Thesis for the Degree of Master of Economics

ALTERNATIVE MEASURES FOR EFFECTIVE MANAGEMENT OF SHRIMP TRAWLING IN ARAFURA SEA, INDONESIA

by

Nurul Af-idati

Department of Marine Business and Economics

The Graduate School

Pukyong National University

August 2008

ALTERNATIVE MEASURES FOR EFFECTIVE MANAGEMENT OF SHRIMP TRAWLING IN ARAFURA SEA, INDONESIA

인도네시아 아라푸라 해역 새우트롤어업의 효과적인 어업관리 수단에 관한 연구

Advisor: Prof. Lee Sang Go

By

Nurul Af-idati

A thesis submitted in partial fulfillment of the requirements
for the degree of

Master of Economic

In the Department of Marine Business and Economics,
The Graduate School,

Pukyong National University

August 2008

ALTERNATIVE MEASURES FOR EFFECTIVE MANAGEMENT OF SHRIMP TRAWLING IN ARAFURA SEA, INDONESIA

A Dissertation

by

Nurul Af-idati

Approved by:

____

(Chairman) Jong-Hwa Choi

______________________________ ______________________________

(Member) Hee-Dong Pyo (Member) Sang-Go Lee

August 2008

누룰 아프이다티의 경영석사

학위논문을 인준함

2008 년 **08** 월

주 심 최 종 화 **(**인**)**

위 원 표 희 동 **(**인**)**

위 원 이 상 고 **(**인**)**

TABLE OF CONTENTS

인도네시아 아라푸라 해역 새우트롤어업의 효과적인 어업관리 수단에 관한 연구

Nurul Afidati

부경대학교 대학원 해양산업경영학과

요 약

본 논문은 인도네시아 아라푸라해에서 행해지는 새우트롤 어업관리의 현 상황을 분석하고, 문제점에 대한 해결책을 제시한다. 최근 어업관리 수단은 최적화된 방식으로 어업자원을 이용하고 유지하기 위해 적용되었다. 동 어업에 적용되고 있는 어업관리의 유형은 허가제 중심의 노력량 관리수단과 기술적 자원관리 수단을 주로 하며, 이와 같은 어업관리 운용주체는 공동체적 어업관리 운영체로 확립되어 있다. 그러나 새우트롤어업의 어업관리는 효과적으로 적용되지 못하여 과잉 어업노력량에 의한 남획이 빈번히 발생하였다.

본 논문의 문제제기는 아라푸라해의 새우트올어업이 지니는 어업관리의 비효율성과 이로 인한 남획 문제에 대한 효과적인 해결책의 시급성에 둔다. 이와 같은 현실적 문제에 대한 접근은

새우트롤어업의 혼획감소장치의 사용이나 어업노력량의 감소방안을 중심으로 효과적인 어업관리의 대체적인 수단개발을 위한 생물경제적 분석방법을 사용하였다.

분석방법은 동 어업에 대한 최대지속적 어획량(C - MSY)과 최대지속적 어획노력량(E - MSY)을 설정하기 위해 잉여생산모델을 사용하였다. 그 모델에는 (1) Schaefer model (2) Schnute model, (3) Walters and Hilborn(HW model), (4) Fox model, 그리고 (5) Clark, Yoshimoto and Pooley(CYP model)이 주로 사용되었다.

Ordinary Least Square(OLS) 회귀분석 결과 WH model 이 가장 적절하며 아라푸라해에서 그것이 지속 가능한 포획수준(23,180ton/year) 과 어획강도(579 트롤어선)를 나타내었다.

생물경제모델의 결과를 토대로 새우트롤어업이 직면하고 있는 어업관리의 실태를 각종 분석 및 정책자료 분석을 종합 정리하여 새우트롤어업의 효과적인 어업관리 수단을 다음과 같이 제안하였다.

아라푸라해의 새우트올어업이 직면하고 있는 어업관리 문제의 해결책으로 제안된 대체적 어업관리 수단은 다음과 같으며, 동시에 본 논문의 결론이 된다. (1) 일부 트롤어선을 다른 트롤어업이 가능한 곳으로 옮겨서 최대 지속가능한 어획량으로 어획량을 제한하고, (2) 면허발급을 제한하고 휴어지역과 휴어기간을 설정하며, (3) 혼획을 최대한 줄이면서 새우어획량은 유지하는 환경 친화적 트롤그물 사용 (4) 위도와 경도를 사용하여 분명한 어획지역의 경계를 설정하고, (5) 공동관리체계와 이행감시제도(MCS) 체계를 통한 어업관리 감시감독을 강화한다.

Alternative Measures for Effective Management of Shrimp Trawling in Arafura Sea, Indonesia

Nurul Af-idati

Departement of Marine Business and Economic, Graduate School,
Pukyong national University

Abstract

This study identified the current status of fisheries management of shrimp trawling in Arafura Sea. Recent management measures are taken to utilize and maintain the fisheries resources in an optimal manner. Those include 2 main approaches which are input control focused on license system and application of technical measures. Main structure of this management is establishing community-based fisheries management.

However, fisheries management of shrimp trawling has not been much effective so that excessive fishing effort is occurred and it results on overfishing. This study identifies ineffectiveness of the fisheries management of shrimp trawling in Arafura Sea and emphasize on the effective solution of the overfishing.

Approaches to the solution are using bio-economic analysis to develop alternative measures of effective fisheries management focus on using BRD of shrimp trawling or reducing fishing effort.

To estimate Maximum Sustainable Yield (MSY) and fishing effort in MSY level (E_{MSY}), this study uses surplus production models which is namely (1) Schaefer (1957) model, (2) Schnute (1977) model and (3) Walters and Hilborn (1976) model and two exponential growth models, (4) Fox (1970) model, and (5) Clark, Yoshimoto and Pooley (1992) model.

