A Study of the Numerical Analysis of ICT and Sensor Network Applications toward Sustainable Coastal Fishery

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Introduction

Earth's surface is 71% covered by the water, with 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 fishermen's life improvement, illegal unregulated unreported (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 information and communication technologies (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 problems. 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 technologies toward sustainable coastal fishery. In particular, 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 license and permission 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 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 Hong Kong, 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 resource 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 incapable to give an immediate evaluation of the fishing operation. Therefore, an automatic computation of the resource stock index was proposed in this study to support the fishery management system using automatically collected data 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 to gather the location data periodically) and catch records (input by the fishermen through their iPad). After calculating, the results were given as a feedback to fishermen via the Internet in real-time.

The estimated resource stock index for the 2012 and 2013 seasons were 85.5 tons and 92.3 tons, respectively and errors of those results against manually calculated were less than 1%. 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, during the calculation, it was found that the estimated resource stock index was getting larger along with the increasing of grid size. In order to check the validity of the resource stock index proposed in this chapter, a range of grid sizes were investigated to examine their adequacy. The examination was conducted through an algorithm of a grid cell area ratio to the total dredged area. Therefore, while in the previous study the spacing of the grid was decided empirically, in this study the adequate grid size could be evaluated. 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. According to the 2013 fishery census held by Ministry of Agriculture, Forestry and Fisheries, there were about 7,000 of set-net fishing unit around the Japanese coast, which produced 400 thousand tons or 13% 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 haul 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, fuel petrol 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 Co Ltd. (a Japanese echo sounder 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 hauling were used as indicators in the analysis. The daily catch record 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 in order to stabilize the variance of daily catch record, or to make the catch record statistically more normal distribution-like. After that, an estimation model was developed via multiple regression analysis using statistics of ping data as variables. 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 classification is carried out via linear discriminant analysis. During the experiment, it was noted that bycatch of several fish species may occurred in set-net fishery. Such kind of situation made it very difficult to classify all of the fish during bycatch. For that reason, it was assumed that only five types of captured fish in an operation to be classified because those fish species were the dominant catch during the experiment. By doing so, the 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 September 2014 and February to March 2015, with 79 respondents. 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 resource 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, resource 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.

Although there are several challenges remain in Indonesian fishery sector, set-net fishery has gained an attention as rising star that has a very big potential to be developed in Indonesian coastal area. At present, the demand of set-net installment is increasing. However, like Japan, the average daily catch is still considered low for the fishermen so there is a possibility loss because cost exceed the sales of fish. In order to make the operation more effective a real-time set-net monitoring system is necessary. Although the monitoring system is still under development, there is a possibility to conduct a technology transference in the future.

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.

Summary in Japanese

研究背景・目的

地球の 71%は水域であり、およそ 97%の水は海にたくわえられている。しかし、人類の必須栄養素のうち 95%は農業でまかなわれているとされ、地球の大部分を占める海からの恩恵、すなわち水産資源は人類の食料供給源として十分に活用されているとは言い難い状況である。FAO は世界漁業・養殖業白書において水産業が供給する必須栄養素量は農業よりも高い成長率を維持していると報告し、また水産業が雇用機会を提供する極めて重要な産業のひとつであるとの観点から水産資源の有効利用を継続して促進しなければならないと報告している。

沿岸漁業は、インドネシアや日本のような島嶼国にとって重要な産業である。インドネシアの沿岸漁業では、貧困削減、漁業者の生活向上、違法操業漁業および乱獲などの問題が乱立し課題となっている。一方、日本の漁業は近代的な技術を確立しその持続的発展において先端的な取り取り組みを行っている。ICT やセンサネットワークの水産業分野への応用も盛んであり、インドネシア水産業は日本の技術に 学ぶところ大であると考えられる。しかしながら、これは日本の沿岸漁業において問題が全くないということを示すものではなく、日本で課題とされていることは資源管理型水産業への移行である。そこで本研究は、持続的な沿岸漁業の確立と資源管理型水産業への移行に向けた ICT ならびにセンサネットワークの応用に関する研究を行うことを研究の目的とする。さらに、研究

を通じて開発された日本の先端技術について、インドネシアの沿岸漁業における問題解決に向けた技術移転の可能性を検証する。

漁業資源管理支援のための全自動リアルタイム情報共有における ICT およびセンサネットワークの応用

日本では、漁業権は許可制であり漁協が管理している。漁協は、資源保全の観点から魚種ごとに細かな制約を設定し自主規制を行っている。これらの規制は年々更新されており、TAC 制度（漁獲可能量規制制度）として多くの魚種に適用されてきているが、TAC が導入されていない魚種では、漁協が自ら定めた自主規制により資源維持を行っているにすぎない。多くの場合、これらの漁獲量規制値は勘や経験によるものがほとんどであるため、漁業者の理解が得られない、漁協の漁獲量把握と管理が困難であるなどの課題ある。そのため、自主規制や規制値の意思決定のための資源量推定や資源維持のための情報共有が重要な課題となっている。

本研究で対象とする魚種は、北海道産マナマコ(*Apostichopus armata*)であり、これは TAC 制度未導入の魚種である。北海道産マナマコは世界のナマコ貿易市場において重も高価なナマコであり、北海道の重要な特産品の一つとなっている。その理由は、中国や香港での北海道産マナマコの需要拡大と価格高騰にある。乾物の北海道産マナマコは“黒いダイヤ”と称されるほど高価に取引されており、このため近年、漁獲量が急激に増加してきた。北海道産マナマコは養殖技術が確

立されておらず、漁獲に頼る以外に生産の方法はなく、したがって乱獲を規制しなければ絶滅危惧の恐れもある魚種であり、TAC 規制がなくとも漁獲を規制し資源の維持管理を適切に行わなければならない魚種である。

マナマコ資源管理を目的に、面積密度法と呼ばれる手法を使用し漁獲可能資源量指標を推定する手法が提案された。この手法は、しかしながら、GIS を用い手動で計算する方法であるため、計算の労力は多大であり計算結果を得るまでに要する時間が長く、結果を直ちに漁業者にフィードバックできないという欠点がある。このため、本研究では、センサネットワークにより自動的にデータベースに蓄積されたデータを使い、漁獲可能資源量指標を自動で計算する手法を提案した。2011 年より現在まで、北海道のマナマコ漁場の一つとして知られる留萌市沿岸のマナマコ桁網漁に本手法を適用し 16 隻の漁船の操業情報を利用して運用試験を実施した。収集したデータはクラウドコンピューティングを利用しデータベースに蓄積され、計算された漁獲可能資源量指標を漁業者間で準リアルタイムに情報共有した。なお、計算に使用されたデータは、漁船の航跡（センサプラットフォームで収集された漁船位置情報）と漁獲情報（iPad アプリを使い、漁業者自身が入力したもの）である。計算された指標はインターネットを介して漁業者が閲覧可能な iPad アプリにてフィードバックし、漁業者の資源管理に対する意識向上と効率的な操業に向けた情報として活用された。

2012 年と 2013 年の漁期において、本提案手法により計算された漁獲可能資源量指標はそれぞれ 85.5 トンと 92.3 トンであり、GIS により手動で計算した

結果を比較したところその誤差はいずれも 1%未満であった。計算された指標は、漁業期間内の毎日、インターネットを介して漁業者に返されるため、漁業者は自身の漁獲量を把握することが可能である。漁業者は、本手法の結果を共有し資源量を把握しながら操業を行った結果、漁業者自らが話し合い、乱獲を防ぎ資源を翌年に残すため、当初予定されていた漁期よりも前に操業を終了させるなど資源維持への関心が高まり、本手法の結果と情報共有が有効に活用されたことが示された。なお、面積密度法を用いた指標の計算では、グリッドの面積を増大させればさせるほど資源量指標が増加するという問題点が指摘されていたが、本研究では、グリッド面積と曳網面積との比を最適にするグリッド面積をシミュレーションにより求める計算アルゴリズムも提案し、これまで経験的に決められてきていたグリッド幅の最適化に関する検討もあわせて実施した。本手法の提案により、沿岸漁業において漁業者の自己管理による資源管理型漁業への移行に貢献できた。

定置網漁業の効率化のためのリアルタイムモニタリング手法と漁獲量予測アルゴリズムの開発

日本や東南アジアにおいて、もっとも一般的な漁法の一つに定置網漁がある。本研究では、定置網漁の効率化のため、定置網を自動的にモニタリングし漁獲量を予測し漁業効率を向上するための支援技術の開発を実施した。農林水産省の 2013 年漁業センサスによると、日本の沿岸漁業ではおよそ 7,000 の定置網施設

があるとされ、総生産漁は 40 万トンであり、日本の水産物生産高のおよそ 13%を占めているとされている。定置網漁の課題の一つは、漁業者が定置網漁場に網上に行くまで、総漁獲量を確認するすべがなく非効率的な操業を強いられている、という点である。事前に漁獲量が予想できないということは、漁獲に必要な氷の準備、漁船の準備、操業回数の予測などが成り立たず、燃料の非効率などにもつながるなど問題である。結果として、漁業者が漁場に到着した際、十分な事前準備がなされていなければ、捉えた魚のすべてを回収し水揚げすることができなくなることもあり、非効率的である。このため、定置網の漁獲量を事前に、かつ、リアルタイムに確認可能なシステムの開発が望まれている。

従来、本研究が対象とするような定置網漁に対するリアルタイムモニタリングの機器は、VHF を利用し定置網に設置された魚群探知機の波形を出力する装置によって行われていた。しかし、従来型の装置は数千万円と極めて高額であり、特殊な機械であるがゆえ運用コストも漁業者にとって少なからず負担となっていた。また、従来型の装置は大型で重量もあるため、設置やメンテナンスに関する漁業者負担が大きく、課題があった。さらには、観測結果をサーマルプリンターやディスプレイに表示するだけのものであり、観測データをデジタル化して保管し過去の記録として利用しようとする思想がなく、漁業者が資源管理のためにデータを活用することは不可能であった。また、魚群探知機の画像は表示されるものの、定置網に捕獲された総水揚げ量などの予測は漁業者が画像を見て推測するしかなく、効率的な漁業の視点からは十分な機器とは言えなかった。そ

こで本研究では、ICT を利用し、魚群探知機のソナー反射強度データをリアルタイムかつ全自動でデータベースに蓄積し、蓄積したデータを分析することで、漁獲量推定や魚種判別を実施し定置網漁業者が操業以前に漁獲の情報を確認することができるシステムの開発を実施することとした。

本研究では、北海道ならびに富山県における定置網漁業の漁場に、KODEN 製魚群探知機を設置し、携帯電話回線経由でデータを取得し実験を行った。解析は、魚群探知機の ping データと呼ばれるエコー反射波強度を解析して行った。解析では、定置網の網上が行われる時刻の 4 時間前までさかのぼり反射強度を統計処理により分析する方法を採用した。実験現地における漁獲情報を教師データとして収集し、エコー反射強度と漁獲量あるいは魚種との関連を多変量解析にて分析した。定置網漁では、漁獲量の分散が極めて大きく日によって漁獲量が大きく異なることから、漁獲量推定では Box-Cox 変換によりデータの分散を最小にする変換を前処理として行い、ping データより作成した指標を変数とする重回帰分析により推定する方法で検討した。本手法の漁獲量推定の誤差を相対誤差で比較したところ、北海道のケースではわずか 1%であったが富山県では 22%と大きく、十分に実用可能といえるほどの精度を得ることはできなかった。また、魚種判別では、定置網漁は基本的に混獲であり多種の魚種を扱うが、数理解析ですべての魚種を判別することは不可能であることから、5 種類の代表的な魚種に種類を絞りこみ魚種判別を行った。その結果、83%程度の正答率で推定を行うことができた。なお、魚種判別においては、季節ごとに漁獲される魚種が変化する

ことから、判別分析をその都度変更し実施しなければならないなど、実用化に向けた課題が残された。現段階では、アルゴリズムには改良点が多く課題が残されているものの、定置網をリアルタイムにモニタリングし漁獲量推定や魚種判別を行うことが可能であることが示唆された。

インドネシア漁業の現状分析と ICT およびセンサネットワークの応用可能性に関する検討

インドネシアは漁獲生産量で世界第 2 位であるが、取り組むべきいくつかの課題が残されている。特に、漁業者の貧困と生活困窮の解消、不法・違法操業の撲滅、乱獲の制限などがインドネシア漁業における喫緊の課題となっている。本研究では、これらの課題を解消するために日本の沿岸漁業に適用されている ICT やセンサネットワーク技術の技術移転可能性とインドネシアにおける適用性に関する検討を実施した。日本の先端技術の適応性検討では、インドネシアにおける漁業の現状を分析する必要があり、このため、インドネシアの首都ジャカルタの北部沿岸漁業においてヒアリング調査を実施した。インドネシアの漁業者の 80%は小規模漁業者に分類され、インドネシア全体の漁獲量の 80%を小規模漁業者が担っているとされている。このため、本研究では小規模漁業者の分析に焦点をあてることとする。インドネシアでは、ICT を利用した漁業支援技術は確立されておらず、技術利用に関する先行研究では、携帯電話の利用が漁獲に及ぼす影響について検討したものが多い。本研究でも、携帯電話の利用による漁獲へ

の影響、漁業者の生活改善における利用、貧困解消のための利用、コミュニティ形成ツールとしての利用などについて研究を実施した。2014 年 9 月と 2015 年 2・3 月の 2 回、ジャカルタ北部沿岸域においてヒアリングおよびアンケート調査を行い、79 件の回答を得た。統計分析の結果、小規模沿岸漁業者において漁場情報の共有が実現されコミュニティ形成のツールとしての効果を上げていることが明らかとなった。また、緊急災害時の連絡用として利用するなど、携帯電話は多岐に渡り利用されていることが明らかとなった。携帯電話の利用はまた、仲買人との金額交渉のためのマーケティング情報の共有にも利用されており、漁業者の収入に有意な影響を与えていることが確認された。以上から、インドネシアの小規模漁業者の貧困問題や生活向上において、多くの状況で情報共有が効果的であることが示され、ICT による情報共有の潜在的な利用価値が高いことが示唆された。

前章にて提案した、漁船情報と漁獲情報を利用した漁獲可能量指標の利用は、不法操業を排除し乱獲リスクを軽減し、インドネシアの漁業が資源管理型漁業へと移行することに貢献できると考えられる。近年、全地球測位システム（GPS）の受信機は安価になりつつあること、あるいは携帯電話の位置情報が利用可能であることなどから、漁船位置情報を取得することは困難ではなくなってきている。携帯電話やセンサの USIM により漁船の情報を特定し漁船位置情報をリアルタイムに取得できれば、地方あるいは中央行政機関が漁船の動向をモニタリングすることが可能になる。これにより、漁船の不法操業を監視し、漁業ライ

センスを持たない違法操業者を取り締まることが可能になるなど、インドネシア国内の漁船はもとより近隣諸国からの違法操業の取り締まりにも活用できるものと考えられる。しかしながら、漁船位置情報を集積しデータベース化して利用するためのシステムがインドネシアでは未だ構築されておらず、今後の課題と言える。また、漁獲可能資源量の指標を計算するためには、漁船位置情報のみならず漁獲情報の収集と分析が必要である。インドネシアでは、2009 年施行の法律により、漁業者は漁獲情報を行政に対し報告することが義務付けられたが、これらは報告書ベースのアナログデータであるためデジタル化し自動分析可能なデータとして加工されなければならない。このように、現状においては本研究が提案する先端技術を直ちにインドネシア漁業に応用することは困難であるが、インドネシアが資源管理型漁業へと移行するための技術移転は十分可能であると結論付けられた。

インドネシアにていくつかの課題が残されているが、最近、定置網漁業は新星として注目を集めており、インドネシアの沿岸地域で開発される可能性高いといわれている。現時点では定置網の設置の重要が増加している。しかし、インドネシアの定置網も日本と同様で一日平均の漁獲量が少ないため、コストが魚の売上を超過し、損失可能性がある。このため、定置網の漁獲量を事前に、かつ、リアルタイムに確認可能なシステムの開発が望まれている。現在リアルタイムモニタリング手法はまだ開発中の段階だが、将来の技術転移が行われる可能性がある。

結論

本研究では、ICT とセンサネットワークを利用した漁業情報収集とその数理解析による情報分析ならびに資源管理情報の共有について研究を行った。研究を通じ、情報共有による資源管理こそが 21 世紀の持続的漁業の発展において効果的であると結論付けられた。

Chapter 1 Introduction

1.1 *Background of the Study*

The Earth's surface is 71 percent covered by water, and the sea hold approximately 97 percent of all Earth's water (USGS, 2015). FAO (2014a, 2015) described that fisheries has continued to grow faster than agriculture in providing source of nutritious food and protein as well as employment opportunity worldwide. FAO (2014a) estimated that approximately 58.3 million people were engaged in the primary sector of capture fisheries and aquaculture in 2012. 37 percent of these people were engaged full time. In 2012, more than 84 percent of all employment in the fisheries and aquaculture sector were in Asia, followed by Africa, with approximately 10 percent. The same report also indicated that the employment in the sector has even grown faster than the world's population growth. In 2012, fisheries represented 4.4 percent of the 1.3 billion people economically active in the broad agriculture sector worldwide or 10 to12 percent of the world's population. As a comparison, there were only 2.7 percent in 1990. FAO (2014a; 2015) even indicated that fisheries and aquaculture are the world's fastest growing food production sector today, and will likely continue to expand to create a lot more opportunities.

Fish is known as one of the food sources that has high nutrition and protein. FAO (2014a) reported that a portion of 150g of fish can provide approximately half of an adult's daily protein requirements. Yet, although fishery has a huge potential as food and protein source, Janick (2001) reported that agriculture sector still provided about 95 percent of human calories and proteins. Later on, FAO (2014a) estimated that in 2010, fish accounted for 16.7 percent of the global population's intake of animal protein and 6.5 percent of all protein consumed. It means this sector has not been fully utilized. With this in mind, fishery should be utilized to support food supply in a sustainable way.

FAO (2014a) reported that Global fishery production in marine waters was 82.6 million tons in 2011 and 79.7 million tons in 2012. These years, 18 countries, includes 11 Asian countries caught more than an average of one million tons per year, which account for more than 76 percent of global marine catches. Thus, Asian countries have an important role in global fisheries. Of the top ten producers of fish there are two Asian archipelagic countries, Indonesia (second largest) and Japan (ranked number sixth). Understandably, coastal fishery is one of the most important sectors in large archipelagic countries like Indonesia (IBP USA, 2008; FAO, 2014b) and Japan (IBP USA, 2010; Popescu and Ogushi, 2013).

Indonesia is the world's largest archipelagic country with more than 17,000 islands (of which 7000 are inhabited), 99,093 kilometer shoreline (BIG, 2015), and the world's fourth most populous nation, 250 million (BPS, 2014). In addition, the Indonesia has approximately six million kilometer square of Exclusive Economic Zone (EEZ), in which ranked fourth in the world (JFA, 2011). As the world's largest archipelagic country, fisheries industry is a very important industry in Indonesia. FAO (2014b) reported that Indonesia’s fishery production reached approximately 8.9 million tons in 2012 (second largest in the world), of which capture fisheries accounted for about 5.8 million tons and aquaculture 3.1 million tons. About 57 percent of the animal protein supply of Indonesian comes from fish and seafood (KKP, 2013a). Per capita annual consumption of fish and has risen from an average of 11kg in the 1970s (FAO, 2014b) to 35kg in 2013 (KKP, 2013a). FAO (2014a) described that the total value of exported fishery commodities was USD 3.8 billion. The fishing industry accounted for 21 percent of Indonesia’s agricultural economy and 3 percent of national GDP in 2012. Additionally, 31.4 million metric tons of fish products (or 21 percent of global production) were sourced from the ASEAN region with Indonesia supplying 33.8 percent of the region’s fish products.

Although the coastal areas and fisheries are considered as one of the most important sectors in Indonesia, there are several problems remain, especially in fisheries sector, such as, fishermen poverty; illegal, unregulated, unreported (IUU) fishing; environmental degradation, pollution and the exploitation of Indonesia's fishery resources; overfishing; poor and inconsistent management; human resource capacity; lack of knowledge as well as technology; new policy dissemination and so on. Recently, the Indonesian government has realized a great potential that has not been fully utilized in fishery sector, especially after the presidential and ministry change in September 2014. Since then, the government has been trying to face those problems (Indonesian Gov. 2014; KKP, 2014a; BAPPENAS, 2015). Moreover, the same sources reported that Indonesia is going to focus on strengthening Indonesia’s maritime potential in order to set itself into a maritime-powered country.

On the other hand, like Indonesia, Japan is known as a large archipelagic country and being surrounded by some of the most productive fishing grounds with a wide variety of resources (Popescu and Ogushi, 2013). Japanese fisheries traditionally play a substantial role for its food supply and form a key element of the economics in coastal areas. To point out, Japan has the world's sixth largest EEZ, and the production volume of Japan's fishery industry is approximately 4.6 million tons, which is ranked as fifth in 2006 (JFA, 2011) and sixth in 2012 (FAO, 2014a). In 2011, Japan’s northeast coast was hit by a tsunami, and was forecast that the destruction of fishing vessels and infrastructure would reduce Japan’s total catch to fall by about one-third (FAO, 2012). However, later on FAO (2014a) revealed that the actual decrease in comparison to 2010 was about 7 percent (4 million tons to 3.7 million tons), with a further decrease of 3.5 percent in 2012. And Japan still remains as one of the top producers of marine fishery.

Japan is known as one of the world's most important producers and consumers of fishery products, which contributes a lot to global fisheries. Despite of being one of the largest fishery producers, for years Japan is also recognized as the world’s second largest fish importing country, after the United States of America (FAO, 2014a). The same report also predicted that the import will likely continue in near future. For Japanese people, fish and fish product are important for the national diet, in which per the consumption is approximately 56.9kg per year, ranked number one in the world (JFA, 2011; E-stat, 2014), compared to a world average of 19.2kg (FAO, 2014b).

Japan is also recognized as a technologically advanced country in various sectors, including primary industry like fishery. Japanese fisheries industry is also generally known for the establishment and the application of modern knowledge and technology toward sustainable fisheries industry. For instance, Japan has applied advanced technology such as, sensor network and Information and Communication Technology (ICT) in fisheries sector, from the acquisition of seabed texture and topography (Wada *et al*., 2005; Hatanaka *et al*., 2008), investigation of fishery resource (Toda *et al*., 2009; Sano *et al*., 2011), efficient and safety fishing production (Kimura *et al*., 2004; Kimura *et al*., 2005), rescue system for fishermen during the operation trip (Wada *et al*., 2004), fishery management (Wada and Hatanaka, 2010; Wada *et al*., 2008, 2012) and many more. With these in mind, there are a lot of lessons, including advanced technology, which can be learnt from Japanese fisheries industry to be applied in Indonesia.

1.2 ***Problem Statement***

Fishery sector in Japan is well known globally for its production, consumption and advanced technology. Yet, there are several problems remains, such as the appropriate management of fishery resource, effective and efficient fishing method, the decreasing of fishermen's number, fishermen aging, declining of per capita fish consumption, the declining of selling power of fishermen and so on (JFA, 2009; JFA 2011; Takai, 2014). The same reports also indicated that until now fishery management and effective fishing method still remain as major issues for Japanese fisheries. Those two issues are important to ensure the healthy sustainable supply of fishery product for the consumer as well as to make sure the healthy development of fishery sector under the condition of limited resource.

Generally, fishery industry is a classic example of common property resources and tends to decrease over time. According to the conventional wisdom, they decrease through a process known as tragedy of the commons, which generally defined as economic problem in which every individual or group tries to reap the greatest benefit from a given resources (Hardin, 1968). As noted above, the appropriate management of fishery resource is needed to avoid the tragedy of the commons, or overfishing in fishing industry. 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 association itself 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).

In order to support the self-management system, the Japanese government also sets Total Allowable Catch (TAC) to impose the catch quota limit for most species in 1997 (Makino, 2011; Popescu and Ogushi, 2013). The Fishery cooperatives then decide the quota distribution and access rules by the recommendations of fisheries scientist for the defined TAC species. Yet, 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 numerical 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.

To deal with the problem, Sano *et al*., (2011) previously developed resource 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. Therefore, the first aim of this dissertation is to support management system in a coastal fishery through the development of automatic resource stock index algorithm by utilizing the ICT and sensor network technology. This study is conducted in

Hokkaido, an island-sized prefecture in northern Japan. Because Hokkaido 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.

As noted above, another point worth of consideration for Japanese fishery is the effective fishing method. Set-net or Japanese style Teichi-ami, is a very popular fishing method and widely used in Japanese coastal areas (Akiyama, 2012; MAFF, 2013). The set-net fishery in Japan has hundreds of years of long history, since the beginning of Edo-period, which is considered to be sustainable, stable and environmentally friendly (Arimoto *et al*., 2007; Akiyama, 2012). In 2013, there were about 7,000 of set-net fishing unit around the Japanese coast, which produced about 400 thousand tons or 13 percent of the total catch in Japan (MAFF, 2014). In addition, because of the popularity of set-net, Japan International Cooperation Agency (JICA) conducted the promotion and technology transference of set-net to ASEAN, including Indonesia, and several central American countries in 2000s (JICA, 2006; Muprasit *et al.*, 2008; Sudirman *et al.*, 2010). Even today, JICA still continue conducting the promotion and technological transference of set-net. The project itself was called “promotion of sustainable marine fisheries resource utilization”. Looking through the project’s name, Japanese and beneficiary government also recognized set-net as a sustainable fishing method.

Set-net fishery is a simple passive method to catch fish, as the fishermen need to install set-net in a coastal area, back to the port and stand-by for the fish to be trapped.

The working principle of set-net is to cut (interrupt) the migration or swimming path of school of fish. In this method the school of fish take the active role in this fishery, i.e. by entering the net after having had their route interested by the leader net. Later, fishermen go to set-net area to haul the trapped fish. Usually, fishermen haul the bag net once a day in the early morning according to their experience.

However, since set net is a passive fishing gear, generally, set-net fishermen do not know the catch amount in advance before arriving to set-net area. Such condition make the fishermen tend to perform the fishing operation ineffectively. Needless to say that the cost spent, such as petrol, labor cost or cost for ice and so on, must be smaller than the fish hauling to obtain the highest possible profit. For example, when the fishermen come to the set-net and only catch a few fish at a low price, they will suffer from the lost because the cost spent might exceed the sales from the catch. 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 hauling process twice. It means that the fishermen will suffer a loss of time, petrol and labor cost, along with extra effort. Moreover, the trapped fish may escape if the fishing operation intervals are too length, or there may not be more fish come when the volume of the trapped fish exceeds the capacity of the bag net and the final trap (Akiyama and Arimoto, 1997; Akiyama, 2006). In order to solve the issues, real-time monitoring of trapped fish within set-net and the catch quantity are needed immediately for supporting the fishermen.

Set-net fishery is considered as the sustainable fishing method and has been promoted to many countries. It means the Japanese fishermen are not the only one who need the monitoring system, but also many fishermen in many beneficiary countries. According to interview with Japanese set-net fishermen in 2014, the catch varies from few kg to several hundred tons and the average daily catch was a few hundred kg. In Indonesia, as the beneficiary country of set-net promotion project, the average of daily catch in 2009 was 60kg (Sudirman *et al.*, 2010). It means most of the operation only a small number of fish amount were caught. Since set-net fishermen is usually controlled under the organization or community-based management system (Arimoto *et al*., 2008), the catch must be divided for each fishermen who participate. Supposed the catch is 100kg and there are ten fishermen participate in a haul, so one fishermen roughly get 10kg. Besides, the fishermen also need to think about the petrol cost, time and effort. There is a possibility of loss in such kind of situation because the cost could exceed the sales of the hauled fish. Thus, the monitoring system of set-net fishery is needed immediately not only by Japanese fishermen, but also by fishermen in beneficiary countries. The monitoring system is needed to prevent the loss because when there is only a little catch amount the fishermen just simple do not need to go to haul the fish.

Conventionally, set-net monitoring system has been practiced for several decades using a very high frequency (VHF) equipment, which utilize replaceable battery as the energy source. Nevertheless, that conventional equipment was very heavy, bulky and expensive (cost more than a hundred thousand dollars). The battery weight is about 100kg and several fishermen even stated that the maintenance, such as replacing the batteries in the equipment, requires a lot of effort. The output information from the equipment is printed by thermal printer, after that, fishermen can check the state of set-net subsequently. It means, the data remain is a paper based output information. Besides, the conventional equipment does not allow one to know the quantity of the trapped fish. Thus, the second aim of this study is to develop a low cost, more effective and efficient monitoring system for set-net fishery, which enable to visualize as well as recognize catch amount by applying the ICT and sensor network technology.

As the largest archipelagic country, with the quantity of fisheries production is being number 2 in the world, there are numerous problems occur in Indonesian fishery sector. After the presidential change in September 2014, the newly appointed president changed Ministry of Marine Affairs and Fisheries to Ministry of Maritime Affairs and Fisheries to strengthen Indonesia's maritime potential and to solve the problems (Indonesian Gov., 2014; KKP, 2014a). At the present time, poverty reduction as well as fishermen`s life improvement, IUU fishing and overfishing are the main priority problems to be solved by the Ministry of Maritime Affairs and Fisheries (KKP, 2014a).

Poverty has been a severe problem for decades in Indonesia, and has been one of the main focuses of Indonesian Government, especially since the signing of the Millennium Development Goals (MDGs) in 2000 (UN, 2008; BAPPENAS, 2010). However, World

Bank (2013) stated that about one-third to nearly half of the population in many coastal regions of Indonesia existed below the poverty line. Such kind of condition indicates that poverty is still a very serious problem to be solved, even after the final year of MDGs in 2015. Therefore, the poverty in coastal area is one of the main targets of the new government (Indonesia Gov, 2014, KKP 2014a).

For ages, relatively high level of IUU fishing has been present with little change over the years. For decades now, Indonesia's rich marine natural resources have been stolen at will by foreign fishing vessels. In Indonesia, a huge amount of illegal and unreported catch, over several million tons annually, which resulting loss of some billions of us dollars has recently been revealed (Nurhakim et al., 2008; Agnew et al., 2009; KKP, 2014b). Thus, the IUU has become the main problems of Indonesian’s fisheries sector, especially after the appointment of the new minister in September 2014, as the IUU has been one of the three main targets to be addressed (KKP, 2014c).

Like the Japanese fishery sector, fishery management problems and overfishing also be a thorny problem in Indonesia as the ministry reported that, there is possibility of overfishing (KKP, 2014c). However, the ministry still faces the problems in arranging database of catch and estimating fish stocks in Indonesian waters. Under the new minister, the data gathering, database arrangement and fish stock estimation is also one of the main topics nowadays (KKP, 2014a). In fact, one of the factors of overfishing in Indonesia is IUU fishing as they are related to each other (Winter, 2009). Many of the IUU fishermen are using aggressive methods to put food on their tables, including the use of explosives, which further endangers fish supplies. Besides, one of the key factors of overfishing is that the TAC system in Indonesia has not established yet (Triyono, 2013).

In order to solve those three main topics of Indonesian fishery sector, the application of newly developed advanced ICT and sensor network technology through the Japanese technology transference can give a very potential important role. However, before going further to the application, it is necessary to conduct the preliminary study and analysis of, to what extent ICT and sensor network technology are used in Indonesian coastal fishery. Particularly, the state of Indonesian fishery in concern to ICT and sensor network technologies. After that this study also aims to formulate the suggestion and possible regulation to solve three main topics of Indonesian fishery sector by utilizing advanced ICT and sensor network technology. The study is conducted in Jakarta as the capital city of Indonesia.

Apart from those three main issues, Indonesia has a big potential to develop set-net fishery. In 2014, KKP reported that set-net fishery development is included in one of their potential strategic plan (KKP, 2014d). Recently, the newly appointed ministry has reaffirmed the prohibition on use of several fishing method such as bottom trawl, bottom gillnet and so on (KKP, 2015). In point of fact, the prohibition of those fishing method has been a discourse in the past few years, yet, the inauguration was announced in January 2015. Therefore, introducing and developing of new fishing technology are become urgent actions to be taken. The ministry has realized that set-net is one of the potential solutions (KKP, 2014d). As noted above, the average daily catch of set-net fishery in Indonesia during the sampling time was still low (Sudirman *et al.*, 2010), so there is a possibility to also apply the monitoring system, which is developed in one of the chapter of this study, in order to support Indonesian fishery in near future.

1.3 *Objective of the Study*

This study discusses the numerical analysis of ICT and sensor network applications toward sustainable coastal fishery. In particular, to solve the issues in Japanese coastal fishery sector, next is to conduct the feasibility study and analysis for their potential application in Indonesia. Specifically the objectives of this research are as follows:

1) To develop an extra method to address the weakness of the previous research (Sano et al., 2011) by making it an automatic real-time system via the application of ICT and sensor network technology and to discuss its application for supporting management system in the actual fishery of sea cucumber in Rumoi City, Hokkaido.
2) To develop an algorithm estimation system of fish trapped amount within the set-net. This study will be focused to improve fishing efficiency of set-net fishery through a sufficient accuracy for practical use, rather than the precision of the resource estimation.
3) To clarify the state of the application of technology in daily life of fishermen in

Indonesian coastal fishery, i.e. to what extent ICT and sensor network technology are utilized. In this chapter the author also would like to formulate the suggestion and possible regulation to solve main issues and the potential of Indonesian fishery sector through the technology transference of Japanese advanced ICT and sensor network technology mentioned in the previous section.

