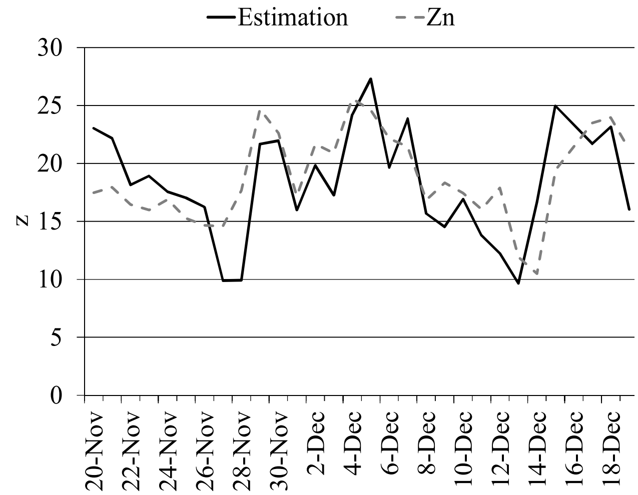

Fig 5. Comparison of BCT catch record and MRA of BCT estimation in Hokkaido experimental site.

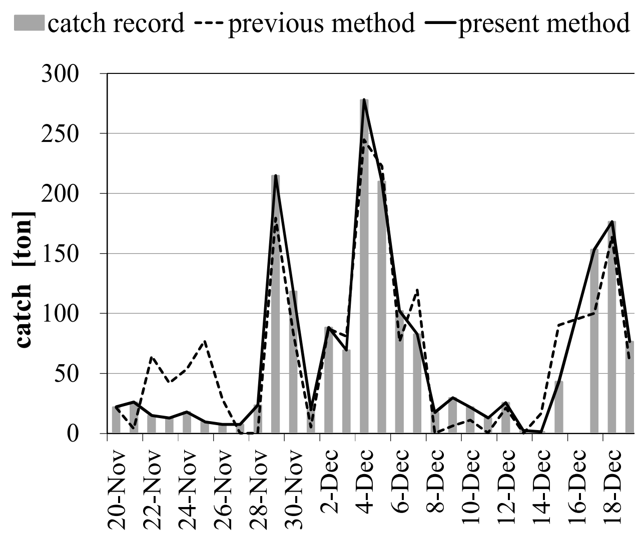

Fig 6. Comparison of catch record and catch estimations using previous and present methods in Hokkaido experimental site.

algorithm the RAE is 1%. It means, the catch estimation using the present method and catch record fit almost perfectly. In short, BCT for pre-conditioning of catch estimation in Hokkaido site results a better estimation.

D. Catch Estimation Using Toyama Catch Record

The remote monitoring system has been collecting the ping data and real catch in Toyama site from April 24th until 18th of July, 2015. Those information are then used as the teacher data to develop a catch estimation model using the same manner as explained above. However, during those three months in Toyama, we found out that the dominant species of fish caught

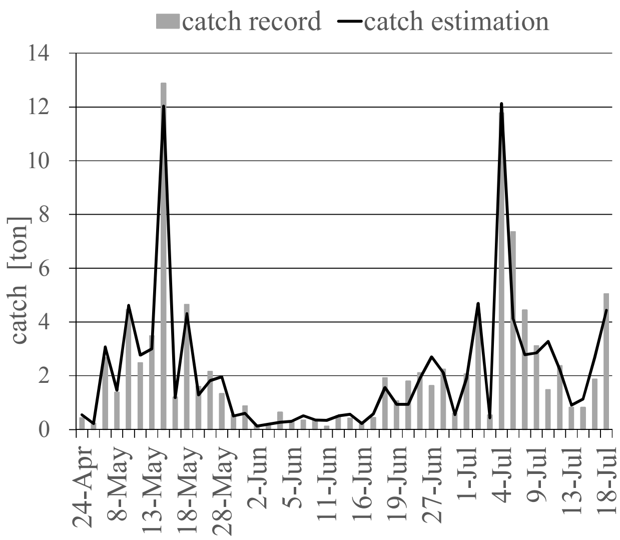

Fig 7. Comparison of catch estimation using the present method and real catch record in Toyama experimental site.

in each month were different. The dominant fish kind in May was Japanese sardine; in June was Japanese Spanish mackerel and Japanese horse mackerel; while in July was anchovy and Japanese Spanish mackerel. After examining numerous of combination of BCT and MRA, the best result for this kind of case was by splitting the catch estimation in each month using entire overlapped layer depth as parameters. As for May, R^2 of the MRA was 0.97, June was 0.81 and July was 0.85, respectively. Results of the comparison between real and estimated catch amount after being put together in Toyama is shown in Figure 7. Figure 7 indicates that the fits of catch estimation and real catch records was fairly good. The RAE of catch estimation in Toyama was 22% compared to the real catch record. We also estimated the catch without conducting a pre-processing transformation via our previous algorithm [3], but the RAE was 43%. At the center of the issue is notion that the present method can address the weakness of the previous issue, namely, the accuracy of catch estimation in set-net improved.

V. Remarks and Future Subject

In this paper, a development of a more accurate catch estimation algorithm for set-net fishing has been presented. The experiment of this study is conducted in Hokkaido, Toyama, Shizuoka and Mie Prefecture, yet, the currently available data was only from Hokkaido and Toyama. The estimation of fish catch amount has been done based on fishermen's empirical estimation through a pre-processing transformation and statistical analysis of reflection data in each layer depth. The study showed that the present system could address the weaknesses of our previous research, i.e. the improvement of estimation accuracy. The RAE for Hokkaido experimental site was 1% and in Toyama is 22%, respectively. Finally it is important to note that the estimation accuracy of the present method is sufficiently adequate for practical application. It should be evident that we need to repeat this process in the same target area for the whole fishing season to determine the appropriate estimation model in each experimental site. In order to do so, data collection from the experimental sites are continued in 2015 and 2016.

Acknowledgement

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