Based on the bioeconomic result, through collecting the problems of ineffective fisheries management of shrimp trawling and many kind of policy analysis, this study suggests some alternative measures for effective fisheries management of shrimp trawling. Those alternative measures are (1) limiting fishing effort to the MSY level by relocating some trawl vessel to new trawlable area, (2) controlling license issuance and establishing closure area and closure season, (3) using environmentally friendly trawl net which optimally reduce by-catch species and maintain shrimp catch (4) establishing clear fishing zone boundary by using longitude and latitude as a definite lines and (5) strengthening regulation enforcement through co-management system and monitoring, controlling and surveillance (MCS) system.

Keywords: Fisheries management, bio-economic analysis, shrimp trawling, Arafura Sea, Indonesia

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

1. Background and Objectives

Arafura Sea is one of 9 Indonesian Fisheries Management Zones, located in the east part Indonesian water a part of Papua province, connected with Banda Sea as a part of Moluccas province, and Timor Sea, which some part of the area is included in Economic Exclusive Zone (EEZ) of Indonesia. It is also a part of Sahul continental shelf which covers almost 150.000 km2 in breadth. The average depth is around 50 m and the maximum depth is less than 100 m (Monintja, 2006). The fisheries in the Arafura Sea are small-scale, multispecies, multi-gears fisheries. In 2006, there were about 71,703 units fishing boat using 25 different type of fishing gears; 86% of the boats are non-powered boats.

The Arafura Sea is one of the most important fishing ground in Indonesia since it has the highest potency of Penaeid shrimp particularly banana shrimp and tiger shrimp (BRKP and P3O LIPI, 2001). As trawl has been considered as the most effective shrimp catch device, since 1969, commercial trawling for shrimp had been run throughout Indonesian waters and it rapidly commercially grew in 1970s. As a result, some negative impacts arose in shrimp fishery such as degradation of ecosystems and conflict between small scale non-trawl fishers against handful of trawl operators which result on injured party.

To deal with such continued threats, the Government of Indonesia set a mission to maintain the loading capacity and increase the environment quality of the marine and fisheries resources, including the sustainable management of shrimp trawling in Arafura Sea to support people's prosperity. The main product of government regulation is trawl banning in all Indonesian waters exclude the Arafura Sea through Presidential Decree no.39 year 1980.

Nevertheless, during the year 2000 – 2005, the shrimp trawling in Arafura Sea has been showing the decreasing catch. Moreover, the enforcement of trawl ban had been failed to recognize Government's role in addressing such fishery resources depletion and social conflict between fishermen in Arafura Sea.

Recognizing the problems and the needs above, this study endeavors to identify the current of shrimp trawling management in Arafura Sea with the drawbacks inside and how to answer them and improve the management by applying some alternative approaches based on available information on the current status of shrimp resources, bioeconomic analysis on shrimp trawling activity and the recent management and regulation from Indonesian government. The study will be useful as an input for the suitable management planning of shrimp trawling fishery in Arafura Sea.

2. Method of study

- Collecting and analyzing related articles, reports and documents related to the management of capture fisheries in Arafura Sea and the ones relevant to the management of trawling activity in Indonesian waters. They are mostly produced by the Directorate

- General of Capture Fisheries (hereinafter DG Capture Fisheries) and Agency for Marine and Fisheries Research which are under the Ministry of Marine Affairs and Fisheries (MOMAF); Ministry of Agriculture; and Research Center for Oceanography under the Indonesian Institute of Sciences.

- Collecting legislative instruments such as Presidential Decree on banning of trawl operation through gradual steps (Presidential Decree no 39/1980) and on the boundary of trawl allowable area in Arafura Sea (Presidential Decree No. 85 of 1982); Ministry of Agriculture Decree on definitions of banned trawl (Ministry of Agriculture Decree No. 503/Kpts/Um/7/1980), on reduction of trawl amount (Ministry of Agriculture Decree No. 542/Kpts/Um/6 of 1981) and on establishment of fishing zones (Ministry of Agriculture Decree No. 392 year 1999); Presidential Instruction on complete implementation of trawl banning(Presidential Instruction No. 11 of 1982)

- Reviewing the collected information on the status of shrimp resource and the fishing effort in the form of catch per unit effort (CPUE) and applying some bioeconomic analysis to estimate sustainable effort and amount of shrimp catch. Utilizing 5 bioeconomic models to analyze the shrimp trawling fishery in Arafura Sea namely, (1) Schaefer (1957) model, (2) Schnute (1977) model, (3) Walters and Hilborn (1976) model, (4) Fox (1970) model, and (5) Clark, Yoshimoto and Pooley (1992) model.

3. Scope of the Study

To achieve the objectives, the study is organized in the following way

- The current status of fisheries resources in Arafura Sea includes shrimp and by catch resources is reviewed (Chapter II)
- Shrimp trawling activities in Arafura Sea and the impacts of the trawling on human and ecology are identified (Chapter III)
- The current management of shrimp trawling in Arafura Sea is described (Chapter IV)
- The drawbacks of current management are analyzed and bio-economic analysis of shrimp trawling activity are applied (Chapter V)
- Conclusion is drawn (Chapter VI)

II. FISHERIES RESOURCES STATUS

1. Marine Resource Status

There are about 230 species found in Arafura Sea involved into 10 categories namely sharks, rays, pelagic fish, demersal fish, cephalopods (squid family), shrimp, crab, shell and invertebrates (Barani, 2006). These marine organisms are in high density and the distribution spreads along Arafura waters and surrounding. For this reason, there are many fishing vessels come and collect the resources for making benefit.

The marine capture production can be classified into 4 categories, pelagic, demersal, crustacean and mollusks. Pelagic fish is fish that spend most of their life swimming in the water column such as tuna, skipjack, and shark etc., while demersal fish is living at or near the bottom, although sometime in mid-water such a scod, haddock, hake, pollock, and all forms of flatfish. Crustacean is included shrimp, lobster and crabs and mollusk is included squid, shell, snail, etc. Among those, demersal fish and crustacean are dominant, with shrimp as preferred valuable catch while small pelagic fish and mollusks are low commercially valuable so they are less utilized and most are discard catch (NFSC, 2003).