1.4 *Structure of the Dissertation*

The structure of this dissertation is shown in Figure 1.1 and the rest of this dissertation is organized as follows. The dissertation is consisted of five chapters. Chapter 1 provides the introduction to the research, which includes background of this research, problems identification, the objectives and also structure of this dissertation. After Chapter 1 is discussed, the study is divided into two parts of investigation. Firstly, Chapter 2 and 3 examine the ICT and sensor network application and its numerical analysis to solve fishery issues in Japan. Next, Chapter 4 discusses the state of Indonesian fishery issues and the feasibility to solve the issues through the application of the previous chapter.

Chapter 2 discusses a development of an automatic system to support self-management in coastal fishery by applying ICT and data sharing scheme. In particular, this chapter describes the development of extra method to address the weakness of the previously developed catchable stock index (Sano et al., 2011) by making it an automatic real-time system via the application of ICT and sensor network technology. Next, this section also discusses the application of the present system for supporting management system in the actual fishery of sea cucumber in Rumoi City, Hokkaido. Moreover, this chapter also provides an investigation of the validity of catchable stock index by examining range of grid sizes.

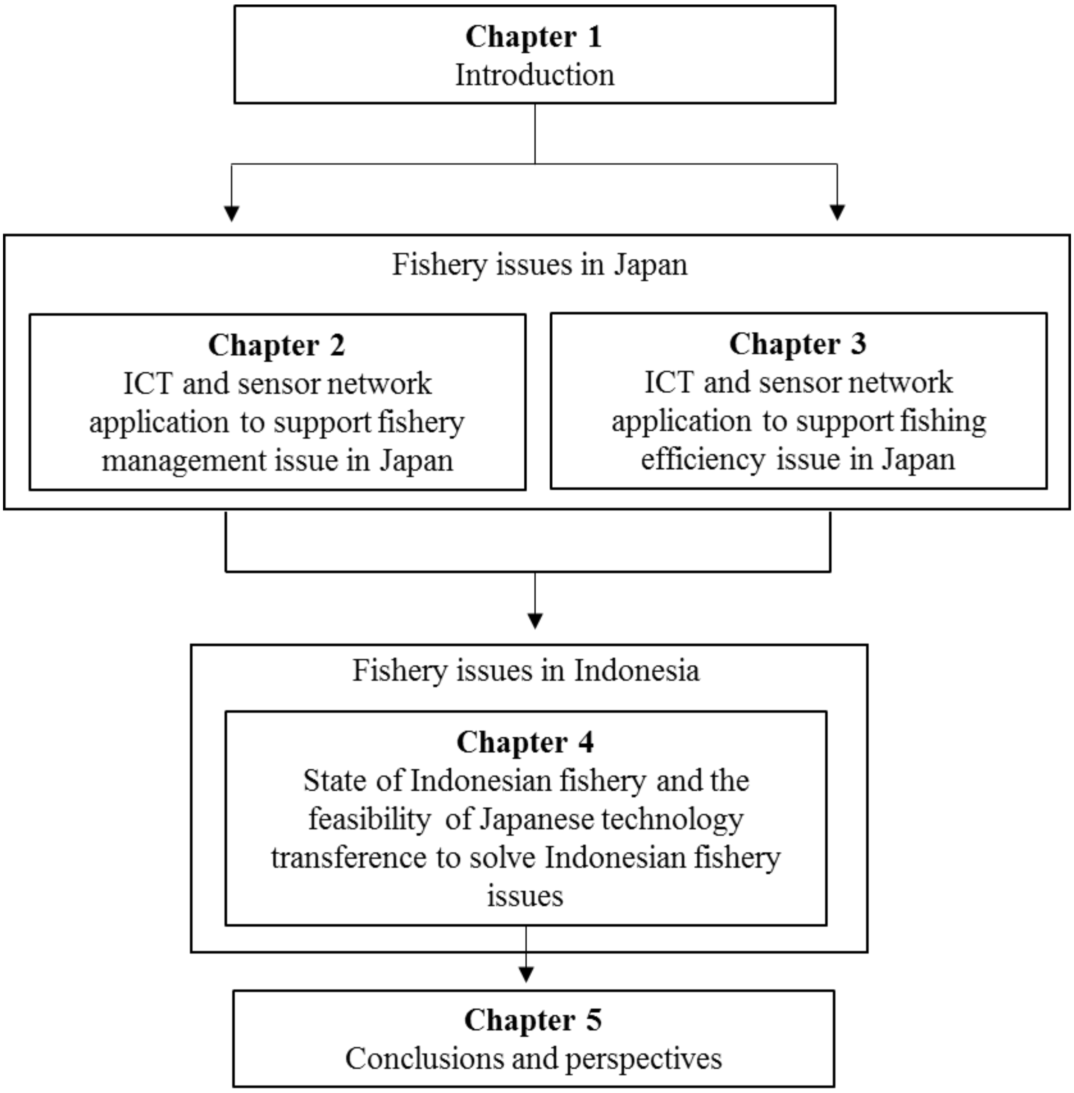


Figure 1.1. Flowchart of this study

Chapter 3 presents the experiments and applications of the remote fish finder system for the more effective set-net fishery. Specifically, the study in this chapter focuses on the algorithm development of catch amount estimation and fish species classification toward real-time monitoring to support fishing efficiency of set-net fishery by making use of the real-time monitoring system based on ICT aided echo sounder.

Chapter 4 examines the state of the applications of technology device in daily life of fishermen in Indonesian coastal fishery. Besides, this chapter provides an overview of the impact of data sharing through the currently being used ICT devices among the fishermen in Jakarta coastal area. The author also discusses on the suggestion and possible regulation to solve three main issues of Indonesian fishery sector through the technology transference of the previously-mentioned advanced ICT and sensor network technology. In addition, the author also describes the possibility of the development of set-net fishery in Indonesia as an alternative fishing method along with the possibility of set-net monitoring system technology in the future.

Finally, Chapter 5 summarizes the conclusion of the study and discusses the remaining problems that should be focused for the future researches.

Chapter 2 The Application of ICT and Sensor Network for Automatic Real-time Data Sharing System to Support Fishery Management

FAO (2014a) reported that the world's marine fisheries expanded continuously to a production peak of 86.4 million tons in 1996 but have since exhibited a general declining trend. The same report also stated that the fraction of assessed stocks fished within biologically sustainable levels has exhibited a decreasing trend, declining from 90 percent in 1974 to 71.2 percent in 2011 (Figure 2.1). Thus, in 2011, 28.8 percent of fish stocks were estimated as fished at a biologically unsustainable level and therefore overfished. Of the total number of stocks assessed in 2011, fully fished stocks accounted for

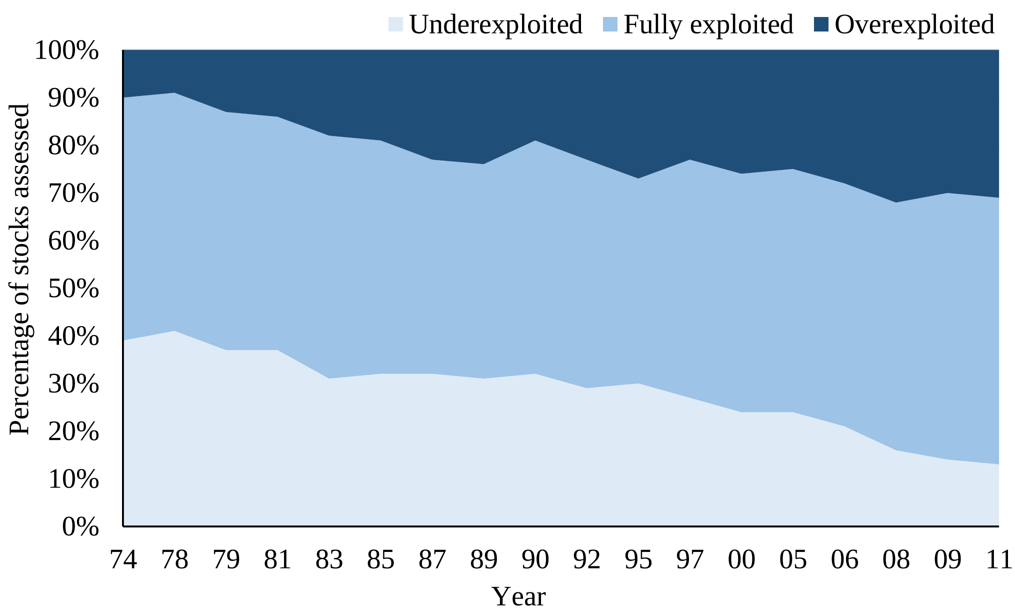


Figure 2.1. World trends of marine fish stocks, 1974 to 2011. Source: FAO, 2014.

61.3 percent and underexploited fish stocks for 9.9 percent. The underexploited fish stocks decreased continuously from 1974 to 2011. After 1990, the number of stocks fished at unsustainable levels continued to increase and peaked at 32.5 percent in 2008 before declining slightly to 28.8 percent in 2011. Thus, effective and cautious management plans should be established before increasing the fishing rate of these fish stocks in order to prevent overfishing.

According to Akamine (2005), Japan is one of the countries that carry out management plan for decades, even right after the World War II. In 1949, Japanese Government established the fishery law to create a fundamental management system and ensure fishery productivity, including to avoid overfishing. Later on, TAC policy was introduced in 1990s to limit the catch (Makino, 2011). However, fishermen and the cooperative face confusion in performing empirical self-management system for the species that is not specified in TAC policy (MAFF, 2010; Sano *et al.*, 2011; HRO, 2014). Therefore, there is a need to support the fishery cooperatives and fishermen, who perform self-management, with scientific and numeric system.

2.1 Brief History and State of Fishery Management in Hokkaido, Japan

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. As a large prefecture, Hokkaido is divided into several cities, and each city has its own autonomous fishery cooperative conducting the self-management system explained above (Akamine, 2005). 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).

Data sharing in coastal capture fishery 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 the author expects to apply data sharing system to support self-management system. Data sharing could be realized optimally by ICT, sensor network technology and real-time framework to support fisheries management (Wada and Hatanaka, 2010; Wada *et al*., 2008; Wada *et al*., 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 microCube (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).

2.2 Sea Cucumber Fishery as the Target of the Study

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 1,000 tons in 1990s to 2,600 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 being popular and expensive, many ecologically unknown facts about the Hokkaido sea cucumber still make it very difficult for them to be cultured. In other word, the fishermen need to catch the sea cucumber from its habitat. If the catch continues to increase without being controlled, there might be an overfishing risk. In the same time, it 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 unsure 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 study 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 the previous research, Sano et al. (2011) presented a method to estimate a certain extent of resource of Hokkaido sea cucumber, namely the resource stock index. The resource 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 resource stock index successfully meets the needs of fishery cooperative and fishermen. Alongside that, there are several weaknesses of the previous study 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, there are necessary to (i) develop an extra method to address the weakness of the previous research (Sano et al., 2011); (ii) discuss its application for supporting self-management system in the actual fishery of sea cucumber in Rumoi City, Hokkaido; and (iii) investigate the validity of resource stock index by examining range of grid sizes.

2.3 Rumoi City, Hokkaido as the Target Area

The study area was located in Rumoi City, a coastal city in the western part of Hokkaido (as shown in Figure 2.2, 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

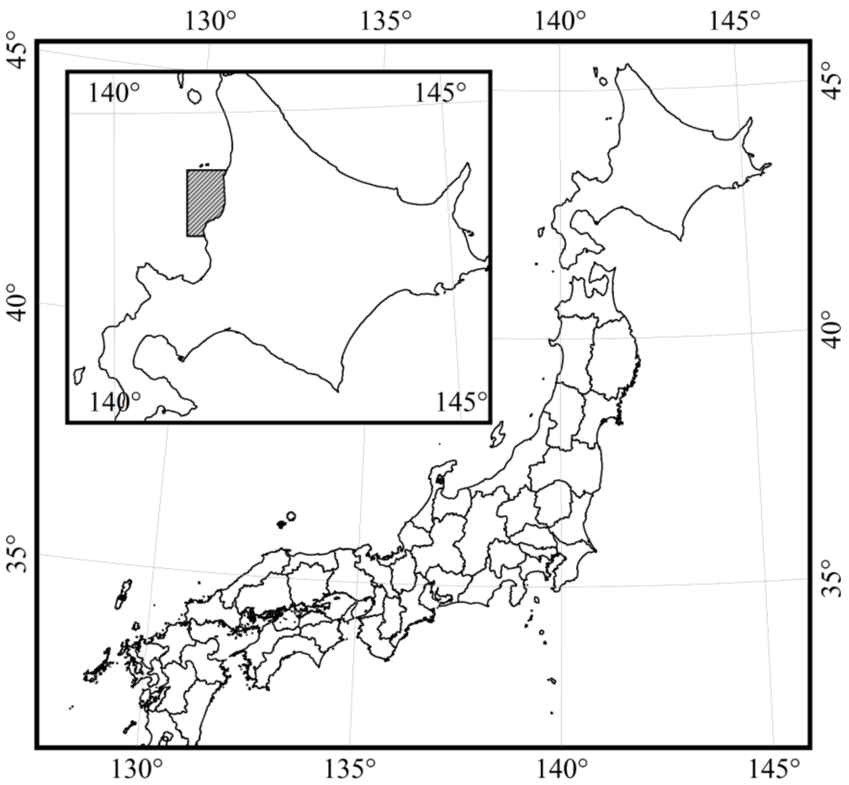


Figure 2.2. Research Location in the coast of Rumoi City, located in the western part of Hokkaido, Japan.

them perform self-management system, as explained above, 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.

2.4 Real-time Fishery Information

The data gathering for assessing the stock of the biological population in fishery sector are divided into fishery-independent and fishery-dependent data (Gulland, 1969; Shirakihara, 1994). Fishery-independent data system is obtained from activities that do not involve the commercial or recreational harvest of fish, or do not depend on fishermen and seafood dealers. On the other hand, fishery-dependent data system is derived from fishery itself (fishing operational data during the fishing season) and is collected through self-reporting, onboard observers, portside and telephone surveys or vessel-monitoring scheme. The fishery-dependent data has several advantages such as, allowance to increase the precise estimations of the area operated on (Engås and Godø, 1986; Koeller, 1991; West and Wallace, 2000). In addition, if fishery-dependent data are processed quickly enough, repeated evaluations can be conducted to assess the performance of the fishing fleet and their ability to address emerging problems during the fishing season (Holmes *et al*., 2011). For those reasons, this study used fishery dependent-data obtained from the user, fishermen and the fishery cooperative.

Fishery dependent-data in this study is data sharing of location data and catch record. To enable the quick calculation of resource stock index, real-time data sharing are preferred. Real-time location data of the entire dredge-net fishing fleet in Rumoi City were automatically collected during the fishing operation from a Global Positioning System (GPS) receiver. On the other hand, real-rime catch records, including start/end time of each operation, were input by the fishermen using their iPad (Apple).

In Japanese coastal fishery, almost all fishing vessels are equipped with a GPS receiver, from which it is possible to collect the location data of the vessels in real-time. In order to collect those data, a sensor network platform, called microCube (Figure 2.3; Wada *et al*., 2008), was introduced to the fishing vessels. The microCube automatically collects the location data at ten-second intervals when the fleet engine is on. Afterward, it will transmit the location data to the database server via email every one minute. The real-time data transmission was enabled due to the installation of USIM card in microCube. In this study, National Marine Electronics Association (NMEA) format for the location data are used. Next, the system will convert the location data of the vessels into the Japanese plane rectangular coordinate system through an orthorectification process. After the conversion, the real-time trajectory of each vessel will be automatically

Figure 2.3. Photograph of a microCube unit used in the vessels to collect and transmit GPS data in real time. Source: Wada, 2013.

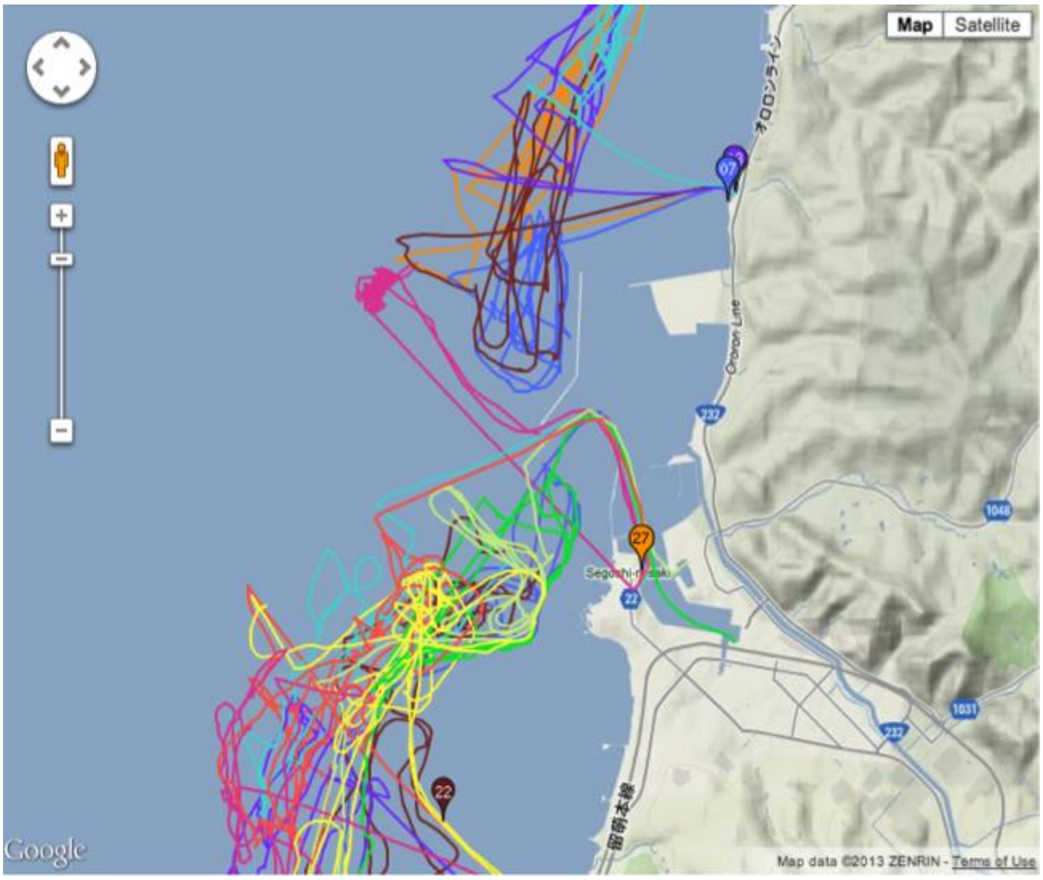


Figure 2.4. Example of real-time vessel trajectories in the target area, overlaid on Google Maps (July 31, 2013).

overlaid on Google Maps and shared to the users via the Internet. An example trajectory is shown in Figure 2.4.

Catch information is also important for estimating the density distribution of the species in the fishing ground. In the previous days, fishermen recorded this information on paper using their individual style. Wada *et al*., (2012) noted that it is difficult for fishermen to record the information for each catch throughout the fishing operation with such a way. ICT have been applied to obtain the catch information more easily, and is referred to as a digital diary in this study. The data in each digital diary includes the ID of the fishing vessel, date of the fishing operation, starting and ending times of each operation and amount of the catch. The diary was at first developed on a laptop PC, but the fishermen complained that it was heavy, slow to start-up and shutdown, and expensive. Moving to the next step, the iOS app version of the digital diary have been developed and installed on fishermen's iPads for the purpose of this study.

Figure 2.5 shows a screen shot of digital diary application used in this study. The number in the left-most column shows the number of fishing operations during the day. The second and third columns show the starting and ending times of an operation, the

Figure 2.5. Screenshot of a digital diary on an iPad. The graphical user interface is written in Japanese, which shows number operation in the day, starting and ending time, elapsed time for one operation, the amount of catch in bucket(a bucket is equal to 20kg) and personal note. Source: Wada et al., 2013.

fourth column shows the elapsed time for the operation. Meanwhile the fifth column shows the catch in units of buckets (assumed to be 20 kg in the computations) and the last column shows the personal notes of fishermen. In addition, fishermen usually started the fishing operation at approximately 06:00 and stopped the operation at 16:00. The time spent in a single operation was approximately 30 minutes up to one and a half hour. It means that there were less than eight operation times in one day. Due to these reasons, the digital diary application was designed with eight times of fishing operation.

2.5 Real-time Data Collection and Transference

Figure 2.6 shows the diagram of automatic data collection and transference in a cloud computing system. First, the location data obtained by the microCube are sent at one-minute intervals via email. The database server then check the email every two minutes, and new data are added to the table stored in the database server. At the same time, fishermen send the catch information using their iPad. An USIM card equipped iPad can readily send catch information directly to HTTP server. On the other hand, USIM card non-equipped iPad needs to connect to the Internet via a wireless LAN in the port in order to send catch information. To obtain any new records of catch information, the database server was automatically set to access the HTTP server at 15-minute intervals. Later, the original software, which was written in the PHP programming language,

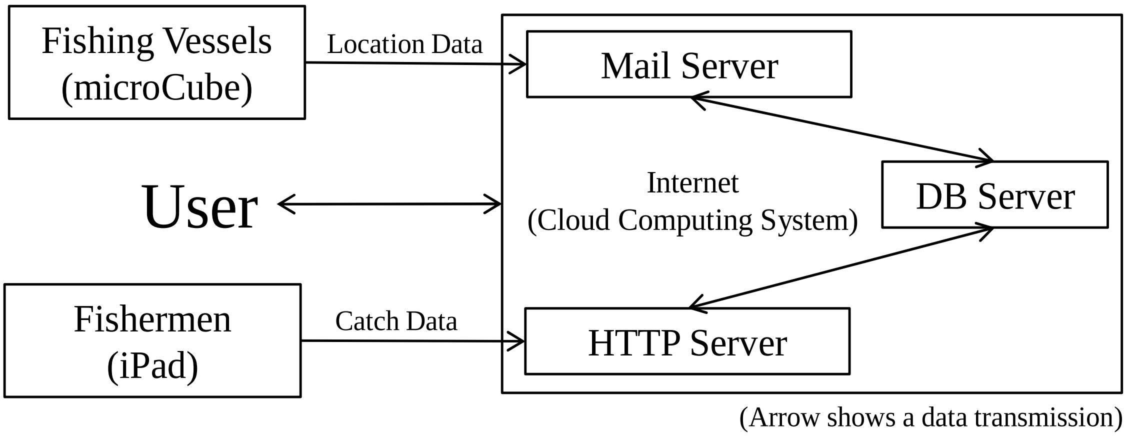


Figure 2.6. Diagram of the real-time data collection and transferring scheme in this study.

performed the data processing and data analysis automatically using a cloud computing service at three-hour intervals. The computation results were then shared with the other users of this data.

2.6 Swept Area Method

Several methodologies are available for estimating a biological population. The methods commonly used in fisheries are the DeLury method, which estimates the catch per unit effort (CPUE; DeLury, 1947); removal method, which employs a constant sampling effort to remove a constant proportion of the population present at the time of sampling (Zippin, 1958; Seber and LeCren, 1967); cohort method, which relies on the catch in number or biomass at an age and growth stage of fish (Pope, 1972; Zhang and Sullivan, 1988); and swept area method, which is employed in direct biomass assessment programs for bottom-dwelling organisms in a defined area (Gunderson, 1993).

The most commonly used method for estimating fish stock is cohort method (Pope, 1972; Pauly, 1984; Zhang and Sullivan, 1988). Yet, sometimes cohort can be unreliable, resulting different estimation that can be overestimate and undervalue (Robbins *et al.*, 2002). Moreover, since there are a lot of unknown biological fact of Hokkaido sea cucumber, it is very difficult to estimate using growth stage and age as parameters. On the other hand, for sedentary sea organisms, such as sea cucumbers, fishermen have generally used dredge-net fishing. It has been assumed that they are an abundant organism in the areas in which they are "swept" (dragged on the sea bottom). This simple way of thinking is the basic concept behind the swept area method (Gunderson, 1993). For this reason, the swept area method is particularly suitable for the resource stock index computation of the sea cucumber.

The information collected by microCube and digital diaries were utilized to estimate the distribution of the density of the catch via an algorithm based on the swept area method. In the swept area method, the density distribution of a marine organism in an area of the fishing ground is simply calculated as the amount of catch divided by the catch area,

$$D = \frac{C}{Y}, \tag{2.1}$$

where D [kg/m^2] indicates density of sea cucumber, C [kg] is the amount of catch recorded in the digital diary and Y [m^2] is the area dredged during the operation. The dredged area is calculated by multiplying the width of the dredge net (3.2m) by the operation distance, which was computed from the GPS records in the vessels. It is assumed that the dredge fishing track are relatively straight, because the velocity of the vessels during the fishing operation was approximately 1 to 1.2m/s.

To produce an accurate distribution map of the total dredged area and total catch, the author divided the total area into districts, each of which was a square grid cell with sides of 100m (Sano *et al.*, 2011). The system automatically identified the trajectories of the fishing vessels in the database server using the start/end times recorded in the digital diaries. Continuing on, the total distance of each trajectory could be calculated, and then the average density of the catch during each operation could be obtained from Eq. (2.1). Because the length of the trajectory in each grid cell could be calculated geometrically (the detail is explained in the next section), the catch during the operation and the specific catch area in each grid cell were allocated by using the ratio of the distance traveled to the total length of the trajectory. The average density in the grid cell, D_j, can be derived as,

$$D_j = \frac{\sum_{i=1}^{N} C_{ij}}{\sum_{i=1}^{N} Y_{ij}}, \tag{2.2}$$

where C_{ij} expresses the catch of the i-th operation in the grid cell j, Y_{ij} indicates the specific area and N is the total number of operations.

In order to provide minimum estimates of abundance, the author assume that the fisheries efficiency is equal to one in an operation. In other word, it is assumed that the amount of resource stock (D_j in Eq. (2.2)) in an area will be reduced significantly or completely removed during the first fishing operation and subsequent operations. Afterward, the minimum estimate of sea cucumber resource stock index is utilized to impose the application of catch limit. With this in mind, the author selected the first calculated density on the first day in a given grid cell as the initial density in that cell.

The resource stock index of sea cucumbers based on the swept area method is computed as follows. The resource stock in a grid cell can be estimated by multiplying the initial density by the area of a grid cell (100m × 100m). The total resource stock index in the fishing ground is simply obtained from the sum of resource stock in each grid cell. After calculating the initial density in all of the grid cells, it is possible to derive the estimated resource stock index in each cell. However, if there are few operations in a particular grid cell, the variances of density of C_{ij} and Y_{ij} become large, and the calculated initial density is not reliable. Sano *et al*., (2011) showed that the variances of density of C_{ij} and Y_{ij} were sufficiently small when the sum of Y_{ij} exceeds 5% of the grid area. Thus, the grid cells for which the sum of Y_{ij} exceeded 500m^2 have been included when estimating the resource stock index.

Another important requirement when using the swept area method is the area of the entire fishing ground. In this study, the author fixed the number of grid cells and the area of the fishing ground to be covered because the estimation of the resource stock index depends on the area of the grid cell in which the initial density is calculated. This is important because, if the area of the fishing ground changes every year, the estimated resource stocks for different years will not be comparable. In addition, the fixed grids covering the fishing ground in the target area were determined by a three-year survey (2010 to 2012) of regular fishing operations. The grids were chosen because during the survey, the fishermen always performed their fishing operation in those areas, which constituted 1,787 grid cells (100m × 100m).

2.7 Algorithm of Automatic Grid Detection of Dredged Area

As written above, the operation distance of each vessel in this study can be determined geometrically. There are two steps to be conducted in order to automatically determine the grids and operation distance in this study. Firstly, the node (longitude and latitude coordinate as x and y) need to be set to form a grid beforehand to detect in which grid the vessel pass though. Next, it is necessary to measure the operation distance of the

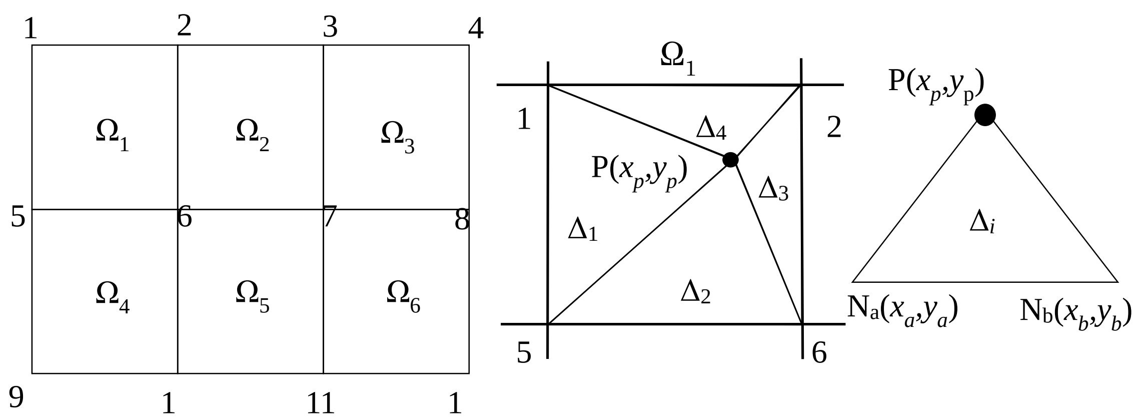


Figure 2.7. Example of set of grids used in this study. (Left): example of how several nodes and grids are used. (Center): four triangles are formed to determine whether the vessel is in that grid. (Right): example of a triangle in the grid.

vessel within each grid that it has passed through. The first step is explained as shown in Figure 2.7. In Figure 2.7 (Left), the nodes and grids (Ω) are set. Suppose P (x_p,y_p) is a location information of a vessel during the operation in a grid. In this study the triangles within a grid are used as a base to determine. The point P is automatically set to measure the closest distance with other surrounding nodes. Next, the area of each triangles are also computed in counterclockwise rotation. In this case, if the area of Δ_1, Δ_2, Δ_3 andΔ_4 are all positive, then the point P is located within the grid Ω_1. The area of a triangle ($A\Delta_i$) in Figure 2.7 (Left) is calculated by Eq. (2.3),

$$A\Delta_i = \frac{1}{2}\left[x_a\left(y_b - y_p\right) + x_b\left(y_p - y_a\right) + x_p\left(y_a - y_b\right)\right] \tag{2.3}$$

where x_a and y_a expresses longitude and in node a, x_b and y_b are longitude and latitude in node b, lastly x_p and y_p are the location of a vessel during the dredge-net operation.

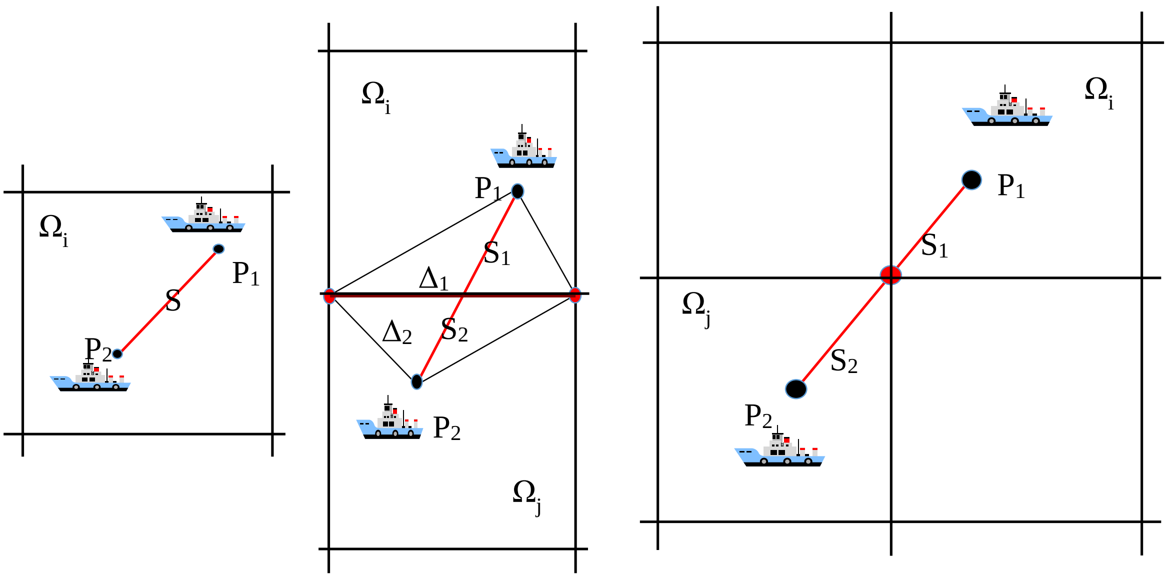


Figure 2.8. Several cases to compute the operation distance of a vessel. (Left): a vessel travel within a grid, Case 1. (Center): A vessel travel by passing two grids, Case 2. (Right): A vessel travel by passing two grids and a node, Case 3.

