Guideline for fishing effort management (*Total Allowable Effort*) In trawl fishery management in Aru and Arafura Sea

2016

Strategies for trawl fisheries bycatch management project

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Strategies for trawl fisheries bycatch management
(REBYC-II CTI; GCP/RAS/269/GFF)

2016

"Guideline for Fishing Effort Management (Total Allowable Effort, TAE) on Trawl Fishery Management in Arafura" is developed based on participations and contributions of stakeholders such as entrepreneurs, research centers, NGOs, academics, and other projects.

Executive summary

This document is one of the three “guidelines” describing the Mapping, Gear Selection and Total Allowable Effort (MGT) management approaches produced at the REBYC-II CTI project. This document provides information regarding background, scope, goals of the literature, theory and models of Total Allowable Effort (TAE) management approach and provisional estimation of technical capacity and Total Allowable Effort in Aru and Arafura Sea industrial fishery.

Firstly, the document explains the process of consultation and setting up the goals, and the methods and data shared with the National Working Group of REBYC-CTI project. This consultation was a participatory process with the stakeholders of Aru and Arafura Sea fishery. The goal of this “guideline” is to act as a tool for assessing the current fishing capacity and estimating if there is over or under capacity in the Aru and Arafura fishery. The guideline also provides a method for estimating the optimal target capacity.

The document then explains key concepts of capacity assessment in fishery. Those concepts include capacity output, capacity utilization and excess capacity. The document provides explanation what are the potential consequences from various capacity conditions. It then explains the theory of accessing the fishing capacity, i.e., the overall technical efficiency of the fishing vessels. Once the policy makers understand the existing technical efficiency of the existing fishing vessels, it would be possible to estimate what is the target capacity and the potential ways of Capacity Reduction Program (CRP). Theory for estimating the technical efficiency uses the output-oriented measures namely the simple CPUE calculation and Stochastic Frontier Analysis (SFA). The theoretical background to assess or determine the target capacity are based on the Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY).

Each method has limitation despite the ability to assess the technical and target capacity. The simple CPUE approach only needs data of days at sea and catch of the vessels or catch of the fleet for certain period (e.g. yearly catch). It does not count other factors impacting vessels productivity such as technology and human skills. The SFA method incorporates also those variables. However, the data are not always available from the industries or government offices. The MSY approach is well known and widely adopted approach. The data needed for the analysis is usually available although sometimes is not available as a time series. The MEY approach is harder to use since it needs the price of the fish products and total cost of the fishing efforts. The strength of MEY is that it provides sort of low boundary for Total Allowable Effort.

This document uses a data set of nine to eleven vessels that operated between years 2000 and 2010 in the study region to estimate the technical efficiency and the total allowable efforts from stakeholders, namely fishing industries and associations in Aru and Arafura Seas. The longer time series data were also used for estimating the TAE.

Main outcome was that the technical efficiency of those vessels operating in Aru and Arafura Sea ranged between 0.6-0.97 when using simple CPUE comparison and between 0.78-0.96 when using SFA. The sustainable TAE (MSY) for Banana Shrimp Fishery is far higher than the existing overall effort in that fishery. However, the sustainable TAE for Tiger Shrimp is almost at the same level as the overall effort in the most recent year of this study. Hence, based on the data that we used in this document, the shrimp trawl fishery did not exhibit excess capacity, i.e. the capacity was in balance for target stocks and their production levels.

In conclusion, due to the fact that the shrimp fishery did not exhibit overcapacity in Aru and Arafura Sea in 2000-2010, this study suggests that maintaining the fishing licenses deployed in Aru and Arafura Sea at the same level would allow sustainable harvest. Constant monitoring the status of the resources and fishing effort is necessary to maintain the exploitation at sustainable level.

Preparation of the document

This document is developed based on series of meetings and workshops:

1. NWG Meeting
   Day/date : Friday, 19 February 2016
   Place : Sahira Butik Hotel
   Agenda :
   - Discussion on scope of work, design and content of the website.
   - Preparation of consultation activities regarding development of the guideline of "Gear Type Selection".
   - Preparation of consultation activities regarding development of the guideline of "Total Allowable Effort (TAE) Management".

2. Progress Report Meeting
   Day/date : 6 and 7 April 2016
   Place : PKSPL Kampus IPB Baranangsiang
   Agenda :
   - Discussion on draft of guideline of "Gear Type Selection".
   - Discussion on draft of guideline of "Total Allowable Effort (TAE) Management".

3. Local Consultative Group Meeting
   Day/date : Thursday-Friday / 19 – 20 May 2016
   Place : Hotel Marina Mamberamo
   Objective : Updating information regarding condition of fishing activities in Aru and Arafura Sea after the moratoria and trawl ban;

4. *National Stakeholder Workshop on Guidelines of MGT Scheme*
   Day/date : Tuesday-Thursday / 21 – 23 June 2016
   Place : The Mirah Hotel
   Objective : Socialization and consultation with the stakeholders regarding how to assess and define the TAE and guideline of choosing fishing gear that will be developed in order to manage the fisheries especially in Aru and Arafura Sea.

INDONESIA REBYC-II CTI
Project symbol: GCP/RAS/269/GFF
Strategies for Trawl Fisheries Bycatch Management

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Acknowledgment

I would like to deeply thank to REBYC-II CTI project, KAPI of DGCF, Local Consultative Group (LCG) in Sorong, university partners, FAO representatives and other enteritis that I do not mention in this document. I particularly appreciate the kind inputs from chairs and participants from a series of meetings including NWG and LCG meeting. I also highly appreciate the support from the following people: Directur of KAPI (Minhadi Noer Sjamsu), REBYC-II CTI National Project Coordinator (Endroyono) and National Technical Officer (Imron Rosyidi) and the staff of the Directorate of Fishing Vessels and Gears (Bagus Oktori Sutrisno Andi Sardi, Lingga Prawitaningrum, Mas Umamah, Elwidya Bastian, Winnie Hertikawati, Kun Budi Nugroho, Taufiq Kurohman, Anjar Hajiono, I Made K Diningrat), the Agency for Marine Affairs and Fisheries (Anung Widodo, Mahiswara, Tri Wahyu B, Widodo), HPPI (Endang, Mertha, Djoko Kusyanto, Tri Antoro), Representatives from Universities and NGOs (Diniah, Ronny I Wahju, Chandra Nainggolan, Abu Darda Razak, Aris Budiharto, Yoga). I also highly appreciate the valuable inputs on the final draft of this document I received from Petri Suuronen and C. M. Muralidharan. Last but not least, I thank the Shrimp Trawl Fishery Association (HPPI) for sharing their data to be used in this document.

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Acronyms used

APBN	: Anggaran Pendapatan dan Belanja Nasional (National Government Budget)
BRDs	: By Catch Reduction Device
CPUE	: Catch per Unit Efforts
CRP	: Capacity Reduction Program
CU	: Capacity Utilization
DGCF	: Directorate General of Capture Fisheries
FFF	: flexible functional form
FMA	: Fisheries Management Area
FMP	: Fisheries Management Plan
FAO	: Food and Agriculture Organization
FAO-IPOA	: FAO – International Plan of Action
GT	: Gross Ton
HPPI	: Himpunan Pengusaha Penangkapan Udang Indonesia (Association of Shrimp Fishers)
ITQs	: Individual Transferable Quota
IUU Fishing	: Illegal, Unreported and Unregulated Fishing
JTED	: Juvenile and Turtle Excluder Device
KAPI	: Directorate of Fishing Vessels and Fishing Gears
MEY	: Maximum Economic Yield
MGT	: Mapping, Gear Selection and Total Allowable Efforts
MMAF	: Ministry of Marine Affairs and Fishery
MSY	: Maximum Sustainable Yield
NOAA	: National Oceanic and Atmosphere Agency

NWG	: National Working Group
OA	: Open Access
REBYC-I	: Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management)
REBYC-II CTI	: REBYC-II Coral Triangle Initiative
SFA	: Stochastic Frontier Analysis
SIPI	: Surat Ijin Penangkapan Ikan (Licenses to Fishing)
SPF	: Surplus Production Frontier
TAC	: Total Allowable Catch
TAE	: Total Allowable Effort
TC	: Total Cost (USD)
TE	: Technical Efficiency
TED	: Turtle Excluder Device
TR	: Total Revenue (TR)
UNCLOS	: United Nation Convention on the Law of the Sea
WPP-NRI	: Wilayah Pengelolaan Perikanan-Negara Republik Indonesia (Fishery Management Area – Republic of Indonesia)
ZEE	: Zona Ekonomi Ekslusif

1. Introduction

1.1. Background

Trawl fishery in Indonesia is considered to have negative impact on the fisheries resources and it is also considered to be destructive to the marine ecosystems and impact negatively on the biodiversity, threatening sustainability of fisheries affecting livelihoods and opportunities also decreasing the food security. Furthermore, this fishing technology creates significant bycatch and jeopardizes the benthic habitats by using heavy otter board, tickler chains and bobbins that are dragged along the seabed. The intensive utilization of trawls is considered have been impacting the environmental and habitat condition, as well as contributed the decline in fisheries resources (overfishing).

Aru and Arafura Sea are known to have high potential in shrimp and demersal fish resources because of the characteristics of its ecosystem, such as muddy or sandy mud substrate, large mangrove coverage, and sloping sea bed contour. Currently, the fishing gear practices that exploit the shrimp resources are trawlers. MMAF prohibits trawlers under the Ministerial Decree no 56 year 2014 and the trawl ban is effective from December 2015.