The level and quality of published information on each resource categories of Arafura Sea is generally poor. However, more recent estimation based on catch and effort data in several certain areas of Arafura Sea has been more reliable. A report on capture fisheries production in Moluccas province and Papua province is often to be representation of catch amount from Arafura Sea since most trawl vessels land their catch in fishing base (fishing port) in both provinces above (Monintja, 2006)

Production of marine captures fisheries in Arafura Sea has been contributing annually 30% of Indonesian fisheries export product. According to the chart below, production of capture fisheries during year 2001 – 2006 had been increased 5.87% per year with some declining level in year 2002 and 2004. The amount of production during 2001 – 2006 is shown in Figure 1 below

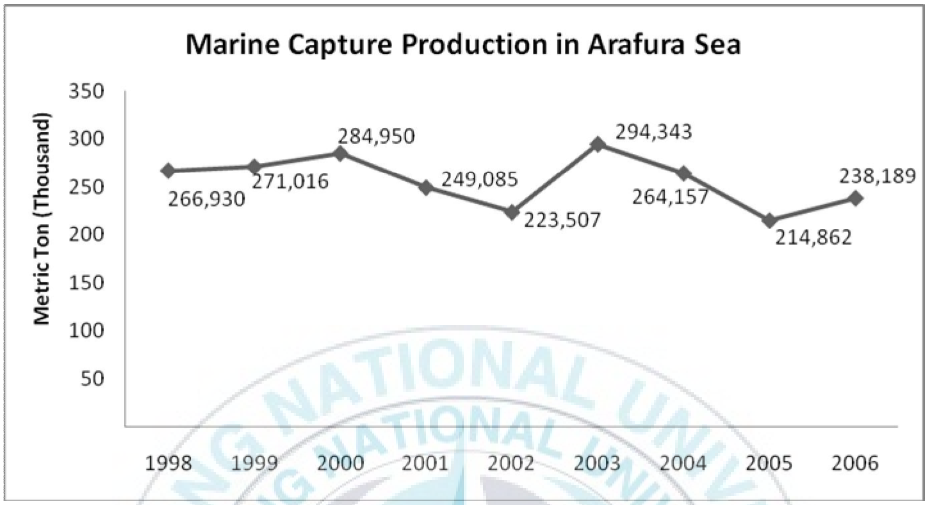


Figure 1. Production of marine capture in Arafura Sea (MOMAF,2007)

According to MOMAF, during 1990 – 1997, marine capture production had been annually increased from 66.324 tonnes to 199.314 tonnes, average of 33% per year. Production of demersal fish increased every year, from 14,525 tonnes to 86.326 tonnes, which the increasing average was 82% per year. The commercial valuable demersal fish were snapper, pompret, cat fish and thread fin fish. In pelagic fisheries, the production was 24.490 tonnes in 1990 and increased 24% annually to 59.934 tonnes in 1997. The commercial valuable pelagic fish were tuna, skipjack, and shark. Apart from the resources mentioned above, bivalve, squid, turtle, jelly fish and sea cucumber were landed and its production was annually increased from 904 tonnes in 1990 to 5,639 in 1997 (DG of Capture Fisheries, 2001)

Furthermore, Indonesian Institute of Sciences in 2004 estimated Maximum Sustainable Yield (MSY) level of fisheries production in Arafura Sea was 771.550 ton annually, of which about 68% is pelagic (526,010 ton), 26% is demersal (202,340 ton), and 5.6% is shrimp and lobster (43,200 ton) as presented in Table 1.

Table 1. MSY of marine resources according fish groups

No.	Fish groups	MSY (10^3 MT/year)	Production (10^3 MT/year)	Use (%)
1.	Large pelagic	50.86	34.55	67.93
2.	Small pelagic	468.66	12.31	2.63
3.	Demersal	202.34	156.80	77.49
4.	Coral fish (consumption)	3.10	22.58	>100
5.	Penaeid shrimp	43.10	36.67	85.08
6.	Lobster	0.10	0.16	>100
7.	Squid	3.39	0.30	8.85
Total amount		771.55	263.37	34.14

Source: Indonesian Institute of Science (2005)

Total annual fishing effort in Arafura Sea tends to increase during the last decade, as well as in all Indonesian waters, which is represented by raising amount of fisheries enterprise operating fishing vessels in this area, particularly for fish trawl and shrimp trawl which have been dominating the fisheries industry. The sustainable potency has attracted many fishing vessels to exploit the resource, both domestic and foreign enterprise.

Recent assessment by agency for Marine and Fisheries Research in 2004 indicates that exploitation level on demersal fish resource has been reaching level 98,43%. In addition, National Comission on Fisheries Resources Assessment affirms the fisheries status of demersal fish is fully exploited and of penaeid shrimp is over exploited. Within this state, increasing fishing effort will only decrease economic efficiency as well as threat fisheries resources sustainability. This tendency led Indonesian government to focus more on sustainability of fisheries industries and of demersal resource that had been exploited for long period.

2. Shrimp Resources

People have higher demand on shrimp than other marine organisms because of its high value, abundance and ability to endure considerable fishing pressure (EJF, 2003). Among other sea products, shrimp also have a favor for many fishery industries, so that they send more trawl vessels to Arafura waters. The crustacean production from Arafura Sea was increased 10% per year from 11.018 tonnes in 1990 to 17.864 tonnes in 1997.

The shrimp trawling fisheries were started by joint-venture enterprises of Indonesian fishing companies and Japanese companies in the late 1960s and early 1970s. They developed quickly and by now the joint venture companies have become national companies. The fisheries contributed about 20,000 to 25,000 ton per year with decreasing trend every year (as shown in Figure 2).

