Introduction

71% of the Earth’s surface is water-covered, and the sea hold approximately 97% of all Earth’s water. Yet, agriculture sector still provides almost 95% of human calories and proteins. Although fishery has a huge potential as food and protein source, this sector has not been fully utilized. FAO described that Fisheries and aquaculture have continued to grow faster than in agriculture in providing source of nutritious food and protein as well as employment opportunity worldwide. With this in mind, fishery should be utilized to support food supply in a sustainable way.

Coastal fishery is one of the most important sectors in large archipelagic countries like Indonesia and Japan. Yet, several problems remain in Indonesian coastal fishery, especially poverty reduction and fisher- men’s life improvement, illegal unregulated unre- ported (IUU) fishing as well as overfishing. On the other hand, Japanese fisheries industry is generally known for the establishment and the application of modern knowledge and technology toward sustainable fisheries industry. Specifically, Japan has applied advanced technology such as, sensor network and ICT in fishery sector. Thus, there are a lot of lessons, including advanced technology, which can be learnt from Japanese fisheries industry to be applied in Indonesia. Although Japanese fishery sector is considered as one of the best in the world, it does not mean that there are no problem. For instance, until now fishery management and effective fishing method are still major issues for Japanese fisheries. The objective of this study is to apply advanced ICT and sensor network technology toward sustainable coastal fishery. Specifically, the study would like to solve the issues in Japanese fishery sector by applying advanced technology and the feasibility of utilizing advanced technologies to address problems in Indonesian fishery sector.

The application of ICT and sensor network for automatic real time data sharing system to support fishery management

In Japan, there is a law that requires all fishermen to obtain fishing permit from local fishery cooperative association. A local cooperative has autonomy to determine and self-manage its own set of regulations such as restrictions on target species, fishing seasons, catch limit and appropriate fishing method. These regulations must be observed by all of its members periodically. 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. For the species that have not been specified in TAC policy, fishery cooperatives and fishermen perform an empirical self-management through a community based system. Consequently, there was a lot of confusion on fishery cooperatives and fishermen on how to set the catch limit. For that reason, there is a

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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.

One of the target species that need to be managed immediately is the Hokkaido spiky sea cucumber (*Apostichopus armata*). Recently, the spiky sea cucumber is considered as one of the most important commodity for Hokkaido, and is currently the most valuable traded sea cucumber in the world. Hokkaido sea cucumber is very popular in Asian market, especially China and Hongkong, and the popularity is even referred as the black spiky diamond. Such kind of situation led to the increase of catch. Despite being popular and expensive, many ecologically unknown facts about the Hokkaido sea cucumber still make it very difficult for them to be cultured. In the same time, it has been categorized as “in danger of extinction” animal that need to be managed. However, Hokkaido sea cucumber has not been specified in TAC policy, and the Hokkaido fishermen are included in those who are unsure in determining the catch limit.

To deal with the problem, a catchable stock index, a method to estimate a certain extent of resource via the swept area method was developed. However, as the calculation of the index was computed manually in a GIS, it was very time consuming, costly and unable to give an immediate evaluation of the fishing operation. Therefore, an automatic computation of the catchable stock index were proposed in this study to support the fishery management system using data automatically collected by the sensor network technologies. The test run of the present method have been conducted in sea cucumber dredge-net fishery on the coast of Rumoi City, Hokkaido, which is known as one of the major sea cucumber catching regions in Hokkaido. Data were collected from 16 vessels in Rumoi since 2011 fishing seasons until now. The index is calculated using real-time data sharing of fishery information in a cloud computing service. The data used were vessels’ trajectories (by introducing a sensor network platform in each vessel) and catch records (input by the fishermen through their iPad). After calculating, the results were then feedback to fishermen via the Internet in real-time.

The estimated catchable stock index for the 2012 and 2013 seasons was 85.5 tons and 92.3 tons, respectively and errors of those results against manually calculated were less than 5%. The computation results were returned to the fishermen via the Internet every day during the fishing season. Therefore, fishermen were able to immediately confirm their catch. By referring to the present system, fishermen voluntarily stopped the fishing season several weeks earlier than their initial schedule to avoid overfishing. Moreover, while in the previous study, the spacing of the grid has been decided empirically, in this study, the adequate grid size could be evaluated, due to the low-cost scheme and 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.