Next, it is necessary to measure the operation distance of the vessel within each grid in order to automatically determine whether the grid is used to calculate the resource stock index or not (the 5% rule as explained above). Presume that S is an operation distance between two location data, $P_1(x_1,y_1)$ and $P_2(x_2,y_2)$ of a vessel. The author set several trajectory cases as shown in Figure 2.8. Figure 2.8 (Left) shows Case 1 of a vessel dredged within a grid. In this case, the operation distance can be calculated as a distance of two points, which can be defined by Eq. (2.4).

$$S = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{2.4}$$

Suppose the vessel dredged by passing through two grids, Ω_i and Ω_j as shown in Figure 2.8 (Center). For this case, the distance S can be divided into S_1, which is the operation distance within grid Ω_i, and S_2 for the distance in grid Ω_j, with S, S_1 and S_2 are defined by Eq. (2.5).

$$S = S_1 + S_2 \tag{2.5}$$

On the other hand, S_1 can be obtained by Eq. (2.6),

$$S_1 = \frac{\Delta_1}{\Delta_1 + \Delta_2} S, \tag{2.6}$$

where Δ_1 identifies area of a triangle in grid Ω_i, and Δ_2 is the area of triangle in grid Ω_j. The area of triangle within the grid was defined in Eq. (2.3). After getting the distance of S_1, S_2 can be calculated by simply subtracting S by S_1. By referring to Eq. (2.5) and Eq. (2.6), the operation distance of a vessel in each grid can be derived.

Case 3 in deriving the operation distance is shown in Figure 2.8 (Right), in which a vessel dredges through one of the node. Like Case 2, the operation distance in the first grid is S_1 and in second grid is S_2. Needless to say that the rule of Eq. (2.5) is applied for this case. For this case, the area of triangle in both grid Ω_i and Ω_j are very close to zero. It means that if the triangle area in both grid are near to zero, it is defined as Case 3, and S_1 is the distance of the location data of the vessel to the node, which can be obtained from Eq. (2.4) and S_2 can be calculated by simply subtracting S by S_1.

2.8 Results of Automatic Resource Stock Index Computation

Sano *et al.*, (2011) has previously developed a method to estimate a certain extent of resource of Hokkaido sea cucumber, namely the resource stock index. The resource stock index has assisted the users to set the catch limitation. However, there are several weaknesses, such as time-consuming calculation process and high cost. In this study, the author improved the method to address those weaknesses by developing automatic catchable computation on a cloud service.

In the previous study Sano *et al.*, (2011) collected and calculated the resource stock index manually using ArcGIS once a week, and therefore, the calculation results were obtained several days after the data collection. This meant that the results were obtained after the fishing season had ended. For that reason, it was impossible to implement immediate management actions, such as reducing fishing season period. In comparison, by using the present system, the data processing could be performed automatically every three hours and almost in real-time for the trajectory of the vessels, (as shown in Figure 8). After finishing the computation, the cloud service immediately shares the results to the user through the Internet. As a result, fishermen could verify the condition during the fishing trip and between operations as well as to plan for the next operation. The next advantage of using automatic computation in the cloud service is, the cost required for such calculations was greatly reduced. Moreover, due to the fast computation process, the present system did not only calculate the resource stock index, but also allowed to calculate the CPUE of sea cucumber at the same time.

Test run for the automatic method have been conducted in Rumoi sea cucumber fishery in 2012 and 2013 fishing season. The present system was able to automatically record the entire sea cucumber fishing operation, with the total of more than 2,200 fishing operation each year. The results show that the total catch amounted to approximately 44 and 40 tons in 2012 and 2013, respectively. The estimated resource stock index was 85.5 tons in 2012 and 92.3 tons in 2013. The final CPUE score was a 27.6 kg/operation and was a 24.6 kg/operation, for the same year.

To evaluate the results of the present automatic algorithm, the same computations have been performed manually with ArcGIS using the data of 2012 fishing season. Afterward, the author examined the evaluation between the automatic algorithm of resource stock index and manual calculation. The difference between the ArcGIS estimate and that of the present method was 0.12%, which is sufficiently close for practical use. This finding indicates that the present automatic algorithm is feasible to be used for the actual fishery of sea cucumber in Rumoi.

As stated above, the computation results are shared to the user via the Internet. One of the ways is to display the computation results in a web page. Figure 2.9 and 2.10 are parts of a screenshot of the web page of information sharing that contains the dredged area and estimated initial density of sea cucumber in each grid. The system is automatically set to share the dredged area, which is overlaid on Google Maps through the Internet in real-time. Therefore, the users could check the computation results using mobile phone or other electronic devices as long as they have Internet access. In order to make it easier for the user to evaluate, several colors and percentage were used as an indicator of a possible risk of overfishing. The percentage of the area in Figure 2.9 shows the ratio between the dredged area and grid cell area. Dark and light blue are areas dredged with less than 100%, while, green, yellow, orange and red are areas exceeding 100%. The red grid cells denote the areas that have been dredged numerous times for sea cucumbers, and indicate a possible risk of overfishing.

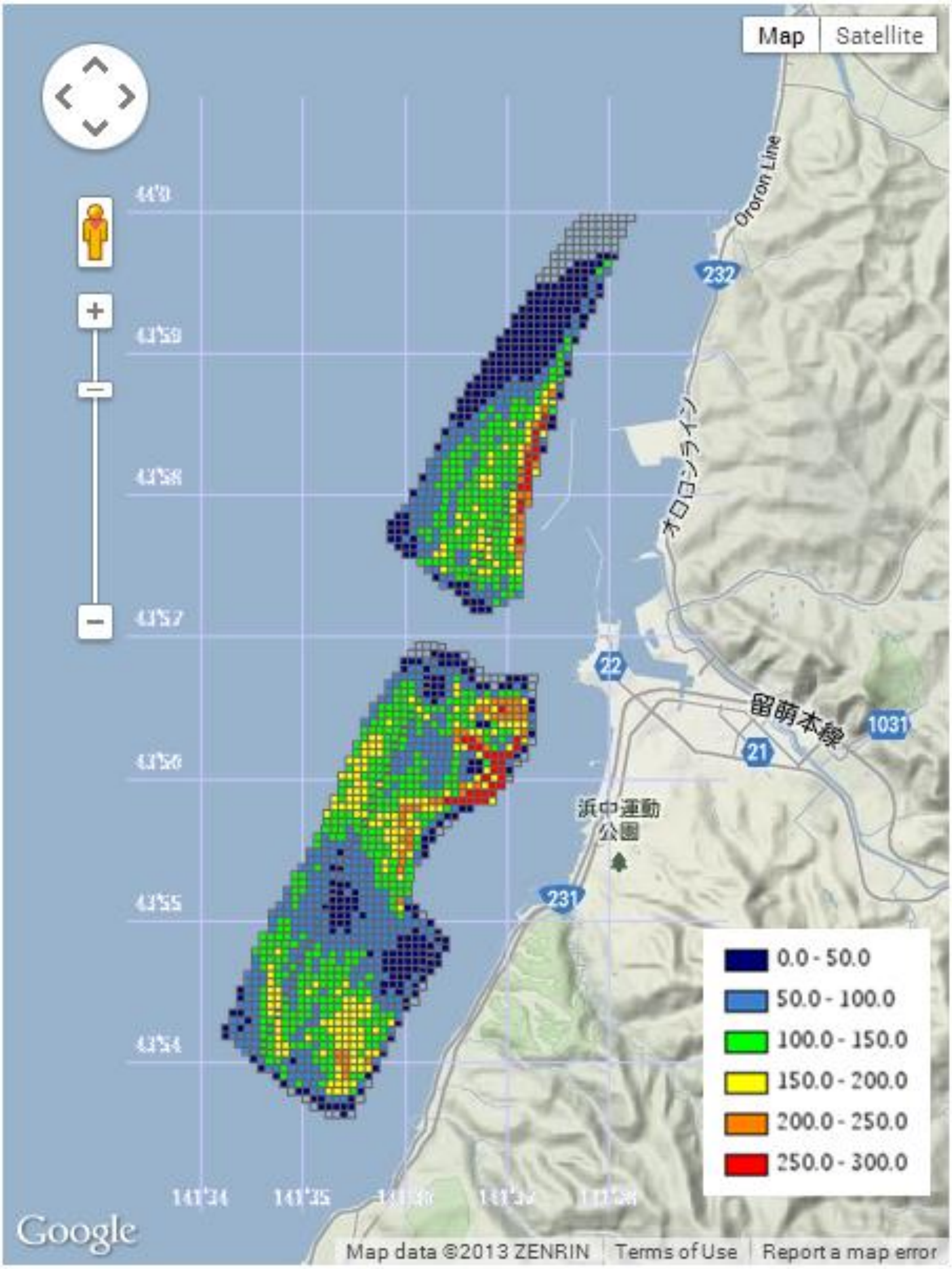


Figure 2.9. Dredged area [%] for the 2013 fishing season, overlaid on Google Maps. The percentage indicate ratio between the dredged area and grid cell area. Red grid cells indicate areas that have been dredged numerous times for sea cucumbers.

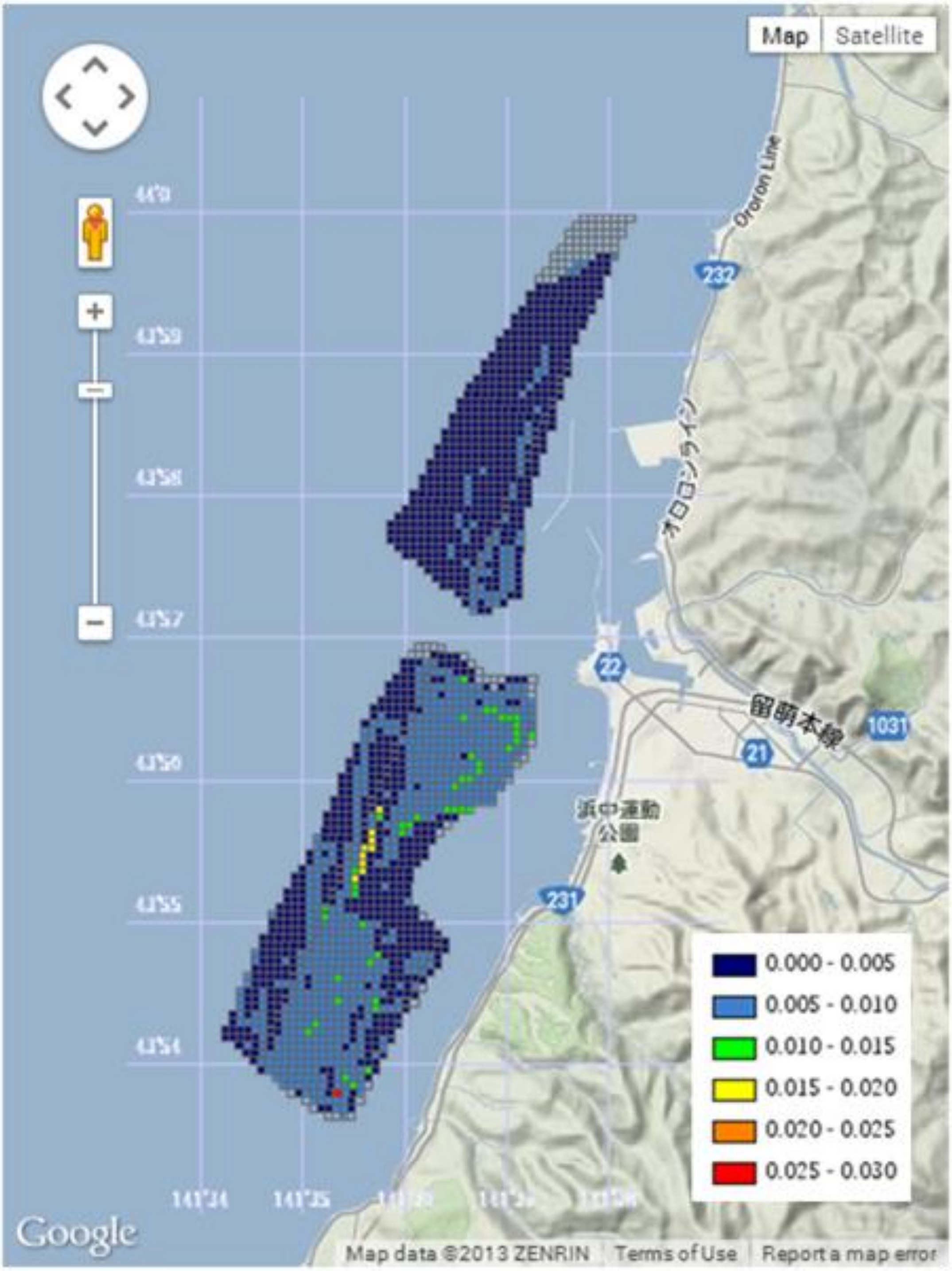


Figure 2.10. Estimated initial density [kg m-2] for the 2013 fishing season, overlaid on Google Maps.

On the other hand, the distribution of the estimated initial density on the fishing ground in the 2013 fishing season is shown in Figure 2.10. Another idea worth considering is the existence of empty grid cells in the northern parts of the fixed grids. Those empty grid cells emphasize that the fishing vessels did not dredge these areas. Those areas are not included in the estimation of the resource stock because the initial density cannot be calculated for empty grid cells. The effects of the empty grid cells are discussed in the next section.

In addition to the real-time sharing through a webpage, an iOS application, so called the marine PLOTTER (Figure 2.11) has also been developed so that the users could easily understand the computation results by checking their iPad. The marine PLOTTER receives data from a cloud computing system and displays the trajectory of the entire fishing fleet in almost real-time. Besides, the automatically updated dredged area in each grid cell (as also shown in Figure 2.9) is overlaid as the background layer. The users used this application during the operation to check the results of the automatic computations and share them with others. As shown in Figure 2.11, the header of the app shows the name and location of the selected vessel, date, time, longitude, latitude, direction in degrees and speed of the vessels in knots.

As stated above, the present system allowed data sharing of sea cucumber resource stock index, CPUE and map of the trajectories with the users in almost real-time via the Internet. That condition enabled the users to monitor the daily fishing operations. In order

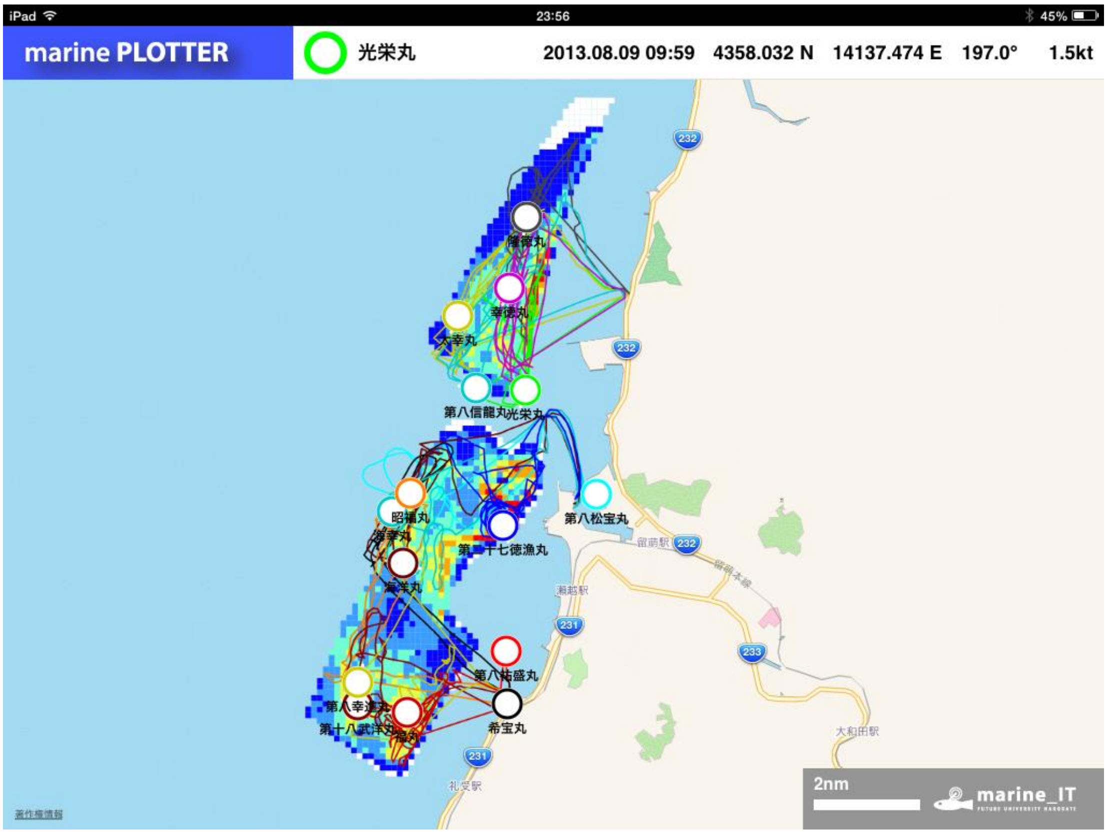


Figure 2.11. Screenshot of marine PLOTTER, which shows the real-time trajectories and dredged area, on an iPad on August 9, 2013. Source: Wada, 2013.

to discuss and evaluate the catch status, the users had a meeting once a week. During the meeting, they always referred to the present system, i.e., digital diary, CPUE, catch amount, resource stock index, dredged area and estimated initial density. As a result of their meeting, they decided to end the fishing season several weeks earlier (20 days earlier in 2012 and 22 days in 2013) than the initial schedule to avoid overfishing. The evidence shows that the present automatic scheme provided a useful information for supporting the decision making in self-management of sea cucumber fishing.

2.9 Grid Size Assessment in the Swept Area Method

As previously mentioned that the areas of the fishing ground and grid size are both important factors in determining the accuracy of resource stock index computation. In the previous study (Sano *et al*., 2011), it was not possible to evaluate the grid size on manual computation process due to the time-consuming computation process and high cost. Then the grid size of 100m was empirically selected because the variance of density of the resource stock index was sufficiently small. Yet, it was not a sufficient evidence to show that the grid size was adequate since one could not compare the variance with other grid size. With this in mind, an analysis is required to determine the validity of resource stock index as well as the adequateness of grid size in this study.

In comparison to the previous study in which calculations using several grid sizes were not possible, in this study, it is possible to freely select the grid size due to the fast and low-cost computation. Next, the author examined changes in the resource stocks index using 2012 data based on various grid sizes: 25, 50, 100, 200, 400, 800 and 1600m. Table 2.1 shows the results for each case, and the index n_s is defined as,

$$n_s = \frac{A_s}{\Omega_s}, \tag{2.7}$$

where s is the grid size, A_s is the total dredged area, and Ω_s is the total grid area on the fishing ground used in the estimation.

Figure 2.12 shows a graph of the resource stocks index (expressed as a black dot) and variance of density (expressed with an x-mark) that are shown in Table 2.1. The dotted line in Figure 2.12 is the result of a linear regression, and it shows that the estimated resource stock has a positive correlation with grid size (R^2 was 0.99 in this case). In other word, the computation of the resource stock index increased along with the grid size because of an increase in the initial density. Nevertheless, the variance decreased with increasing grid size. An interpretation of the facts indicates that, although the variance in the initial density was relatively small, sufficient evidence was not found to show that the grid size was adequate. Consequently, the validity of the computation is still to be established.

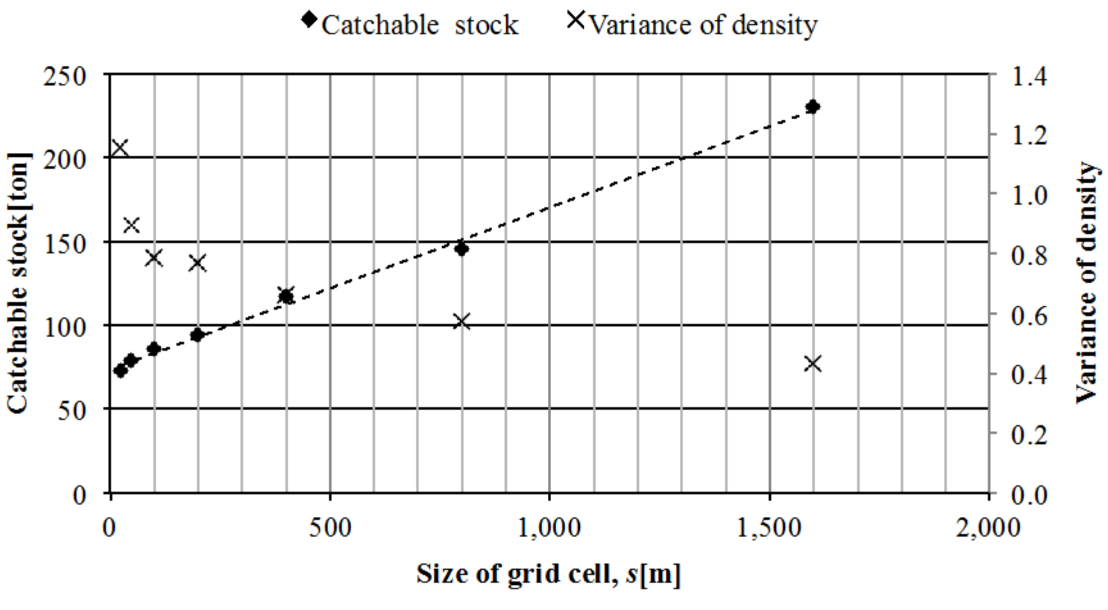


Figure 2.12. Comparison of resource stock and variance of density estimates for each grid size.

Table 2-1. Comparison of 2012 fishing season estimates using several grid sizes.

Grid size s [m]	Initial stock [ton]	Average Density $\overline{D}_j$ [g m^{-2}]	Variance of density	Grid area Ω_s [m^2]	Total dredged area ΣY_{js} [m^2]	Index n_s [%]
1600	229.7	3.620	0.428	51,200,000	19,161,677.85	37.43
800	145.5	3.477	0.574	30,720,000	18,279,144.10	59.50
400	116.8	3.477	0.660	23,680,000	17,687,384.75	74.69
200	94.0	3.425	0.764	19,760,000	17,123,381.82	86.66
100	85.5	3.378	0.783	17,870,000	16,694,001.18	93.42
50	78.6	3.342	0.893	17,870,000	16,669,043.09	93.28
25	72.3	3.362	1.151	17,870,000	16,561,317.26	92.68

The distribution of the index n_s with changing grid size followed a bell-shaped curve (Figure 2.13). The peak of the curve occurred at a grid size of 100m. From the values of n_s, the characteristic length of the fishing operations was determined, and found to be dependent on the movement of the fishing vessels. Since the velocity of the vessels during the operation in this fishery was approximately 1 to 1.2m/s, with 10 seconds sampling duration, the vessels moving 10 to 12m during each data sampling period. If the characteristic length was 12m, for example, then a grid size of 1600m would be too large and 25m would be too narrow. For at 1600m grid size, n_s would be small because the grid was too coarse. Consequently, interpolation would result in an overestimation, which is why the computed resource stock index increased with a wider grid. On the contrary, if the grid was too narrow, the number of empty grid cells (where no information was collected because no fishing vessels passed through) would be large. Before moving

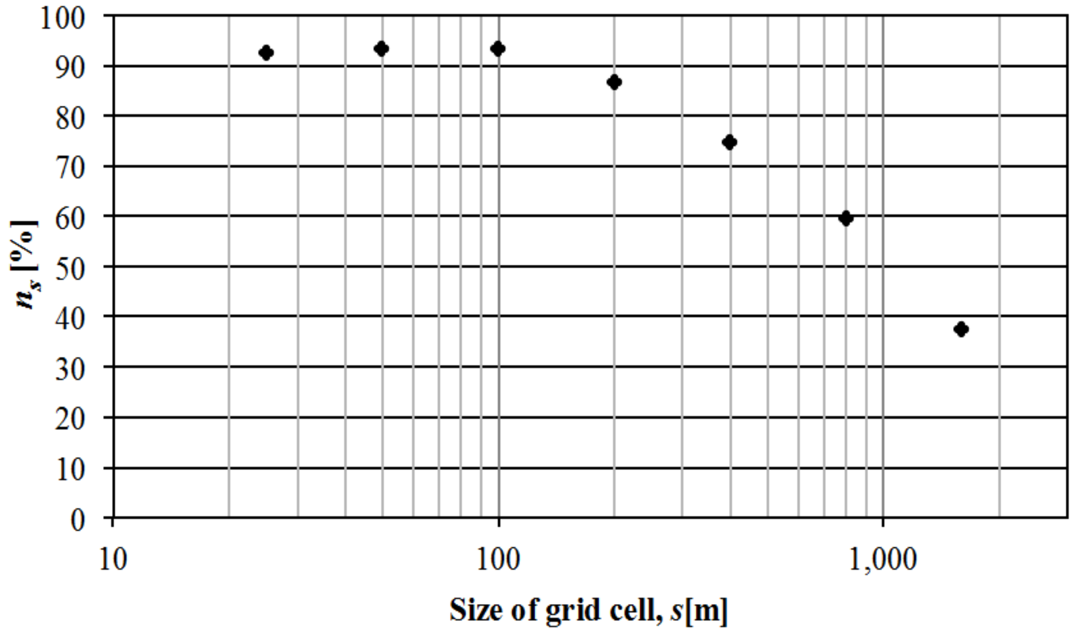


Figure 2.13. Values of an index of dredged area for different grid sizes.

on, it should be pointed out that the fishing vessels tended to be concentrated in several areas, and there were empty grid cells (Figure 2.9and 2.10). The initial density of an empty grid cell was zero, so it was not used in estimating the resource stock index, which is why the estimated resource stock decreased with narrower grids. The author found that the appropriate grid size was dependent on the characteristic length of the vessels' movements, and it was best to have n_s as large as possible. As a result, 100m grid size was the most adequate in this study, see Table 2.1 and Figure 2.13.

2.10 Impact of the Present Data Sharing Scheme to the Resource

Sano (2015) reported the impact of the present data sharing scheme for sea cucumber resource in Rumoi. Figure 2.14 shows the trend of catch in black white diagonal pattern, resource stock index in light grey color and sea cucumber remainder in dark grey color. The remainder in this study is gained from subtraction of resource stock index and catch. As shown in Figure 2.14, the initial resource stock was decreasing from 2008 to 2011, before the system was applied the fishermen did not notice the overfishing. But since 2011 the resource information has been shared among fishermen and they became aware of the risk of overfishing. The awareness influences the decision making of fishermen themselves. Firstly, as written above, they monitor the catch status and resource stock index, have a meeting periodically and voluntarily, shortened the fishing duration during the fishing season. Secondly, the fishermen and fishery associative decided to reduce catch quota limit. In particular, before the present system was applied, they decided to limit the catch quota to be 5tons, but now they limited it to be 3tons each vessel. Next is the changed the catch limit size of sea cucumber. Previously, they allowed themselves

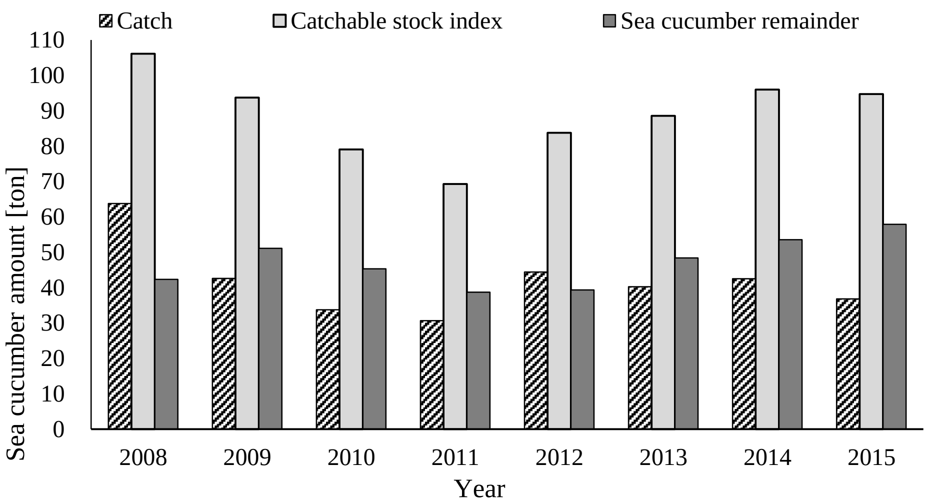


Figure 2.14. The impact of the present system to resources of sea cucumber in Rumoi. Source: Sano, 2015.

to catch sea cucumber that exceeds 100g, but now they decided to be 130g.

The awareness stated above has resulted the increase of resource stock index of sea cucumber in the period of 2011 to 2014 and has started to achieve a stable condition of resource at around 90 to 100tons since 2014. Another important point is the sea cucumber remainder in Rumoi coastal area. During the increasing period of resource, the average of remainder during the increase was 48tons. In other word, it is better for the fishermen in Rumoi to at least keep 48tons of sea cucumber remainder to maintain the resource in the following years and to avoid overfishing.

2.11 Remarks of Chapter 2

In this chapter, a development of an automatic system to support self-management in coastal fishery by applying ICT and data sharing scheme has been presented. The study showed that the present system could address the weaknesses of the previous research. Specifically, the cost required for such calculations, such as time and energy, were greatly reduced by utilizing automation in the cloud service.

During the test run in sea cucumber fishing in Rumoi city, Hokkaido, the automatic computation results were provided to the fishermen via the internet each day during the fishing season. Because of that, fishermen and fishery cooperative enabled to perform a self-management system, namely, check the state of their operations immediately. By referring to the present system, they voluntarily decided to stop the fishing season several weeks earlier than scheduled in both 2012 and 2013. Besides, the present system also made a good impact to the sea cucumber resource. It can be concluded that the present automatic algorithm provided useful information for supporting the self-management of this coastal fishery.

In order to check the validity of resource stock index proposed in this chapter, a range of grid sizes were investigated to examine their adequacy in application through an index. The examination of grid sizes were enabled due to the fast and low-cost computation. The index defined in this study shows the importance of the ratio of the area of a grid cell to the total dredged area.

Chapter 3 The Development of Catch Estimation Algorithm toward Real-time Monitoring to Support Fishing Efficiency of Set-net Fishery

3.1 The State of Remote Monitoring for Set-net Fishery

Set-net (Teichi-ami) is one of the major catching methods in Japanese coastal fishery (Akiyama, 2012; MAFF, 2013) due to its sustainability (Arimoto *et al*., 2007; Akiyama, 2012). 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 haul condition after arriving at set-net area. Due to such condition, the fishermen tend to unable to perform the fishing operation effectively. In other word, the fishermen cannot predict the cost needed for the operation such as the ice, labor, petrol and other cost. Consequently, they come to the set-net area with uncertainty and there are possibilities to suffer the lost. This can be seen when the fishermen come to the set-net and only catch a few fish at a low price, they will suffer from the lost because the cost spent might exceed the sales from the catch. 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, petrol and labor cost, along with extra effort. In order to avoid such condition, real-time monitoring of trapped fish within set-net is needed.

One of most important issue for the effective fishing is the petrol cost. Table 3-1 shows the data record of petrol consumption by a vessel for set-net hauling in September to December 2014. The table contains the relation between catch amount, engine operating time and petrol consumption. Roughly, the catch per 1 liter of petrol was 50kg. Yet, in November it was two times bigger, the haul was 100kg per 1 liter of petrol. It points out that the operation could be done more effectively. For instance, October and November had the same 30 days of hauling operation but the petrol consumption were very different. There are two possibilities of such kind of condition. The first one is there were several days with a little amount of catch but the fishermen still went to set-net to haul the fish. Another possibility is that there were several days with a lot of catch amount but the fishermen did not well prepared so they needed to go back to the port and do the operation a couple of time in one day. In other word, several unnecessary trips were likely occurred.

Table 3-1. The petrol used in September to December 2014. Source: Wada, 2015

Item	September	October	November	December
Catch[ton]	55.9	125.3	364.9	112.7
Engine operating time[hour]	55.5	113.6	181.3	116.8
Petrol consumption[l]	1,122	2,306	3,467	2,362
Number of operation[day]	22	30	30	24
Average engine operating time[hours/day]	2.52	3.78	6.04	4.87
Catch per 1Liter of petrol[kg]	49.8	54.3	105.2	47.7

Another point worthy of consideration is the catch record if a set-net to be compared with the petrol issue. Figure 3.1 shows an example of frequency of 2011 to 2014 historical catch record in a set-net in Shizuoka site. The catch amount of a set-net of the haul operation were below 1ton. Moreover, approximately one third of them were less than half of ton. It means most of the operation only a small number of fish amount were caught. There is a possibility of loss in such kind of situation because the cost, especially petrol, could exceed the sales of the hauled fish.