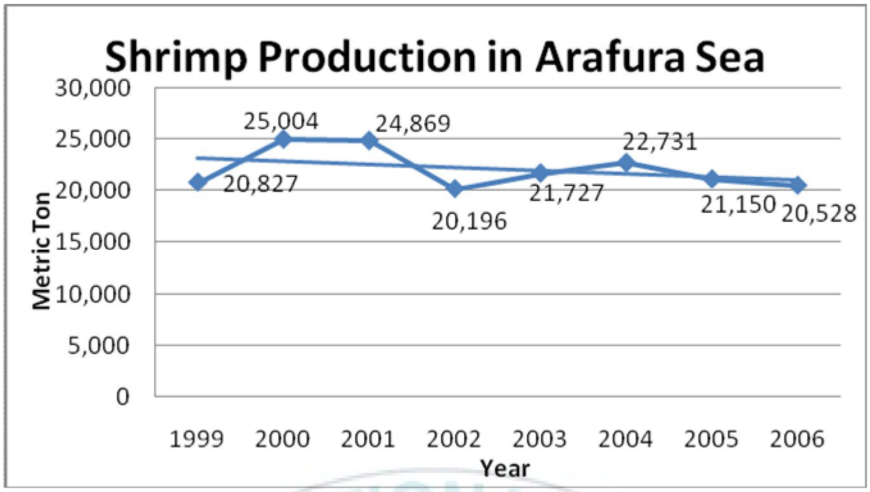


Figure 2. Shrimp production in Arafura Sea from 1999 to 2006

The chart above is amount of shrimp production in Maluku and Papua province according to Annual Statistic Book of Indonesian Capture Fisheries (2007) which is representing the shrimp production in Arafura Sea. During 1999 to 2006, the highest shrimp production was in year 2000, that is 25,004 MT and the least production was in year 2002, that is 20,196 MT with the average 22,358 MT.

The shrimp caught by shrimp trawl fishing gear in Arafura Sea consists of various species, which most is a part of genus *Penaeus*, *Metapenaeus*, *Parapenaeosis* dan *Metapenaeosis*. Those are classified into 5 categories, namely Endeavour shrimp, Spinny Lobster, Tiger shrimp, White shrimp and others. The composition is dominated by Tiger shrimp (*Penaeus semisulcatus*) and White shrimp (*Penaeus merguiensis*) (Martosubroto, 2005; Evans and Wahju, 1996). Other crustacean compositions were swimming crab, mud crab and lobster in relatively small quantities. The growth of shrimp production for each species is shown in Figure 3.

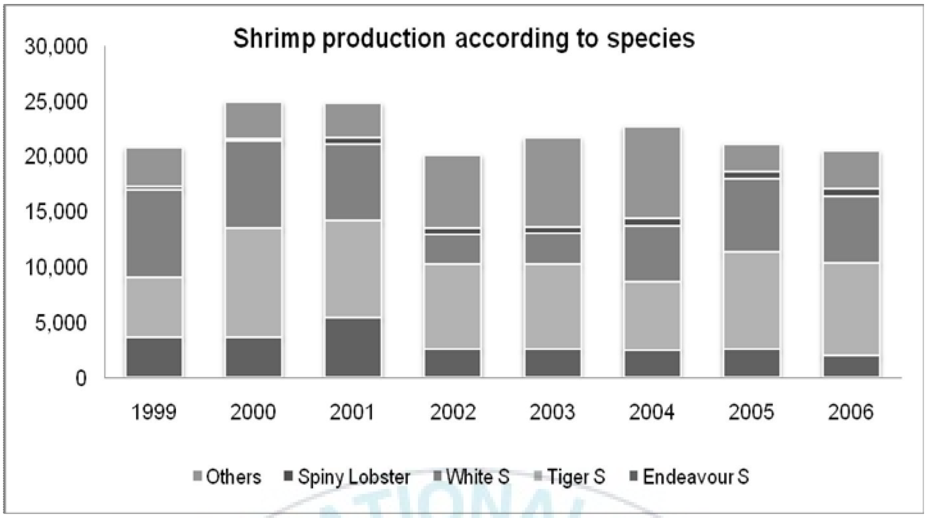


Figure 3. Shrimp production for each shrimp species in Arafura Sea

During the last decade, the shrimp production for each species is fluctuating with declining trend. As demonstrated in the Figure 2.3, tiger shrimp and white shrimp are likely to decrease every year but there is a significant growth in 2004 and 2005 successively. Tiger shrimp as the main shrimp product had reached the highest production volume, 9,837 MT, in 2000 and then decrease during the following years until 2004. A year after, there was an increasing stock of tiger shrimp, therefore the production can be elevated to the level of 8,000 MT as it was occurred in 2001. The production of Spinny lobster is the least among 6 categories and it tends to increase until 2006.

3. By-catch: Resource Potency and Problem

Shrimp trawling is a relatively unselective fishing method because large volumes of non-target species are typically retained in the codend in which consists of hundreds species. In the tropical countries, it can catch over 400 marine species in their nets. The organism exclude target species is called as by-catch species, this term also include died organisms as consequence of interaction with trawl net although they are not hauled up to the vessel, some of which are landed and some of them are discarded.

In large fisheries industry this by-catch is usually discarded overboard, but in small scale fisheries it has commercial value and is used either for human or animal consumption. In general, the by-catch has low value compared to the shrimp as main target, and the large majority of it was discarded. Almost 10% of world's capture is by-catch. In shrimp fisheries, by catch could be 5 – 10 times of shrimp catch weight. It is estimated that total weight of discarded by-catch in world's commercial fisheries is reaching 27 million metric ton, with annual average is 17,9 – 39,5 million metric ton (Alverson et al, 1994)

In Indonesia, several authors have presented the ratio estimations in specific conditions: In 1981, when there were many trawlers still in operation (124 units), the ratio in Dolak, Kaimana and Aru waters (Detail fishing area of Arafura Sea is provided in Chapter 3) was approximately 19:1 and 95% of the by-catch was utilised (Naamin Sumiono, 1983). In 1991, when the number of trawlers operated in the Arafura Sea was around 87 units, the ratio was approximately 8:1 to

13:1 (Widodo, 1991, Badrudin and Karyana, 1993). In the sub areas of Sele and Bintuni, in October to November 1992 the ratio of by-catch to shrimp was found being approximately 9:1 (Iskandar et al, 1993). Between 1991 and 1998 data from a research vessel operating in the Arafura waters indicate that ratio fish: shrimp varies from 3:1 to 26:1, with an average of 10:1. According to DG Capture Fisheries (2001), in Arafura Sea, shrimp trawling fishery produces by-catch-to-shrimp ratio of 10:1. This essentially means that 10 kg of marine organisms caught in order to obtain 1 kg of shrimp.