The Development of Catch Estimation Algorithm toward Real-time Monitoring to Support Fishing Efficiency of Set-net Fishery

Another point worthy of consideration for Japanese fishery is the effective fishing method in set-net fishery as one of the most popular fishing methods in Japan and southeast Asia. In 2009, there were about 13,000 of set-net fishing unit around the Japanese coast, which produced 540 thousand tons or 13 percent of the total catch in Japan. One of the problems of set-net fishing is that fishermen do not know the catch amount in advance and only will be aware of the harvest condition after arriving at set-net area. Such fishing operation is not the most effective one for the fishermen because they cannot predict the cost needed for the operation, such as the ice, labor, gasoline and other cost. Consequently, they come to the set-net area with uncertainty and there are possibility to suffer the lost. 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 via VHF (Very High Frequency) transmission equipment. However, there are several problems
of the VHF equipment. 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 large cost. The second weakness is their large size, which makes the process of installation and its maintenance a difficult task. Several fishermen even stated that the maintenance, such as replacing the batteries in the device for example, requires huge labor cost. Next, the data record from the equipment is 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. Besides, the data itself is analog data, which cannot be used in numerical analysis and so on. In addition, the conventional equipment only allows one to see the reflection intensity and does not allow to know the quantity of the trapped fish in number. Therefore, it is desirable for fishermen to know the condition of fish trapped before they head to set-net area. The system is not only needed to show the intensity of the fish trapped, but also needed to estimate catch amount. Specifically, the study of effective fishing focusses on the development of catch estimation and fish classification algorithm toward real-time monitoring to support fishing efficiency of set-net fishery by making use the real-time monitoring system based on ICT aided echo sounder.

The experiment of this study is conducted in Hokkaido and Toyama prefectures using a fish finder made by KODEN (a Japanese fish finder maker). The estimation was carried out by observing the reflection intensity (ping data) of echo sounder in certain depth. Statistics of ping data in four hours before the harvesting were used as indicators in the analysis. The real catch amount during the experiment were used as teacher data to develop an estimation model. The catch estimation algorithm is conducted via Box-cox transform for pre-conditioning of teacher data and multiple regression analysis for the estimation model using statistics of ping data. While fish classification is carried out via linear discriminant analysis. In order to confirm the accuracy of estimation, Relative Absolute Error (RAE) is calculated using real catch data. As for Hokkaido the RAE was 1% and Toyama was 22%, respectively. On the other hand, fish species within set-net could be classified with 83% of correctness. The results also indicate that it is better to conduct the estimation by splitting the catch record by following the fish season. The result shows that there is a possibility to apply the present algorithm as a real-time estimation system for set-net fishery.

State of Indonesian fishery and the feasibility of ICT and sensor network applications to solve Indonesian fishery issues

With the quantity of fishery production being number 2 in the world, Indonesia fishery still have numerous problems to be tackled. Currently, poverty reduction as well as fishermen's life improvement, IUU fishing and overfishing are recognized as the major challenges of Indonesian fishery sector. Those major challenges could be handled by technology transfer from Japan, in particular, by applying advanced ICT and sensor network technology that has already been utilized in Japanese coastal fishery. In order to conduct the feasibility study of advanced technology application in Indonesia, the field survey is conducted in Jakarta, the capital city of Indonesia. As 80% of fishermen in Indonesia are categorized as small scale fishermen and more than 80% of the total national catch is also produced by them, this study is focused on small scale fishermen. From the field survey in Jakarta, it is found that mobile phone is utilized by most of the fishermen. Yet, they have not applied advanced ICT and sensor network. Many studies have been conducted to describe the function of mobile phone for marketing the catch. However, this study revealed that the function of mobile phone is not only for marketing the catch, but also for life improvement, poverty reduction and community support tool. Questionnaire survey was conducted in the northern coastal area in Jakarta in 2014 and 2015, and 79 respondents were corrected. Mobile phone has the role for community support tool of small scale fishermen, notably, for sharing information among fishermen, such as, sharing a good fishing ground and sharing a polluted area. Besides, fishermen also use mobile phone as an emergency tool during the fishing trip. The results also
provide the modules of marketing channels exploited by small scale fishermen in target area and the impact of information sharing in increasing fishermen's income. It means that ICT has an immense potential to solve poverty problem and life improvement of fishermen in Indonesia.

IUU fishing and overfishing issues could also be potentially solved by using the way of thinking of the previous automatic catchable index, namely, introducing sensor network aided ICT device to the fishing vessels. Nowadays, the price of a Global positioning System (GPS) device is getting cheaper, hence, the author proposes to make the provision of ICT aided sensor network platform, such as a low cost phone that with GPS function, to be installed on each vessel. GPS provides the vessel’ location data and the USIM card has a function to transmit the location data in real-time as well as to give a unique ID to each vessel so it can be monitored by both of local and central government. The installation of the device could be gradually provided during the fishermen's vessel and fishing license renewal. By doing so, it will be useful to track the IUU fishing and to distinguish domestics and foreign fishing vessels along with the legal and illegal ones. The fact is that there is no database for fish stock in Indonesia. For that reason, it is difficult to say whether overfishing has occurred or not. The catchable stock index can be an answered to solve the issue, if the vessels’ location data can be obtained. Another thing that needs to be obtained, is the catch data. Since fishermen are required to report the catch data to the local government from 2009, the government need to convert the data to be digitalized. After that, catchable stock index might be applied. The proposed scheme is difficult to be immediately applied in Indonesia, nonetheless, it could potentially be helpful to build a database to support Indonesian fishery to prevent overfishing.

**Conclusion**

Data sharing through the study of numerical analysis of ICT and sensor network technology have been discussed in the study. The authors would like to conclude that the information sharing, resource management and effective fishing are important toward the sustainable fishery in 21st century.