By conducting the real-time monitoring and numerical estimation for the fishermen, they can make a better decision-making. For instance, when there is only a little catch amount, they do not need to go hauling and they can simply save the petrol cost. Besides, they can save the energy and effort to do another thing. On the contrary, when there are

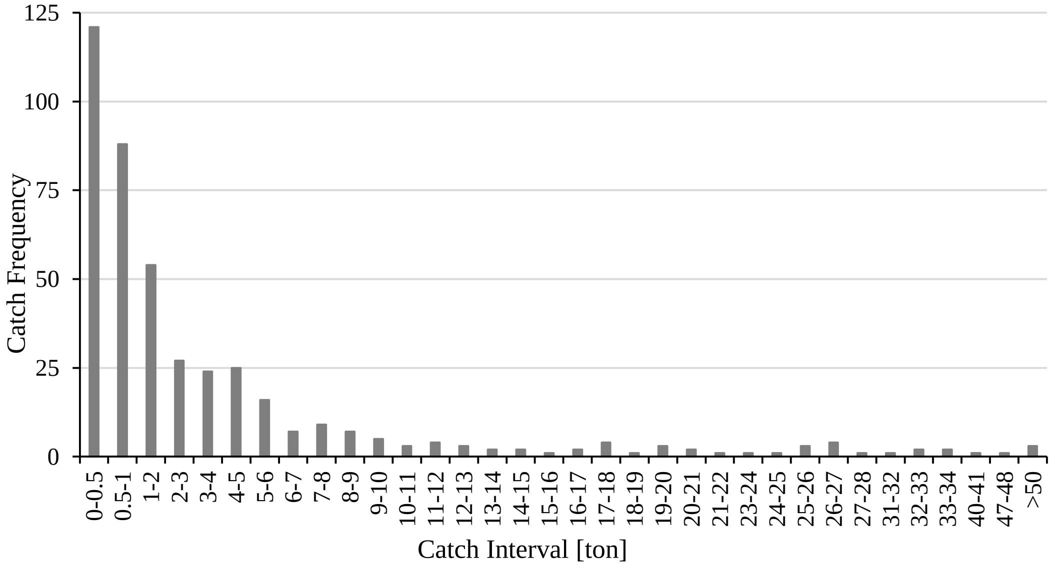


Figure 3.1. History data of 2011 to 2014 catch frequency in a set-net site.

a lot of fish trapped in the final trap, fishermen need to prepare more so that they do not need to do the operation for a couple of time. In short, there is a possibility to support the decision making of fishermen to save the petrol cost.

There are various type of set-net employed in Japan, yet, the most popular set-net at the present time is *Otoshi-ami* type (Akiyama, 2012; MAFF, 2013). Set-net is formed by frame rope and sinker. Set-net is generally composed of three main parts as shown in figure 3.2. The first one is leader net for leading fish into the pound net. The second part is impounding net, an area that prevent fish from escaping and also to make them swim toward the final trap. And the last part is the final trap, where the fishermen haul the fish. In order to monitor the hauling condition of a set-net, an equipment is usually installed on the final trap so that fishermen know the hauling condition in advance.

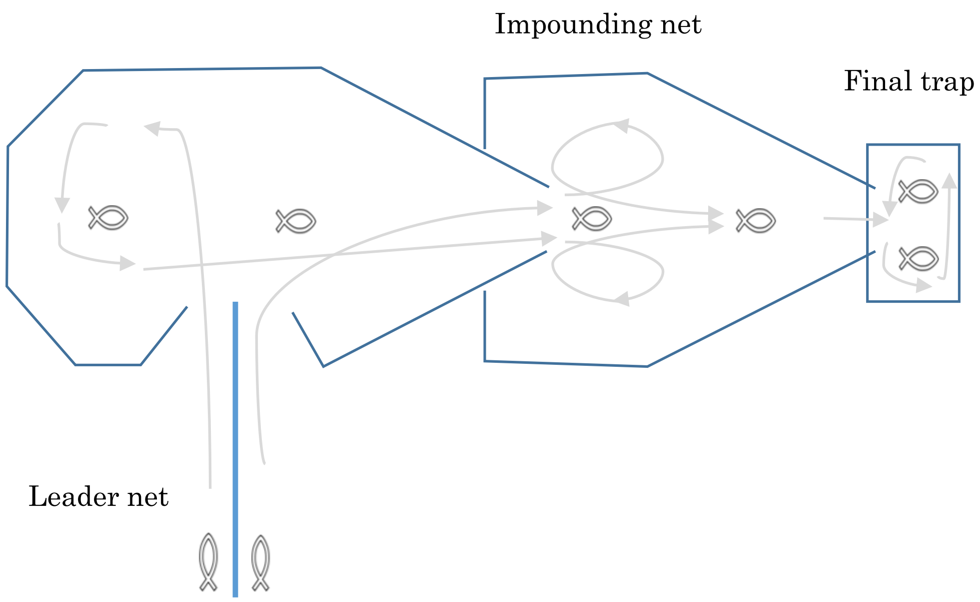


Figure 3.2. Sketch of *Otoshi-ami* set-net. The light grey arrows show fish swimming direction.

Optic and acoustic instrumental system have been used in order to improve the efficiency of set-net fishery. For instance, radio transmission system for underwater image (Akiyama *et al.*, 2003), mobile phone networks transmission systems for transmitting underwater video camera pictures (Ishiguro *et al.*, 2003; Akiyama, 2007) and so on. However, those optical system does not penetrate more than a few meters below the water surface in the sunny day time. Therefore, acoustic instrumental such as sonars and echo sounders which transmit and receive sound waves can be used to detect fish or other object far beyond the range of human vision (Simmonds and MacLennan 2005). The most extensively used acoustic equipment for set-net monitoring system is a VHF equipment developed several decades ago (Hashimoto and Maniwa, 1964; Kato *et al*., 1964).

In japan, conventionally, set-net monitoring system has been practiced using a VHF equipment. The transducer of the conventional equipment is set on the final trap of set-net and the echogram data is sent to a display ashore with 40 MHz radio frequency (Hashimoto and Maniwa, 1964; Kato *et al.*, 1964). The cathode ray tube (CRT) display and a thermal printer printing device were used for displaying the echogram data from the equipment as shown in Figure 3.3. Figure 3.3 (Left) shows a thermal printer and the right one shows CRT display. In an interview with set-net fishermen in 2014, they stated that in fact, it is important to set the transducer at the entrance of final trap. However, when the fishermen want to set two of them, two set of display devices are needed, and obviously the cost will be doubled.

Figure 3.3. Data display devices for conventional equipment. (Left): Thermal paper printing device. (Right): CRT display of fish intensity. Source: Yasui, 2014.

Although the VHF equipment are extensively used, 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, such as the battery, which also requires a lot of effort and 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, as shown in Figure 3.3. It 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. The data storage is also a problem of a paper based data because it requires a lot of space. Besides, the historical data is difficult to be analyzed. In addition, the conventional equipment only allow one to see the reflection intensity and does not allow one 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.

The estimation in primary industry from image data series has been conducted for years. Saville and Hatanaka (2013) reported the algorithm to estimate the paddy field by using satellite image. The algorithm itself was conducted by deriving the numerical value from the images data series, then determine the characteristics of the data series through minimum, mean and maximum value. After that, the statistical method was carried for estimation and classification. Moreover, the fishermen generally did the empirical estimation based on their experience when they were observing the information from the mentioned conventional equipment (Figure 3.3). They also predicted the catch amount and fish species by observing the characteristics of reflection intensity. Specifically, the reflection intensity in certain depth of the water and the sea bottom reflection. Because they empirically understand that when a large amount of fish are trapped, the sea bottom will not be reflected. While fish species are usually predicted from the depth where the fish swim, because the fishermen perceive that certain kind of fish usually swims in a certain depth in a certain time or season. Based on those ideas, an algorithm of computerized empirical estimation is possible to be established.

The aim of this chapter is to develop an algorithm of catch amount estimation and to classify the fish species within set-net from computerized empirical estimation as the part of real-time remote fish finder system. The remote fish finder system is developed in order to reduce the cost of set-net fishery by providing the estimated results to the fishermen via the internet in real-time. This study will be focused to improve fishing efficiency of set-net fishery through a sufficient accuracy for practical use, rather than the precision of the resource estimation.

3.2 Experimental Site

In order to develop the catch estimation algorithm, the author cooperated with several set-net fishermen for conducting the experiment. The experiments for this study are conducted in the coast of Hokkaido, Toyama, Shizuoka and Mie Prefecture (as shown in Figure 3.4, 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 from Hokkaido and from Toyama prefecture. The first experiment has started from the end of June, 2013 in Hokkaido region. The experimental site in Hokkaido is operated from April until December, yet, currently, only a few data is available in this site. The currently available data is from November 20 to December 19, 2013. After conducting a test run in Hokkaido, later on, the remote fish finder is installed in Toyama, Shizuoka and Mie. The site in Shizuoka operated in the whole year, but the real catch records is not available yet. The site in Mie, meanwhile, is not operated. It means the model of catch estimation for those experimental sites cannot be developed. Therefore, in this chapter author only discuss the development of catch estimation algorithm by using the previous Hokkaido records and Toyama.

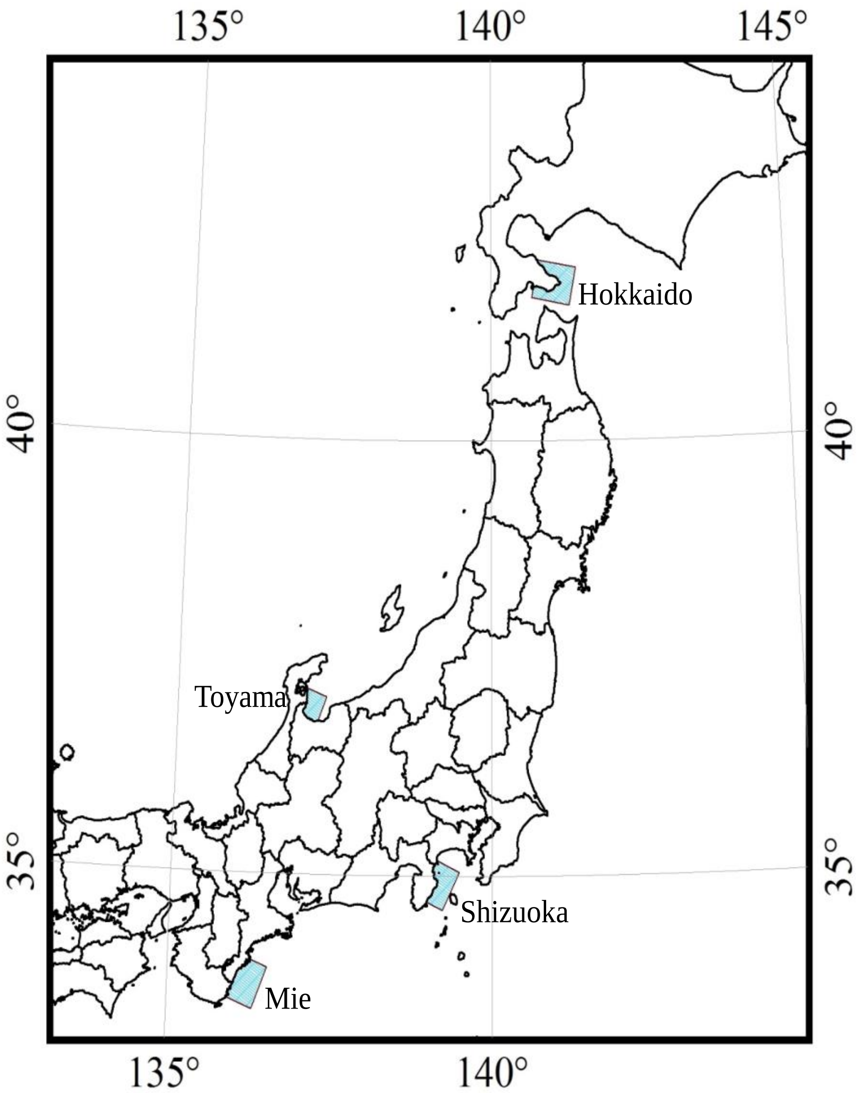


Figure 3.4. The experimental sites in Hokkaido, Toyama, Shizuoka and Mie Prefecture, which are located within the blue shaded part.

Currently, the remote monitoring system has collected the real catch in Toyama site from April 24th until 18th of July, 2015.

3.3 Remote Fish Finder System

The remote fish finder system is developed as a collaborative research with Hakodate Future University and Koden Electronics Co., LTD. The remote fish finder system is constructed by ultrasonic fish finder for observing school of fish; cloud server for storage, distribution and analysis of observational data; and iPad application for data display. The remote fish finder in this study use a floating echo sounder on a raft, which is constructed by a control board, communication antenna and marine battery. The raft is floating outside the final trap of set-net so as not to disrupt the fish hauling process (Figure 3.5; Figure 3.6).

In this study two types of floating raft are used. First, Figure 3.5. (Left) shows the raft in Hokkaido site, and the (Right) shows the buoy in Toyama site. The transducer is suspended to a depth of approximately 50 cm from water surface inside the main trap using a small float. The cable length of a transducer is 100 m, and one control board can be connected with two transducers. Based on the interview with the fishermen, they stated that they need to monitor in at least two spots within the set-net. First, transducer in the final trap is the one that mainly utilized to monitor the set-net condition and estimate the catch amount along with fish species. The other one in the entrance is utilize to monitor the fish that run away. Therefore, in this study, the floating fish finders are placed in those two spot, as shown with the red stars in Figure 3.6.

Figure 3.5. Picture of the floating fish finder under the experiment. (Left): shows the raft in Hokkaido experimental site. Source: Wada, 2014. (Right): shows the modification of the raft to be a buoy, which is installed in Toyama site. Source: KODEN, 2014.

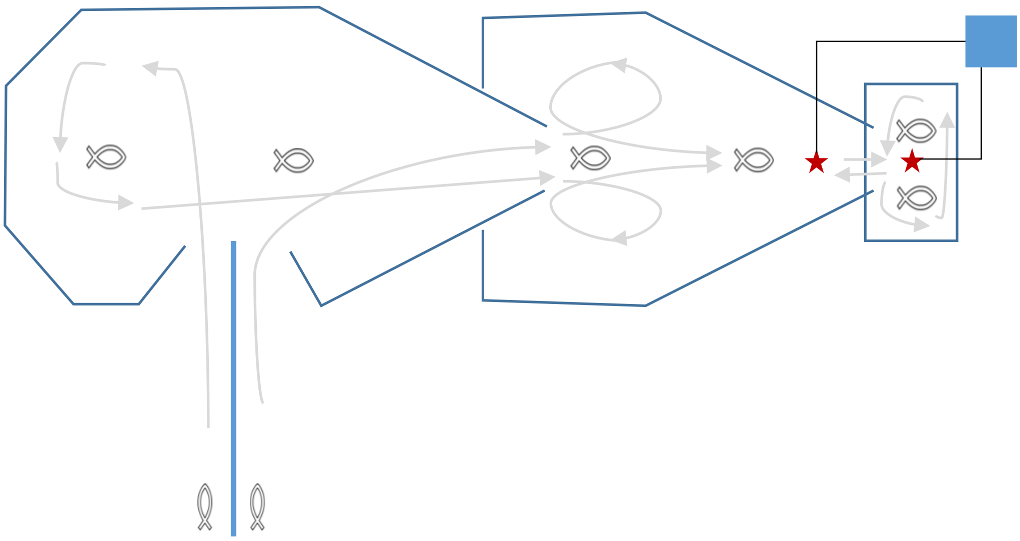


Figure 3.6. The installment place of floating fish finder. Red stars indicate transducers, blue rectangular is the raft and black line is the cable.

The control board is constructed by analog and digital section. Analog section performs data reception and transmission of ultrasonic wave. The analog data is afterward converted into digital data by the A/D converter in the CPU. The spatial resolution in this study is split into 320 parts. In case of 80m water depth, reflection intensity for each 0.25m spatial resolution (depth) is possible to be obtained. While, resolution of reflection intensity is divided into 256 levels. Digital section performs control of data reception and transmission of ultrasonic wave, as well as uploads the acquired data to the cloud server. The control board is equipped with a mobile phone communication module so the Internet connection is enabled through packet data, then the acquired data is uploaded via SMTP.

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 uploads 20 sets of the acquired data. Since the maximum depth of the area where the set-nets are installed is 70m, the transmitting power of the floating echo sounder can be set to 16W. Due to such kind of power saving, the 12V-160 Ah marine battery can be operated for a long term (for approximately three months). The low electricity is a very important for set-net monitoring system because fishermen mentioned that they must replace the battery of the conventional equipment once in a couple of week. By setting into a low electricity, it makes several times longer. Yet, low electricity setting comes with a limited frequency of transducer. The next challenge is to build an estimation model from the limited data. This chapter presents the estimation model from a limited data source.

In this study, iPad application was developed in order to meet the need of displaying the echo sounder data in real time. The application is connected to the server, hence allowing to display reflection data from the experimental site in real time. The user interface of iPad application in this study is shown in Figure 3.7. The screen of the iPad application is divided into two parts, the upper and lower, so that the echo signals of two transducers can be displayed simultaneously. The upper part of data displays echo signal in the main trap of set-net, while lower part displays echo signal in the entrance of main trap. There are buttons for screen capture, data reloading and time setting. By using the application, the fishermen can display the data with the iPad application at any time and from anywhere.

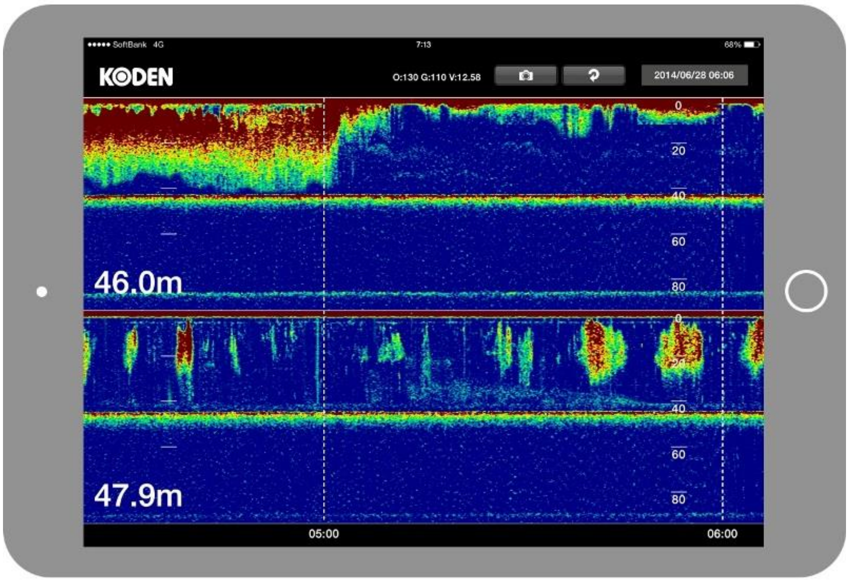


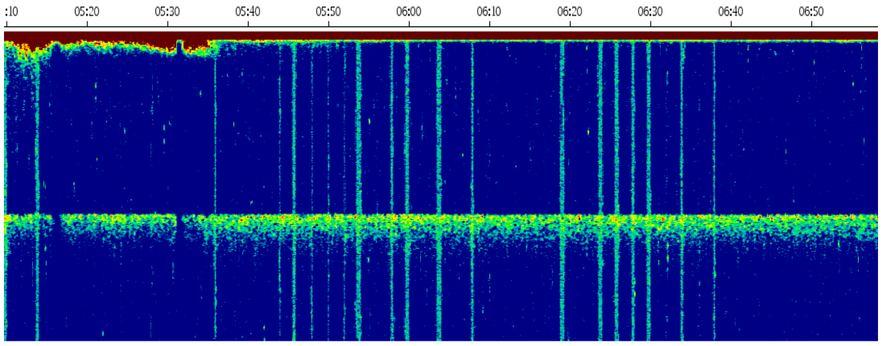
Figure 3.7. User Interface of iPad application for data display. Source: Yasui and Wada, 2013.

3.4 The algorithm of Catch Amount Estimation

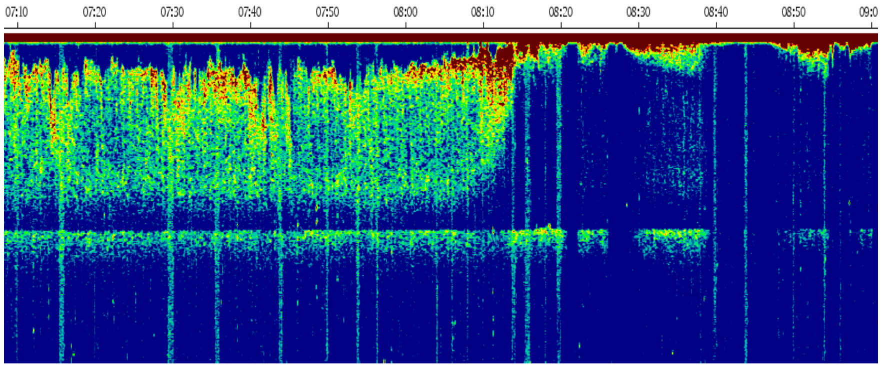
3.4.1 Characteristics of reflection data record in Hokkaido site

Each fish kind has its own habit and its characteristics, such as making a colony in a certain depth or will move toward surface of swim in a certain depth during after sunrise and so on. In the last one month of experiment, the records of catch amount and captured fish kinds within the set-net were collected from the fishermen. By analyzing the relationship between those records and reflection data, the fish characteristics could be grasped. Based on those characteristics, the value and pattern of reflection data will differ. It may be possible to estimate the catch amount and fish kind through the reflection pattern.

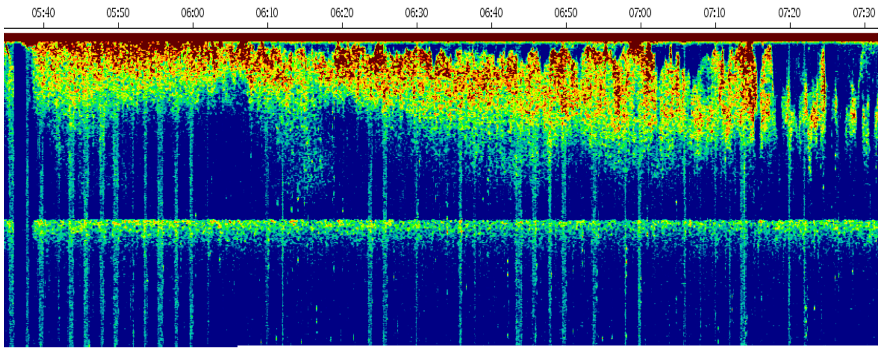
Figure 3.8 show the characteristics of reflection data on several fishes during the experiment in Hokkaido site. In Figure 3.8 (a), fish finder could not capture the signs of fish even during a 23 ton squid catch. While in (b), the signs of fish filled the waters in a broad area of waters before sunrise, and the fish moved toward the surface after sunrise during a 210 ton sardine catch. During a 13 ton of mackerel catch, the signs of fish in (c) also filled the waters depth up to a certain depth but they did not move toward the surface even after sunrise. As also shown in Figure 3.8 (b), the sounder value in sea bottom became small when a large amount of fish was gathering in the surface. Thus, the reflection value of sea bottom is also an important factor for the estimation. Fish kind in a set-net may be distinguished by the characteristics of fish swim in a certain depth in a certain season or time. On the other hand, catch amount may be estimated through the intensity of reflection data in each layer depth.



(a). November 28, squid 23 ton



(b). December 5, sardine 210 ton



(c). November 21, mackerel 13 ton

Figure 3.8. Example of the characteristics of several fishes that reflected in time series data before and after the sunrise. The colors, except blue, indicate the ping value.

Before moving to the development of estimation algorithm, it is necessary to do the data selection as the variable indicator. The selection of indicators, by dividing the waters into several layers depth, decide the ping data series at a specific time and statistical information of those selected ping value. In order to ensure that there is no data lost and to distinguish characteristics of the different group of fish swimming in the set-net in a certain depth at the same time, the ping value are divided into several layers depth, i.e. 0 to 10 m, 5 to 15 m, 10 to 20 m, 15 to 25 m and so on until the depth limit (50 to 60 m). Sunrise was selected as the specific tin this study, i.e. mean ping values of each 5 or 10-minute interval from 3 up to 6 A.M. That period of time was selected based on the interview with the fishermen that several kind of fishes usually move, toward the surface or to a certain depth, because of the appearance of sunrise. The empirical statement of fishermen can also be confirmed in Figure 3.8. After that, basic statistical information, namely mean, maximum and minimum value during 3 up to 6 A.M in each layer depth were utilized to extract the characteristics of reflection data.

3.4.2 The first attempt to develop the catch amount algorithm using Hokkaido data

The catch amount of within the set-net could be estimated by a linear multi-regression analysis based on fishermen's empirical estimation. Selected data in different layers of water depth were used to determine the intensity of reflection data. In this study, multiple regression analysis (MRA) is determined by Eq. (3.1),

$$y = c_0 + \sum_{i=1}^{m} c_i x_i , \tag{3.1}$$

where y [ton] indicates the estimate of catch amount, c_i is coefficient in i-th layer depth, yet, the intercept (c_0) is set to zero to avoid negative estimation. While m is number of layer depth and x_i is statistics of sounder value in i-th layer depth.

Various examination of MRA have been conducted using combination of layers depth and statistics of sounder value. The best result in this study was obtained by using the maximum value of the entire overlapped layer depth (0 to 10 m, 5 to 15, 10 to 20,..., 40 to 50 m) and the minimum value of sea bottom (45 to 55 m and 50 to 60 m) in five minutes interval of time, with multiple $R^2 = 0.89$. Regression analysis result indicated the significance level (α) of maximum value of 20 to 30 and 25 to 35 m layer depth was 0.05, 15 to 25 m was 0.01, and minimum value of 50 to 60 m was 0.001, respectively. It points out that the layer depth from the surface to 35m and sea bottom were very important indicator for estimating the catch amount. Sea bottom are not reflected when a large amount of fish trapped in a set-net, as shown in Figure 3.8 (b). In order to check the autocorrelation in the residuals from this regression model, Durbin-Watson (DW) test was computed. DW statistics was found to be 1.51, while p-value was 0.02, so the autocorrelation is likely positive. The autocorrelation was occurred because when a large amount of fish move toward the surface, the bottom will not able to be reflected. That circumstance is resulting correlation between sounder value on the surface and in the bottom of the water. Such kind of phenomena was regarded as a matter of course, therefore, the autocorrelation does not affect the results of this model.

Results of the comparison between real and estimated catch amount in one month experiment started from November 20 to December 19, 2013 is shown in Figure 3.9. The bars show real catch record, meanwhile, line shows estimated catch record. Missed estimations were found in the first one week period of experiment due to the occurrence of bycatch of squid, mackerel, sardine and other fishes. The catch between in November 28 to December 7 were sardine dominant catch, and the last few days of experiment were mackerel dominant catch. The similarity of real catch record and estimated catch amount was examined through Pearson's-R correlation. The correlation during bycatch was -0.23, while during the single dominant catch was 0.95. The result identifies that the catch of single dominant fish could be estimated better than during bycatch using this algorithm.

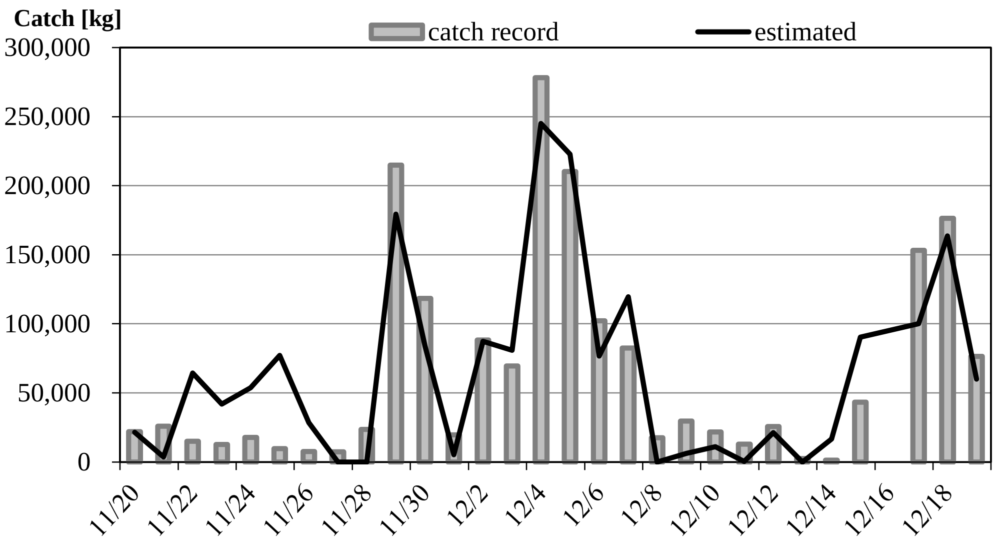


Figure 3.9. Comparison of estimated catch amount and real catch record in one month experiment

3.4.3 Selection of ping data for parameters

In the previous section the author has explained the development of catch amount algorithm using Hokkaido sampling data. 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. Therefore, in this section, the main objective is to discuss the development of a more accurate catch estimation algorithm based on our previous section. The accuracy improvement is developed by applying pre-processing transformation of real catch record, as teacher data for MRA to make the data more statistically normal distribution-like.

In the previous section, the author selected the data of three hours before 6:00 A.M as the time of fishermen went to haul 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 hauling several hours earlier than 6:00 A.M. and vise 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 hauling habit of set-net fishermen in each place, in difference seasons, for instance, the time of fish hauling. In order to solve the problem, a sensor network platform, called microCube (Wada *et al.*, 2008, the same sensor network as shown in figure 2.3) is introduced 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 automatically 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 data is enabled due to the availability of SIM card in microCube.

During the interview with the fishermen in spring 2015, as soon as they turn the engine on, they will go to set-net to haul the catch. By introducing the microCube in the fishing vessels, it is possible to detect the trajectory of the vessels and hauling time automatically. Then the time boundary for selecting parameters data is identified 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 hauling. Continuing on, the ping data of several hours before the fish hauling is selected as the parameters to estimate the catch. Figure 3.10 shows the example of speed of the vessel in Toyama experimental site in May 2015. Based on that, it can be seen that the fishermen habitually turn the engine on at around 3:20 A.M., leave it for a 5-minute idle and then get moving to the set-net. Moving in sequence, they arrive in set-net and haul the catch at around 4:00 A.M. After hauling the catch, the fishermen go back to the port.

The remote monitoring system also indicates that the hauling time in Toyama was at 4:00 A.M. (Figure 3.11). With this in mind, the ping data from 0:00 A.M. to 3:50 A.M. is selected as parameters in Toyama.

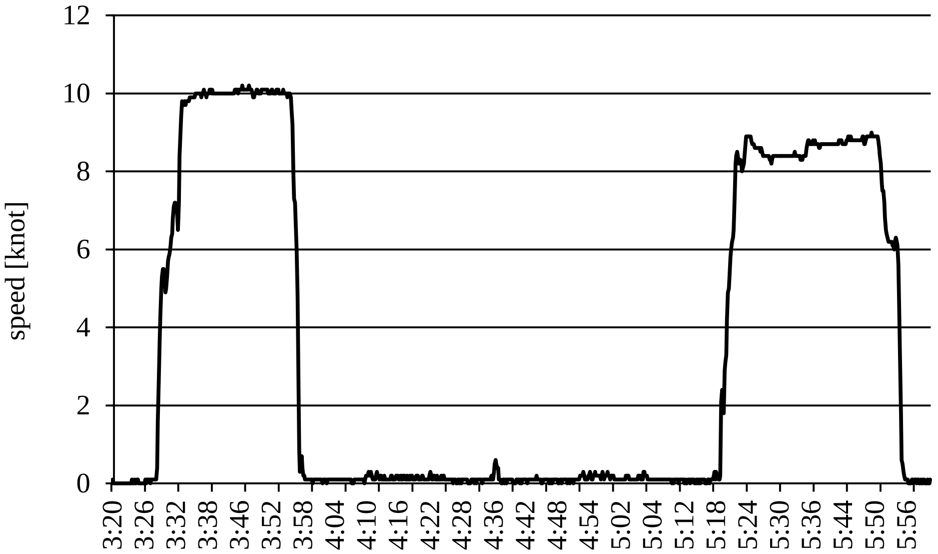


Figure 3.10. Example of speed of the vessel in Toyama experimental site in May 2015.

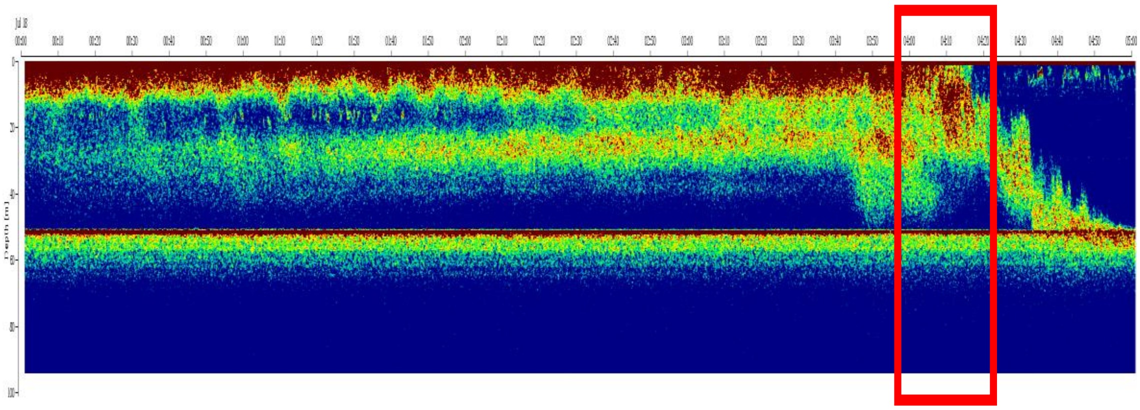


Figure 3.11. The Toyama Ping data series (0:00 A.M. to 3:50 A.M.) that is selected for parameters on 18th of July, 2015. The fish hauling activity was done by the fishermen at 4:00 A.M is indicated by red rectangular frame. The longitudinal direction shows water depth, whereas lateral direction is time.