The large differences observed for this ratio probably greatly reflect the conditions on different fishing grounds exploited; however, the average still accords with the estimate given for tropical areas, in general, by Allsopp in 1982. Nevertheless, the quantity of landed fish does not only depend on the number of trawlers and fishing ground, but, also varies according to season. During the peak shrimp season, the quantity of by-catch retained tends to be minimal due to limits in fish hold capacity. The fisheries resource potency included by catch species in Arafura Sea is reaching 332,186 ton/year through shrimp trawling equipped with By-catch Excluder Device. Most of them are discarded because it is not economical to keep it on vessel (Eayrs, 2007).

A survey taken by Indonesian MOMAF in 2005 (Monintja, 2006), there are 43 fish species consist of pelagic fish, demersal fish, mollusk and crustacean are parts of shrimp trawl by-catch in Arafura Sea. Some species have important economic value such as jewfishes (*Argyrosomus amoyensis*), croakers (*Johnius dussumieri*), Grunt sweetlips (*Pomadasys macullatus*), nomei (*Harpadon micropectoralis*), lizard fishes (*Saurida tumbil*), *Secutor ruconis*, and Sarden (*Sardinella fimbriata*). These by catch species were captured together with other targeted shrimp as a main target. The ratios of by-catch and shrimp weight are 1:28 in Dolak waters, 1:13 in Kaimana waters and 1:11-41 in Aru Islands waters.

Purbayanto et al (2004) estimated the potential by catch obtained from shrimp trawling in Arafura is around 332,186 ton/year by 336 units of shrimp trawls. This amount is consist of samplings from Dolak waters (195.09 – 216.30 ton/trip) which is well known for its abundance, followed by Aru Islands waters (77.07 ton / trip), and Kaimana waters (9.24 – 48.30 ton/trip) as presented in Table below.

Table 2. The estimation of by-catch resource in Arafura Sea

Fishing Ground	Volume By-catch		
	(ton/haul)	(ton/day)	(ton/trip)
Dolak waters	1,03 0.93	7,21 6.50	216,30 195.09
Aru waters	0,37	2,57	77,07
Kaimana waters	0,04 0.23	0,31 1.61	9,24 48.30
Average	**0,52**	**3,64**	**109,20**
Amount of shrimp trawl			**336**
Estimation of by catch potency (ton/year)			**332,186**

Source: Purbayanto et al., 2004

By the calculation above, the amount of by catch potency is not including the uncounted lost of by catch as a consequence of illegal fishing. Comparing to the capture production, the potency of by catch above is even higher 130% to the average marine capture production in Arafura Sea during the last 8 years (shown in Figure 1).

Among the by catch species, some large fish are selected by the crew for their own consumption onboard or were frozen and sold by them when the trawler returned to fishing port in Papua or Mollucas. Most of them are dead when discarded, and a high proportion of it was taken by seabirds and dolphins. These non-target species are discarded by shrimp fishermen, either they are inedible or are simply not worth retaining when shrimp is worth up to 30 times more per kilogram (EJF, 2003). Most species are dead when they are discarded. Seabirds and dolphins followed the trawler when the catch was on board. They took a high proportion of the discards. (Evans and Wahju, 1996)

Discarding by catch is categorized into a wasting action on natural resources which is inflicting financial to Indonesia government as well as damaging the environment of Arafura Sea. By calculating economically, assume that the price of a kilogram by catch is Rp 1,000 (0.11 US$) therefore if at least 70% of discarded by-catch is utilized, it able to generate more than Rp 232 million (25,578 US$) in a year. This value will be higher if the by catch is processed become product for human consumption or other needs.

According to Monintja et al (2006) in a report on shrimp trawls landing in Merauke harbor, Sorong harbor, and Aru harbor, the organism caught while trawling in Arafura waters are dominated by demersal fish, jelly fish, crab, squid, octopus and fish juvenils. Other groups of by catch species such as sea snake, sea turtles, crab and other organisms were rarely caught. A large number of people sell by catch from the shrimp trawling activities for human consumption or for the production of animal feed. The non targeted species found as by-catch from trawl fishing in the Arafura Sea is very important for the shrimp fishing industry. Unutilized by-catch, most probably, will greatly increase with the ever growing number of fish trawlers in the Arafura Sea.

The catch data during 1990 – 1998 recorded by Association of Shrimp Trawl Companies showed that the fishing vessels were generally 50 GT trawls or lesser, stern trawls, while the larger one are outrigger trawl. Haul duration is between 2 and 3 hours with towing speeds varying from 2 to 3 knots. In comparison to shrimp quantity, a relatively large quantity of other organisms was caught by shrimp trawl. The table below provides the list of species caught by shrimp trawl in Arafura Sea.

III. SHRIMP TRAWLING AND THE IMPACTS

1. Fishing Area

Indonesian marine resources spread over 5.8 million km^2 sea water, comprising of 3.1 million km^2 of Inclusive Territorial Maritime Zone and 2.7 million km^2 of Indonesia's Exclusive Economic Zone (EEZ). This area divided into 9 Fisheries Management Areas (FMA, one of which is FMA of Arafura Sea. One of them is Fisheries Management Area of Arafura Sea is 150.000 km^2 in breadth and located between Maluku (*Moluccas*) Province (South East Maluku

Regency) and Papua Province (Sorong, Fakfak, Manokwari and Merauke Regencies) (Dwiponggo, 1991).

Arafura Sea is located in the east part Indonesian water a part of Papua province and connected with Banda Sea as a part of Moluccas province, and Timor Sea. Some part of the area is included in Economic Exclusive Zone (EEZ) and some is a part of Sahul continental shelf. Sea conditions are relatively calm and the seabed is sandy and muddy. Along southern coastal Papua, there are dense mangrove forests and it has the water color is almost grey and muddy brown in outlet areas due to the strong river currents which are connected by small and large river outlets (Monintja, 2006).