FAO coordinated the global REBYC-I project (Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management) in 2002-2008. The project focused mainly to the development and testing of technology for reducing the by catch and improving technical management of industrial shrimp fisheries in tropical countries. The regional follow-up project, REBYC-II CTI (2012-2016), has taken a wider approach in the management of bycatch and other impacts of trawl fishing.

Through REBYC-I it was demonstrated that the installation of *Bycatch Reduction Devices* (BRDs) on trawl vessels, including *Turtle Excluder Device* (TED) and *Juvenile and Trash Fish Excluder Device* (JTED) can help to reduce bycatch in places like Sorong, Merauke, Ambon, Tual, Sibolga and Tarakan.

Some lesson learnt and output from the REBYC-I period in Indonesia were, particularly for Arafura Fishery:

a. The bycatch from trawl fishery in Aru sometime contains Endangered, Threatened, and Protected (ETP) species.
b. As a general practice of trawl industries, bycatch were not collected as part of the catch but were discarded at sea. However, in small scale fisheries, bycatch was part of the landings and was often used as aquaculture feed.
c. Most importantly, the REBYC-I project contributed to the release of Indonesia from shrimp ban from the US due to National intention on a better shrimp trawl fishery.

In Indonesia, the REBYC-II CTI project aims to provide information that would help to improve the management the trawl fishery bycatch by applying the approach called Mapping, Gear and Total Allowable Effort (MGT) scheme. MGT refers to Mapping the critical habitat to be avoided in providing licenses for the fishing vessels, using best practices, gears and estimating and recommending the allowable efforts in the Aru and Arafura Sea that which is to be agreed by the stakeholders to participate in the fishing capacity management. The project provides recommendation for fisheries management in Aru Sea that is adaptive and participatory among the stakeholders.

This guideline study is a tool for assessing the current fishing capacity and estimating the capacity target desired by the government of Indonesia. It is hoped that this guideline serves as one of the agreed approach by the stakeholders and industries in estimating fishing capacity for a participatory fishing capacity management in Indonesia. The guideline development approach is a participatory approach where the Directorate General for Capture Fisheries (DGCF) outlines several methods to stakeholders in Aru and Arafura Fisheries in assessing and estimating the fishing capacity. Besides participatory approach, the fisheries recommendations for by-catch of trawl fisheries is designed to be an adaptive approach, which at any point of time, may be revised if needed based on the monitoring results or scientifically sound justification for adaptation. To this end, this guideline will serve as a reference for estimating the Total Allowable Efforts as part of the MGT scheme to be implemented in adaptive fisheries management in Aru and Arafura Sea.

This paper elaborates the definition and measurement of capacity output and CU, and then provides an empirical illustration of capacity measurement for the Shrimp Trawl Fishery in Aru and Arafura Sea, Indonesia. We use a panel data set of nine to eleven vessels operating between the years 2000 and 2010 to compute estimates of capacity output and utilization, and associated variable input utilization (implied "optimal" days), based on alternative assumptions and estimating methods.

Based on the data that we used in this document, the shrimp trawl fishery did not exhibit excess capacity than required for current harvest levels, and certainly for target stocks and production levels. The measured level of capacity, and implications for capacity management to meet regulatory goals, differ somewhat according to the conceptual foundation and estimating method chosen. However, the finding is key recommendation for shrimp fishery management in near future.

1.2. Scope, goal and benefits

The scope of this guideline is includes mechanism of data collection, tabulation and data reporting, as well as methods of data analysis used in the determination of TAE in order to improve the trawls fisheries management in Aru and Arafura Sea. The mechanism built is participatory, which requires active participations from each stakeholders involved in the activity of trawl fisheries in Arafura, from regional to national level.

Goals

The goals of this document are to serve as:

a. A guideline for identifying the roles of economic parameters and criteria/indicators which are relevant with the fishing activities using trawls in Aru and Arafura Sea.
b. A guideline for collecting, tabulating, and reporting the data and information of economic parameters and indicators in accordance to the data period involving fishing actors, research centres (MMAF and non-MMAF), Regional Government, and other stakeholders.
c. A guideline for using the methods of data analysis for calculating TAE in trawl fisheries management in Aru and Arafura Sea.

Benefits

The benefits of this document are:

a. A common understanding regarding economic parameters and indicators in the determination of TAE in trawl fisheries in Arafura.
b. A uniformity of data format and report regarding economic parameters and indicators in the determination of TAE in trawls fisheries in Arafura.
c. Ability to use the methods of data analysis in the determination of TAE in trawls fisheries in Arafura.

Outcome

The expected outcome from the "*Total Allowable Effort"* (TAE) in trawl fisheries in Arafura are:

a. As the basis of determining the allowed fishing efforts which still provide sustainable profitability for each fisheries business unit in Arafura and in accordance with the carrying capacity*:*
   i. TAE for all types of fishing gears that can be operated in Arafura.
   ii. Fishing efforts for each group of this fishing gear that can be operated in Arafura.
   iii. Number and unit of fishing efforts for each vessel in the certain group/type of fishing gears.

1.3. Existing legal support on Fishing Capacity Management

Six pieces of legal policies are directly relevant regarding fishing capacity in Indonesia fisheries.

1. Act No. 31 of 2004 and added or revised by Act No. 45 of 2009 Act regarding Fisheries.
2. Act No. 32 of 2004 and added or revised by Act 12 of 2008 and added or revised by Act No. 23 of 2014 concerning Regional Government (Autonomy Act).
3. Act No. 33 of 2004 concerning Financial Distribution Central and Regional Government.
4. The Ministerial Decree of MMAF No. 56 year 2014 on the moratorium of ex-foreign made vessels.
5. The Ministerial Decree of MMAF No. 2 year 2015 regarding Prohibition of Use trawl (Pukat Hela) and Seine Nets (Pukat Tarik) in WPP-NRI came into force on the 9th of January, 2016.
6. Ministerial decree of MMAF No 54 year 2014 regarding Fishery Management Plan (FMP) for FMA 718 (including Aru and Arafura sea).

Act No. 31 of 2004 and added or revised by Act No. 45 of 2009 concerning Fisheries

Act No. 31 of 2004 is the legal basis for fisheries management in Indonesia. Enacted on 6 October 2004, it replaces the former Fisheries Act (No. 9 of 1985), and then the Act No. 45 of 2009 revised it again. Under the Fisheries Act, coral reefs are classified as fish resources (Article 1.4 of Act 45/2009). Article 7 of Act 45/2009 provides the right for the Minister of Marine Affairs and Fisheries to implement management measures to control fishing activities. The mandates that MMAF should carry out are: (i) determining fishing method or gear; (ii) determining the maximum sustainable yield (MSY) or total allowable catch (TAC) for domestic and foreign fishing; (iii) specifying fishing and aquaculture activities; (iv) preventing activities such as pollution and destructive fishing of the resource and its ecosystems; and (v) rehabilitation of the resources and its habitat. The fisheries management regime is input control through licensing. Each individual or a business unit operates a fishing vessel(s) in Indonesia ZEE must have a permit (Article 27).

In this act, local government and national government work together in developing data centre and information. Government and local governments prepare and develop information systems and data fishery statistics and carry out the collection, processing, analysis, storage, presentation and dissemination of data. These entities also share potential of, updating the movement of fish, means and infrastructure, production, handling, processing and marketing of fish, as well as socio-economic data related to the implementation of fish resources management and the value chain of the fishery products. This is in accordance with the spirit of Ecosystem approach to Fisheries Management within a co-management regime and the inclusion of other parties into the fishery management processes.

The Laws of decentralization Authorities

The democratization of Indonesia's politics since the reformation era in 1999 has resulted in new laws on decentralization that have tremendous impact on marine resources management. Two of the key Acts that are analysed below are Act No. 32 of 2004 concerning Regional Government and Act No. 33 of 2004 concerning Financial Distribution Central and Regional Government.

Act No. 32 of 2004 and added or revised by Act 12 of 2008 concerning Regional Government (Autonomy Act) and added or revised by Act no 23 of 2014.

The Regional Government Act grants authority to the regional governments to manage their own natural resources. Article 18.4 grants to the Provinces jurisdiction over Indonesia's territorial sea that extends up to 12 nautical miles from the archipelagic baseline.

Article 18.3 provides for the authority of the regional governments (province, district and city). This includes (i) exploration, exploitation, conservation and management of the coastal resources; (ii) administrative matters; (iii) spatial planning; (iv) law enforcement activities with regard to local regulations and regulations that have been decentralized by the central government; (v) involvement in maintaining national security and sovereignty.

Excluded are some functions that are retained by the central government. These include the functions for foreign affairs, security, and defence, judicial, national fiscal and monetary, and religion (Article 10.3). The regional governments have full authority to manage their own business. However, in general, the role of the provincial government has decreased dramatically. Most functions are now devolved from central and provincial governments, including public works, health, education and culture, agriculture, communications, industry and trade, direct investment, environmental management land use, co-operatives and labour (Article 14).

For fishery sector, this Act of Decentralization delegates some of the national authority (e.g. MMAFF) to Provincial government for the issuance of licenses of vessels under 30GT. The fishing ground area for those vessels under 30 GT is below 12 miles. However, there is no limit of the number of licenses that can be issued by the Provincial government regardless of the fishery conditions. That exacerbates the issue of over-capacity in Indonesia waters.