3.4.4 The algorithm of catch amount estimation by applying Box-Cox Transformation as the pre-processing sample data

As noted above, 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, the author applied pre-processing transformation of real catch record, so that the catch record is more appropriate to be teacher data of MRA.

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

$$z_n = \begin{cases} \left(y_n{}^{\lambda} - 1\right) \big/ \lambda, & \lambda \neq 0 \\ \log\left(y_n\right), & \lambda = 0 \end{cases} \tag{3.2}$$

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. 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, it is necessary to return the MRA of BCT estimation to catch unit (y_n) via the reverse transformation. Or in other word, first apply the pre-processing using Eq. (3.2), then estimate using MRA using Eq. (3.1) and finally, return the estimate to catch unit via reverse transformation of Eq. (3.2).

3.4.5 Catch amount estimation using Hokkaido data

In this section the author will discuss the development of catch estimation algorithm using the present pre-processing algorithm compared to the previous algorithm using Hokkaido data. First, the real catch record (y_n) in Hokkaido is transformed to z_n, shown in dash gray line in Figure 3.12. Then, z_n is estimated by MRA using $\lambda = 0.10295$ and the result is shown in the thick line in Figure 3.13. 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

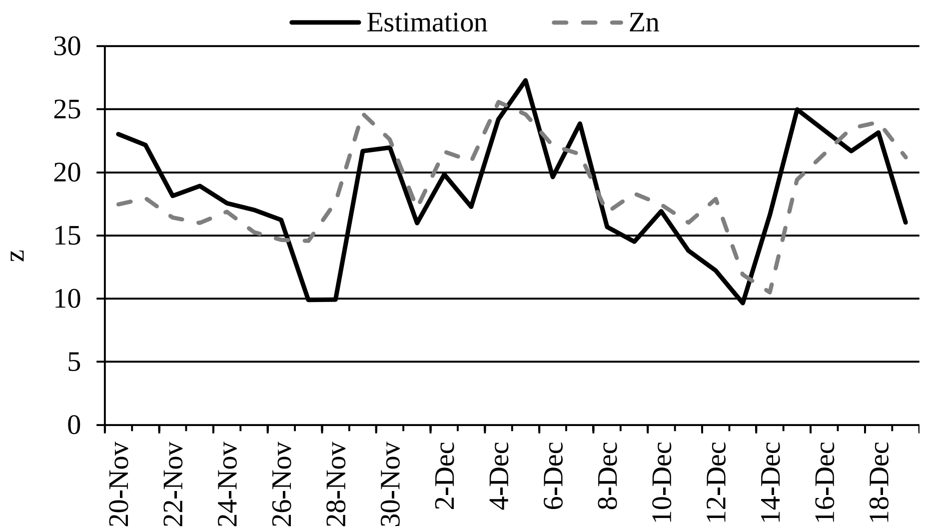


Figure 3.12. Comparison of BCT catch record and MRA of BCT estimation in Hokkaido experimental site.

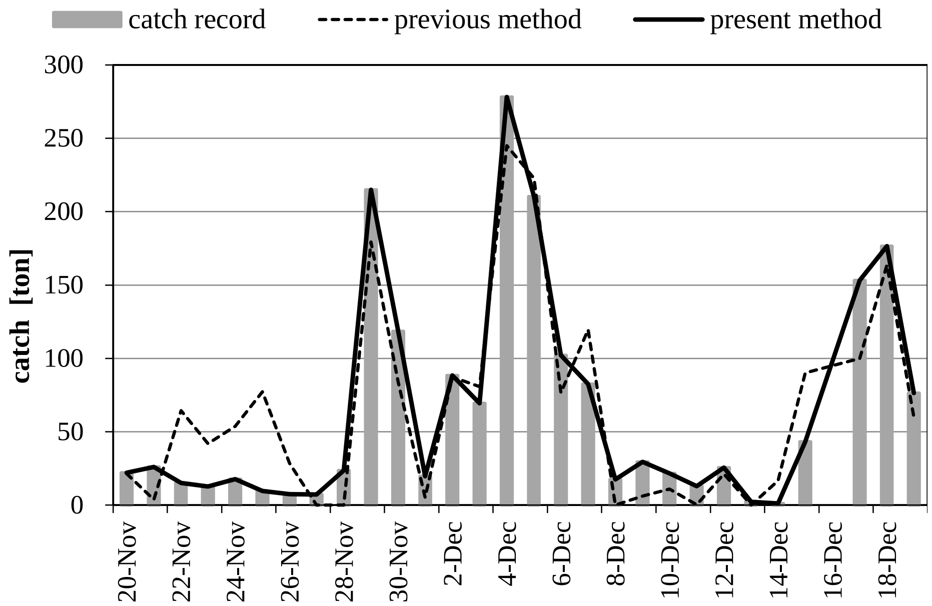


Figure 3.13. Comparison of catch record and catch estimations using previous and present methods in Hokkaido experimental site.

(45 to 55 m and 50 to 60 m). In this case, R^2 of the MRA was 0.97. Next, it is necessary to conduct reverse transformation of to the catch unit to get the catch amount estimation. Figure 3.13 shows the comparison between catch record, the catch amount 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 3.13. 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%, or 60% of correctness. Yet, after applying the present algorithm the RAE is 1%, 99% of correctness. 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.

3.4.6 Catch amount estimation using Toyama data

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 in the previous section. Yet, before moving on, it should be pointed out that, the author found the data record of June 13th and June 25th inappropriate. This can be seen in Figure 3.14, when the catch of June 13th was 257kg, but the fish finder could not reflect the condition within set-net correctly. The fish finder could not even reflect the sea bottom and there were only reflection of a strange object. Probably there were problem occurred during that day. The author also found the inappropriate reflection on June 25th. Therefore, those two data series were neglected. Yet, this kind of condition lead into a question of

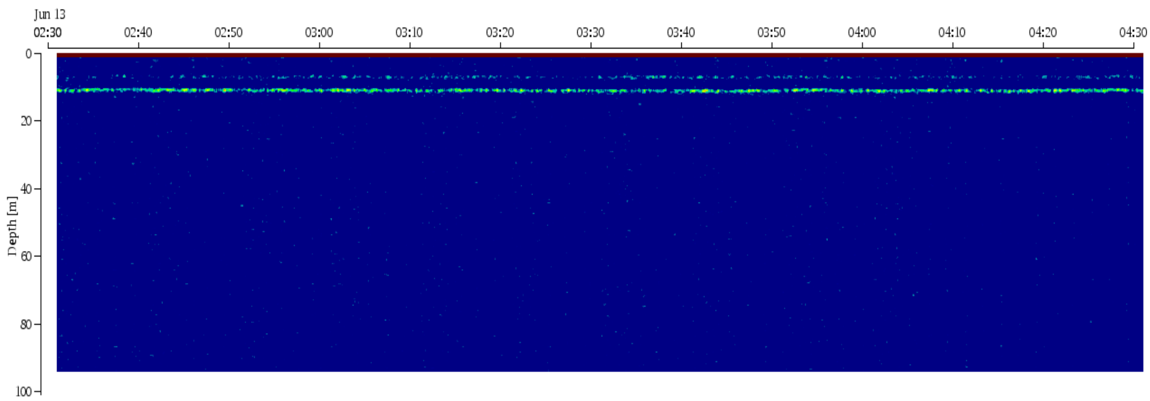


Figure 3.14. Toyama ping data series on June 13th did not reflect the condition within set-net correctly, the sea bottom did not even reflected.

detecting automatically an appropriate data series. Although it is possible to detect it manually, it will be very difficult to detect it automatically. Such kind of issue remains as a future subject.

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. The reason of monthly splitting has given the best results is because of the difference of fish kind each month. During the experiment it was found that the fish kind change seasonally, because of that the ping value characteristics also change seasonally. Consequently, it is better to conduct the estimation by splitting the catch record by following the fishing season. 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 3.15.

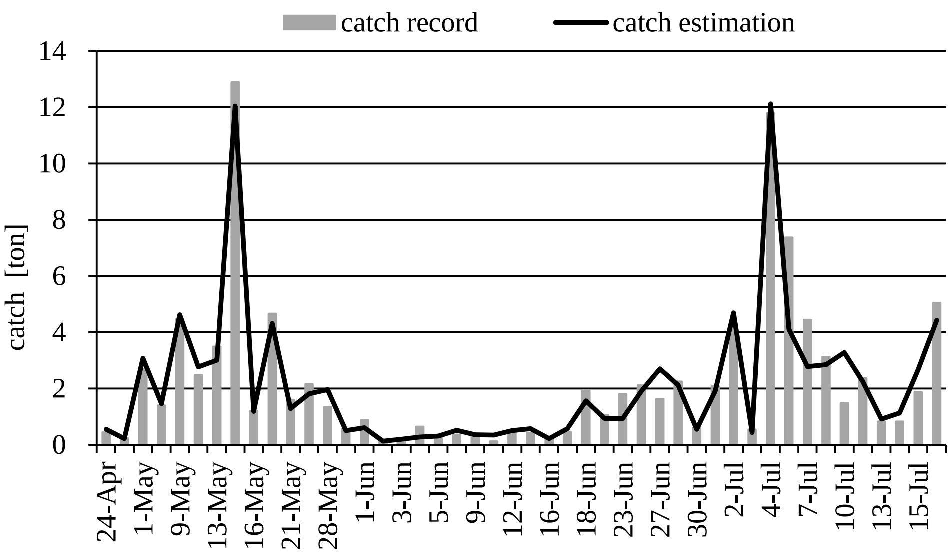


Figure 3.15. Comparison of catch estimation using the present method and real catch record in Toyama experimental site.

Figure 3.16 indicates that the fits of catch estimation and real catch record was fairly good. The RAE of catch estimation in Toyama was 22% compared to the real catch record. The author also estimated the catch without conducting a pre-processing transformation via the previous algorithm for comparing the result, 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 improvement of catch amount estimation.

3.5 The Algorithm of Fish Species Classification

3.5.1 Fish species classification in Hokkaido site

The study of fish species classification have been conducted numerous time for several decades by using quantitative echo sounder to detect swim bladder of fish. For example Williamson (1982), Ye and Furusawa (1995), Manik (2009, 2015) and so on. However, quantitative echo sounder is even larger than the conventional set-net monitoring equipment, it is about the size of fishermen's vessel. Besides, the electricity consumption is very high. Such kind of condition make it impossible to have the quantitative echo sounder placed on the set-net to classify the fish species.

Saville and Hatanaka (2013) reported the algorithm to conduct land use classification from satellite image data series. Firstly, derive the numerical data of image data series, and obtain the characteristics of the data series. After determining features of the paddy area, linear discriminant analysis (LDA) is assessed for land-use classification using statistical values of data series. This algorithm could be applied in this study in order to classify the fish within set-net by using limited frequency of ping data series. Based on the algorithm, fish features can be determined from statistics of ping data in several layer depth so it will be used further as indicators for LDA assessment to classify the fish.

Fishermen also predicted certain type of fish in the set-net empirically through the characteristics of reflection intensity in a certain depth in a certain time. Based on the algorithm and empirical idea of fishermen, LDA was carried out in order to determine the discrimination function z_i in Eq. (3.3) for the classification of fish kind within set-net,

$$z_i = \alpha_i + \sum_{j=1}^{m} \beta_{ij} p_j , \tag{3.3}$$

where α_i indicates constants in each discrimination function z_i, m is number of layer depth, β_{ij} are coefficients on z_i in j-th layer depth and p_j is statistics of ping value in j-th layer depth. p_j are the maximum value of the entire overlapped layer depth and minimum value of sea bottom. Those statistics was chosen in Eq. (3.3) because they generated the best combination result in the previous catch amount estimation.

For this study, the author assumed that only two types of captured fish to be classified (mackerel, sardine and other fish kinds) because those fish kinds were the dominant catch during the experiment. Moreover, it would be very difficult to classify all of the fish species without enough sampling data. After applying LDA for fish classification, the result of 83% correctness was obtained. Figure 3.16 shows the plotted result of fish classification, with M specifies mackerel, S is sardine and O is other fish captured in the set-net. As shown in Figure 3.16, the distribution of fish species was differed substantially. In Figure 3.16, sardine were distributed when z2> 0, mackerel were between z2> 0 and z1< 0, whereas other kind of fishes were between z2< 0 and z1> 0. Fish kind classification is likely possible to be performed through this algorithm. However, several part of the classification were failed, probably due to the small number of data sampling. It may be possible to determine the classification by settling the targeted season and dominant fish kind. The actual set-net fishing is carried out from April to December in the target area,

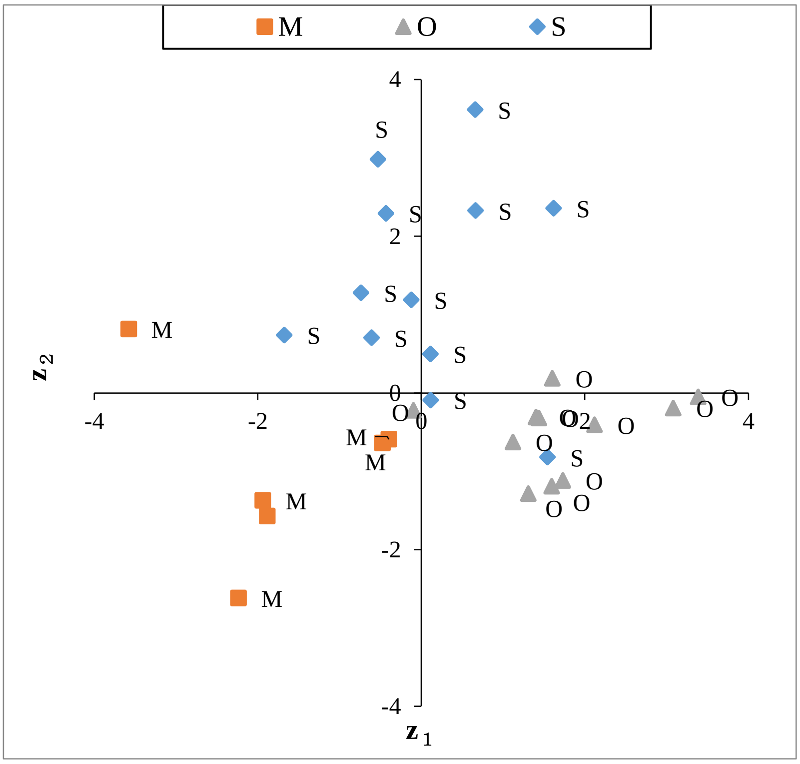


Figure 3.16. The plotted result of LDA of fish classification in Hokkaido site using one month catch record.

so the experiments and analysis must be continued in a whole fishing season. The accuracy for fish kind classification is expected to increase by taking more sampling data.

3.5.2 Fish species classification in Toyama site

The author also conducted the fish species classification using Toyama experimental site via discrimination function in Eq. (3.3). During three months experiment in Toyama, it can be seen that the dominant species of fish caught were different. Specifically, the dominant fish were sardine, Japanese horse mackerel and Japanese Spanish mackerel. For that reason, the author assumed that only three kinds of captured fish to be classified. Yet, as illustrated in Figure 3.15, the catches were mainly concentrated in May to June and June to July. And therefore, the author decided to try the conduct the fish kind classification by splitting into two data groups, namely April 28th to June 5th and the second group is June 8th to July 18th, 2014.

The results of plotted result of fish kind classification in Toyama using the first group data is shown in Figure 3.17. As shown in the figure, the distribution of fish species was differed substantially with 89% correctness. The JPHM in Figure 3.17 indicated Japan horse mackerel, S is sardine and O is other fish captured in the set-net. On the other hand, Figure 3.18 shows the plotted result of fish classification using the second group data record. The classification using the second group of data also differed substantially, resulting 81% correctness. Only two types of dominant fish were found using the second group, namely JPSM that stands for Japanese Spanish mackerel and O that indicates

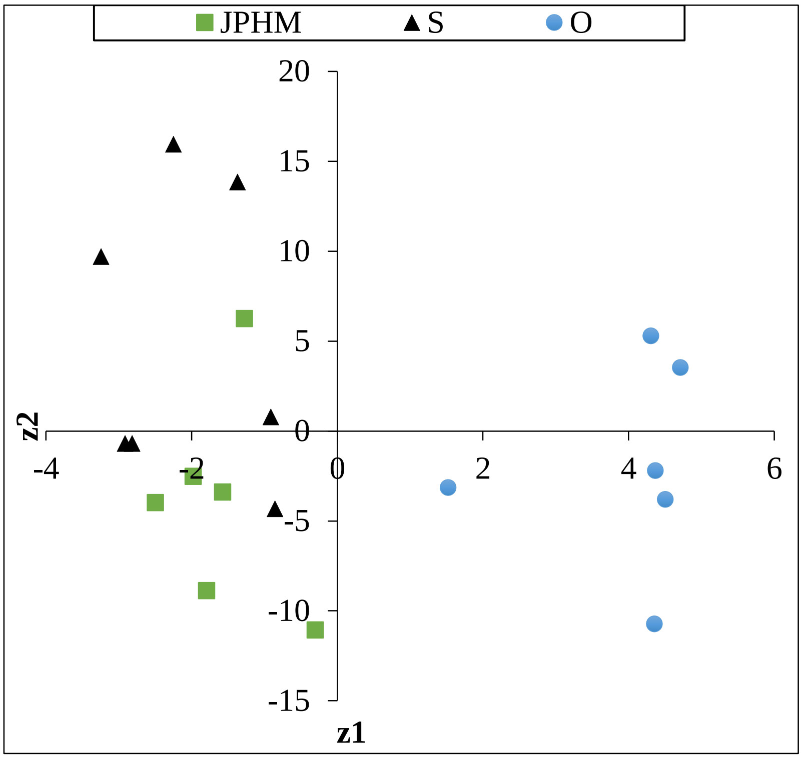


Figure 3.17. The plotted result of LDA of fish kind classification in Toyama site using April 28th to June 5th catch record.

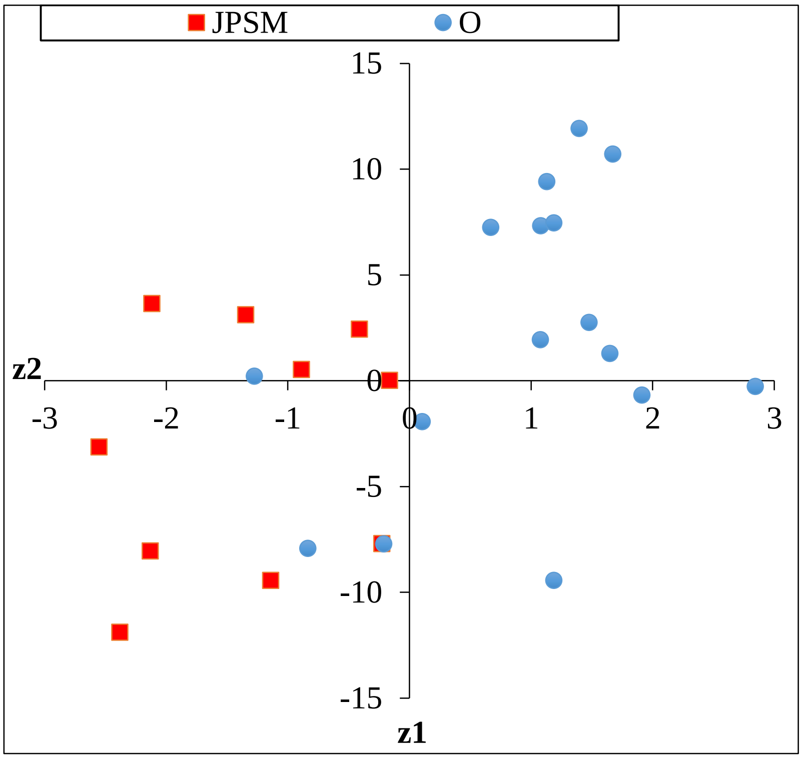


Figure 3.18. The plotted result of LDA of fish kind classification in Toyama site using June 8th to July 18th catch record.

other. The author also tried classification without splitting the data into groups, however, the result was poor (60% correctness). After conducting the fish classification, the author found that there is a possibility to build an automatic algorithm to predict the type of fish that will be caught. However, only one most dominant type of fish can be predicted because it is very difficult to estimate more than one type of fish due to extrapolation. This issue remains as a future subject.

3.6 Flaw in Fish Estimation

In the previous section the author has discussed the fish estimation with eleven overlaid 10m layer depth as the parameters. However, the information contained in the eleven parameters are too much and also contain unrelated information. Such condition make the model to be adjusted forcedly and might lead to a flawed regression model. One of the way to improve the model development is by reducing the parameters. For example, since the fish usually swim within 30m of water depth, the parameters can be limited to several layers from the surface to 30m water depth. Yet, instead of overlaying the 10m layer depth, several 0.25m spatial resolution (depth) in several certain depth can be used as the parameters of fish estimation. By conducting this way of thinking, the number of parameter can be reduced. The other way to estimate is to build a regression model by observing the relationship of ping value in each spatial resolution from the surface to the sea bottom (can be percentages or summation of ping values) and catch record several minutes before the hauling or by combining both of the stated method.

3.7 Remarks of Chapter 3

The algorithm development of fish catch amount and classification of fish kind has been discussed based on fishermen's empirical estimation through statistical analysis of reflection data in each layer depth. On the first attempt of development using Hokkaido catch record, the author applied MRA to conduct the estimation. The results of catch estimation has been obtained with multiple R^2 = 0.89, yet, several missed estimation was found due to bycatch. The result shows that single dominant fish kind could be estimated better than bycatch using this algorithm. On the other hand, fish kind classification was carried via LDA with 83% of correctness.

The accuracy of catch amount estimation on the first attempt was however, 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. In this study, BCT is applied as the pre-processing transformation in order to stabilize the variance of daily catch record. In other word, to make the catch record statistically more normal distribution-like. As for May, the multiple R^2 of the MRA was 0.97, June was 0.81 and July was 0.85, respectively. The results also indicate that it is better to conduct the estimation by splitting the catch record by following the fish season. The study showed that the present system could address the weaknesses of the first attempt of estimation, i.e. the improvement of estimation accuracy. This is illustrated by the 1 percent of RAE in Hokkaido experimental site and 22% in Toyama site, respectively.

However, there are several issues remain in catch estimation and fish classification. By being 20% error, the catch estimation is still not reliable enough. The catch estimation results showed that there was no parameter under 5 percent of significance level of MRA in Toyama site. The information contained in the estimation model is too much and also contain unrelated information. Such condition make the model to be adjusted forcedly and might lead to a flawed regression model. One of the ways to improve the model development is by reducing the parameters. For example, by limiting to 30m depth with ping value in several 0.25 resolution depth or by observing ping value in each resolution depth and the previous catch record. Besides, the presented algorithm still cannot predict the catch in the near-future accurately, and therefore, it is necessary to address this issue as the future subject.

In order to detect the independently swimming fish, such as tuna, wavelet transform could be applied to derive its characteristics before estimating the catch amount. Next issues are the development of an algorithm to detect the inappropriate ping data series and the classification of more than one fish species due to the extrapolation. Moreover, it should be evident that the data of current meter and seawater temperature can probably be used as the parameters in estimating the catch and the fish species.

All of these findings indicate that, although this monitoring system is still under development, there is a possibility to apply the present algorithm as a real-time estimation system for set-net fishery to support the fishermen's decision making in order to make it more effective.

Chapter 4 State of Indonesian Fishery and the Feasibility of ICT and Sensor Network Applications to Solve Indonesian Fishery Issues

In the previous chapters, the author has discussed the numerical analysis of advanced ICT and sensor network technology that can be useful for Japanese fishery sector. The Japanese technology transference and application of newly developed advanced ICT and sensor network technology can also give a very potential important role for Indonesian fishery sector. However, before going further to the application, it is necessary to conduct the preliminary study and analysis of the current state of Indonesian coastal fishery as well as to what extent ICT and sensor network technology are being used in the sector. This chapter also provides an overview of the impact of the currently being-used-devices among the fishermen in Jakarta coastal area. Moreover, this chapter examines the possible solution to tackle issues in fishery sector by matching the master plan of newly elected governmental policies through the application of advanced technologies.

4.1 Introduction to the ICT Device Utilization in Indonesia Coastal Fishery

Alongside with agriculture, coastal fishery is one of the most important primary industries in an archipelagic country like Indonesia where more than 70 percent of the nation area is sea (IBP USA, 2013). The 99,093kilometer shoreline is one of the longest in the world (BIG, 2015), and approximately 150 million Indonesians live within 60 kilometers of the coast (Dahuri and Dutton, 2000). Many of these people live within the large coastal cities that occupy a predominant position in the national economy. Although the coastal areas are considered one of the most important regions in Indonesia, several problems remain, especially in fisheries sector, such as, fishermen poverty; illegal, unregulated, unreported (IUU) fishing, overfishing, human resource capacity, technology as well as new policy dissemination and so on. The Indonesian government has realized a great potential that has not been fully utilized in fishery sector, especially after the presidential and ministry change in September 2014, and has been trying to face those problems (Indonesian Gov., 2014; KKP, 2014a; BAPPENAS, 2015). At the present time, poverty reduction as well as fishermen's life improvement, IUU fishing and overfishing are the main priority problems to be solved by the Ministry of Maritime Affairs and Fisheries (KKP, 2014a).

Poverty has been a severe problem for decades in Indonesia, and has been one of the main focuses of Indonesian Government, especially since the signing of the MDGs in 2000 (UN, 2008; BAPPENAS, 2010). However, World Bank (2013) stated that about one-third to nearly half of the population in many coastal regions of Indonesia existed below the poverty line. Such kind of condition indicates that poverty is still a serious problem to be solved, even after the final year of MDGs in 2015, and therefore, the poverty in coastal area is one of the main targets of the new government (Indonesia Gov., 2014, KKP, 2014a). Most of low-income people in Indonesian coastal areas are small scale fishermen (KKP, 2011). According to Government regulation (Act) No: 31/2004 and Act No: 45/2009, small scale fishermen in Indonesia is defined as a person whose livelihood are fishing by using fishing vessel less than 5 gross ton (KKP, 2010). FAO (2014a, 2014b) even referred Indonesian small scale fishermen as artisanal fishermen due to their traditional way of fishing, lack of technology and low income. Small scale fishermen are very important for Indonesian fisheries, as about 80 percent of fishermen in Indonesia are categorized as small scale fishermen (KKP, 2009; KKP, 2013b), and it is estimated that more than 80 percent of the total national catch was produced by small scale fishermen (KKP, 2009; KKP, 2013b; FAO, 2014). Therefore, this study will be focused on small scale fishermen.

Meanwhile, ICT is generally defined as a set of equipment that enable to strengthen and accelerate the dissemination and information sharing, facilitate communication process, regardless of geographical characteristics (Meng *et al.*, 2013). In other word, it is a term that includes any communication tool or application such as radio, television, mobile phones, computer and network hardware and software, satellite systems and so on. Access to telecommunications services has been substantially expanding in coastal and rural areas, especially through the spread of the Internet and mobile phones in all over the world (Jensen, 2007). According to Quibria and Tschang (2001); Waverman *et al*. (2005); Guislain *et al.* (2006); and Qiang (2009) that ICT penetration can positively impact the economic growth of developing countries in general aspect.

MCIT (2014) reported that the utilization of ICT, especially mobile phone, has penetrated almost all the citizenry of Indonesia. The report also indicates that this kind of situation includes low-income people, and even the below-poverty-line people in remote or coastal areas. Major challenges of Indonesian fishery sector could be handled by applying ICT. Poverty reduction and the life improvement of small scale fishermen could be handled by applying ICT, especially mobile phone. It is because using mobile phone can increase the income through the better marketing of the catch (Chhachhar and Omar 2012). Yet, the author theorizes that the main factor of fishermen life improvement, especially in Indonesia, is the information sharing among fishermen as a community with mobile phone as a tool to make it more effective. Moreover, the function of mobile phone is not only for life improvement economically, but also as a community tool.

Despite the fact that the benefit of ICT penetration in developing countries has been frequently reported, few detailed studies of ICT utilization, especially mobile phone among small scale fishermen in coastal areas have been conducted. Specifically, the objectives of this chapter are: (i) to investigate mobile phone as the information sharing tool among fishermen; (ii) to identify the utilization of mobile phone for emergency communication tool; (iii) to understand the marketing channels of small scale fishermen; (iv) to discuss mobile phone utilization for marketing and for increasing fishermen's income; and finally (v) to examine the application of advanced ICT and sensor network technologies to handle IUU and overfishing issues in Indonesia. This chapter provides an illustration of the role of mobile phones as community support tool in coastal areas and feasibility to apply ICT and sensor networks technologies for the better Indonesian coastal fishery. The target of this study is small scale fishermen in North Jakarta coastal area, Indonesia.

4.2 Target Area and Data Gathering

The study area was located in North Jakarta, which contains the entire coastal area of Jakarta, Indonesia. The area was chosen because Jakarta is the capital city of Indonesia that has the role as the governmental and economic center and has the best infrastructure in Indonesia. It can be assumed that the ICT infrastructure is better than other areas in Indonesia, so that Jakarta can be a role model for other areas in the future. All of the fishermen in Jakarta reside in North Jakarta due to its direct access to the sea. Currently, there are over 20,000 fishermen in North Jakarta with 8,000 of them not having Jakarta ID card who are temporary fishermen that come to Jakarta for only several weeks or months and then go back to their own region (outsider fishermen). The rest of 12,000 people live in Jakarta and have Jakarta identity card, approximately 8,000 of them are classified as small scale fishermen (North Jakarta Gov., 2015).

North Jakarta is subdivided into 6 sub-districts, namely, Cilincing, Koja, Kelapa Gading, Tanjung Priok, Pademangan and Penjaringan. In Jakarta there are six official

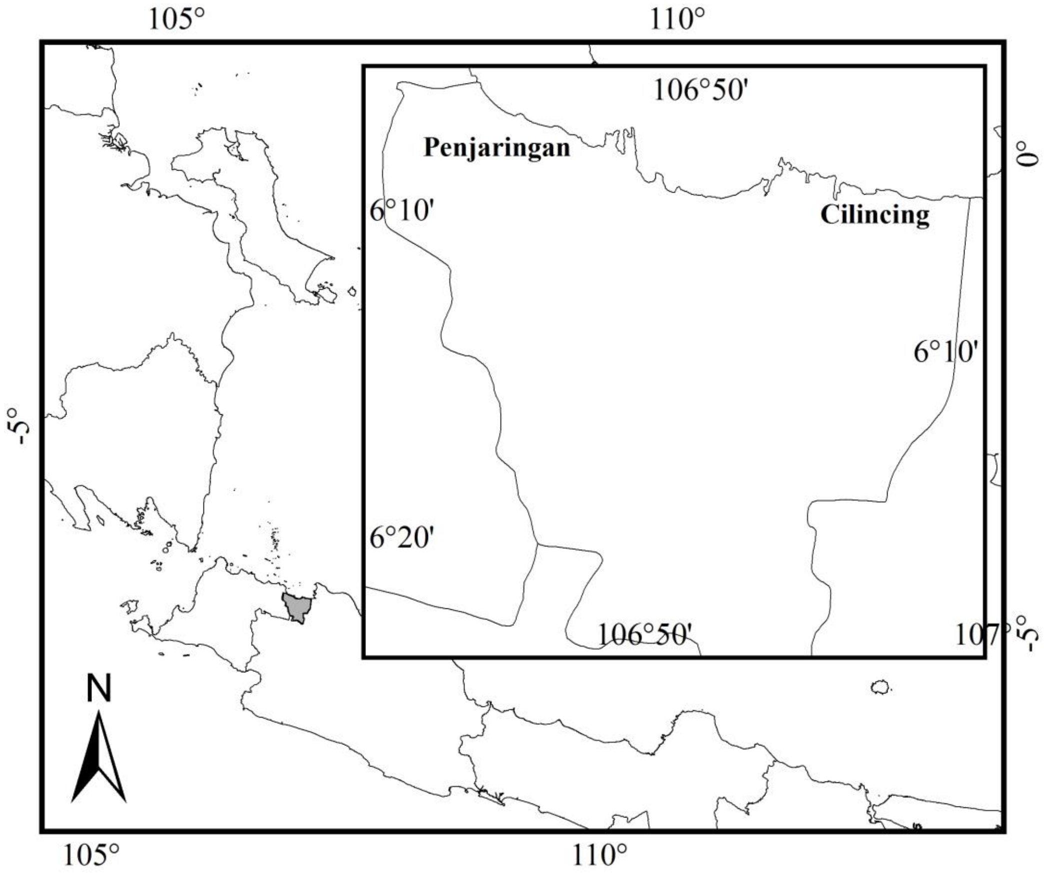


Figure 4.1. Jakarta as the target area in this study is shown in the shaded part. The data gathering mainly took place in Penjaringan and Cilincing sub-district.

ports for fishermen (Muara Angke, Kamal Muara, Muara Baru, Marunda, Kalibaru and Cilincing), in which all of them are all located in Cilincing and Penjaringan sub-district. Based on the interview with the people in charge in fisheries department of North Jakarta in September 2014, small scale fishermen mostly live around Muara Angke and Cilincing port. The target were small scale fishermen near the area of Muara Angke, in Penjaringan sub-district and Cilincing port, in Cilincing sub-district, North Jakarta, as shown in Figure 4.1. Penjaringan sub-district is located in the western part of North Jakarta and Cilincing sub-district is in the eastern part of North Jakarta.