Bordered by Banda Sea, Arafura Sea is affected by upwelling phenomenon which is occurred in that area. It brings excess nutrient content for supporting phytoplankton population which is important in marine food chain. Besides, the flowing out from river brings discharge water which also contain high organic nutrient from inland (Badrudin et al, 2004). According to Badrudin *et. al.* (2004) the ecological state of Arafura Sea is defined as Large Marine Ecosystem (LME), a region of ocean and coastal space that encompass river basins and estuaries and extend out to the seaward boundary of continental shelves and the seaward margins of coastal current. Supported by condition stated above, Arafura Sea is considered to be one of the most productive water for marine organism life and shrimp as well.

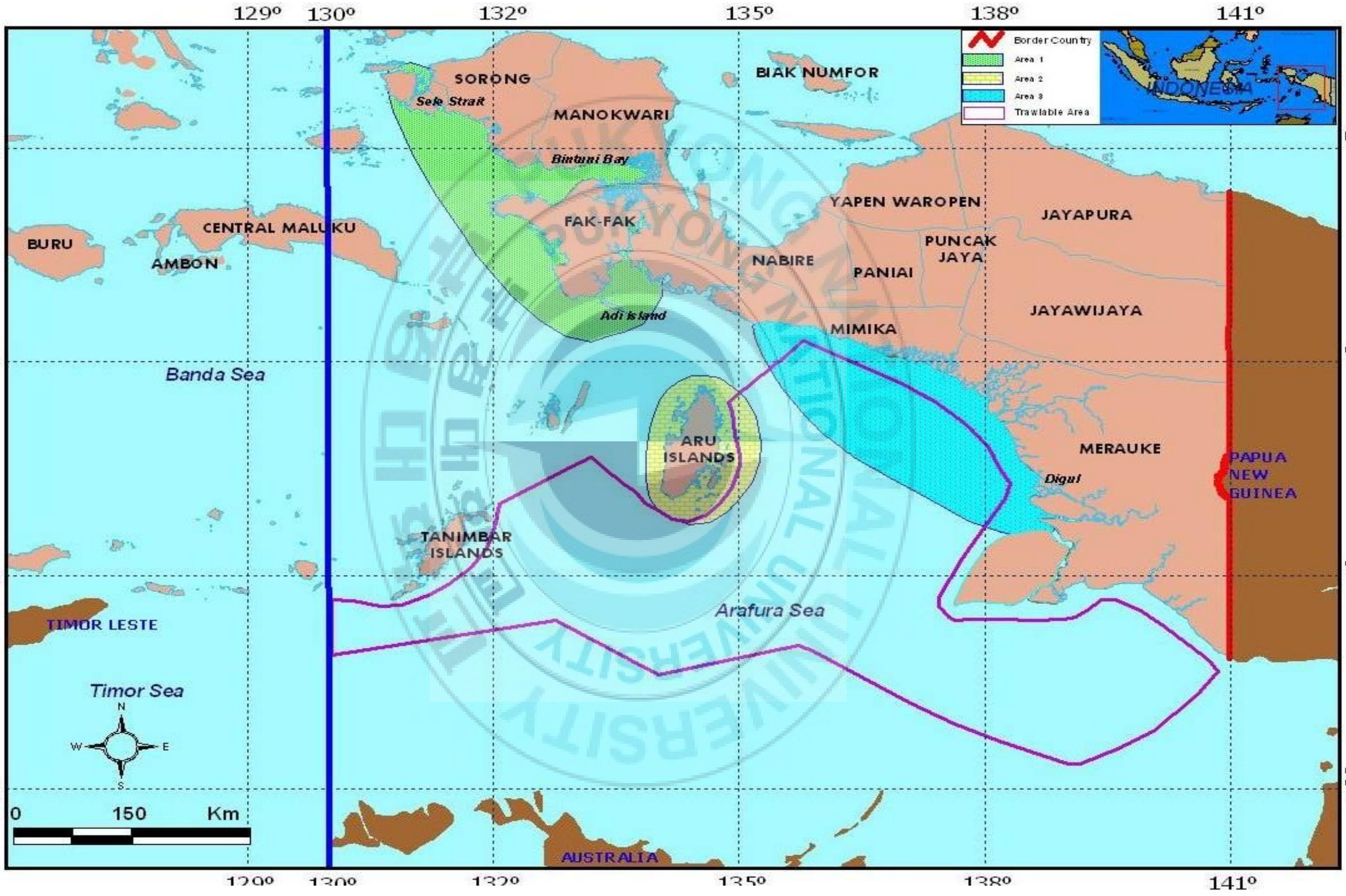


Figure 4. Trawling Area in Arafura Sea within 10 m isobaths line and EEZ

Shrimp trawling is an important fishery since the shrimp is a major export commodity in Indonesia. Nevertheless, the only remaining “trawlable area” in the country is Arafura Sea. As it is regulated by Presidential Decree No. 85 of 1982, trawl is allowed to be operated in the eastern of 130° longitude beyond 10 meter of isobath[1] line as shown in Figure 3.1. Geographically, the shrimp fishing ground is concentrated in 3 areas namely bird head, Dolak waters and Aru waters.

1) Bird head area, a part of Papua Island resembling a shape of bird head, includes Sele strait, Bintuni bay, Fak fak waters, Adi Island surroundings dan Kaimana waters. This area is spread out about 15,000 km^2 in breadth and shrimp trawling is operated in water whose depth is from 5 to 35 m. Seabed consist of sandy mud with water color is close to grey. Along Sele coast, Bintuni bay and Kaimana water there are large, dense mangrove forest and many of large and small river mouths.

2) Dolak water includes Kokonao, Aika, Mimika, Uta rivermouth, Aiduna and Digul rivermouth. The area is about 45,000 km^2. The shrimp trawl has been operated in water whose depth is between 5 – 50 m The seabed consists of mixed mud and sand. As it is connected with many more river mouths rather than other areas, the strong outflow from inland into Dolak water is affecting water color, which is tend to be brownish.