Act No 33 of 2004 concerning Financial Distribution Central and Regional Government (Financial Distribution Act)

The Financial Distribution Act provides for almost a complete transfer of budgetary management from the central to local government. Article 10 of the Financial Distribution Act provides that the equilibrium funds consist of money derived from the National Income and Expenses (*Anggaran Pendapatan dan Belanja Negara*/APBN) that are divided into three components: (i) share cropping funds; (ii) general funds; and (iii) specific allocation funds. The equilibrium funds that are derived from sharecropping funds are sourced from tax and natural resource conversion (Article 11.1). Sharecropping funds sourced from tax include land and building tax, tax on land and building acquisitions, and income tax (Article 11.2). The share cropping funds sourced from natural resource conservation come from forestry, general mining, <u>fisheries</u>, oil mining, natural gas production, and geothermal production (Article 11.2).

In practice, this indirectly encourages the local government to generate funds from fishery sector under the authority of local government. A good example is the issuance of many fishing vessels under 30 GT. The fees paid by the fishing vessels go to the local government income. In reality, this is misused by the fishing industries. Many vessels were marked down as many big vessels bigger than 30 GT were registered as 29 GT vessels and applied the licenses from the local government. This practice deeply further exacerbates the overcapacity. However, it is hard to estimate the extent of the mark down vessels unless the government requires each vessels to be evaluated for the detailed physical properties and their accuracies.

Ministerial Decree of MMAF no 2 year 2015 on the trawl banning in Indonesia waters.

The motivation behind the decree is the presumed rate of environmental destruction caused by trawl on the bottom of the sea. Degradation of fish resources is also another consequence of widespread use of trawls and the use of fishing gear that resembles a trawl by small and medium-scale fishermen. The prohibition of the use of fishing gear that is less environmentally friendly by ministerial decree was issued on January 8, 2015 about prohibiting any use trawl (Pukat Hela) and Seine Nets (Pukat Tarik) in Indonesia waters. It came into force on the 9th of January, 2016.

The small and medium scale boat owners had a huge protest regarding this decree. The MMAF responded to their demand by issuing the circular paper Number 72/MEN-KP/II/2016 on the restriction of use of fishing gear “cantrang” in WPP-NRI issued on 11 February 2016, effective December 2016 gradually sets limit on its use through the following requirements:

1. Re-measurement of the size of fishing vessel (GT), only vessels <30 GT are allowed to use "mini trawlers" if the governor allows them to do so.
2. Only operated in the management area under the province's responsibility (less than 12 miles), however, for fishing vessels <30 GT, the licenses were issued by the provincial government and MMAF (national authority) has no control over it.
3. The size selectivity and capacity that is mesh size >2 inches, and head rope at least 60 meters.

Trawl Ban phase II gave a great impact for the shrimp fishery in the Aru and Arafura Sea. As the previous law allowing shrimp and fish in Aru and Arafura Sea to be exploited using large vessels and trawls gear, the current trawl ban acts like a sudden stop to these vessels from fishing in Aru Sea. The approximate number of vessels are around 129 for shrimp trawling and about 440 for fish trawling (FMP for WPP 718).

The impact was greater because the fishing industries in Aru Sea generally use foreign-made vessels. The economic reason is that the used large vessels are cheaper. Under the Ministerial Decree No.56 / 2014 regarding Moratoria, the foreign-made vessels should be evaluated on their legal documents and compliance in doing fishing activities in Indonesia waters. Those vessels that pass the evaluation process can undertake fishing activities until the end of the business license granted in the previous year before the moratoria issued.

Ministerial Decree of MMAF no 56 year 2014 on the moratorium of ex-foreign made vessels.

Background of the Ministerial Decree No.56/2014 was triggered by IUU fishing activities been carried out by fishing vessels built abroad (called ex-foreign), double flagging and illegal vessels belong to other countries but illegally caught fish in Indonesia waters. It is difficult for inspectors from Directorate of Surveillances and Indonesian Navy to identify illegal and legal foreign fishing vessels using the Indonesian flag in Indonesian waters. This has encouraged foreign fishing vessels to fish without a permit (SIPI). This problem was further compounded by changing the ship's name to an Indonesia name.

Offenses often committed by ex-foreign fishing boats violate the provisions of the regulations in the decree 30/2012 on fishery business that has been updated by decree 26/2013, namely:

1. The catch was not landed in Indonesia, but was brought directly to the home country of the vessel;
2. Catch were directly transferred at at sea without reporting to the Indonesian fishing port and to be brought out of country (illegal transhipment);
3. The vessels employed foreign crew and that conflicts with Law No.45 / 2009 on the Amendment of Act No. 31 of 2004 on Fisheries, Article 35A.

Implementation of the moratorium on 3 November 2014 has successfully identified foreign-made ships numbering 1,132 vessels. These boats have various fishing gears and operated throughout Indonesia. Trawl was the dominant fishing gear (54%), with 8% shrimp trawl and 46% fish trawl.

Trawlers (ex-foreign) authorized to fish in certain waters such as the Strait of Malacca, the South China Sea and Aru and Arafura Sea are 616 units. Trawl is the dominant fishing vessels operating in the Arafura sea-Aru with a total of 84%, with 9% shrimp trawl and 75% fish trawl.

Results of the evaluation of 1132 ex-foreign ships carried out by the IUU Task Force fishing found that:

a. 699 vessels were categorized as black listed by the MMAF. Their licenses were revoked at once by MMAF.

b. 390 Indonesian-flagged vessels can be de-listed (de-registration) if they pay the appropriate amount of tax liability and get cleared by the Directorate General of Taxes, and secure clearance from the Directorate of Sea, otherwise the vessel will be destroyed;
c. 43 ships declared clear and awaiting government policy.

During the evaluation process it turned out that 414 units were unaccounted for and believed to have escaped and returned to their home country. The remaining 718 units are still in 27 ports in Indonesia (personal communication with Endroyono, KAPI, May 2016).

Many of the shrimp vessels in Aru Sea were considered in group c, clear and clean. However, the licenses cannot be renewed due to the trawl ban.

Ministerial decree of MMAF no 54 year 2014 regarding Fishery Management Plan (FMP) for FMA 718 (including Aru and Arafura Sea)

The government of Indonesia has endorsed the Fishery Management Plan (FMP) for FMA 718 (including Aru and Arafura Sea) on Ministerial decree no 54 year 2014. Therefore, this TAE guideline serves two purposes. The first and most obvious is to fulfill a call by FAO and commitment undertaken by the United States and all other FAO Members set forth in the 1999 FAO IPOA/capacity including Indonesia. Specifically, the FAO-IPOA for the management of fishing capacity provided in Section II (Preparation and Implementation of National Plans) that States should:

"*Develop, adopt and make public, by the end of 2002, national plans for the management of fishing capacity and, if required, reduce fishing capacity in order to balance fishing capacity with available resources on a sustainable basis. These should be based on an assessment of fish stocks and giving particular attention to cases requiring urgent measures and taking immediate steps to address the management of fishing capacity for stocks recognized as significantly overfished*…."

2. Capacity and related concepts in fisheries

The activity of controlling the fishing gears by limiting the fishing efforts, TAE *(Total Allowable Effort) management,* is a management instrument for getting the optimum benefits for the fisheries entrepreneurs as well as fair accesses to fisheries resources for the micro-scale, small-scale, medium-scale, and large-scale industries.

The number of allowed fishing efforts (TAE) is divided among all type of fishing gears in accordance with the availability of the resources. Furthermore, the allowed fishing efforts will be allocated for each type of selected fishing gears, including:

a. *Maximum fishing capacity*, limitation in the dimension of main fishing gears (length of *head rope* of trawl, *float rope* of *gill net* and purse seine, as well as the number of bait on longline).
b. *Maximum setting*, limitation in the maximum number of allowed fishing efforts (unit) per period (time unit).
c. *Maximum entity*, limitation in the maximum number of entrepreneurs allowed to use the fisheries resources in one specific period (time unit).
d. *Individual quota*, limitation in allowed fishing quota for each individual/fisher.

FAO called for an immediate action regarding fishing capacity in 1998 by encouraging the world fishery to reduce at least 30% of the main high values species (FAO, 1998). The ultimate goal of this action is to regain higher fish stock levels, that resources be rebuilt to at least maximum sustainable yield (MSY) levels within a ten-year period. Under this regulatory regime fishery must severely limit fishing activity, which requires establishing and reducing excess capacity.

The first country responded to the International Plan of Action declared by FAO in 1998 was the United States. The U.S. government was aware of their excess fishery capacity and capitals and in the 1990s. In 2004, the government of United States National Plan of Action for fishing capacity management was endorsed by the House of Representatives. As a result of these international agreements and plans of action, and a NOAA Fisheries Strategic Plan objective to eliminate over capitalization in 15 percent of federally managed fisheries by 2004, NMFS established a national capacity task force.

What is excess capacity?

Excess capacity is a long term consequence. Excess capacity involves over-investment in stock resources exploitation such as capital (vessel and equipment) in the long run. This implies inefficient allocation and a waste of economic resources. Excess capacity also exacerbates or is a consequence of common property problems that inherent in fisheries. It gives pressure to continue harvesting exceeding the sustainability point. With revenues spread among many vessels operating with little or almost zero, reductions in fleet size become increasingly crucial, and yet politically and socially more difficult (FAO guideline for capacity management). In Indonesia with limited entry regime management, once the government issues a permit, it is a forever permit. Vessels reductions are only marginally viable, and thus more vulnerable to changes in the resource base and regulations. This series of market failures makes it difficult to develop and implement regulations, or fishery management schemes, to effectively deal with the resulting problems. Therefore, determination of capacity levels in fisheries, and the resulting excess capacity that exacerbates regulatory, economic, and biological problems in fishing industries and regions, is a global concern.