The study was conducted using primary and secondary data. Primary data was obtained from random interview and questionnaires survey of small scale fishermen in North Jakarta. Moreover, another primary data was also collected from the interview with the people in charge in fisheries department of North Jakarta and experts in this sector. The primary data gathering was conducted in September 2014, February and March 2015. On the other hand, the secondary data was gathered from government official reports, books and journals. For instance, annual catch and income record of fishermen in target area.

The questionnaire consisted of a demographic part and an assessment the frequency of mobile phone usage. Respondents used a five-point scales, 1 defines ‘never’ to 5 that defines ‘very frequently’, to indicate the frequency of mobile phone utilization to a specific question. The data gathered were then analyzed using statistics, e.g., frequencies, percentages, mean scores, interquartile (IQR), t-test and regression analysis. A multiple regression analysis of income difference between 2014 (after) and 2010 (before introduction of mobile phones) will be performed between the variables of education, age, mobile phone possession, fishing ground sharing, bonded middleman and utilization of mobile phone for marketing. However, inflation rate and economic growth rate, will not be considered, in this study, because the target is to measure how important mobile phone is for income increase, not the value of the money itself.

4.3 Demographic Data of Small Scale Fishermen in North Jakarta

After going to field survey, the author interviewed 79 small scale fishermen in the target area, yet, the author cut 11 of them, because their record were not available in the official report gathered from the sub-districts offices. In order to check and derive income data of the respondents, the author matched every respondent with the record from sub-district offices. Yet, the available income record is the record from 2010 to 2014. Therefore, the author assume that 2010 record indicates the income before mobile phone possession, and 2014 record is the actual income after utilizing mobile phone.

During the field survey, the author found that all respondents were male with the average age of 39.2 years old; consisting 30 to 39 year old (49%), 40 to 49 year old (34%), 50 to 60 year old (10%), 20 to 29 year old (6%) and 10 to 19 year old (1%), in decreasing order of occurrence. In other word, most of them are generally categorized in the peak of productive age. Most of them have been educated in elementary school (59%, n = 40), 19% of them were junior high school graduated, 10% of respondents were senior high school graduated and the rest of 12% did not have chance to go to school. Ninety percent (90%) of them (n = 61) possess a mobile phone and most of them (66%) had been using mobile phone since 2009, 29% of them, from 2010 while 4% started using mobile phone no later than 2011.

Their average total catch of 2014 was 2,713 kg per fishermen. The average annual income of the fishermen in target area in 2014 was 35 million IDR (roughly equal to 2,900

USD during that time). In comparison, the average of income of Indonesian citizen in 2014 was. 41 million IDR, so fishermen income in North Jakarta was below the average of national income. The situation of fishermen village in North Jakarta is shown in Figure 4.2. The fishermen in target area are living in wretched condition. It also indicates that the poverty in target area is still a serious problem. Moreover, based on interview with the government people in charge and several fishermen in target area, the source of family income is commonly only the head of household. In other word, they rely on the income of catching fishes, with the wife does not working and act as a housewife. The role of women in coastal communities in the target area was still low.

Figure 4.2. The situation of fishermen village in North Jakarta

Figure 4.3 shows the fishing vessels that are used by small scale fishermen in target area. Small scale fishermen in North Jakarta generally operate using a very small fishing vessel with the capacity of 1 to 3 gross tons and 6 to 18 horse power diesel engine. Since the capacity is small, it can only be boarded by one or two people. All instrument of the vessel are operated manually. The fishermen usually operate to catch the fish at a distance of one to five km from the shoreline, yet, they do not dare to operate more than ten km from shoreline. The catch in an operation vary from few kg to tens of kg. In addition, the fishermen in target area operate from the middle of March to the middle of December because heavy rain and strong wind usually occur in December to the middle of March.

Figure 4.3. Fishing vessels that is used by small scale fishermen in North Jakarta

In the off season, the fishermen usually only do the maintenance of their fishing vessel. They wait and see the situation and the condition of the wind as well as the height of waves, if it is possible they would try to go to sea to catch some fish. During that time, fishermen tend to rely on their saving and government support because many of them do not have any other skill except fishing.

4.4 Mobile Phone as the Information Sharing Tool Among Fishermen

Mobile phone information sharing can be determined from question about the fishing ground information sharing. In this case the respondents answered in a five point likert scale, 1 indicates ‘never’, 2 is ‘rarely’, 3 is ‘occasionally’, 4 is ‘frequently’ and 5 defines ‘very frequently’. Sixty six percent (66%) of the respondents (n = 45) indicated that they frequently or very frequently share the information of fishing ground (mode = 4, median = 4, IQR = 2), with z-score = 0.43. specifically, fishermen in target area are most likely to share the information of good fishing ground (67%) and polluted area (33%). This result indicates that fishermen in North Jakarta are most likely to share the information of fishing ground through their mobile phone.

Pattern of information sharing among fishermen in North Jakarta is as follows, in an event when there is a fishermen who catch a lot of fish, the fishermen will share the information of place to several of his fishermen friends via mobile phone, by either calling or sending short message service (SMS). Then those people will further forward the information to the other fishermen. This kind of information sharing also occurs in sharing the polluted fishing ground area. According to the interview with the fishermen during the survey, a polluted fishing ground is also a place that needs to be avoided because the fish caught in a polluted area is not salable. The fishermen stated that the waste usually exist in a depth of 0-15 m. When there is waste polluting the fishing ground, dead fish will float, while the rest of live fish will usually swim deeper or swim further off shore, making it very difficult to catch. Hence, the small scale fishermen in Jakarta keep sharing these two pieces of information.

This kind of information sharing is very unique, because usually fishermen do not want to give the information about the fishing ground, which is considered as their privileged information. Even though Jakarta government (2015) reported that the catch decreased from 2000 to 2012, the fishermen still shared the information of fishing ground. According to the fishermen, the information sharing in North Jakarta has been habitually practiced for decades. In the previous days, they shared information of good fishing grounds from mouth to mouth, and such habit continued after introduction of mobile phones. They usually shared the fishing ground information after arriving to the port or on the next day. One illustration is right after prayer in congregation in the mosque they would talk with each other and shared the information. Right after the prayer in the mosque was considered as a good time for them because in Indonesia there is a habit of having a chat after the congregation prayer. The author found that, the fishermen became more satisfied after possessing mobile phone, because the fishing ground information sharing runs more smoothly. They do not need to wait to share and get some fishing ground information until the congregation prayer time, and able to do the information sharing in near real time.

4.5 The Utilization of Mobile Phone for Emergency Communication

The question frequency of mobile phone use for an emergency occasion during the trip was also examined by using the same manner as the previous topic. The result shows that 85% of the respondents (n = 58) indicated that they frequently or very frequently used mobile phones in emergency occasions during the trip (mode = 4, median = 4, IQR = 1, and the z-score = 0.89). Consequently, it can be concluded that the fishermen in North Jakarta apparently utilize mobile phone to during emergencies and to communicate emergency situations.

All respondents who utilize mobile phone in an emergency occasion answered that they habitually contact their family first either by calling or sending SMS, in order to let their family know that they are safe, yet, will be home late. According to fishermen and their family in target area, the feel a lot safer and they worry less after having a mobile phone compared to decades ago. Results also indicate 69% of them use mobile phones to contact a friend for help, when they have mechanical problems while 31% use mobile phone to seek help in a bad weather. Previously, the fishermen in the target area used to help each other in an emergency during the trip incidentally, for instance, when they find other fishermen that need help, they usually help voluntarily. With the existence of mobile phone the fishermen have the option to take actions, especially in case of emergencies when fishermen were at sea. Under these circumstances, it is clear that mobile phone in coastal area acts as a community support tool.

4.6 Marketing Channels of Small Scale Fishermen in North Jakarta

Before analyzing the role of information sharing via mobile phone to improve fishermen's life, it is necessary to look at the marketing channels in the target area. Marketing channels of small scale fishermen in North Jakarta can be divided into four categories (Figure 4.4). The survey reveals four types or modules of marketing fish in the study area. In type 1, the marketing chain is controlled by a bonded middleman who lends

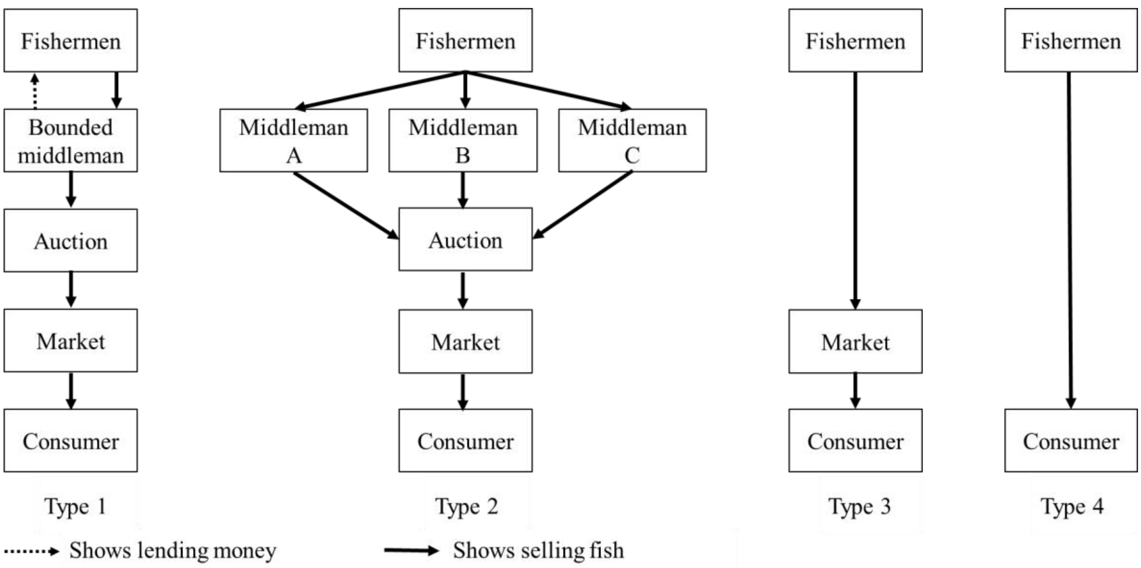


Figure 4.4. Marketing channels of small scale fishermen in North Jakarta.

money to fishermen on the condition that the fishermen must sell all of the catch exclusively to that middleman. In type 2, fishermen can compare fish prices and choose whom (middleman) to sell the catch to. While in type 3, fishermen sell their catch directly to the consumer at the fish market, without going through any middleman. Type 4 is categorized when fishermen sell the catch directly to the consumer. The survey also reveals 28 out of 68 respondents (41%) stated they were bonded to certain middlemen (categorized as Type 1). The rest of them were free to choose the type of marketing channels for their catch. The rest of 40 respondents would sell their catch by depending on the circumstances, sometimes they sell the catch through Type 2 marketing channel, but in other occasion they sell the catch to the stores on the market or also occasionally sell directly to the consumer.

4.7 Fishermen's Life Improvement as an Impact of Information Sharing Through the Utilization of Mobile Phone

As reported above, 41% (n = 28) of the respondents are bonded to middlemen, with no choice of marketing channel, as in type 1 (Figure 2). The rest of 59% (n = 40) can choose their own path of marketing channels, namely types 2, 3 or 4. On this basis, the marketing channels could be divided into type 1 and non-type 1. The survey reveals 33 out of those 40 respondents in non-type 1, or 83%, answered that they frequently or very frequently used mobile phones to sell the catch (mode = 5, median = 5, IQR = 1), and the z-score = 1.75. This result indicates that they are in likelihood of using mobile phone for marketing. Seven (7) respondents in non-type 1 did not utilize mobile phone for their marketing simply because they did not have mobile phones. This paper gives evidence that mobile phone is used by the fishermen in target area for marketing.

As noted above, most of the fishermen in North Jakarta started to use mobile phones before 2011. Therefore, it is assumed that 2011 is the time indicator in this study, namely comparison of income before and after 2011. In order to identify the income difference of 2010 and 2014 based on marketing channel, the author conducted t-test. The p-value of t-test was 4.02×10^{-9}, which means, the null hypothesis is rejected. In other words, the study indicates that fishermen who are independent or not bonded to middlemen have more income than those bonded to middlemen. Next, the author also checked the income difference of 2010 and 2014 based on mobile phone possession using t-test. P-value of t-test was 3.93×10^{-5} so that the null hypothesis is rejected. To put it another way, fishermen who utilize mobile phones in the conduct of fisheries business tend to have more income than those without mobile phones. In short, mobile phone has given ways of communication to fishermen for selling their catch in different places of market. Such kinds of information not only have increased the income of small scale fishermen but also have provided access to connect with community and market for selling their catches at better prices. This paper agrees with the supposition of Chhachhar and Omar (2012) that utilization of mobile phones enhances marketing of catch among fishermen and provides them with viable options or choices for sales point or market of their produce; however, in this case, without passing through any intermediary or middleman.

The author then calculated the multiple regression analysis of income difference between 2014 and 2010 (y_2) by the several variables from the questionnaire as determined in Eq. (4.1),

$$y_2 = x_1c_1 + x_2c_2 + x_3c_3 + D_4c_4 + x_5c_5, \tag{4.1}$$

where x_1 indicates variable of education, x_2 is age, x_3 is fishing ground sharing, D_4 is a dummy for bounded middleman and x_5 is mobile phone utilization for marketing. While c is the coefficient of each variable.

Results of multiple regression analysis of income different between 2010 and 2014 are shown in Table 4.1. The multiple regression analysis of income difference before and after introduction of mobile phones indicates the significance level (α) of fishing ground sharing was below 0.001, age was 0.001, mobile phone for marketing and education were 0.005, with the multiple R^2 at 0.98. The highest estimate coefficient of the result were fishing ground sharing (two million IDR) and mobile phone for marketing (one million IDR). It points out that fishing ground information sharing via mobile phone was the most dominant factor that dictate increase in income of fishermen in North Jakarta. Next, age (or can be interpreted as experience of being fishermen) and education were also dominant factors in this study. Hence, the factor of income increase is not only mobile phone utilization for marketing the catch as reported by Chhachhar and Omar (2012), but

Table 4.1. Result of multiple regression analysis of income different between 2010 and 2014 among fishermen in Jakarta coastal area

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	α
Education	573,421	232380	-2.468	0.01633	*
Age (experience)	66,885	19752	3.386	0.00123	**
Fishing ground sharing	2,177,531	235198	9.258	2.32E-13	***
Bonded middleman	447,728	1611211	-0.278	0.78201	
Mobile phone for marketing	1,093,323	477589	2.289	0.02543	*

Significant codes: Near 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 2118000 on 63 degrees of freedom
Multiple R-squared: 0.9754, Adjusted R-squared: 0.9734
F-statistic: 499.5 on 5 and 63 DF, p-value: < 2.2e-16

also the effective information sharing via mobile phone and their experience, in which plays immense role to increase the income of small scale fishermen in North Jakarta coastal area.

Although information sharing system through mobile phone is very unique and can increase the income of fishermen, it can also lead to a tragedy of the commons. Supposed that fishermen continue the information sharing of a good fishing ground along with the fish species, it will perceptibly lead the fishermen to go to the same place to catch the same species of fish. In other word, there is a probability of overfishing, which then, the fish stock will decrease massively. In order to avoid that, it is important for the government to not only promote information sharing via mobile phone in Indonesia, but also to regulate the new policy such as TAC or limiting the size of the fish to be catch and so on. Yet, to regulate a new policy, a strong fish stock database is necessary. The recommendation of building a database via ICT is discussed in the next section.

After conducting the field survey in Muara Angke and Cilincing port, North Jakarta, the author also found that most of the small scale fishermen in the target area have formed the joint venture business group of fishermen (KUB), with the number of members ranging from 14 to 30 people per group. Currently, there are 58 KUBs in Cilincing and 23 KUBs in Muara Angke port, respectively. Based on the interview with both of the people in charge of north Jakarta government and fishermen in September 2014, KUB is an unwritten requirement to obtain government assistance for small scale fishermen. It is because after getting the assistance, each KUB will be monitored and must report their progress periodically to the government. KUB has been proclaimed as the government programs since 2012, under the provisions of Government Law No. 16/2006 and Ministerial Decree No. 14/2012 (KKP, 2012). Yet, in the study area, most of the fishermen started to form KUB in 2013. Each KUB also required to report the amount of catches as well as the income and their activities to sub-district office every month.

Based on the findings, poverty reduction and life improvement of coastal community in target area could possibly be achieved by improving the essential function of KUB and improving the effective use of information sharing via ICT. According to the interview with the fishermen, although there has been KUB which is defined as a joint venture business group of fishermen, but the group was used by the fishermen only as a formality for the governmental procedure and for getting the governmental support and not a community business group. Such condition is very unfortunate because fishermen already conducted the fishing habit as a community and even more effective after thy started using mobile phone. The government should support and encourage information sharing though a mobile phone utilization and conduct the training to build the capacity and know-how of fishermen in order to improve their way of managing KUB as a community business group. One example is conducting a training to conduct a cooperative business to sell the catch collectively via information sharing using ICT device (mobile phone) among KUB members so that they have a selling power, namely more stable and sustainable supply of fish for the market compared to sell the fish single handedly. Besides, it is also important for the government to organize several basic skill training other than fishing technique, such as construction work, basic fish processing technique or even small scale aquaculture, along with the basic entrepreneurship for fishermen so they can still be productive during the off season.

4.8 ICT and Sensor Network Applications to Solve IUU and Overfishing Issues in Indonesian Fishery

As stated above, there are three main topics, namely, life improvement of small scale fishermen, IUU fishing, and national database as well as fish stock estimation. Poverty reduction and life improvement of small scale fishermen has been discussed above, and in this section the author provide the examination to reduce IUU and overfishing challenges in Indonesia. IUU and overfishing issues could possibly tackled by applying advanced ICT and sensor network technology through Japanese technology transference.

The ministry reported that, there is possibility of overfishing (KKP, 2014c), however, still experiencing problems in arranging database of catch and estimating fish stocks in Indonesian waters. Such condition is occurred because currently, database of fishing vessel and fish stock has not available yet in Indonesia. Under the new minister, the data gathering, database development and arrangement as well as fish stock estimation is also one of the main topics nowadays (KKP, 2014a).

IUU fishing has been one of the main problems in Indonesian fishery sector for decades. Generally said, IUU lead to maritime and fishery security complication, i.e. domestic fishermen within the country are not well managed, so there is difficulties to distinguish domestics and foreign fishing vessels as well as to distinguish the legal and illegal one. There are currently an estimated over 5,000 illegal foreign fishing vessels operating in Indonesian waters that it says rob the local industry of as much as $25 billion a year in lost catches (KKP, 2014b). The same report indicates that the ministry has been fighting against IUU fishing intensively under the new government.

Based on Indonesian central Government Law No. 31/2004 and Law No. 45/2009, fishermen in Indonesia are required to have license for their vessel and for themselves to identify that they are fishermen (DPR, 2009). Although the available data could be helpful to control the IUU, the government does not utilize that information. IUU fishing and overfishing issues could also be potentially solved by using the way of thinking of the previously mentioned automatic catchable index. Specifically, technology transference and introducing sensor network aided ICT device to the fishing vessels. Most of the fishermen in Indonesia is categorized as small scale fishermen, and therefore, by making microCube (Wada *et al*., 2008) for marine traffic monitoring system for small scale vessels (Taka *et al*., 2013) to track domestic fishermen could be very helpful. 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 with GPS function as a network sensor, 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. By conducting such kind of work, marine traffic for small scale vessels can be monitored systematically.

On the other hand, with the fact is that there is no appropriate database for fish stock and fishing vessels in Indonesia, it is difficult to say whether overfishing has occurred or not. Here, the diary system to record their catch for the national database could be utilized. Fish stock can be estimated automatically by combining marine traffic monitoring system and digital diary through a resource stock index. As noted above, the catch records have been reported periodically by each KUB to the local government in a paper based data format. Those data should be utilized to build fish stock database. Next, the person in charge of database in the local government level should convert the paper based catch record into a digital form and further report it to the central government to build national database. The other way to gather the catch record is by applying digital diary system (Wada *et al.*, 2012). For example, if every fishing vessel is provided with low cost phone that with GPS function, the device will be allowed to record location data but also allowed to gather the catch record. The benefit of using a digital diary is that the data is already in a digital form so it will save cost, time and effort.

The suggestion to solve the IUU and overfishing issues in Indonesia is explained as follows. First of all, the provision of sensor network to the vessels is important. The installation of the device could be gradually provided during the fishermen's vessel and fishing license renewal because they must renew the license periodically. Figure 4.5 shows the diagram of automatic real-time data collection and transference to support Indonesian fishery. The way this scheme works is similar to the one in Chapter 2. The sensor network platform is automatically transmit location data periodically to database server when the engine of the vessel is on. Therefore, the government can monitor local vessels through the Internet. 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. Another thing that needs to be obtained is the catch data to build a national and regional

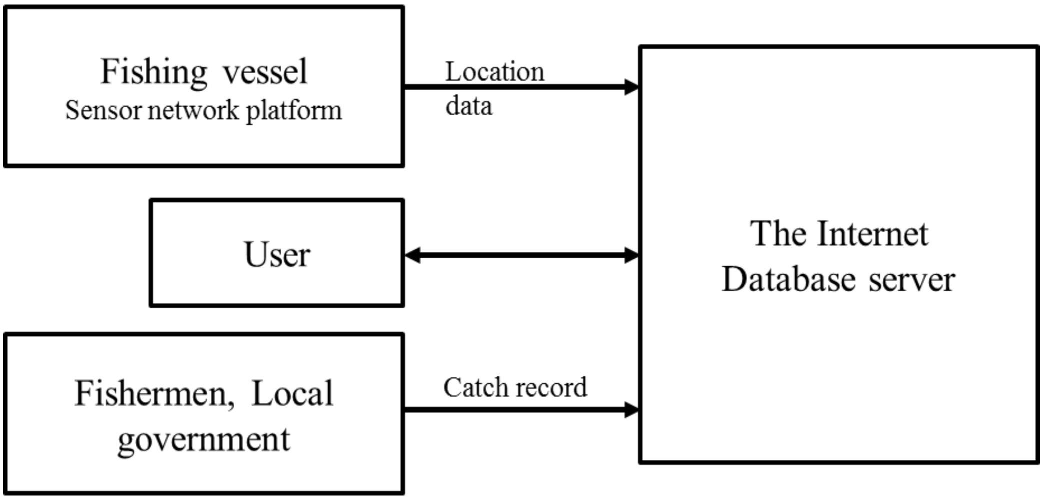


Figure 4.5. Diagram of the real-time data collection and transferring scheme to solve IUU and overfishing issues in Indonesia.

fish stock database. After gathering the catch record, automatic resource stock index might be applied. As a result, the risk of overfishing could be determined.

The proposed scheme is in accordance with government policy plan, namely to build a reliable database of fishing vessel and fish stock. However, it is difficult to be immediately applied in Indonesia, nonetheless, it could potentially be helpful to support Indonesian fishery to reduce IUU and prevent overfishing.

4.9 Set-net Fishery as a Potential Fishing Method in Indonesia

Although there are several issues remain in Indonesian fishery sector, set-net fishery is considered as a rising star and has a very big potential to be introduced and developed in Indonesian coastal area (Wudianto, 2007; KKP, 2014d; Zaenal, 2015). KKP (2014d) and Zaenal (2015) described that set-net fishery development is included in one of their potential strategic plan. There are several reasons behind the ministry to include set-net fishery promotion and development in Indonesia, such as, supporting small scale fishermen to reduce the petrol cost and promote environmentally friendly fishing method (Wudianto, 2007) as well as to provide a new alternative of fishing method to the fishermen.

Recently, small scale fishermen face some problems due to the increase of petrol price and other operation cost, limited management capability, fisheries policy and development. In order to solve those problems, empowerment of the coastal fishing community such as KUB, subsidies of the fuel price, simplifies of fisheries policy and introducing of new fishing technology are necessary. Yet, the most sustainable way to solve the problems is by maximizing the fishing community, maximizing KUB function and introducing the new fishing method to the fishermen (Arimoto *et al*., 2008). By doing so, it is expected to make the fishermen to become more profitable (Sudirman *et al*., 2010).

In 2015, the newly appointed ministry has been prohibited several fishing method such as bottom trawl, bottom gillnet, seine net and dredge net (KKP, 2015). Those fishing gear are considered to be harmful for the environment and the biota itself. Therefore, introducing and developing of new fishing technology are become urgent actions to be taken. The ministry has realized that set-net is one of the potential solutions because set-net is known for environmentally friendly fishing method (Wudianto, 2007; KKP, 2014d).

The promotion and development of set-net fishery in Indonesia has been conducted since a couples decades ago (KKP, 2014d; Arimoto *et al.*, 2008). The project that was considered to be the most successful was the latest JICA promotion project in 2007 to 2010 simply because the average daily catch was the highest (Sudirman *et al.*, 2010; KKP, 2014d). In Indonesia there are some traditional tools that has almost the same principle with set-net, namely, *jermai, sero, ambai, belat* and so on. Most of Indonesian fishermen have known such kind of tool for a long time and thus, most fishermen without resistance accepted the promotion and development of set-net in Indonesia.

Most of the materials of those Indonesian traditional fishing tools are made of bamboo, only the final trap bags that are made of net. Since bamboo is used to form the frame, the tools can only be set in shallow water, approximately two to three meters water depth, so those tools has many limitations. On the other hand, set-net is formed by a frame rope and sinker and it can be set to tens of meters of water depth and therefore, it has more access to trap the fish. Such condition made the fishermen even more open to set-net (Sudirman *et al.*, 2010; KKP, 2014d).

As noted above, the average daily catch of set-net fishery in Indonesia during the sampling time was still low (Sudirman *et al.*, 2010). KKP (2014d) reported that in the first attempt to introduce set-net was held in 1980s, and in 1990s. The average daily catch during those time were only 20 to 30kg. Even though the set-net were accepted because of its easiness, the catch amount did not satisfy the fishermen. The average daily catch of the latest set-net promotion in Sulawesi Island in 2007 to 2010 was approximately 60kg (Sudirman *et al.*, 2010) and the fishermen accepted set-net technology gracefully. Since then, several provinces in Indonesia has requested the ministry to also install set-net in their area. For instance, the ministry has approved a Lampung government request to install set-net and is going to be installed in Lampung province in the beginning of 2016 (South Lampung Gov., 2016).

Like Japan, the daily catch of set-net was still considered low for the fishermen. Since set-net fishermen is usually controlled under the organization or community-based management system (Arimoto *et al.*, 2008), the catch must be divided for each fishermen who participate. It means an average daily catch of 60kg will probably cause the loss to fishermen due to the high cost and profit sharing system. It is desirable for set-net fishermen to be able to monitor the catch condition within set-net so when there is only a few fishes trapped the fishermen do not need to go to set net to haul the final trap and wait until the next day. Moreover, the demand of set-net installment is increasing, which will also increase the number of set-net fishermen. They will have the same problem, a few catch and real-time monitoring system. It means the demand of monitoring system will increase through the time. As discussed on the previous chapter, currently, the set net monitoring system is still under development and hopefully can be applied in Japan in several years later. By that time, there is a possibility to conduct the Japan-Indonesia technology transference of set-net monitoring system.

4.10 Remarks of Chapter 4

This chapter presents evidence of the role of mobile phones as a community support tool in improving the lives of small scale fishermen in coastal areas economically. Particularly, in information sharing between fishermen, for marketing and during emergency situations during the fishing trips. The results also provide the modules of marketing channels exploited by small scale fishermen in target area and the impact of data sharing and phone utilization in increasing fishermen's income. In cognizance of this potential, government should support and encourage acquisition of mobile phones by small scale fishermen in Indonesia to improve livelihood, reduce poverty and challenge the problems of the fishery sector. Government should also build the capacity and know-how of fishermen in utilization of mobile phones to gain more income as well as profit and provide training for community business and management skills and improve fishermen incomes. However, information sharing via mobile phone might also lead to overfishing so the government need to consider this phenomenon and regulate a new policy to control the catch.

In this chapter, the author proposed a scheme to handle the IUU and overfishing issues in Indonesia through applications of ICT and sensor network technologies. ICT and sensor network technologies have an immense potential to solve IUU and overfishing issues in Indonesia in near future. The scheme could be potentially applied step by step by installing ICT device such as low cost phone with GPS function as a network sensor in fishing vessel during the renewal of fishermen's license. Therefore, those data could be analyzed to solve IUU and overfishing step by step.

Although there are several issues remain in Indonesian fishery sector, set-net fishery has a very big potential to be developed in Indonesian coastal area. At the present moment, the demand of set-net installment is increasing. However, like Japan, the average daily catch is still considered low for the fishermen so there is a possibility of cost exceed the sales of hauled fish. In order to make the operation more effective, set-net monitoring system is necessary. Although the monitoring system is still under development, there is a possibility to conduct a Japan-Indonesia technology transference in the future.

Chapter 5 Conclusion and Future Works

5.1 Concluding Remarks

Data sharing through the study of numerical analysis of ICT and sensor network technology have been discussed in the study. Several conclusions can be concluded from the discussion such as:

In Chapter 1, the author argued the background, problem statement and also describe the objectives in this study. Two third of earth surface is covered by water with 97% of sea, yet, agriculture still provide approximately 95% of human calories and protein. Although fishery has a huge potential as food and protein source, this sector has not been fully utilized. Fishery should be utilized to support food supply in a sustainable way.

Fishery should be utilized to support food supply in a sustainable way. Fishery sector is one of the most important sectors in large archipelagic countries like Indonesia and Japan. Indonesia is known as the second largest fish producer in the world with 18 thousand island and over 99 thousand kilometer shoreline. Yet, several problems still remain in Indonesian coastal fishery, especially poverty reduction and fishermen's life improvement, illegal unregulated unreported (IUU) fishing and overfishing. Currently, those three problems are the top priority to be solved by Ministry of Maritime Affairs and Fisheries Republic of Indonesia (KKP). Apart from those three main issues, Indonesia has a big potential to introduce and develop the Japanese type set-net fishery. To illustrate, KKP reported that set-net fishery development is included in one of their potential strategic plan in 2014.

On the other hand, Japan is a large archipelagic country and one of the top ten fish producers of marine fishery in the world. 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. With this in mind, there are a lot of lessons, including advanced technology, which can be learnt from Japanese fisheries industry to be applied in Indonesia. Japanese fishery sector is considered as one of the best in the world, but it does not mean that there are no problems. For instance, until now fishery resource management and effective fishing method are still major issues for Japanese fisheries. Therefore, the objective of this study is to apply advanced ICT and sensor network technologies toward sustainable coastal fishery. In particular, 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.

In Chapter 2, a development of an automatic system to support self-management in coastal fishery by applying ICT and data sharing scheme has been presented. 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, a resource stock index (a method to estimate a certain extent of resource via the swept area method) has been developed previously. 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 chapter aimed 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 via swept area method in an originally developed cloud computing service. The author have conducted the test run of the present method in sea cucumber dredge-net fishery on the coast of Rumoi City, Hokkaido, Japan. The 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 results in this chapter showed that the present system could address the weaknesses of the previous research (Sano *et al*., 2011), i.e. fast computation process and low cost. The estimated resource stock index for the 2012 and 2013 seasons was 85.5 tons and 92.3 tons, respectively. During the test run in sea cucumber fishing in Rumoi city, fishermen voluntarily decided to stop the fishing season several weeks earlier than scheduled in both 2012 and 2013 by referring to the present system.

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 order to check the validity of resource stock index proposed in this paper, the author also examined a range of grid through an index. The index defined in this study shows the importance of the ratio of the area of a grid cell to the total dredged area. As a result, 100m grid size was the most adequate in this study.

The present system also made a good impact to the sea cucumber resource. Since the present method was applied in 2011, the resource information has been shared among fishermen and they became aware of the risk of overfishing. The awareness influences the decision making of fishermen themselves. The awareness stated above has resulted the increase of resource stock index of sea cucumber in the period of 2011 to 2014 and has started to achieve a stable condition of resource at around 90 to 100tons since 2014. During those period, the average of remainder during the increase was 48tons. In other word, it is better for the fishermen in Rumoi to at least keep 48tons of sea cucumber remainder to maintain the resource in the following years and to avoid overfishing.

This study systematizes information to support a better self-management of a coastal fishery resource at the local level (Rumoi City). In light of the evidence, the present automatic algorithm provided useful information for supporting the self-management of this coastal fishery.