[1] Isobath: Contour line linking region of the same depth; a contour line connecting points of equal water depths on a chart (http://fishbase.org)

3) Aru water includes Aru Islands waters area in east, south and west part which spread about 13.000 km^2. Shrimp trawling is operated in water whose depth is ranging of 5 – 50 m. The seabed consists of mixed mud and sand or sand only. The dense mangrove forest is found along the cost of Aru water (DG Fisheries Capture, 2001)

However, the distribution of shrimp trawl in Arafura is affected by size vessels, the smaller vessels tend to operate in shallow water, while the larger vessels are able to reach considerable areas to fish further from seashore, around EEZI areas.

2. Fishing Effort

Trawling is the most common method to catch shrimp commercially. It is a 'catch-all' technique that involves dragging large, fine-mesh nets along the seabed. Once groups of shrimp cease to supply a sufficient yield, trawlers will move on to the next aggregation. In Arafura Sea, trawl has been used since late 1960s, when the shrimp fishery started commercially. Fishing enterprise operating trawl vessels in Arafura Sea can be classified into 4 categories according to the stakeholders, namely (1) Joint venture : Indonesian fisheries enterprise cooperates with foreign party such as, Government of Indonesia and Government of some neighbour countries (Philippine and Thailand). (2) National company: Indonesian private fisheries companies using domestic capital origin (3) Cooperatives: Cooperatives that the members are fishery-related community (4) State company: The company belongs to the Government of Indonesia.

According to the scale of enterprise, there are 2 fishery groups namely, artisanal and industrial fisheries. Artisanal fishery is low level commercial fishery. The fishers are those who by virtue of their limited fishing range and a host of related socioeconomic characteristics, are confined to narrow strip of land and sea around their community, are faced with a limited set of options, if any and are intrinsically dependent on the local resources (Charles, 2001). Industrial fisheries differentiated by full capitalized activity of capture fisheries or having large investment; operating fishing vessel more than 50 GT in size; applying modern fishing gear (such as shrimp trawling, large purse seine and, gill net, pole-and-line vessel- and tuna longline) which is equipped with advanced mechanical or electrical device; involving skilled fishermen who has fisheries capture knowledge through formal secondary or higher education; and the fishing activity is run in Fishing Zone IV (from 12 – 200 miles from coastline)

In authority of license issuance of both fisheries, the central government deals with large vessel more than 30 GT, whereas the fishing licences of other smaller vessels are under local government or official province of Papua.

Nevertheless, fisheries activities in Arafura Sea are mostly conducted by artisanal fishermen, the non-powered canoes are dominating, followed by boats with outboard engines and boats with inboard engines. These boats are various in the size of fleet structure, ranging from 19 to 849 GT (DG Fisheries Capture, 2001). The small vessels which are less than 100 GT are mostly wooden canoe without engine or with inboard engines. These boats are mostly operating in shallow water since the power engine for further movement to offshore are limited. Most operated fleet in Arafura Sea are boats with outboard engines, large industrial fleets and non-powered canoes, while the boats with engines are dominated by boats in 5 GT size (shown in Table 4)

Table 3. Table of fishing vessel operating in Maluku and Papua waters.

Year	Unmotorized	Outboard engine	Inboard engine	Total
2000	55.397	5.847	3.211	64.455
2001	49.016	4.542	1.497	55.055
2002	46.350	4.742	2.769	53.861
2003	63.487	5.708	2.755	71.950
2004	63.921	5.883	1.851	71.655
2005	59.542	5.695	1.581	66.818
2006	65.413	5.003	1.387	71.703

(Source: DG of Fisheries Capture, 2007)

Table 3 above demonstrates the amount of non-powered fishing canoes operating in Papua and Maluku which shows more than 80% of annual total amount fishing vessels exploit the area. This shows that the area is relatively accessible for traditional fishing mostly for supporting the need of daily consumptions. The availability to exploit Arafura Sea has led the usage of unmotorized boats to increase every year since 2001, as it is shown in Table 3. The least amount of vessel is belongs to boats with inboard engines, which intensively exploits fisheries resource in high production and effectiveness.

Table 4. Fishing boats number according to the Gross Ton

Size	2001	2002	2003	2004	2005	2006
< 5 GT	348	386	514	563	641	609
5-10 GT	436	434	568	495	463	381
10-20 GT	401	347	397	496	336	284
20-30 GT	267	264	266	261	121	98
30-50 GT	7	285	290	5	5	4
50-100 GT	19	455	170	24	11	9
100-200 GT	7	404	295	6	4	2
>200 GT	12	194	255	1	0	0
Total	1.497	2.769	2.755	1.851	1.581	1.387

(Source: DG of Fisheries Capture, 2007)

The type of shrimp trawl commonly operating in Arafura Sea is otter trawl, which consists of trawl doors or otter board. The function of otter boards is to keep the net open laterally as the net is forced through the water. The trawl net itself is like a large funnel-shaped bag in which all marine organisms are collected and transported into the 'codend' at the back side of net. The net could dig in as much as 10 - 15 cm in the seabed surface. It works by dragging the trawl along the bottom of the seabed at a rate of about 2 to 3.5 knots (around 4.5-6.5 km/hr), scraping up shrimp and everything else in the net path. As such it is known as bottom trawling (Stephan, C. *et al*. 2000). Sizes of the 'swept' width of the trawling gear vary, though they typically reach 25-30 m (EJF, 2003)

There are some types of otter trawls have been used since shrimp trawling started commercially in Arafura Sea, the first is single rig trawl that use only one rig for a vessel and second is multi rig trawl that is using more than 1 rig for a vessel, so that the sweeping area of the seabed is increase and expectedly more shrimp catch per unit effort (Figure 3.2). The longer the rig headrope, the larger the swept area. Thus it expectedly gives more catch also both shrimp and other organisms in the sea bottom.