Except in countries like the United States, Iceland and New Zealand, management of fishing capacity among the developed countries is still largely accomplished through moratoria on new entrants, limited access systems, and vessel buy out programs, rather than individual transferable quotas (ITQs) that could potentially encourage market forces to help match capacity to total allowable catches (TACs). Capacity management in developing or less developed countries, especially those in the tropics with wide species diversity, also relies primarily upon limited access.

In Indonesia, the most relevant laws endorsed by the Ministry of Marine Affairs and Fisheries in 2014 and 2015 directly impacts the reduction of fishing capacity in Indonesia waters. The foreign-made vessel moratoria has reduced the number of large vessels at about 1132 vessels since 2014. More than fifty vessels out of 1132 operated in Aru Sea. The prohibition of trawl gear in Indonesia water has decreased the number of vessels catching the fish, although the vessels still have valid licenses. Before the implementation of the moratorium, a total of 5,329 boats were registered by the central government of Indonesia (30 Oct 2014 data). More recent data indicates a 41% decline, to 3,127 registered boats in the central government registry (MMAF, 2016). The reduction in efforts from this particular law seems tremendous. The trawl ban that is effective since October 2015 automatically stopped the many trawlers in Aru Sea (www.integrasidjpt.kkp.com).

What is capacity utilization?

A measure that has recently gained increase use in the fisheries literature is *capacity utilization* (see, for example, Dupont *et al*., (2002); Felthoven, (2002)). This is primarily an output-based measure, determined as the ratio of the current to potential output under normal working conditions. A similar input based measure could be defined as the ratio of current fishing effort to potential fishing effort, again assuming normal working practices and given the state of the resource. The measure ranges from zero to one, with a value less than 1 indicating underutilization of the existing capacity (i.e. the current output is less than the potential output given the characteristics of the vessel and the state of the stocks) (FAO Fisheries Circular No. 994 FIPP/C994 ISSN 0429-9329).

2.1. Excess capacity versus overcapacity

The existence of underutilized capacity is an indication that *excess capacity* exists in a fishery, and that fewer boats, if fully utilized, could potentially have caught the same total catch. Excess capacity is a short run phenomenon and depends on the state of the resource and the environment (natural, social and economic) in which the fishers operate. A fishery with a fluctuating stock may exhibit excess capacity in some years and full capacity in others. Similarly, if market conditions are unfavourable, a fleet may exhibit excess capacity that disappears once prices return to the normal level. Yet, in spite of this temporary and changing excess capacity, overcapacity in the fishery may not exist.

Overcapacity is a longer-term problem and reflects a divergence between the resources used to harvest the resource (and the resultant current level of output) and the resources needed (and corresponding output) to harvest the resource at an "optimal" level. Optimal, in this sense, will largely be driven by the objectives of fisheries management, be they economic, social or conservation based (or some combination of all three). For example, a fishery is severely exploited due to overcapacity, the "optimal yield" or catch at sustainable capacity may he higher than current catches if the optimal goal is a combination of economic and social objectives to increase revenue and employment.

2.2. Target capacity and overcapacity

The most important and relevant concept to overcome any overcapacity, central to the definition of overcapacity is the concept of *target capacity*. This is the level of either output or inputs that are required to meet the objectives of the fisheries management plan for the fishery in question. For example, if the management objectives focused on maximizing the output from the fishery, then maximum sustainable yield (MSY) would be an appropriate target output capacity, and the fleet size required to achieve MSY would be an appropriate target input capacity. Conversely, if economic profitability was a consideration, the maximum economic yield (MEY) and the number of boats (the fleet level) associated with that would be considered an appropriate target capacity.

Target capacity was previously defined as the desired level of capacity, but this depends on the objectives of the management plan for the fishery.

Three potential target capacity levels include levels that:

a. maximize total fishery profits (the effort at the maximum economic yield, E_{MEY}),
b. maximize total fishery output (the effort at the maximum sustainable yield, E_{MSY}),

3. Theory of capacity utilization and fishing capacity

In this guideline, the capacity assessment will be output based as they are widely used in measuring some fishery capacity. The other strength of using output based method is the easily ready data of outputs of given key inputs.

The capacity utilization measurement in this guideline mainly focused on four quantitative techniques identified and presented during the National Working group and Local Consultative Group in Jakarta and Sorong, Papua respectively. The hope is to use this guideline to estimate capacity utilization levels and use it to determine target capacity in a fishery. The methods are the Peak to Peak, The Stochastic Production Frontier and Maximum Sustainable Yield using Surplus Production Model and Maximum Economic Yield.

The "peak-to-peak" method of Klein (1960) is a quantitative approach that has been used to estimate technical capacity in fisheries. The stochastic production frontier (SPF) is an alternative method that has been used to estimate efficient (frontier) production in fisheries (Kirkley, Squires, & Strand, 1995;

Kirkley, Squires, & Strand, 1998). Kirkley and DuPaul (1994) incorporated uncertainty in the fisheries and non-technical factors into estimating vessel's efficiency. SFP also may be a useful method for developing a measure of capacity under certain circumstances. A third method that gained the most attention from local stakeholders and industries is the Surplus Production Function in a way that the data needed is regularly collected by the industries such as time series and yearly catch and efforts. The fourth method is the Bio-economic approach where the biological production was estimated using the Surplus Production Function and combined with economic parameters playing key roles in fishery management.

The selection of appropriate method to be employed in estimating the fishing capacity mainly depends on the nature of the fishery, the data available, and the intended use of the capacity measure. In this report, the four basic techniques that might be used to calculate capacity and capacity utilization are discussed. It is anticipated that the discussion of the various methods will offer analysts and or policy makers with good understanding and efficient information and knowledge to estimate capacity for different fisheries.

3.1. Output-oriented measures of technical and allocative efficiency

The work of Boles (1966), Aigner and Chu (1968) and Fare et al. (1985; 1994) substantially advanced the concept and literature on output-oriented measures of technical efficiency.

In contrast to the input-oriented measure of TE which assesses TE relative to a radial input reduction given a constant output level, the radial output-oriented measure of TE provides a measure of the amount by which outputs may be proportionally expanded given inputs held constant. The output-oriented measure is illustrated in Figure 3-1 which depicts the production possibilities curve for a producer using one input (x_1) to produce two outputs (Q_1 and Q_2).

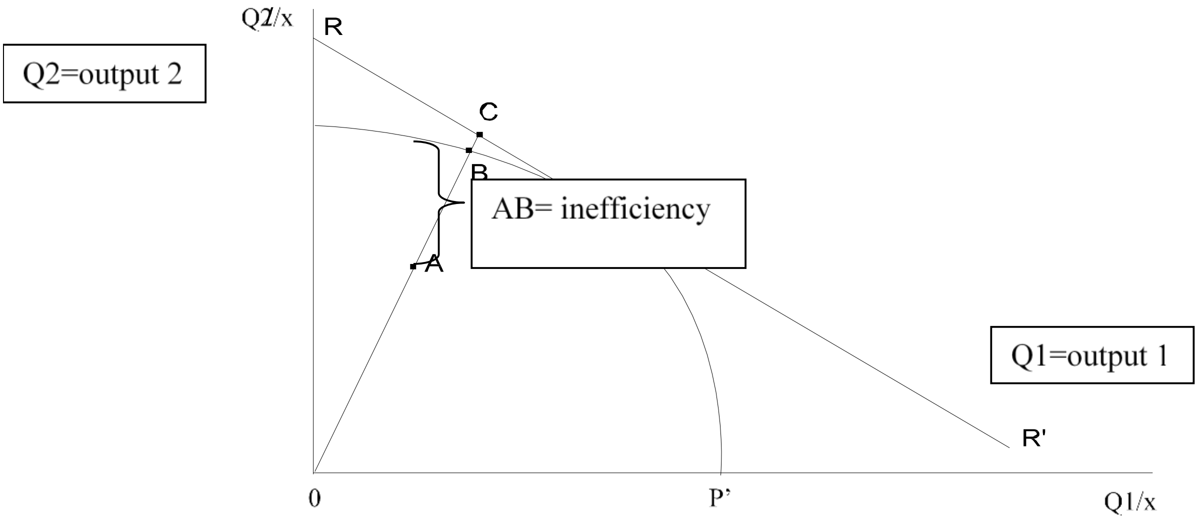

Figure 3-1: Technical and allocation efficiency: output orientation

Adopted from Coelli et al. (1998) *An Introduction to Efficiency and Production Analysis.*

The curve PP' represents the production possibilities frontier. All points along the frontier are technically efficient (e.g., point B). All points on the interior of P' represent technical inefficiency (e.g., point A). The distance defined by AB represents technical inefficiency; this is the amount by which outputs could be increased with no change in the level of x. The ratio 0A/0B is an output-oriented measure of technical efficiency. Färe et al. (1985; 1994), however, define technical efficiency in terms of OB/OA which indicates the total efficient production level for each output. Subtracting 1.0 from the Färe et al. (1985; 1994) output-oriented measure indicates the proportional by which outputs may be expanded relative to their observed levels.