The development an algorithm of catch amount estimation from computerized empirical estimation as the part of real-time remote fish finder system is discussed in Chapter 3. 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. In 2013, there were about 7,000 of set-net fishing unit around the Japanese coast, which produced 400 thousand tons or 13% of the total catch in Japan. Recently, set-net fishery is a popular fishing method in South East Asia, including Indonesia. Since set-net is a passive fishing method, fishermen do not know the catch amount in advance and only will be aware of the haul 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. Therefore, in this chapter, the author discussed the development of the algorithm for estimating catch amount and fish species classification of set-net fishery to support set-net fishermen.

The experiment of this study is conducted in Hokkaido and Toyama prefectures using a fish finder made by KODEN Co Ltd. (a Japanese echo sounder 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 hauling were used as indicators in the analysis. The daily catch record 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 in order to stabilize the variance of daily catch record, or to make the catch record statistically more normal distribution-like. After that, an estimation model was developed via multiple regression analysis using statistics of ping data as variables. 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.

Fish species within set-net were classified via linear discriminant analysis using the same statistics of ping data with catch amount estimation. For the fish classification, the author assumed that only five types of captured fish in an operation to be classified because those fish species were the dominant catch during the experiment. In particular, sardine, mackerel, Japanese horse mackerel, Japanese Spanish mackerel and other fish. Fish species classification via the present algorithm resulted approximately 83% of correctness both in Hokkaido and Toyama experimental site. Besides, the results showed that splitting the data based on seasonal fish species resulting a better fish classification in target area.

All of these findings indicate that, although the monitoring system is still under development, there is a possibility to apply the present algorithm as a real-time estimation system for set-net fishery to support the fishermen’s decision making.

Chapter 4 examined the state of Indonesian fishery including three main issues in coastal fishery, possible regulation to solve three main issues and set-net as a potential fishing method. This chapter presents evidence of the role of mobile phones as a community support tool in improving the lives of small scale fishermen in coastal areas economically. The results in Chapter 4 showed that the function of mobile phone is not only for marketing the catch, but also for life improvement, poverty reduction and community support tool, such as tool for information sharing and for seeking help during an emergency. In this chapter, the author also provided the modules of marketing channels exploited by small scale fishermen in target area and the impact of data sharing and phone utilization in increasing fishermen's income. In cognizance of these potential, governments should support and encourage acquisition of mobile phones by small scale fishermen in Indonesia to improve livelihood, reduce poverty as one of the major challenges in Indonesian fishery sector.

The government should support and encourage information sharing though a mobile phone utilization and conduct the training to build the capacity and know-how of fishermen in order to improve their way of managing KUB as a community business group. KUB should not be utilized by the fishermen only as a formality for the governmental procedure and for getting the governmental support, but as a community business group. One example is conducting a training to conduct a cooperative business to sell the catch collectively via information sharing using ICT device (mobile phone) among KUB members so that they have a selling power, namely more stable and sustainable supply of fish for the market compared to sell the fish single handedly.

Although information sharing system through mobile phone is very unique and can increase the income of fishermen, it can also lead to a tragedy of the commons. Supposed that fishermen continue the information sharing of a good fishing ground along with the fish species, it will perceptibly lead the fishermen to go to the same place to catch the same species of fish. In other word, there is a probability of overfishing. In order to avoid that, it is important for the government to not only promote information sharing via mobile phone in Indonesia, but also to regulate the new policy such as TAC or limiting the size of the fish to be catch and so on.

In this chapter, the author also proposed a scheme to handle the IUU and overfishing issues in Indonesia through the technology transference of the previously-mentioned advanced ICT and sensor network technology. ICT and sensor network technologies have an immense potential to solve IUU and overfishing issues in Indonesia in near future. The scheme could be potentially applied step by step by installing ICT device such as low cost phone with GPS function as a network sensor in fishing vessel during the renewal of fishermen's license. 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 IUU and overfishing in the same time.

Even though several issues still remain in Indonesia fishery sector, set-net fishery is considered as a rising star that has a very big potential to be developed in Indonesian coastal area. In the present time, the demand of set-net installment is increasing. However, just like Japan, the real-time monitoring system is desirable in near future. Currently, the set-net monitoring system is still under development as discussed in the previous chapter, yet, there is a possibility to apply the system in the future.

Finally, the authors would like to conclude that the information sharing, resource management and effective fishing are important toward the sustainable fishery in 21st century.

5.2 Future Subject

In this study several issues remain as future subject. Firstly, in Chapter 2, the author have presented a development of an automatic system to support self-management in coastal fishery by applying ICT and data sharing scheme. For further research, the author suggest to also conduct the socio-economic analysis of the sea cucumber fishermen in Rumoi, Hokkaido in accordance with the catch quota reduction. The socio-economic analysis includes their cost volume profit analysis and level of satisfaction of the self-management system. The application of the present system should be continued in the future in Rumoi so that the trend of appropriate quotas in that area can be specified more adequately. The authors intend to apply the present system to other fishery operation in different area in near future and wish to use them for the coastal fishery resource management.

For the real-time monitoring system of set-net fishery in Chapter 3, the development of an algorithm to automatically detect the inappropriate ping data series is necessary. Then, catch estimation is still not reliable enough because the estimation model contained too much information. In order to increase the accuracy of the estimation, it would be a good idea to limit the water depth with only using several layers. The detection of independently swimming fish, such as tuna, wavelet transform could be applied to derive its characteristics before estimating the catch amount. Next is the classification of more than one fish species due to the extrapolation. Besides, it would be potential to classify the fish species first and then estimate the catch amount afterwards.

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Appendices

Apendix A

This contains script to automatically calculate the catch amount of sea cucumber.

```
<?php

//
//Automatic calculation of catch
//
//Calculate from NMEA log
//
//    grid based on the manual design
//

require_once("dbconnect.inc");
require_once("function.inc");
require_once("heimen.inc");
require_once("tky2wgs.inc");

global $debug;
$debug = false;      // debug graph print if true

// table rumoi_sano_grid

$otbl = "rumoi_sano_grid";

//======================
// calculation time
//======================
$now = date("Y-m-j H:i:s",time());
print $now . "¥n";

//==================
```

```
// meshread
//=================

$fm = fopen("rumoi_mesh.txt","r");

$mx = 0; //number of grid
$nx = 0;  //node number
$ie = array();          //grid condition
$lon = array();
$lat = array();
$nxx = array();
$nyy = array();
$zone1 = array();
$zone2 = array();

$max_x = -999999;
$max_y = -999999;
$min_x =    999999;
$min_y =    999999;
while($mesh = fgetcsv($fm)){
        $im = $mesh[0];    // mesh number

        $in = $mesh[1];
        $ie[$im][0] = $in;  // ie0nodenumber
        $lon[$in]      = $mesh[2];     // ie0node longitude
        $lat[$in]      = $mesh[3];     // ie0node latitude
        $nxx[$in]      = $mesh[4];    // ie0x coordinate
        $nyy[$in]      = $mesh[5];    // ie0x coordinate
        if($max_x < $nxx[$in])        $max_x = $nxx[$in];
        if($max_y < $nyy[$in])        $max_y = $nyy[$in];
        if($min_x > $nxx[$in])        $min_x = $nxx[$in];
        if($min_y > $nyy[$in])        $min_y = $nyy[$in];

        $in = $mesh[6];
        $ie[$im][1] = $in;  // ie1node
        $lon[$in]      = $mesh[7];     // ie1node longitude
```

```
$lat[$in]      = $mesh[8];      // ie1node latitude
$nxx[$in]      = $mesh[9];      // ie1x coordinate
$nyy[$in]      = $mesh[10];     // ie0x coordinate
if($max_x < $nxx[$in])        $max_x = $nxx[$in];
if($max_y < $nyy[$in])        $max_y = $nyy[$in];
if($min_x > $nxx[$in])        $min_x = $nxx[$in];
if($min_y > $nyy[$in])        $min_y = $nyy[$in];

$in = $mesh[11];
$ie[$im][2] = $in;  // ie2node
$lon[$in]      = $mesh[12];    // ie2node longitude
$lat[$in]      = $mesh[13];    // ie2node latitude
$nxx[$in]      = $mesh[14];    // ie2x coordinate
$nyy[$in]      = $mesh[15];    // ie2x coordinate
if($max_x < $nxx[$in])        $max_x = $nxx[$in];
if($max_y < $nyy[$in])        $max_y = $nyy[$in];
if($min_x > $nxx[$in])        $min_x = $nxx[$in];
if($min_y > $nyy[$in])        $min_y = $nyy[$in];

$in = $mesh[16];
$ie[$im][3] = $in;  // ie3node number
$lon[$in]      = $mesh[17];    // ie3node longitude
$lat[$in]      = $mesh[18];    // ie3node latitude
$nxx[$in]      = $mesh[19];    // ie3x coordinate
$nyy[$in]      = $mesh[20];    // ie3x coordinate
if($max_x < $nxx[$in])        $max_x = $nxx[$in];
if($max_y < $nyy[$in])        $max_y = $nyy[$in];
if($min_x > $nxx[$in])        $min_x = $nxx[$in];
if($min_y > $nyy[$in])        $min_y = $nyy[$in];

$zone1[$im][0] = $mesh[21];
$zone1[$im][1] = $mesh[22];
$zone1[$im][2] = $mesh[23];
$zone1[$im][3] = $mesh[24];

$zone2[$im][0] = $mesh[25];
```

```
            $zone2[$im][1] = $mesh[26];
            $zone2[$im][2] = $mesh[27];
            $zone2[$im][3] = $mesh[28];

            $mx++;

            if($mesh[1] > $nx)$nx = $mesh[1];                 //ie0node number
            if($mesh[6] > $nx)$nx = $mesh[6];                 //ie1node number
            if($mesh[11] > $nx)          $nx = $mesh[11];  //ie2node number
            if($mesh[16] > $nx)          $nx = $mesh[16];  //ie3node number
}

print "Total num of grids = " . $mx . "¥n";
print "Total num of points = " . $nx . "¥n";
print "max_x = " . $max_x . " min_x = " . $min_x . "¥n";
print "max_y = " . $max_y . " min_y = " . $min_y . "¥n";

fclose($fm);

//print_r($ie);
//print_r($nxx);
//print_r($nyy);



//=======================
//    READ vessel in rumoi
//=======================
   $vessel = getVessel();

//==================
// diary read
//==================

   $diary = new DbConnect();
   $diary->dbname = "njc";
   $diary->getConnection();
```

```
    $sql = "Select * from diary
                where (mdate >= '2012-07-01')
                and     (mdate <= '2012-08-09')
                and     (harv > '0.01')
                order by ipadip, mdate, kai";

    $result_id = $diary->doQuery($sql);
    if(!$result_id){
            print "Query Failed ¥n";
            print $sql . "¥n";
    }

    $diary->doClose();

    $data = array();
    $limit = pg_numrows($result_id);

    print $limit . " data ¥n";

    for($i = 0; $i < $limit; $i++){
            $data[$i] = pg_fetch_array($result_id, $i);
    }

//============================
//    grouping diary
//============================
    for($i=0; $i<$limit; $i++){
            $ipadip = trim($data[$i]['ipadip']);

            //======================
            //    diary check
            //======================
            $hstart = $data[$i]['hstart'];
            $hend = $data[$i]['hend'];
            if($hstart == "") continue;
```

```
if($hend == "") continue;

//==========================
// neglect error data
//==========================

$htime = $data[$i]['htime'];
if($htime == "") continue;

list($hji, $hfun) = split(":",$htime);
$htime = $hji*3600.0 + $hfun*60.0;

if($htime < 600) continue;          //less than 10 minutes
if($htime > 18000) continue;              //more than 5 hours


$iv_num = 0;
$vvid = array();
$vvcode = array();
foreach($vessel as $vvv){
        $vvipad = trim($vvv['ipadid']);
        if($vvipad == $ipadip){
                $vvid[$iv_num] = $vvv['vid'];
                $vvcode[$iv_num] = $vvv['code'];
                $iv_num++;
        }
}

//==========================
// if not continue;
//==========================
if($iv_num < 1){
        //print "Data Not Rumoi " . $ipadip . "¥n";
        continue;
}
```

```
//==========================
// if yes, data set
//==========================
$mdate = $data[$i]['mdate'];
$kai = $data[$i]['kai'];
$htime = $data[$i]['htime'];
$harv = $data[$i]['harv'];

$vid_0 = $vvid[0];
$vcode_0 = $vvcode[0];

if($vvid[0] == "rumoi28") $vid_0 = "rumoi27";

//============================
//    starting data process
//============================

gyokaku($vid_0,$vcode_0,$mdate,$hstart,$hend,$harv,$kai,
        $mx,$nx,$ie,$nxx,$nyy,$zone1,$zone2,$hsum);

//=====================================================
// output calculation
// DB csv write
//=====================================================
$fp = fopen("result.csv","a");

for($k=0; $k<$mx; $k++){
        if($hsum[$k]['date'] == NULL) continue;
        $str    = $vid_0 . ",";
        //$str .= $vcode_0 . ",";
        $str .= $mdate . ",";
        $str .= $kai . ",";
        $str .= $k . "," ;
        $str .= $hsum[$k]['area'] . ",";
        $str .= $hsum[$k]['harv'] . "¥n";
        fwrite($fp,$str);
```

```
		}
		fclose($fp);

//=====================
//	finish diary group
//=====================
	}

//========================
//	write into DB
//========================

	$rumoi_res = new DbConnect();
	$rumoi_res->dbname = "njc";
	$rumoi_res->getConnection();

	//delete previous

	$sql = "delete from $otbl";

	$result_id = $rumoi_res->doQuery($sql);
	if(!$result_id){
		print "Query Failed ¥n";
		print $sql . "¥n";
	}

	// add result

	$fp = fopen("result.csv","r");
	while($rec = fgetcsv($fp)){
		$sql	= "Insert into $otbl Values (
				'$rec[0]' , '$rec[1]', '$rec[2]',
				'$rec[3]' , '$rec[4]', '$rec[5]')";

		$result_id = $rumoi_res->doQuery($sql);
		if(!$result_id){
```

```
                print "Query Failed ¥n";
                print $sql . "¥n";
            }
    }

    $rumoi_res->doClose();
    fclose($fp);

//=====================
// calculation time
//=====================
$now = date("Y-m-j H:i:s",time());
print $now . "¥n";



//========================================
//    read from Vesseltable
//========================================

function getVessel(){

    $vessel = new DbConnect();
    $vessel->dbname = "njc";
    $vessel->getConnection();

    $sql = "Select * from vessel where tablename = 'rumoi'";

    $result_id = $vessel->doQuery($sql);
    $vessel->doClose();

    $data = array();
    $limit = pg_numrows($result_id);

    print "Num of vessel in rumoi is " . $limit . "¥n";

    for($i = 0; $i < $limit; $i++){
```

```
            $data[$i] = pg_fetch_array($result_id, $i);
   }

   return $data;
}
//====================
// divide catch data
//====================
function gyokaku($vid,$vcode,$mdate,$hstart,$hend,$harv,$kai,
                        $mx,$nx,$ie,$nxx,$nyy,$zone1,$zone2,&$hsum){

global $debug;

            //===================
            // set date
            //===================

            list($sy, $sm, $sd) = split("-",$mdate);
            list($hst_hh, $hst_mm) = split(":",$hstart);
            list($hen_hh, $hen_mm) = split(":",$hend);

            $hst = mktime($hst_hh,$hst_mm,0,$sm,$sd,$sy) - 9*3600;
            $het = mktime($hen_hh,$hen_mm,0,$sm,$sd,$sy) - 9*3600 + 60;

            $htotal = $het - $hst;                          //time [s]

            $hsd = date("Y-m-d",$hst);   //UTM
            $hst = date("H:i:s",$hst);

            //finish time search
            $hed = date("Y-m-d",$het);  //finish time in UTM
            $het = date("H:i:s",$het);

            //===================
            //    read trajectory
            //===================
```

```
$koseki = new DbConnect();
$koseki->dbname = "njc";
$koseki->getConnection();

if($hsd == $hed){
        $sql = "Select Distinct
                vessel, sdate, stime, lat, long, sokudo from rumoi
                Where (vessel = '$vid')
                And (sdate = '$hsd')
                And (stime between '$hst' and '$het')
                Order by sdate, stime";
} else {
        $sql ="(Select Distinct
                vessel, sdate, stime, lat, long, sokudo from rumoi
                Where (vessel = '$vid')
                And (sdate = '$hsd')
                And (stime >= '$hst'))
                Union
               (Select Distinct
                vessel, sdate, stime, lat, long, sokudo from rumoi
                Where (vessel = '$vid')
                And (sdate = '$hed')
                And (stime <= '$het'))
                Order by sdate, stime";
}

$result_id = $koseki->doQuery($sql);
$koseki->doClose();

$data = array();
$limit = pg_numrows($result_id);

print " koseki num = " . $limit . " on " . $mdate . " " . $vid . " " . $kai . "¥n";

for($i = 0; $i < $limit; $i++){
```

```
		$data[$i] = pg_fetch_array($result_id, $i);
	}

	if($limit < 60){			//error if 10 minutes
		return true;
	}

	//==========================================
	// derive distance
	// error or not
	//==========================================

	$kei = 12;				// rectangular plane coordinate 12
	$ox = 0.0;
	$oy = 0.0;
	$otime = "";				//
	$dist    = 0.0;				//
	$ttime = 0.0;				//

	$xp = array();				// point data
	$yp = array();
	$ipn = 0;			// point data    number
	$pdate = array();
	$ptime = array();
	$plat = array();
	$plong = array();

	for($i=0; $i<$limit; $i++){
		//===============================
		// format coordinate
		//===============================

		$lat    = nmea2do($data[$i]['lat']);
		$long = nmea2do($data[$i]['long']);
		$sokudo = $data[$i]['sokudo']*1.00;
```

```
// if TKY change to WGS
if($vcode == "TKY"){
        tky2wgs($lat,$long, $L, $M);
        $lat = $L;
        if($M < 0){
                $M=$M+180;
        }
        $long = $M;
}

// SKIP
if($lat < 42.0) continue;
if($lat > 45.0) continue;
if($long < 140.0) continue;
if($long > 142.0) continue;

//=====================
//    rectangular plane    coordinate
//=====================

 $zahyo = new Heimen;
 $zahyo->genten($kei);

 $rlat = deg2rad($lat);
 $rlon = deg2rad($long);

 $res = $zahyo->henkan($rlat, $rlon);
 $hx = $res['Y'];            //longitude X
 $hy = $res['X'];            //latitude Y


$sdate = $data[$i]['sdate'];
$stime = $data[$i]['stime'];

if($otime == ""){
       $ox = $hx;
```

```
        $oy = $hy;
        $otime = $stime;

        $xp[$ipn] = $hx;
        $yp[$ipn] = $hy;
        $pdate[$ipn] = $sdate;
        $ptime[$ipn] = $stime;
        $plat[$ipn] = $lat;
        $plong[$ipn] = $long;

        $ipn++;
        continue;
}

if($stime == $otime) continue;

$ds = calc_dist($ox, $oy, $hx, $hy);

list($sji,$sfun,$sbyo) = split(":",$stime,3);
list($oji,$ofun,$obyo) = split(":",$otime,3);
$dt = ($sji-$oji)*3600 + ($sfun-$ofun)*60 + ($sbyo-$obyo);

if($dt < 1) continue;
$vel = $ds / $dt;



//if(($ttime < 300) and ($vel > 2.0)){
         //$ox = $hx;
         //$oy = $hy;
         //$otime = $stime;

         //$xp[$ipn] = $hx;
         //$yp[$ipn] = $hy;
         //$pdate[$ipn] = $sdate;
         //$ptime[$ipn] = $stime;
```

```
		//$plat[$ipn] = $lat;
		//$plong[$ipn] = $long;

		//continue;
//}

//if($vel > 4.0){
		//$ox = $hx;
		//$oy = $hy;
		//$otime = $stime;

		//$xp[$ipn] = $hx;
		//$yp[$ipn] = $hy;
		//$pdate[$ipn] = $sdate;
		//$ptime[$ipn] = $stime;
		//$plat[$ipn] = $lat;
		//$plong[$ipn] = $long;

		//continue;
//}



//$hlast = $htotal - 300;
//if(($ttime > $hlast) and ($vel > 3.0)){
		//return true;
//}

//if($sokudo > 2.0){
		//$ox = $hx;
		//$oy = $hy;
		//$otime = $stime;

		//$xp[$ipn] = $hx;
		//$yp[$ipn] = $hy;
		//$pdate[$ipn] = $sdate;
		//$ptime[$ipn] = $stime;
```

```
			//$plat[$ipn] = $lat;
			//$plong[$ipn] = $long;

			//continue;
		//}

		//

		$dist += $ds;
		$ttime += $dt;

		 $xp[$ipn] = $hx;
		 $yp[$ipn] = $hy;
		$pdate[$ipn] = $sdate;
		$ptime[$ipn] = $stime;
		$plat[$ipn] = $lat;
		$plong[$ipn] = $long;

		$ox = $hx;
		 $oy = $hy;
		$otime = $stime;
		$ipn++;
	}

	if(($dist > 10000.0) or ($dist < 50.0)){
		print "==============================¥n";
		print " Error occured! ¥n";
		print "==============================¥n";
		print "VID=" . $vid;
		print " " . $mdate;
		print " " . $kai . "kai";
		print " " . $hstart;
		print " " . $hend;
		print " harv=" . $harv;
		print "¥n";
```

```
		print "===> DISTANCE may be wrong " . $dist . "¥n";
		return false;
	}

	$dens = $harv * 20.0 / $dist / 3.2;	// (kg/m2)
							// 3.2m

	print "dist = " . $dist . " ttime = " . $ttime . " dens = " . $dens . "¥n";



	$hsum = array();
	for($i=0; $i<$mx; $i++){
		$hsum[$i]['harv'] = 0.0;
		$hsum[$i]['area'] = 0.0;
		$hsum[$i]['date'] = NULL;
	}

	$gflg = false;
	for($i=0; $i<$ipn-1; $i++){

		$ppx = $xp[$i];
		$ppy = $yp[$i];

		//print $ppx . " " . $ppy . "¥n";

		for($iim=0; $iim<$mx-1; $iim++){
			$res = calc_belong($ppx,$ppy,$iim,$ie,$nxx,$nyy);
			if($res){
				$ppm = $iim;
				//print " Serial = " . $i . " : Elem = " . $ppm . "¥n";
				$gflg = true;
				$last_n = $i+1;
				break;
			}
		}
```

```
		if($gflg)  break;
	}

	if(!$gflg){
		print " No element is found ¥n";
		return false;
	}

	//print " Next step " . $last_n . "¥n";

	$ob = false;
	for($i=$last_n; $i<$ipn-1; $i++){

		$flg = false;

		$pnx = $xp[$i];
		$pny = $yp[$i];

		//
		if($ob == true){
		   $gflg = false;
		   for($iim=0; $iim<$mx-1; $iim++){
			$res = calc_belong($pnx,$pny,$iim,$ie,$nxx,$nyy);
			if($res){
				$ppm = $iim;
				$gflg = true;
				break;
			}
		   }
		}

		if(($ob == true) and ($gflg == false))  continue;

		if($ob == true){
			$ppx = $pnx;
			$ppy = $pny;
```

```
        $ob = false;
        continue;
}


$sss = calc_dist($ppx, $ppy, $pnx, $pny);

if($sss < 4.0){
        $res_w = wariate( $vid, $mdate, $kai,
                        $ie, $nxx, $nyy,$zone1,$zone2,
                        $sss, $dens,
                        $ppx, $ppy, $pnx, $pny,
                        $ppm, $ppz, $hsum, $flg);

        if($flg == false){
                $ob = true;
                continue;
        }

        $ppx = $pnx;
        $ppy = $pny;
        $ppm = $ppz;

        continue;

}


$bkn = intval($sss / 2.0) + 1;          //分割数
$bdx = ($pnx - $ppx) / $bkn;
$bdy = ($pny - $ppy) / $bkn;

for($bb=0; $bb<$bkn; $bb++){
        $pnx = $ppx + $bdx;
        $pny = $ppy + $bdy;
        $sss = calc_dist($ppx, $ppy, $pnx, $pny);
```

```
                    $res_w = wariate( $vid, $mdate, $kai,
                                    $ie, $nxx, $nyy,$zone1,$zone2,
                                    $sss, $dens,
                                    $ppx, $ppy, $pnx, $pny,
                                    $ppm, $ppz, $hsum, $flg);

                    if($flg == false){
                            $ob = true;
                            continue;
                    }

                    $ppx = $pnx;
                    $ppy = $pny;
                    $ppm = $ppz;
                    continue;

            }
        }

        return true;

}

function wariate( $vid, $mdate, $kai,
                $ie, $nxx, $nyy,$zone1,$zone2,
                $sss, $dens,
                $ppx, $ppy, $pnx, $pny,
                $ppm, &$ppz, &$hsum, &$flg){

global $debug;

        $res = calc_belong($pnx,$pny,$ppm,
                            $ie,$nxx,$nyy);

        if($res){
```

```
        $hsum[$ppm]['area'] += $sss * 3.2;        // length 3.2m
         $hsum[$ppm]['harv'] += $sss * 3.2 * $dens;
         if($hsum[$ppm]['date'] == NULL){
                 $hsum[$ppm]['date'] = $mdate;
         }
        $flg = true;
        $ppz = $ppm;
         return true;
}


$flg = false;
for($j=0; $j<4; $j++){
        $zone = $zone1[$ppm][$j];
         if($zone <= 0) continue;
         $res = calc_belong($pnx,$pny,$zone,
                                 $ie,$nxx,$nyy);
         if($res){
                $flg = true;
                 $ppz = $zone;
                 $pzn = $j;
                 break;
         }
}

if($flg){

        if($pzn == 3){
                $lla = $ie[$ppm][3];
                $llb = $ie[$ppm][0];
        } else {
                $lla = $ie[$ppm][$pzn];
                $llb = $ie[$ppm][$pzn+1];
        }

        $lax = $nxx[$lla];
```

```
		$lbx = $nxx[$llb];
		$lay = $nyy[$lla];
		$lby = $nyy[$llb];

		$del1 = calc_area($lax,$lay,$lbx,$lby,$ppx,$ppy);
		$del2 = calc_area($lax,$lay,$pnx,$pny,$lbx,$lby);
		$del1 = abs($del1);
		$del2 = abs($del2);
		$sss1 = $del1 / ($del1 + $del2) * $sss;
		$sss2 = $sss - $sss1;

		if($sss1 > 141.42){
			return false;
		}

		if($sss2 < 0.0){
			return false;
		}

		$hsum[$ppm]['area'] += $sss1 * 3.2;
		$hsum[$ppm]['harv'] += $sss1 * 3.2 * $dens;

		$hsum[$ppz]['area'] += $sss2 * 3.2;
		$hsum[$ppz]['harv'] += $sss2 * 3.2 * $dens;
		if($hsum[$ppz]['date'] == NULL){
			$hsum[$ppz]['date'] = $mdate;
		}

		return true;
	}
	$flg = false;
	 for($j=0; $j<4; $j++){
		 $zone = $zone2[$ppm][$j];
		 if($zone <= 0) continue;
		 $res = calc_belong($pnx,$pny,$zone,
						$ie,$nxx,$nyy);
```

```
		if($res){
			$flg = true;
			$ppz = $zone;
			$pzn = $j;
			break;
		}
	}

	if(!$flg){
		$ppz = $ppm;

		print "==============================¥n";
		print " Error occured! ¥n";
		print "==============================¥n";
		print " ==> Point dose'nt belong Zone1 nor Zone2, ";
		print "VID=" . $vid;
		print " " . $mdate;
		print " " . $kai . "kai";
		print "¥n";

		return false;
	}
	$ddx = ($pnx - $ppx) * 0.5;
	$ddy = ($pny - $ppy) * 0.5;

	$p3x = $ppx + $ddx;
	$p3y = $ppy + $ddy;

	$flg = false;
	for($j=0; $j<4; $j++){
		$zone = $zone1[$ppm][$j];
		if($zone <= 0) continue;
		$res = calc_belong($p3x,$p3y,$zone,
					$ie,$nxx,$nyy);
		if($res){
			$flg = true;
```

```
                    $p3z = $zone;
                    $p3n = $j;
                    break;
            }
    }

    if($flg){
            $sss3_1 = calc_dist($ppx,$ppy,$p3x,$p3y);
            $sss3_2 = $sss - $sss3_1;

            if($sss3_1 > 141.42){
                    return false;
            }

            if($sss3_2 < 0.0){
                    return false;
            }

            if($p3n == 3){
                    $lla = $ie[$ppm][3];
                    $llb = $ie[$ppm][0];
            } else {
                    $lla = $ie[$ppm][$p3n];
                    $llb = $ie[$ppm][$p3n+1];
            }

            $lax = $nxx[$lla];
            $lbx = $nxx[$llb];
            $lay = $nyy[$lla];
            $lby = $nyy[$llb];

            $del1 = calc_area($lax,$lay,$lbx,$lby,$ppx,$ppy);
            $del2 = calc_area($lax,$lay,$p3x,$p3y,$lbx,$lby);
            $del1 = abs($del1);
            $del2 = abs($del2);
            $sss1 = $del1 / ($del1 + $del2) * $sss3_1;
```

```
 $sss2 = $sss3_1 - $sss1;

if($sss1 > 141.42){
		return false;
}

if($sss2 < 0.0){
		return false;
}

 $hsum[$ppm]['area'] += $sss1 * 3.2;		// length 3.2m
 $hsum[$ppm]['harv'] += $sss1 * 3.2 * $dens;

 $hsum[$p3z]['area'] += $sss2 * 3.2;		// length 3.2m
 $hsum[$p3z]['harv'] += $sss2 * 3.2 * $dens;
 if($hsum[$p3z]['date'] == NULL){
		$hsum[$p3z]['date'] = $mdate;
 }


 if($p3n == 0){
    if($pzn == 0){
		$lla = $ie[$p3z][3];
		$llb = $ie[$p3z][0];
    } else if($pzn == 1){
		$lla = $ie[$p3z][1];
		$llb = $ie[$p3z][2];
    } else {
		$ppz = $ppm;
		print "================¥n";
		print "Case4 ERROR ¥n";
		print "================¥n";
		return false;
    }
 } else if($p3n == 1){
    if($pzn == 1){
```

```
            $lla = $ie[$p3z][0];
            $llb = $ie[$p3z][1];
    } else if($pzn == 2){
            $lla = $ie[$p3z][2];
            $llb = $ie[$p3z][3];
    } else {
          $ppz = $ppm;
            print "================¥n";
            print "Case4 ERROR ¥n";
            print "================¥n";
            return false;
    }
 } else if($p3n == 3){
    if($pzn == 3){
            $lla = $ie[$p3z][2];
            $llb = $ie[$p3z][3];
    } else if($pzn == 0){
            $lla = $ie[$p3z][0];
            $llb = $ie[$p3z][1];
    } else {
          $ppz = $ppm;
            print "================¥n";
            print "Case4 ERROR ¥n";
            print "================¥n";
            return false;
    }
 }

 $lax = $nxx[$lla];
 $lbx = $nxx[$llb];
 $lay = $nyy[$lla];
 $lby = $nyy[$llb];

 $del1 = calc_area($lax,$lay,$lbx,$lby,$p3x,$p3y);
 $del2 = calc_area($lax,$lay,$pnx,$pny,$lbx,$lby);
$del1 = abs($del1);
```

```
		$del2 = abs($del2);
		 $sss1 = $del1 / ($del1 + $del2) * $sss3_2;
		 $sss2 = $sss3_2 - $sss1;

		if($sss1 > 141.42){
			return false;
		}

		if($sss2 < 0.0){
			return false;
		}

		 $hsum[$p3z]['area'] += $sss1 * 3.2;		// length 3.2m
		 $hsum[$p3z]['harv'] += $sss1 * 3.2 * $dens;

		 $hsum[$ppz]['area'] += $sss2 * 3.2;		// length 3.2m
		 $hsum[$ppz]['harv'] += $sss2 * 3.2 * $dens;
		 if($hsum[$ppz]['date'] == NULL){
			 $hsum[$ppz]['date'] = $mdate;
		 }

		return true;
	}

	 if($pzn == 0){
		 $lla = $ie[$ppz][2];
	 } else if($pzn == 1){
		 $lla = $ie[$ppz][3];
	 } else if($pzn == 2){
		 $lla = $ie[$ppz][0];
	 } else if($pzn == 3){
		 $lla = $ie[$ppz][1];
	 }

	 $lax = $nxx[$lla];
	 $lay = $nyy[$lla];
```

```
        $sss1 = calc_dist($ppx,$ppy,$lax,$lay);
        $sss2 = $sss - $sss1;

                if($sss1 > 141.42){
                        return false;
                }

                if($sss2 < 0.0){
                        return false;
                }

        $hsum[$ppm]['area'] += $sss1 * 3.2;
        $hsum[$ppm]['harv'] += $sss1 * 3.2 * $dens;

        $hsum[$ppz]['area'] += $sss2 * 3.2;
        $hsum[$ppz]['harv'] += $sss2 * 3.2 * $dens;
        if($hsum[$ppz]['date'] == NULL){
                 $hsum[$ppz]['date'] = $mdate;
        }


        return true;
}

?>
```