Not surprising, there is also an allocative measure of efficiency which corresponds to the mix of outputs that maximize revenue. The ratio OB/OC is a measure of allocative efficiency which indicates the percent by which revenue may be increased without changing the input level. There also is an overall economic efficiency measure which equals the product of the output oriented technical efficiency measure and the allocative efficiency measure; it equals the ratio OA/OC. Färe and Grosskopf (1998) discuss additional concepts of efficiency and other important decompositions and illustrate how the overall revenue-based measure of efficiency can be decomposed into the product of allocative efficiency, output scale efficiency, an output congestion efficiency, and the output- oriented measure of technical efficiency.

The stochastic frontier analysis

Stochastic frontier analysis (SFA) is used to the technical efficiency of individual production units such as vessels or boats. The theory was introduced simultaneously by Meeusen & van den Broeck (1977) and Aigner, Lovell & Schmidt (1977), but since then more complex models have been developed. The technical efficiency (TE) of a vessel is defined as the ratio of observed output to maximum feasible output, given the resource and environmental conditions. In cases where the observed TE of firm i takes on a value of unit, the i-th firm is said to be fully technical efficient, while TEi <1 indicates the firm is experiencing a inefficiency of the observed output from maximum feasible output. In the former case, the firm may be said to lie on the production frontier, while in the second case it would find itself below the frontier.

In previous method, all of the noise is considered as inefficiency only. Noise is the random error on a statistical regression. In SFA, the random component of an ordinary regression is split into a one-sided stochastic component, that captures the inefficiency, and a pure white noise component, a random error. The stochastic component describes random shocks or uncertainties that may affect the production process but are not directly attributable to the producer or the underlying technology. Typically, these shocks could be brought by changes in weather, economic adversities, fish stock uncertain fluctuation or just being unlucky and or any measures that are not related to the technology or the production process.

SFA has widely been applied to the in fisheries sector, both aquaculture and capture fisheries. Early studies on efficiency in the harvesting sector include Kirkley, Squires & Strand (1995; 1998), Coglan, Pascoe & Harris (1999), Sharma & Leung (1999), Squires & Kirkley (1999), Pascoe, Andersen & de Wilde (2001) and Pascoe & Coglan (2002). The model developed by Battese & Coelli (1995) has been employed by Fousekis & Klonaris (2003) to investigate the technical efficiency of the trammel net fishery in Greece while Ghee-Thean et al. (2012) use stochastic frontier analysis to analyze how technology and other determinants have affected the fishing efficiency of a trawl fishery in Malaysia. Susilowati et al. (2005) studied Java Purse seiners technical efficiency using Data Envelopment Analysis.

The basics of the SPF

Of all the parametric approaches for estimating technical efficiency, the SPF approach has probably become the most widely used approach. The literature on the SPF approach is too immense to adequately discuss in the present report; therefore, only the necessary basics are presented. A more complete discussion on the SPF approach is available in Bauer (1990), Battese (1992), Coelli et al. (1998), Førsund et al. (1980), Greene (1993), Lovell (1993) and Schmidt (1976).

A major disadvantage of previous approaches for estimating TE is that all random noise is attributed to inefficiency. Alternatively, all deviations from the frontier are attributed to inefficiency. To deal with this criticism, Aigner et al. (1977) and Meeusen and van den Broeck (1977) proposed the stochastic production frontier in which there are two random variables: (1) a random error term (v), and (2) a non-negative random variable–typically denoted by u. The random variable u, as in the deterministic and statistical full frontiers, specifies technical inefficiency. The random error v is the conventional error term in regressions and is assumed to be normally distributed with a mean of zero and a constant variance.

Considering the statistical frontier, the SPF may be specified as

$$Y_i = \beta_0.(X_i)^{\beta_i} \ldots.(X_N)^{\beta_N}$$

$$ln(y_i) = \beta_0 + \sum_{i=1}^{N} \beta_i . ln(X_i) + v_i - u_i, i = 1,2, \ldots.. N \qquad (2)$$

$$\ln(Catch) = = \beta_0 +. ln(CPUE_i) + \ln(Trip) + \ln(BBM) + \ln(Capt.\exp \quad) + v_i - u_i$$

Where y and x represent the inputs and outputs, respective; v is a random error term assumed to be normally distributed with a mean of zero and a constant variance, and u, which is the technical inefficiency term, and assumed to have a nonnegative distribution. The random error, v, serves to account for measurement error and other random factors, such as the effects of weather or unexpected factors on production. The random error term, v, is assumed to be independent of the non-negative random variable, u. A Cobb-Douglas specification is assumed; other specifications such as the trans-log and transcendental, however, may also be used.

What exactly is going on with the stochastic production frontier? The SPF imposes the condition that output values are bounded above by the stochastic or random variable,

$$exp^{(\beta 0 + \sum_{i=1} \beta i \ln xi + vi)}$$

The stochastic error, which accounts for noise, has values between - infinity and positive infinity (i.e., its value may be positive or negative). Therefore, the SPF output levels vary about the deterministic part of the frontier model, which is:

$$exp^{(\beta 0 + \sum_{i=1} \beta i \ln xi)}$$

The deterministic frontier is defined by the curved line relating output to input. We find that our stochastic frontier is defined by deviations from the deterministic frontier. Output levels are bounded from above by the stochastic

One major problem, of course, is that estimation of the SPF requires specification of some underlying functional form. Moreover, the specification must be multiplicative in inputs, the random error term, and the non-negative random variable for inefficiency. Given flexible functional form (FFF) specifications, however, there should be few problems associated with specification of the underlying functional form.

3.2. Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY) model

These two models are widely used both for estimating the potential sustainable yield (MSY) and maximizing economic yield or profits from a fishery (MEY) and what are the associated fishing capacity with both points. In the MEY model, so called bioeconomic model, the model combines both the biological properties of fishery resources with the economic parameters of the fishery, namely the fish price and the cost of fishing. Bio-economic models can be used to compare static open access solutions to maximum sustainable yield (MSY) and maximum economic yield (MEY), as well as optimal dynamic utilization.

Stock assessment techniques are well established that allow for the estimation of sustainable yields in fisheries, provided sufficient data are available to estimate the required model parameters. These models can be used to estimate both target output capacity and effort levels with the goal of biological sustainability, namely enough recruitment and growth for the fishery stock. However, bioeconomic is also a device to estimate target capacity when incomes and employment are the critical factors besides the stock sustainability. Optimization of bioeconomic model can be used to estimate the optimum yield and fleet size that are both sustainable and which also improve fishers' incomes. Multi-objective models can be developed that allow the "optimal" to be defined in terms of several criteria (e.g. employment, profitability) (FAO Fisheries Circular No. 994 FIPP/C994 ISSN 0429-9329).

The Surplus Production Model related the output-oriented technical efficiency and sustainable resource use. It is well illustrated by the well-known Gordon- Schaefer model (Gordon, 1954; Schaefer, 1957) in Figure 3-2

Let *TR* denote total sustainable revenue (i.e. revenue corresponding to a steady state equilibrium of the resource stock) – the output price is fixed and exogenously determined – *TC* denote total private cost, and $TC = cE$, where c denotes a constant cost per unit of fishing effort E. When $TR = TC$, sustainable (steady-state) resource rents, $\pi = TR - TC$, are dissipated by excessive fishing effort and the fishery is in an open-access Nash equilibrium in which the resource stock is in steady-state equilibrium. Let $TR0$ denote total steady-state revenue with full output-oriented technical efficiency, giving an initial Pareto-inefficient Nash equilibrium in open-access with effort $E0$. Since $E0 > E_{MSY}$ in this example, the resource stock falls below the maximum sustainable yield (MSY) level, where the MSY resource stock is a sustainable target stock size.

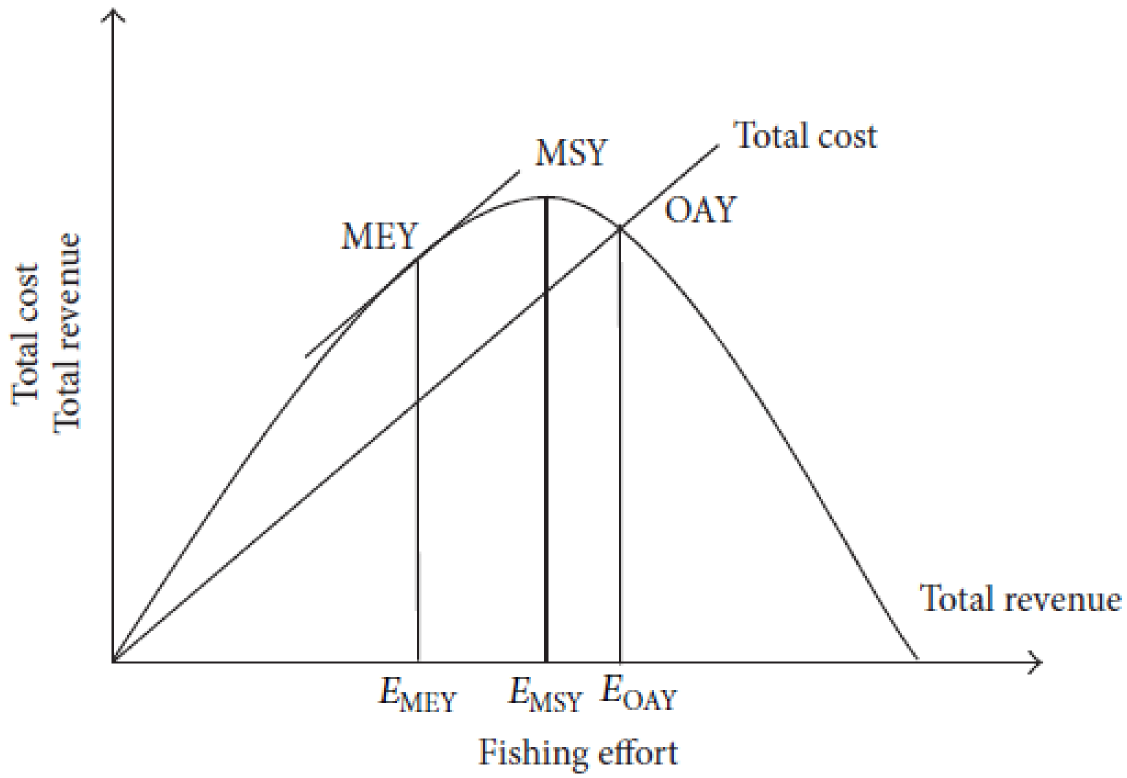

Figure 3-2: Relationship between Total revenue/Total cost on Efforts

The curve *TR* in Figure 3-2 depicts the sustainable total revenue. When the resource manager decides to maximize the profits provided the Total Cost Curve, the largest difference between TR curve and TC curve happens somewhere in the left side, before the MSY point. That optimal points, so called Maximum Economic Yield (MEY), corresponds to the effort level or target for maximizing the profits from fisheries.

The Gordon Schaefer (GS) model originated from Gordon (1954) and Schaefer (1957). Therefore, the GS surplus production model has been selected for this study. The model has a big advantage of requiring limited data and could produce rough guidance on fleet size in the case of single-species as well as multispecies fishery.

Fisheries based on highly productive biological resources with large r (intrinsic growth rate) and K (carrying capacity) may sustain a large fishing effort under OA [26]. In all populations, natural surplus growth is small for both high and low stock level and the largest for some intermediate level. However, the GS model is based on the logistic growth equation:

$$F\ (X) = rX\ (1 - \frac{X}{K}) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(1)}$$

Where (X) is surplus biomass growth per unit of time; X is stock biomass. The equation describes a parabolic curve as a function of X. The harvest rate (H) is assumed by the simple relation of Schaefer catch function:

$$H(E, X) = qEX \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(2)}$$

Where E is fishing effort and q is a constant catchability coefficient. Sustainable yield occurs when harvest equals the surplus growth; that is, when rate of change of biomass:

$$\frac{dx}{dt} = F(X) - H\ (E, X) = 0 \dots\dots\dots\dots\dots\dots\dots\dots \text{(3)}$$

This implies qEX = r (1 − x/K) based on (1) and (2). Therefore, biomass at equilibrium, $X,$ is solved to be:

$$X \quad = K\left(1 - \frac{qE}{r}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(4)}$$

Inserting (4) into (2) gives the long-term catch equation:

$$H(E) \quad = qKE\left(1 - \frac{qE}{r}\right) = qKE - \frac{q^2KE^2}{r} \dots\dots \text{(5)}$$

Dividing both sides of (5) by effort (E) gives the linear relationship between catch per unit of effort (CPUE) and fishing effort:

$$CPUE = \frac{H}{E} = qK - \frac{q^2KE}{r} \dots\dots\dots\dots \dots \text{(6)}$$

Assuming constant price, equation (5) can be used to define total revenue (TR) in equilibrium as a function of standardized effort:

$$TR\ (E)\ =\ p\ \cdot\ H(E) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(7)}$$

Where p denotes a constant price per unit of harvest. Total cost of fishing effort (TC) is given by:

$$TC\ (E)\ =\ c\ \cdot\ E \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(8)}$$

Where *c* denotes unit cost of effort including opportunity cost of labor and capital. From equations (7) and (8), the equilibrium resource rent (Π) can be derived as a function of fishing effort:

$$\Pi(E) = TR(E) - TC(E) \ldots\ldots\ldots\ldots\ldots \ldots.. (9)$$

By using the unit cost of harvest and the resource rent per unit harvest, we can find the open-access equilibrium level of the fish stock. The unit cost of harvest follows by use of (2) and (8).

$$H(X) = TC(E) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

$$H = cE$$

$$qEX = cqX \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

This demonstrates that the unit cost of harvest decreases with an increase in the stock size.

With the constant price of fish, the resource rent per unit harvest is:

$$b(X) = p - cqX \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots\ldots. (12)$$

At the open-access equilibrium, the stock level $X\infty$ follows from b ($X\infty = 0$), and open access stock biomass:

$$X\infty = cpq \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots\ldots (13)$$

The long-term harvest function can be expressed:

$$CPUE = \frac{H}{E} = qK - \frac{q^2KE}{r} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

So, CPUE could be expressed by:

$$CPUE = a + bE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Where:

$$CPUE = \frac{H}{E}, a = qK, and\ b = (-\frac{aq}{r}).$$

Since data on catch and effort are available for the Shrimp fishery in Aru and Arafura, this allow us to estimate the parameters *a* and *b* by linear regression of the catch per unit of effort on effort.

Effort at maximum sustainable yield can be obtained from (12) by taking the partial derivative of *H* with respect to *E* and setting it equal to zero as:

$$\frac{dH(E)}{dE} = \frac{d\left(qKE\left(1-\frac{qE}{r}\right)\right)}{dE} = \frac{d\left(qKE - \frac{q^2KE^2}{r}\right)}{dE} = 0 \qquad (16)$$

$$E_{MSY} = \left(\frac{-\alpha}{2\beta}\right) \qquad (17)$$

Hence, the output at MSY is

$$Y_{MSY} = \left(\frac{-\alpha^2}{4\beta}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

The maximum economic return is realized at a lower total fishing effort for positive economic rent that is only obtained at efforts lower than E_{OA}. Maximum economic yield (MEY) is attained at the profit maximizing level of effort which is obtained using (9):

$$\frac{dTR(E)-TC(E)}{dE} = 0 \quad (19)$$

Therefore, the effort at MEY is

$$E_{MEY} = \left(\frac{\frac{c}{p}-\alpha}{2\beta}\right) \quad (20)$$

4. Empirical illustration: The shrimp trawl fishery in Aru and Arafura Sea, Indonesia

This section provides a description on the data use and what kind of data needed to apply the theory into the estimation of technical efficiency and target capacity, namely MSY and MEY points.

The Data

Our data for the Aru and Arafura Sea (FMA 718) trawl fishery has been used in this document. The data was provided voluntarily from an existing Shrimp trawl association as part of the participatory approach during the process of REBYC-CTI project. The catch record was during the last 10 years for banana and tiger shrimp. The industries confirmed that the fishing ground for the two species are different in the area of Aru and Arafura Sea, in this document, the data set was modelled separately.

The data are at vessels level monthly that are collapsed into a yearly data for the models, for nine shrimp trawlers over the time period 2000-2014. The nine vessels are relatively homogeneous in terms of characteristics, and all faced identical economic conditions such as output prices and factor costs, and environmental conditions such as weather. Actual days fished, however, slightly varied in accordance with a wide variety of internal and external factors, which are not readily observable but may be accommodated to some extent by incorporating noise in the data through the stochastic specification. They are also accounted for by recognizing customary and usual operating procedures, by limiting the characterization of "optimal" output production (catch) and variable input use (days) to those observed within the data set (feasible).

Understanding the theory and concept of technical efficiency (see previous chapter) is a prerequisite for estimating and assessing capacity and capacity utilization. This section will explore the examples of estimating those measures using various approaches. The approaches range from a very simple once- output divided by single input and the stochastic production frontier. Section 5 also provides exercise on estimating total allowable efforts using Maximum sustainable yield and Maximum Economic yield.

A summary of data needed and the type of data for each method is provided in Table 4-1. The data needs for estimation are catch, effort (days or trips), vessels' size, number of crew, years of captain experience, cost of fishing and price of products.

Table 4-1. Data needed and the type of data for each method

Type of Data	Peak to Peak (CPUE)	Stochastic Frontier Production	Maximum Sustainable Yield	Maximum Economic Yield
Catch (kg/ton)	☑	☑	☑	☑
Effort (trips) or Days at Sea (days)	☑	☑	☑	☑
Gross Tonnage (GT)		☑		
Number of Crew		☑		
Captain experience (years)		☑		
Price of fish (IDR)				☑
Cost of fishing (IDR/year)				☑

Table 4-2. The catch record for banana shrimp fishery in Aru and Arafura

Year	Catch (kg)	Effort (days)	CPUE
1	246,426	673	366.16
2	465,618	1,473	316.17
3	553,424	1,793	308.66
4	642,214	2,028	316.67
5	1,068,610	2,077	514.50
6	935,475	1,876	498.65
7	728,205	1,914	380.46
8	626,028	1,931	324.20
9	995,205	2,160	460.74
10	840,556	2,152	390.59
11	758,107	2,402	315.61
12	804,812	2,453	394.12
13	1,061,650	2,465	430.69
14	889,922	2,258	394.12
15	1,006,422	2,153	467.45
16	313,762	565	555.33

(Source: HPPI, 2015)

Table 4-3. The catch record for tiger shrimp in Aru and Arafura Sea

Year	Catch (Kg)	Effort (days)	CPUE
1	732,251	3,377	216.83
2	786,433	3,419	230.02
3	859,762	3,325	258.58
4	861,147	3,461	248.81
5	937,759	3,274	286.43
6	981,018	3,202	306.38
7	969,384	3,190	303.88
8	968,956	3,163	306.34
9	906,456	3,190	284.16
10	790,854	3,158	250.43
11	702,643	2,827	248.55
12	935,189	3,085	303.14
13	1,140,018	3,101	367.63
14	1,110,621.5	3,061	362.83
15	1,082,953.5	3,052	354.83
16	606,080	1,430	423.83
Average	898,220	3,082	291.44

(Source: HPPI, 2015)

5. Data sharing and management

5.1. Action plan on data sharing

A series of Meetings on consultation were carried out during the compilation of the guideline. The meetings include consultation meetings with the REBYC-CTI management in Bogor (February 2016), National Consultative Workshop with NWG REBYC-CTI in Bogor (March, 2016), Local Consultative Workshop of REBYC-CTI in Sorong (May, 2016), and National Working Group Workshop of REBYC-CTI in Bogor (June, 2016) and Final consultation with National Working Group Workshop (July, 216).