Apendix B

This contains script to automatically calculate the resource stock index of sea cucumber.

```
<?php

//
```

```
//

require_once("dbconnect.inc");

    $rumoi_res = new DbConnect();
    $rumoi_res->dbname = "njc";
    $rumoi_res->getConnection();

    $gsize = 1600;
    $tbl = "r" . $gsize . "m";
    //$tbl = "rumoi_sano_grid";



    $sql    = "select grid, min(hdate) as mdate, sum(area) as s_area from $tbl
                    group by grid order by mdate";

    $result_id = $rumoi_res->doQuery($sql);
    if(!$result_id){
            print "Query Failed ¥n";
            print $sql . "¥n";
    }

    $rumoi_res->doClose();

    $data = array();
    $limit = pg_numrows($result_id);
    for($i = 0; $i < $limit; $i++){
            $data[$i] = pg_fetch_array($result_id, $i);
    }

    $fn = $gsize . "_syoki.csv";
    $fp = fopen($fn,"a");

    $rumoi_res = new DbConnect();
    $rumoi_res->dbname = "njc";
    $rumoi_res->getConnection();
```

```
$hsum = array();

$ic = 0;
$sdate = array();//
$odate = "2000-01-01";    //

$dens = 0.0;
for($i = 0; $i < $limit; $i++){
        $gid = $data[$i]['grid'];
        $mdate = $data[$i]['mdate'];
        $s_area = $data[$i]['s_area'];

        //if($s_area < 500) continue;
        //if($s_area < 125) continue;

        $thu = $gsize * $gsize * 0.049999;
        if($s_area < $thu)  continue;

        if($mdate != $odate){
                $sdate[$ic] = $mdate;
                $ic++;
        }

        $odate = $mdate;

        $sql    = "select * from $tbl
                    where grid = '$gid'
                    and hdate = '$mdate'";

        $result_id = $rumoi_res->doQuery($sql);
        if(!$result_id){
                print "Query Failed ¥n";
                print $sql . "¥n";
        }
```

```
$rres = array();
$num = pg_numrows($result_id);
for($k = 0; $k < $num; $k++){
        $rres[$k] = pg_fetch_array($result_id, $k);
}

if($num < 1){
        print "ERROR ";
        print $mdate . " " . $gid . "¥n";
        continue;
}

$xk = 0.0;
$yk = 0.0;

for($k=0; $k<$num; $k++){
        $xk += $rres[$k]['catch'];
        $yk += $rres[$k]['area'];
}

$ave = $xk / $yk;
$area = $yk;
$var = 0.0;

for($k=0; $k<$num; $k++){
        $xk = $rres[$k]['catch'];
        $yk = $rres[$k]['area'];
        $den = $xk / $yk;
        $var += ($den-$ave)*($den-$ave)*$yk;
}

$var = $var / $area;

//$str    = $mdate . ",";
//$str .= $gid . ",";
//$str .= $num . ",";
```

```
        //$str .= $var . ",";
        //$str .= $ave . ",";
        //$str .= $area . "¥n";
        //fwrite($fp,$str);

        if(isset($hsum[$mdate])){
                $hsum[$mdate] += $ave * $gsize * $gsize;
        } else {
                $hsum[$mdate]    = $ave * $gsize * $gsize;
        }

        $str = $gid . "," . $area . "," . $ave . "¥n";
        $dens += $ave;
        //fwrite($fp,$str);
}

//$str = "¥n";
//fwrite($fp,$str);

//$dens = $dens / $limit;
//$str = $dens . "¥n";
//fwrite($fp,$str);

$str = "¥n";
fwrite($fp,$str);

$rumoi_res->doClose();

$sekisan = 0;
for($i=0; $i<$ic; $i++){
        $tdate = $sdate[$i];
        $sekisan += $hsum[$tdate];
        $str = $tdate . "," . $sekisan . "¥n";
        fwrite($fp,$str);
}
```

```
    fclose($fp);
?>
```

Apendix C

This contains script to CPUE of sea cucumber fishery in Rumoi City.

```
<?php
require_once("dbconnect.inc");

//
// setting.txt
// diary table
// shigentable

//************************************
//************************************

$gsize = 100;

$fp = fopen("setting.dat","r");
while($line = fgets($fp)){
        $dat = split(",",$line);
        if($dat[0] == "district")       $district = trim($dat[1]);
        if($dat[0] == "year")                   $year = $dat[1]*1;
        if($dat[0] == "d_kaishi")       $d_kaishi = trim($dat[1]);
        if($dat[0] == "d_syuryo")       $d_syuryo = trim($dat[1]);
        if($dat[0] == "gyosen")                 $gyosen = $dat[1]*1;
}
fclose($fp);

if($district == "")     exit();     //
if($year == "")                     exit();
if($d_kaishi == "")     exit();
```

```
if($d_syuryo == "")      $d_syuryo = "1900-01-01";

$today = date("Y-m-d",time());
$now = time();

//*************************************************
//*************************************************

  $rumoi_res = new DbConnect();
  $rumoi_res->dbname = "njc";
  $rumoi_res->getConnection();

  $last = $d_syuryo;
  if($d_syuryo < $d_kaishi)       $last = $today;

  $sql = "select * from diary
       where (mdate >= '$d_kaishi')
       and      (mdate <= '$last')
       and      (harv != '')
       order by ipadip, mdate, kai";

  $result_id = $rumoi_res->doQuery($sql);
  if(!$result_id){
           print "Query Failed ¥n";
           print $sql . "¥n";
    exit();
  }

  $rec_num = pg_numrows($result_id);
  print "Total num. of rec = " . $rec_num . "¥n";

  $data = array();
  for($i=0; $i<$rec_num; $i++){
    $data[$i] = pg_fetch_array($result_id, $i);
  }
```

```
    //*******************************************
    //*******************************************
    $total_k = 0;
    $total_c = 0;
    $total_r = 0;
    for($i=0; $i<$rec_num; $i++){
      $ipad = $data[$i]['ipadip'];
      $harv = $data[$i]['harv'];
      $release = $data[$i]['release'];

      $sql = "select vid from vessel
                    where ipadid = '$ipad'
                    and     tablename = 'rumoi'";

      $result_id = $rumoi_res->doQuery($sql);
      if(!$result_id){
                    print "Query Failed ¥n";
                    print $sql . "¥n";
                    exit();
      }

      $limit = pg_numrows($result_id);
      if($limit != 1)       continue;

      $total_c += $harv*1.0;
      $total_r += $release*1.0;
      $total_k++;
    }

    $rumoi_res->doClose();

    print "総漁獲量：  " . $total_c * 20.0 . "¥n";
    print "総放流量：  " . $total_r * 20.0 . "¥n";
    print "曳網回数：  " . $total_k . "¥n";
    print "通算 CPUE：  " . $total_c * 20.0 / $total_k . "¥n";
?>
```

Apendix D

This contains script to examine the appropriate grid sizes in resource stock index of sea cucumber.

```
<?php
//

//    ZONE1, ZONE2

require_once("heimen.inc");

// Grid

$p_max = 7142;          //node number
$m_max = 1788;          // mesh number

$fp = fopen("rumoi_sano.txt","r");

$ie_count = 0;
while($grid = fgetcsv($fp,4096,",")){
      $pid = $grid[0];
      $mid = $grid[1];
      $lon[$pid] = $grid[2];
      $lat[$pid] = $grid[3];
      $ie[$mid][3 - $ie_count] = $pid;
      $ie_count++;
      if($ie_count > 3)   $ie_count = 0;
}

fclose($fp);

// rectangular plane    coordinate
  $kei = 12;                          //
  $zahyo = new Heimen;
  $zahyo->genten($kei);
```

```
$fw = fopen("rumoi_mesh.txt","w");

$xx = array();
$yy = array();
for($i=0; $i<$m_max; $i++){
	$ie0 = $ie[$i][0];
	$ie1 = $ie[$i][1];
	$ie2 = $ie[$i][2];
	$ie3 = $ie[$i][3];

	$lat0 = $lat[$ie0];
	$lat1 = $lat[$ie1];
	$lat2 = $lat[$ie2];
	$lat3 = $lat[$ie3];

	$lon0 = $lon[$ie0];
	$lon1 = $lon[$ie1];
	$lon2 = $lon[$ie2];
	$lon3 = $lon[$ie3];

	$rlat = deg2rad($lat0);
	$rlon = deg2rad($lon0);
	$res = $zahyo->henkan($rlat,$rlon);
	$xx0 = $res['Y'];
	$yy0 = $res['X'];
	$xx[$ie0] = $xx0;
	$yy[$ie0] = $yy0;

	$rlat = deg2rad($lat1);
	$rlon = deg2rad($lon1);
	$res = $zahyo->henkan($rlat,$rlon);
	$xx1 = $res['Y'];
	$yy1 = $res['X'];
	$xx[$ie1] = $xx1;
	$yy[$ie1] = $yy1;
```

```
$rlat = deg2rad($lat2);
$rlon = deg2rad($lon2);
$res = $zahyo->henkan($rlat,$rlon);
$xx2 = $res['Y'];
$yy2 = $res['X'];
$xx[$ie2] = $xx2;
$yy[$ie2] = $yy2;

$rlat = deg2rad($lat3);
$rlon = deg2rad($lon3);
$res = $zahyo->henkan($rlat,$rlon);
$xx3 = $res['Y'];
$yy3 = $res['X'];
$xx[$ie3] = $xx3;
$yy[$ie3] = $yy3;

$line[$i]    = $i . ",";

$line[$i] .= $ie0 . ",";
$line[$i] .= $lon0 . ",";
$line[$i] .= $lat0 . ",";
$line[$i] .= $xx0 . ",";
$line[$i] .= $yy0 . ",";

$line[$i] .= $ie1 . ",";
$line[$i] .= $lon1 . ",";
$line[$i] .= $lat1 . ",";
$line[$i] .= $xx1 . ",";
$line[$i] .= $yy1 . ",";

$line[$i] .= $ie2 . ",";
$line[$i] .= $lon2 . ",";
$line[$i] .= $lat2 . ",";
$line[$i] .= $xx2 . ",";
$line[$i] .= $yy2 . ",";
```

```
        $line[$i] .= $ie3 . ",";
        $line[$i] .= $lon3 . ",";
        $line[$i] .= $lat3 . ",";
        $line[$i] .= $xx3 . ",";
        $line[$i] .= $yy3 . ",";

        $mid_x[$i] = ($xx0 + $xx1 + $xx2 + $xx3) / 4.0;
        $mid_y[$i] = ($yy0 + $yy1 + $yy2 + $yy3) / 4.0;
}



for($i=0; $i<$m_max; $i++){
        $mx = $mid_x[$i];
        $my = $mid_y[$i];

        $nz1 = 0;//zone1 number
        $nz2 = 0;//zone2 number

        for($k=0;$k<4;$k++){
                $zone1[$k] = -1;
                $zone2[$k] = -1;
        }


        for($j=0;$j<$m_max;$j++){

                if($i == $j)        continue;

                $nx = $mid_x[$j];
                $ny = $mid_y[$j];

                $dx = $nx - $mx;
                $dy = $ny - $my;
                $ds = sqrt($dx*$dx + $dy*$dy);
```

```
			// ZONE1
			if($ds < 101){
				$zone1[$nz1] = $j;
				$nz1++;
				//if($nz1 > 3)	break;
				continue;
			}

			// ZONE2
			if($ds < 142){
				$zone2[$nz2] = $j;
				$nz2++;
				//if($nz2 > 3)	break;
				continue;
			}
		}

		$str	= $line[$i];
		$str .= $zone1[0] . ",";
		$str .= $zone1[1] . ",";
		$str .= $zone1[2] . ",";
		$str .= $zone1[3] . ",";
		$str .= $zone2[0] . ",";
		$str .= $zone2[1] . ",";
		$str .= $zone2[2] . ",";
		$str .= $zone2[3] . "¥n";

		fwrite($fw,$str);
	}

	fclose($fw);

	for($i=0; $i<$m_max; $i++){
		$xp = $mid_x[$i];
		$yp = $mid_y[$i];
```

```
		for($k=0; $k<4; $k++){
			$j = ($k + 1) % 4;
			$i1 = $ie[$i][$k];
			$i2 = $ie[$i][$j];

			$x1 = $xx[$i1];
			$y1 = $yy[$i1];
			$x2 = $xx[$i2];
			$y2 = $yy[$i2];

			$area = calc_area($x1, $y1, $x2, $y2, $xp, $yp);
			if($area < 0){
			   print " Error in condition of mesh " . $i . "¥n";
			}
		}

}
function calc_area($x1, $y1, $x2, $y2, $x3, $y3){

		$area = 0.5 * ( $x1 * ($y2 - $y3) + $x2 * ($y3 - $y1) + $x3 * ($y1 - $y2) );
		return($area);
}


?>
```

```
<?php
//
//

//require_once("mesh_gn.inc");
require_once("dbconnect.inc");
require_once("heimen.inc");
```

```
$dk = 0.005;
$gsize = 100;
$zoom = 5;
if($gsize > 200)        $zoom = 8.0;
//$tbl = "r" . $gsize . "m";
$tbl = "rumoi_sano_grid";

$rumoi_res = new DbConnect();
$rumoi_res->dbname = "njc";
$rumoi_res->getConnection();



$sql    = "select grid, min(hdate) as m_hdate from $tbl
                group by grid order by grid";

$result_id = $rumoi_res->doQuery($sql);
if(!$result_id){
          print "Query Failed ¥n";
          print $sql . "¥n";
}

$data = array();
$limit = pg_numrows($result_id);
for($i = 0; $i < $limit; $i++){
   $data[$i] = pg_fetch_array($result_id, $i);
}

$g_info = array();
for($i=0;$i<$limit;$i++){
   $g_info[$i][0] = $data[$i]['grid'];
   $g_info[$i][1] = $data[$i]['m_hdate'];
}

$loop = $limit;
$mcol = array();
```

```
$sum_dens = 0.0e0;
$num_grid = 0;

$fname = "density.csv";
$fp = fopen($fname,"w");

for($i=0;$i<$loop;$i++){
   $grid    = $g_info[$i][0];
   $hdate = $g_info[$i][1];

   $sql    = "select grid, sum(catch) as s_catch, sum(area) as s_area
                  from $tbl
                  where (grid    = '$grid')
                  and      (hdate = '$hdate')
                  group by grid";

   $result_id = $rumoi_res->doQuery($sql);
   if(!$result_id){
                print "Query Failed ¥n";
                print $sql . "¥n";
   }

   $data = array();
   $limit = pg_numrows($result_id);

   for($j=0;$j<$limit;$j++){
                $data[$j] = pg_fetch_array($result_id, $j);
   }


                $area = $data[0]['s_area'];
                if($area < 1)          continue;

                $catch = $data[0]['s_catch'];
                $density = $catch / $area;
```

```
            $str = $catch . "," . $area . "¥n";
            fwrite($fp,$str);

            $sum_dens += $density;
            $num_grid++;

            $in = intval($density / $dk);
            if($in > 5) $in = 5;
            if($in < 0) $in = 0;
            $mcol[$grid] = $in;
}

fclose($fp);

$rumoi_res->doClose();

  print " Average density = " . $sum_dens / $num_grid . "    grid = " . $num_grid . "¥n";



  //header("Content-type: image/png");
  //header("Cache-control: no-cache");

  $fm = fopen("rumoi_mesh.txt","r");
  $mx = 0;
  $nx = 0;
  $ie = array();
  $lon = array();
  $lat = array();
  $nxx = array();
  $nyy = array();
  $zone1 = array();
  $zone2 = array();

  $max_x = -999999;
  $max_y = -999999;
```

```
$min_x =    999999;
$min_y =    999999;
while($mesh = fgetcsv($fm)){
        $im = $mesh[0]; // mesh number

        $in = $mesh[1];
        $ie[$im][0] = $in;          // ie0node number
        $lon[$in]     = $mesh[2]; // ie0node longitude
        $lat[$in]     = $mesh[3]; // ie0node latitude
        $nxx[$in]     = $mesh[4]; // ie0x coordinate
        $nyy[$in]     = $mesh[5]; // ie0x coordinate
        if($max_x < $nxx[$in])    $max_x = $nxx[$in];
        if($max_y < $nyy[$in])    $max_y = $nyy[$in];
        if($min_x > $nxx[$in])    $min_x = $nxx[$in];
        if($min_y > $nyy[$in])    $min_y = $nyy[$in];

        $in = $mesh[6];
        $ie[$im][1] = $in;          // ie1node number
        $lon[$in]     = $mesh[7]; // ie1node longitude
        $lat[$in]     = $mesh[8]; // ie1node latitude
        $nxx[$in]     = $mesh[9]; // ie1x coordinate
        $nyy[$in]     = $mesh[10];            // ie0x coordinate
        if($max_x < $nxx[$in])    $max_x = $nxx[$in];
        if($max_y < $nyy[$in])    $max_y = $nyy[$in];
        if($min_x > $nxx[$in])    $min_x = $nxx[$in];
        if($min_y > $nyy[$in])    $min_y = $nyy[$in];

        $in = $mesh[11];
        $ie[$im][2] = $in;          // ie2node number
        $lon[$in]     = $mesh[12];            // ie2node longitude
        $lat[$in]     = $mesh[13];            // ie2node latitude
        $nxx[$in]     = $mesh[14];            // ie2x coordinate
        $nyy[$in]     = $mesh[15];            // ie2x coordinate
        if($max_x < $nxx[$in])    $max_x = $nxx[$in];
        if($max_y < $nyy[$in])    $max_y = $nyy[$in];
        if($min_x > $nxx[$in])    $min_x = $nxx[$in];
```

```
        if($min_y > $nyy[$in])    $min_y = $nyy[$in];

        $in = $mesh[16];
        $ie[$im][3] = $in;           // ie3node number
        $lon[$in]      = $mesh[17];               // ie3node longitude
        $lat[$in]      = $mesh[18];               // ie3node latitude
        $nxx[$in]      = $mesh[19];               // ie3x coordinate
        $nyy[$in]      = $mesh[20];               // ie3x coordinate
        if($max_x < $nxx[$in])    $max_x = $nxx[$in];
        if($max_y < $nyy[$in])    $max_y = $nyy[$in];
        if($min_x > $nxx[$in])    $min_x = $nxx[$in];
        if($min_y > $nyy[$in])    $min_y = $nyy[$in];

        $mx++;

        if($mesh[1] > $nx)           $nx = $mesh[1];               //ie0node number
        if($mesh[6] > $nx)           $nx = $mesh[6];               //ie1node number
        if($mesh[11] > $nx)          $nx = $mesh[11];              //ie2node number
        if($mesh[16] > $nx)          $nx = $mesh[16];              //ie3node number
}



$shift_x = 50;
$shift_y = 50;

$size_x = abs($max_x - $min_x);
$size_y = abs($max_y - $min_y);

$image_x = intval($size_x / 100)*$zoom +50;
$image_y = intval($size_y / 100)*$zoom;

$scale_x = ($image_x - $shift_x*2) / $size_x;
//$scale_y = ($image_y - $shift_y*2) / $size_y;
$scale_y = $scale_x;
```

```
// Image draw

$im = ImageCreate($image_x,$image_y);

// Define Color
$w = ImageColorAllocate($im, 255, 255, 255);
$b = ImageColorAllocate($im,   0,   0,   0);
$g = ImageColorAllocate($im, 100, 100, 100);
$lb = ImageColorAllocate($im, 200, 200, 255);
$c[0] = ImageColorAllocate($im,   0,   0, 110);
$c[1] = ImageColorAllocate($im,  63, 128, 205);
$c[2] = ImageColorAllocate($im,   0, 255,   0);
$c[3] = ImageColorAllocate($im, 255, 255,   0);
$c[4] = ImageColorAllocate($im, 255, 128,   0);
$c[5] = ImageColorAllocate($im, 255,   0,   0);



$tfr = "../../TTF/luxirr.ttf";

$lat = 43.88;
$lon = 141.54;
$dd = 1/60;

    $zahyo = new Heimen;
    $zahyo->genten(12);

for($i=0; $i<20; $i++){
        $rlat = deg2rad($lat);
        $rlon = deg2rad($lon);
        $res = $zahyo->henkan($rlat, $rlon);
            $hx = $res['Y'];
            $hy = $res['X'];

        $x1 = ($hx - $min_x)*$scale_x + $shift_x;
        $y1 = $image_y - ($hy - $min_y)*$scale_y - $shift_y;
```

```
		if(($lat > 43.90) and ($lat < 44.04)){
			imageline($im,0,$y1,$image_x,$y1,$lb);
				$int_lat = intval($lat);
				$int_fun = intval(($lat - $int_lat)*60);
				$str = $int_lat . "" . $int_fun;
			imagettftext($im,8,0,5,$y1-5,$b,$tfr,$str);
		}
		if(($lon > 141.57) and ($lon < 141.65)){
			imageline($im,$x1,0,$x1,$image_y,$lb);
				$int_lon = intval($lon);
				$int_fun = intval(($lon - $int_lon)*60);
				$str = $int_lon . "" . $int_fun;
			imagettftext($im,8,0,$x1-15,$image_y-5,$b,$tfr,$str);
		}

		$lat += $dd;
		$lon += $dd;
}


$x1 = $image_x - 100;
$y1 = $image_y - 170;
$d1 = 0;
for($i=0; $i<6; $i++){
		imagefilledrectangle($im, $x1, $y1, $x1+20, $y1+10, $c[$i]);
		imagerectangle($im, $x1, $y1, $x1+20, $y1+10, $b);

		$d2 = $d1 + $dk;
		$str = sprintf("%2.3f", $d1) . " - " . sprintf("%2.3f", $d2);
		imagettftext($im,8,0,$x1+25,$y1+8,$b,$tfr,$str);

		$y1 += 20;
		$d1 = $d2;
}

// draw mesh
```

```
    for($i=0; $i<$mx; $i++){
        $i0 = $ie[$i][0];
        $i1 = $ie[$i][1];
        $i2 = $ie[$i][2];
        $i3 = $ie[$i][3];

        $x0 = ($nxx[$i0] - $min_x)*$scale_x + $shift_x;
        $x1 = ($nxx[$i1] - $min_x)*$scale_x + $shift_x;
        $x2 = ($nxx[$i2] - $min_x)*$scale_x + $shift_x;
        $x3 = ($nxx[$i3] - $min_x)*$scale_x + $shift_x;

        $y0 = $image_y - ($nyy[$i0] - $min_y)*$scale_y - $shift_y;
        $y1 = $image_y - ($nyy[$i1] - $min_y)*$scale_y - $shift_y;
        $y2 = $image_y - ($nyy[$i2] - $min_y)*$scale_y - $shift_y;
        $y3 = $image_y - ($nyy[$i3] - $min_y)*$scale_y - $shift_y;

        if(isset($mcol[$i])){
            $col = $c[$mcol[$i]];
        } else {
            continue;
            //$col = $w;
        }
        //imagerectangle($im, $x3, $y3, $x1, $y1, $b);
        imagefilledrectangle($im, $x3, $y3, $x1, $y1, $col);

        //imagerectangle($im, $x3, $y3, $x1, $y1, $g);
    }

    ImageColorTransparent($im, $w);
    ImagePng($im,"dens_sano.png");
    ImageDestroy($im);

?>
```

Apendix E

This contains script to derive the mean ping data of set-net fishery from the database server.

```
<?php


     db_connect($connect_id);
     if($connect_id == false){
          print "PostgreSQLcannot connect<BR>¥n";
          exit();
     }

    $st_serial = mktime(0,0,0,04,24,2015);
    //$sid = '_08048564749';     //
    //$sid = '_08046314748';     //
    $sid = '_08048562974';       //

  // $LOOP = 30*24; //
      $LOOP = 100*24*6;
      $offset = 0;

//===============================================
    $n_layer = array();
    $s_layer = array();

//===============================================

    for($day=0; $day<$LOOP; $day++){

    //$st_serial = $st_serial + 3600;
    //$en_serial = $st_serial + 3599;

    $st_serial = $st_serial + 600;
          $en_serial = $st_serial + 599;
```

```
$hour = date("H", $st_serial)*1;
        //if(($hour < 0) && ($hour > 3))      continue;
        if($hour > 3)      continue;

        $sql = "SELECT a_data,b_data FROM gyotan
                WHERE (sid = '$sid')
                AND (serial between '$st_serial' and '$en_serial')
                ORDER BY serial";

        $result_id = pg_query($connect_id, $sql);
        if($result_id == false){
                print "query failed<BR>¥n";
              pg_close($connect_id);
                exit();
}

        $data = array();
        $limit = pg_numrows($result_id);

for($i=0; $i<11; $i++){
              $n_layer[$i] = 0;
              $s_layer[$i] = 0.0;
}

        for($i = 0; $i < $limit; $i++){
                $data[$i] = pg_fetch_array($result_id, $i);
        }

$d_sum_a = 0.0;
$d_sum_b = 0.0;
$n_sum_a = 0;
$n_sum_b = 0;

$str = date("Y/m/d H:i:s", $st_serial);

for($i=0; $i<$limit; $i++){
```

```
$a_data = split("¥n",$data[$i]['a_data']);
$b_data = split("¥n",$data[$i]['b_data']);

for($j=0; $j<20; $j++){

        $dd = split(",",$a_data[$j]);
        if(!isset($dd[100]))            continue;

        $len = 0;
         $ave = 0;


        for($k=5; $k<320; $k++){
                $ave = $ave + $dd[$k];
                $len++;

                // Layer 0: depth < 10m
                if($k<33){
                        if ($dd[$k]<253){
                                $s_layer[0] += $dd[$k];
                                $n_layer[0]++;
                        }
                }

                // Layer 1: 5m < depth < 15m
                if(($k>17) and ($k<48)){
                        if ($dd[$k]<253){
                                $s_layer[1] += $dd[$k];
                                $n_layer[1]++;
                        }
                }

                // Layer 2: 10m < depth < 20m
                if(($k>32) and ($k<65)){
                        if ($dd[$k]<253){
```

```
				$s_layer[2] += $dd[$k];
				$n_layer[2]++;
			}
		}

		// Layer 3: 15m < depth < 25m
		if(($k>47) and ($k<80)){
			if ($dd[$k]<253){
				$s_layer[3] += $dd[$k];
				$n_layer[3]++;
			}
		}

		// Layer 4: 20m < depth < 30m
		if(($k>64) and ($k<96)){
			if ($dd[$k]<253){
				$s_layer[4] += $dd[$k];
				$n_layer[4]++;
			}
		}

		// Layer 5: 25m < depth < 35m
		if(($k>79) and ($k<112)){
			if ($dd[$k]<253){
				$s_layer[5] += $dd[$k];
				$n_layer[5]++;
			}
		}

		// Layer 6: 30m < depth < 40m
		if(($k>95) and ($k<128)){
			if ($dd[$k]<253){
				$s_layer[6] += $dd[$k];
				$n_layer[6]++;
			}
		}
```

```
        // Layer 7: 35m < depth < 45m
        if(($k>111) and ($k<144)){
                if ($dd[$k]<253){
                        $s_layer[7] += $dd[$k];
                        $n_layer[7]++;
                }
        }

        // Layer 8: 40m < depth < 50m
        if(($k>127) and ($k<159)){
                if ($dd[$k]<253){
                        $s_layer[8] += $dd[$k];
                        $n_layer[8]++;
                }
        }

        // Layer 9: 45m < depth < 55m
        // bottom
        if(($k>143) and ($k<175)){
                if ($dd[$k]<253){
                        $s_layer[9] += $dd[$k];
                        $n_layer[9]++;
                }
        }

        // Layer 10: 50m < depth < 60m
        if(($k>158) and ($k<191)){
                if ($dd[$k]<253){
                        $s_layer[10] += $dd[$k];
                        $n_layer[10]++;
                }
        }

}
if($len > 0){
```

```
                        $ave = $ave / $len;
                        $d_sum_a += $ave;
                        $n_sum_a++;
                }
        }
        for($j=0; $j<20; $j++){

                $dd = split(",",$b_data[$j]);
                if(!isset($dd[100]))            continue;

                $len = 0;
                 $ave = 0;
                for($k=5; $k<261; $k++){
                        $ave = $ave + $dd[$k];
                        $len++;
                }
                if($len > 0){
                        $ave = $ave / $len;
                        $d_sum_b += $ave;
                        $n_sum_b++;
                }
        }
}

if($n_sum_a > 0){
        $d_sum_a = $d_sum_a / $n_sum_a;
        $d_sum_b = $d_sum_b / $n_sum_b;
        $str .= "," . $d_sum_a . "," . $d_sum_b;
}

$layer_ave = "";
for($i=0; $i<11; $i++){
        if($n_layer[$i] > 0){
                $a_layer = $s_layer[$i] / $n_layer[$i];
                $layer_ave .= "," . $a_layer;
        }
```

```
        }

        $str .= $layer_ave . "¥n";
        if($d_sum_a > 0.0) print $str;

    }   // day Loop End

    pg_close($connect_id);

function db_connect(&$connect_id){
        $connect_id = pg_connect("", "", "koden");
        if($connect_id == false){
                return false;
        } else {
        return true;
        }
}

?>
```

Apendix F

This contains script to conduct a Box-Cox transform to a ping data of set-net, estimate via multiple regression analysis as well as the fish classification via linear discriminant analysis.

```
################################
# Multiple Regression Analysis
#
################################

#himimean10m.csv
# Set Working Directory
setwd("C:/Users/saville/Documents/phd_ 研 究 /set_net/setnet_estimation_nomura.csv/Box-Cox")
```

```
getwd()

da <- read.csv("all_offset.csv",header=T)
head(da)
tail(da)

################################
# multiple regression analysis
################################

himimrgl <- lm(catch ~0+., data = da)
summary(himimrgl)

himimrgl2 = lm(catch~0+l1+l3+l5+l7+l9+l11, data=da)
summary(himimrgl2)

himimrgl3 = lm(catch~0+l2+l4+l6+l8+l10, data=da)
summary(himimrgl3)


################################
# Box-Cox Transform
################################
attach(da)

# assign number of sample to N
N = length(catch)
N

#calculate variance of likelyhood
vy = var(catch)*(N-1)/N
vy

LL1 = -N*(log(2*pi*vy)+1)/2
LL1
```

```
#calculate lambda in box-cox
LogL = function(theta, catch, N)
{
  lambda = theta
  if (lambda == 0)
    {
      z = log(catch)
    }
  else
    {
     z = (catch^lambda -1)/ lambda
    }
  vz = var(z)*(N-1)/N
  LL = -N*(log(2*pi*vz) +1)/2 + (lambda - 1) * (sum(log(catch)))
  return (LL)
}
#put lambda    from function
LLF = optimize (LogL, lower=-1, upper=1, maximum=T, catch=catch, N=N)
lambda = LLF$maximum
LL2 = LLF$objective

lambda

AIC1 <- -2*LL1 + 2*2
AIC1
AIC2 <- -2*LL2 + 2*3
AIC2

#transformed catch, includes lambda, and assign to z
z = (catch^lambda -1)/lambda

z

write.csv(z, file="boxcox.csv")
```

```
################################
# MRA after box-cox
################################

bcglm = glm(z~0+l1+l2+l3+l4+l5+l6+l7+l8+l9+l10, family=poisson)
summary(bcglm)

bcglm =
glm(z~0+log(l1)+log(l2)+log(l3)+log(l4)+log(l5)+log(l6)+log(l7)+log(l8)+log(l9)+log(l10),
family=poisson)
summary(bcglm)

bcmra = lm(z~0+l1+l2+l3+l4+l5+l6+l7+l8+l9+l10+l11)
summary(bcmra)

###############
# LDA of fish
###############

setwd("C:/Users/saville/Documents/phd_研究/set_net/himi")

da <- read.csv("himi_may.csv",header=T)
head(da)

library(MASS)    #call MASS library

z <- lda(fish~., data=da)    #LDA
z

apply(z$means%*%z$scaling,2,mean) #Mean of the z function
table(da[,1],predict(z)$class) #predict the class based on LDA result
plot(z,dimen=3) #Plotting the result
```

Apendix G

This contains the questionnaire form used during field survey in Indonesia.

Date :
Code : 1. Penjaringan 2. Cilincing

1 Name : Fishery association:
2 Sex : 1. Male 0. Female ( )
3 Age :

4 Education : 1. No education 4. Senior highschool
2. Elementary school 5. College
3. Junior highschool

5 Mobile phone posesson : 0. No (stop here) 1. Yes (continue to 6)

6 When did you start use a mobile phone : ( )

7 How often do you use mobile phone for fishing ground information sharing?
1. Never 4. Frequently
2. Infrequently 5. Very frequently
3. Occasionally

8 What kind of information do you usually share?
1. Never share any 4. Both of (2.) and (3.)
2. Good place 5. Other, specify
3. Polluted place ( )

9 How often do you use mobile phone for an emergency during your fishing trip?
1. Never 4. Frequently
2. Infrequently 5. Very frequently
3. Occasionally

10 In what kind of emmergency?
1. Never 4. Both of (2.) and (3.)
2. Mechanical problem 5. Other, specify
3. Bad weather ( )

11 Are you bonded to a middleman? 0. Yes 1. No (continue to 12)

12 How often do you use mobile phone for marketing your catch?
1. Never 4. Frequently
2. Infrequently 5. Very frequently
3. Occasionally

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