5.1.1. Consultative meeting with the KAPI-DGCF

The meeting was held in the University of Bogor on March 16, 2016. The goal of the meeting was to agree on the outline and content of the guideline. The guideline particularly will include several key aspects: capacity related concepts, theory on capacity concept, data sharing and management of data needed for capacity related estimation, empirical examples of determining capacities of Aru Shrimp Fishery. The representative of Directorate of Licenses and Directorate of Fishery Resources of DGCF hope to apply the guideline for the management of Fishery Management Area (WPP) in Indonesia.

5.1.2. Consultative meeting with the National Working Group Meeting of REBYC-CTI

The meeting was held in the Sahira Butik Hotel in April, 2016. The goal of the meeting was to inform the NWG REBYC-CTI on the TAE guideline particularly its outline and content of the guideline. The meeting also serves as an initial step for data collection needed for capacity estimation during the composition of this guideline from the stakeholders particularly the fishery industry. The NWG recommends that the guideline includes the estimation of fishing capacity in Aru Shrimp Fishery.

5.1.3. Data collection during the Local Consultative Meeting in Sorong

The meeting was held in Mamberamo Hotel in Sorong, Papua Barat. The goal is to inform, consult and collect data from stakeholders in Sorong. Sorong Fishing Port is the base for Aru Fishery including Shrimp Fishery. Several data were able to be collected from the industries particularly shrimp trawlers and fish trawlers. There was also Pull and Line association that have some data and shared the data as well. As a follow up of that meeting, the author gathered further data with the association from its headquarter office in Jakarta.

5.1.4. Guideline presentation on NWG-REBYC II meeting in Bogor

The meeting was held in the Mirah hotel in Bogor on June 2016. The author presented the guidelines from the theory, data and results of estimation as part of illustration example. The illustration used data shared by the industries particularly HPPI. Good inputs were obtained during the meeting and incorporated into the draft.

5.2. Data management

All of the data related or being used in the development of this guideline will be owned by the secretariat of REBYC-II CTI and will not be further shared with any other parties. Also, none of the members of NWG-REBYC-II CTI has any right to use the data for personal manuscript/paper for publication unless with the consent of all NWG member or the owner of the data.

6. Estimating the technical efficiency

6.1. Estimating technical efficiency using simple approach

The Table below gives a further example of calculating the relative technical efficiency using data from one of the shrimp association fished in Aru Sea. Provided the stakeholder's permission, we can exercise the calculation on technical efficiency to have learn the level of capacity utilization for Aru Sea Fishery, particularly shrimp fishery in Aru.

Table 6-1. Relative technical efficiency of fleet (consist of 9-11 vessels per year) over time

Year	Catch (kg)	Effort (days)	CPUE	TE
1	246,426	673	366.16	0.71
2	465,618	1,473	316.17	0.61
3	553,424	1,793	308.66	0.60
4	642,214	2,028	316.67	0.62
5	1,068,610	2,077	514.50	1.00
6	935,475	1,876	498.65	0.97
7	728,205	1,914	380.46	0.74
8	626,028	1,931	324.20	0.63
9	995,205	2,160	460.74	0.90
10	840,556	2,152	390.59	0.76
11	758,107	2,402	315.61	0.61
12	804,812	2,453	394.12	0.77
13	1,061,650	2,465	430.69	0.84
14	889,922	2,258	394.12	0.77
15	1,006,422	2,153	467.45	0.91

(Source: author calculation based on data from HPPI Indonesia, banana shrimp fishery)

Table 6-2. Relative technical efficiency of vessels in a given year (2009) for banana shrimp

Tahun	Vessel's name	TOTAL (kg)	Trips	Hasil	CPUE	Rel Tech Eff
2009	Vessels1	69,038.50	283	244	244	0.85
2009	Vessels2	74,457.00	294	253	253	0.88
2009	Vessels3	70,696.50	286	247	247	0.86
2009	Vessels4	71,137.00	284	250	250	0.87
2009	Vessels5	73,709.50	286	258	258	0.90
2009	Vessels6	76,070.00	288	264	264	0.92
2009	Vessels7	65,087.50	286	228	228	0.79
2009	Vessels8	69,698.50	297	235	235	0.82
2009	Vessels9	84,244.00	293	288	288	1.00
2009	Vessels10	59,636.50	291	205	205	0.71
2009	Vessels11	77,078.50	284	271	271	0.94

(Source: author calculation based on data from HPPI Indonesia, banana shrimp fishery)

Table 6-1and Table 4-2 show results of technical efficiency estimation. They are fleet level and vessels level technical efficiency. This figure serves different purposes for evaluating the performance of the fishing vessels or fleet both for the industry itself or the policy makers. For example, Table 4-2 shows that the fleets in 2001 and 2006 were having the almost lowest efficiency compared to the highest one in 2004 (the highest CPUE). That gives messages for the industry, for example, to evaluate what operational challenges or constrains on those years and what technical conditions encourages high productivity in 2004. Provided that insight, industry may take actions to implement several measures to improve the fleet efficiencies in the future years for an even better profits.

Table 6-2 depicts that vessels9 is the highest technical efficiency. The industry or association may evaluate the other vessels technical condition. Or if there is capacity reduction program is needed in the future, the least efficient vessel is probably the first ones to be retired. Policy maker may use this finding as one of the strategy for that purpose as well, if needed.

1.1 Estimating technical efficiency using Stochastic Production Frontier (SPF)

The SFP model was run in R-code using maximum Likelihood Method. From the software, the results were presented in Table 6-3.

Table 6-3. Results of regression of variables impacting yield in R-code

	Estimate	Std. Error	z value	Pr (>|z|)	
Intercept	2.4243297	0.6707839	3.6142	0.0003013	***
Log(trip)	0.3718414	0.1103630	3.3693	0.0007537	***
Log(fuel)	0.5851281	0.1364777	4.2874	1.808e-05	***
Log(GT)	-0.0831766	0.1718277	-0.4841	0.6283365	
Log(Cex)	-0.0589439	0.0277751	-2.1222	0.0338220	*
SigmaSq	0.0163523	0.0064765	2.5249	0.0115746	*
Gamma	0.8327242	0.1633181	5.0988	3.418e-07	***

(Source: author calculation using R-Code)

Table 6-4. Estimation of technical efficiency using SPF method at vessels level yearly using R-code

No	Catch (Kg)	Trips (days)	Fuel (liter/year)	Captain Experience (yrs)	Efficiencies
1.0	107,411.5	306.0	500,300.0	16.0	0.93
2.0	102,569.5	290.0	489,400.0	19.0	0.93
3.0	85,612.5	258.0	433,300.0	32.0	0.91
4.0	103,064.5	295.0	520,850.0	13.0	0.89
5.0	98,753.0	302.0	469,700.0	13.0	0.90
6.0	97,360.5	257.0	380,750.0	5.0	0.96
7.0	88,851.0	267.0	449,500.0	18.0	0.89
8.0	98,664.0	286.0	495,830.0	10.0	0.88
9.0	120,230.5	283.0	726,810.0	19.0	0.92
10.0	128,235.0	314.0	733,070.0	30.0	0.94
11.0	79,869.5	206.0	323,400.0	5.0	0.95
12.0	102,661.5	269.0	390,000.0	17.0	0.98
13.0	94,087.0	257.0	407,100.0	20.0	0.96
14.0	101,379.0	310.0	442,940.0	33.0	0.96
15.0	95,553.5	266.0	429,360.0	14.0	0.94
16.0	65,173.0	213.0	387,900.0	14.0	0.78
17.0	107,909.5	304.0	454,310.0	6.0	0.94
18.0	100,933.5	305.0	449,650.0	19.0	0.94
19.0	95,310.0	296.0	434,770.0	11.0	0.90
20.0	125,527.5	300.0	944,510.0	20.0	0.83

21.0	107,801.5	269.0	717,000.0	31.0	0.88
22.0	86,617.5	269.0	497,150.0	6.0	0.79
23.0	66,597.0	147.0	349,000.0	18.0	0.94
24.0	56,210.0	137.0	262,150.0	21.0	0.95
25.0	56,256.0	134.0	286,270.0	34.0	0.95
26.0	54,554.5	142.0	265,190.0	15.0	0.92
27.0	56,929.5	148.0	251,460.0	15.0	0.95
28.0	59,335.0	133.0	264,420.0	7.0	0.95
29.0	48,781.5	123.0	255,350.0	20.0	0.91
30.0	60,898.0	159.0	271,230.0	12.0	0.94
31.0	73,648.0	108.0	435,010.0	21.0	0.98
32.0	9,542.0	25.0	66,900.0	32.0	0.77
33.0	61,590.0	152.0	276,250.0	7.0	0.94
			Average Efficiency		0.91

(Source: author calculation using R-Code)

The SPF method uses several input variables such as Gross Tonnage (GT), number of days at Sea (Trips), fuel consumed (tons), and Captain Experience (Years). The results are in Table 6-4. From SFP model, it shows that trips, fuels and captain experience are important factors toward fleets' productivity (catch). The fleet's technical efficiencies are ranging from 0.77 – 0.98. Incorporating other input factors into the SPF model improves the estimation. Comparison of Table 6-2 and Table 6-4 reveals that technical efficiencies of those vessels are improved using SPF model.

Once, the performance of the vessels is known, the industries may use the information to retire the vessels or fleet that are least productive or lowest technical efficiency. Another use of technical efficiency information is also for estimating the total boats or license allowed at certain fishery provide the policy maker knows the sustainable level of catch.

7. Estimating target capacity using MSY and MEY

The overall goal of fisheries management is to provide sustainable biological, social, and economic benefits from renewable aquatic resources. For the long-term sustainability and for enhancing the revenue of the fishery, static as well as the dynamic behaviour of the system should be investigated by achieving the targeted reference points. Maximum economic yield (MEY) and maximum sustainable yield (MSY) represent different fisheries objectives which are the basis of identifying suitable management measures.

Table 7-1. Harvest function parameters based on the regression using the available 10 years catch record for banana shrimp.

Parameters	coefficient	standard error	t-stat
α	448.46	72.84	6.16
β	-0.02	0.04	-0.66

The harvest function for the Shrimp fishery in Aru and Arafura Sea is based on (14) and values of parameters estimated from Table 7-1 was found to be

$$H\ (E)\ =\ 448.46E\ +\ -0.02\ E\text{^}2$$

The harvest function exhibits a downward sloping quadratic function for the banana shrimp. That shows that the more efforts put in place, the smaller the catch the fisher will get. The rate of catch change with respect to effort is calculated from the derivative of the catch function with respect to efforts. The rate is positive at effort equal to zero. However, the rate of catch change is decreasing at a rate 0.02 multiply by effort at that time.

Calculation of reference points is the key step towards approaching the bioeconomic analysis; hence, MSY, MEY, corresponding effort levels, and economic rent were calculated in response to changes in the biological parameters.

The values of effort at MSY and MEY were calculated using Equations (11) and (19) while harvests at MSY, and MEY, were calculated using this fishery's harvest equation (12) and (20). Economic rent is the difference between total revenue and total cost.

Therefore, total cost and total revenue were calculated using (7) and (8).

Table 7-2. Economic parameters to be used for the MEY calculation for shrimp fishery in Aru and Arafura Sea.

Parameter	Unit	Value (IDR million)
Cost (c)	(IDR million /effort)	30.00
Price (p)	(IDR million /Ton)	122.00

The economic parameters data were collected from the operating cost of shrimp trawl fishery per effort. It is to be noted that the value of this cost is at the lower bound since this number does not include the capital cost and the depreciation of the capital cost and also perhaps the marketing cost. The use of this cost data will influence the MEY reference point because the total cost data will be tilted down (TC line on Figure 3-2) when the cost does not include other component of fishing industry costs. The price data is the import price data for shrimp to be sent to mostly Taiwan and Japan.

Table 7-3. Results in terms of Yield/Production and efforts from the bioeconomic models using ten-years catch records of banana shrimp fishery.

	MSY (kg)	MEY (kg)
Production (Tons/year)	2,060,199.63	2,060,199.01
Effort (total days/year)	9,187.85	9,182.81

The results show that there is only slight difference in terms of efforts between Maximum Economic Yield and MSY. The reason being said that only operating data was able to be collected during the data gathering. Hence, the total cost function slope is rather flat. Therefore, the resulted economically optimal effort (MEY, maximizing profit) is near the optimal yield (MSY, maximizing the catch). The cost data needed include the capital cost, maintenance cost, depreciation cost, the marketing and office and staff cost, interest to the Bank needed to be paid, licenses and fees for the fishing vessels. However, during the composition of this guideline, only operating cost per day were available.

As indicated in Table 7-3, MSY was 2,060,200 tons and produced at effort value of 9,188 days at sea per year. Similarly, the MEY was at 2,060,199.01 tons and effort value of 9,183 days fishing. When these estimated values were compared with the recorded catch and effort values (Table 4-2), it has been found that the current catch level does not exceed to MSY value that is obtained from this empirical model. Based on the data of Banana Shrimp Fishery, the average days at Sea is around 1898 (~2000) days.

Provided that the existing days at sea is far below the sustainable total days at sea by the model, we may be tempted to compute that the sustainable level of efforts are around five times the existing efforts. However, it may be too early to conclude that provided that the analysis only using some available data of Banana Shrimp fishery.

The next results are reference points using catch record for Tiger shrimp fishery. The data used on the calculation of the models were presented on Table 7-4. The harvest function to found is:

$$H(E) = 890.66E - 0.08\,E\text{^}2$$

Similarly, the harvest function also exhibits a downward sloping quadratic function for the tiger shrimp. That shows that the more efforts put in place, the smaller the catch the fisher will get. The rate of catch change with respect to effort is calculated from the derivative of the catch function with respect to efforts. The rate is positive at effort equal to zero. However, the rate of catch change is decreasing at a rate 0.02 multiply by effort at that time. The rate of catch change is steeper for tiger shrimp than banana shrimp.

Table 7-4. Harvest function parameters based on the regression using the available 10-years catch record for tiger shrimp fishery in Aru and Arafura Sea.

Parameters	coefficient	standard error	t-stat	R^2
[illegible]	680.73	72.84	6.16	0.53
[illegible]	-0.09	0.04	(0.66)	

Table 7-5. Results in terms of Yield/Production and efforts from the bioeconomic models using five-years catch records of tiger shrimp fishery.

Parameters	MSY	MEY
Production (tons)	1,281,664.06	1,281,662.55
Effort (days)	3,765.57	3,761.49

As indicated in Table 7-5, MSY was 1,281,664tons and produced at effort value of 3,765 days at sea per year. Similarly, the MEY was at 1,281,662 tons and effort value of 3,761 days fishing. When these estimated values were compared with the recorded catch and effort values (Table 4-3, it has been found that the current catch level does not exceed to MSY value that is obtained from this empirical model. Based on the data of Tiger Shrimp Fishery, the average days at Sea are around ~3000 days. However, the Tiger shrimp fishery is still at sustainable exploitation rate, below the MSY level.

Similar results are shown here for tiger shrimp. The total efforts are similar between the Maximum Economic Yield and MSY. The reason being said that only operating data was able to be collected during the data gathering. Hence, the total cost function slope is rather flat. Therefore, the resulted economically optimal effort (MEY, maximizing profit) is near the optimal yield (MSY, maximizing the catch). The cost data needed include the capital cost, maintenance cost, depreciation cost, the marketing and office and staff cost, interest to the Bank needed to be paid, licenses and fees for the fishing vessels. However, during the composition of this guideline, only operating cost per day were available for tiger shrimp fishery.

Above all, the shrimp fisheries in Aru and Arafura Sea were exploited at sustainable rate using the data available for the purpose of this document.

8. Concluding remarks

Particularly in Aru and Arafura Sea and the national level, capacity and its management are receiving lots of attention in Indonesia fishery in the spirit of managing fishery toward sustainable and prosperous fishery for the people. Nonetheless, considerable confusion has reigned over relevant definitions and tractable means of measuring capacity levels and excess capacity in fishing industries. In this paper we define a sequence of technological-economic definitions of capacity and excess capacity for fishing industries, and provide example of empirical estimates of these measures for the Shrimp Trawl Fishery in Indonesia using two different methodologies. The various definitions, and alternative estimation techniques (Technical efficiencies namely: simple approach, and stochastic production frontier estimation, SPF and Biological and Economical Models namely: Maximum Sustainable and Maximum Economic Yield) generate somewhat different measures of capacity output, and capacity utilization or excess capacity. The specific foundations developed for the definition and measurement of this range of indicators and parameters, however, facilitate their interpretation, and use for policy guidance.

The empirical analysis suggests no excess harvesting capacity – or higher potential than actual production – for the vessels in our panel data set, although the potential output numbers are different from the same models using different dataset. The first dataset is catch record from association catching shrimp from fishing grounds in Aru and Arafura Sea. The data is time series for ten years. The second dataset comes from association catching tiger shrimp in Aru and Arafura Sea. However, the results from the two datasets reveal that the shrimp fishery in Aru and Arafura Sea are both at sustainable level. In other words, the shrimp fishery is at sustainable stock level and environmentally healthy at this time.

The finding from the model estimating Total Allowable Effort using MSY and MEY models were supported by the technical efficiency results both using Simple Approach and Stochastic Production Frontier. One possible relation is that from the obtained MSY effort, we can then calculate how many boats allowed using the average technical efficiency for each boat and average productivity.

The finding indicates that there exists acceptable level of effort in shrimp fishery in Aru and Arafura Sea prior to the trawl ban enacted. Therefore

a. Maintain the level of licenses/permit deployed in Aru and Arafura Sea.
b. Besides maintain the licenses, the government needs to control and monitor the evaluation of performance of Aru and Arafura Sea Fishery.
c. Given the sustainable level of efforts, hence there is a need to protect the shrimp resource.

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