Figure 5. Single rig shrimp trawl

However, amount of catch is not solely affected by the size of rigs, but also affected by fisheries stock in the area where trawls are operated. Larger size of trawl will not increase catch amount if shrimp stock in sweeping area is low. Therefore, if large advanced trawl vessel operates in the area with low shrimp stock, it will be meaningless. This kind of fishing activity is not efficient, since larger trawl need more operational cost while catch amount of shrimp and other valuable fish is low, in other word, the input (operational cost) spent is lower than the output (benefit) gained.

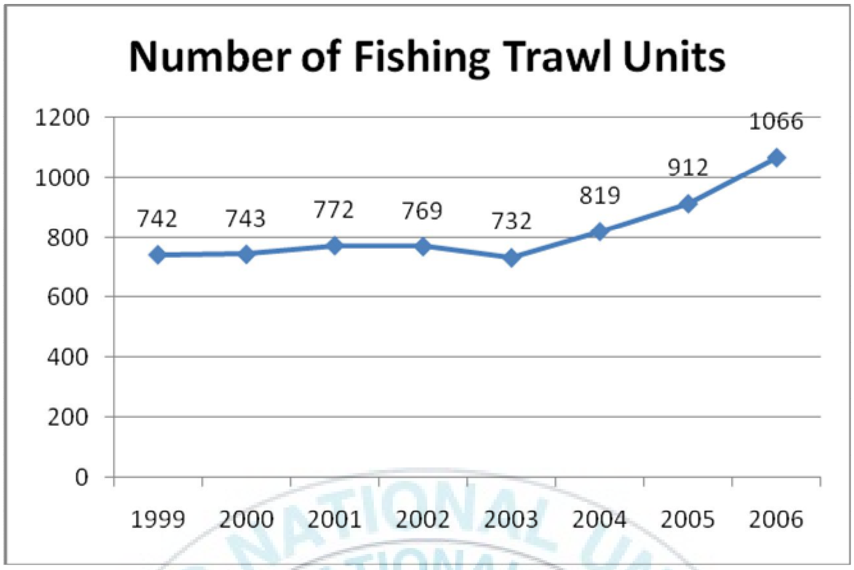


Figure 6. Number of fishing trawl unit in Arafura Sea

Since Government of Indonesia issued trawl restriction through President Decree in 1980, shrimp trawl net (*pukat udang*), a similar to shrimp trawl but the seine net attached with By-catch Excluder Device (BED) that allow non target species release to the sea. The shrimp trawl has been become the replacing gear through President Decree in 1982. The structure of shrimp trawl net is remain unchanged from the used otter shrimp trawl both rig structure and operating ways. The only difference is that shrimp trawl net is attached by a filter to exclude non target species (by catch) (Monintja, 2006). For simplicity, the term "shrimp trawl" will be keep used throughout instead of shrimp trawl net.

The shrimp trawl has been greatly contributing shrimp capture production in Arafura Sea. In fishing effort, the duration of fishing trip for trawl vessels is from 40 to 60 days and the average of fishing days at the sea is approximately 280 days in a year with 7 – 9 hauls in a day.

Those effort results shrimp production fluctuating every year with average annual production is 21,012.7 ton. Those effort results shrimp production fluctuating every year with average annual production is 21,012.7 ton as shown in Table 5 below

Table 5. Shrimp production and trawl amount in Arafura Sea

Year	Shrimp catch (ton)	Trawl amount (unit)
1994	14,634	342
1995	18,581	375
1996	17,750	381
1997	25,418	323
1998	21,625	542
1999	21,026	741
2000	25,023	744
2001	24,832	772
2002	20,193	765
2003	21,045	775
2004	22,731	819
2005	21,150	912
2006	20,528	1066
Average	21,118	658

As shown in Table 5 the shrimp production fluctuating every year with the inclining trend and opposite with the fishing effort using shrimp trawl. The amount of annual fishing effort in Arafura Sea tends to increase during the last decade, as well as in all Indonesian waters, which is represented by raising amount of fisheries enterprise operating fishing vessels in this area. Fish trawl and shrimp trawl have been dominating the fisheries industries. The fisheries potency has been attracting many fishing vessels to exploit the resource, both domestic and foreign enterprise. However, this seemed have not been supported by increasing shrimp stock so that the Catch per Unit Effort (CPUE) has been declining since 1998. The increasing fishing effort will only decline economic efficiency of shrimp trawling beside it will threat shrimp resource.

According to Raam (1995), due to the dropped off in catch per unit effort (CPUE) of ground fish resources in Australian sector of the Arafura Sea during early 1990s, the fishing license for foreign countries especially Taiwan, Thailand and Japan has been terminated in 1990. The sudden drop in CPUE provides evidence that both high growth rate and recruitment rate of demersal resources were incapable to balance the high rate of exploitation. In contrast to the situation in the Australian sector of the Arafura Sea and the Timor Sea, where the license for foreign fishing vessels had been terminated, fishing activities in the Indonesian sector either by national fishing companies or by *ex chartered fishing vessels*, in which all the crews were from original countries (mainly Thailand), were almost limitless. However, the fisheries bilateral agreement, in which involving Indonesian Government, Government of Philippine and Government of Thailand, was ended in year 2005.

3. Impacts

3.1. Discards of By-catch Species

Trawler operators of the Arafura Sea, which are mostly artisanal fishers, are lacking of preservation capacity and processing technology in the vessel. Thus, the excessive by-catch of commercial species exceeds the processing capacity or preservation capacity of the trawl vessels and so the by-catch has to be discarded. This might occur if the crew are unable to sort the catch before the onset of spoilage, if ice supplies are insufficient to preserve it or if the storage space is inadequate.

The discard practice might also be the result of high-grading. This is the practice where fishermen dump previous catch to make room for a more valuable or fresher catch. For example, in some small-scale shrimp fisheries, catches landed in the early part of a fishing trip may be discarded to make space for a similar-sized catch taken at the end of the trip. The research on how much amount of discarded catch has not been well researched but failure to account this mortality is a counter to the notion of sustainable fisheries and may threaten the health of ecosystem.

The actual cases in fishing landing areas, such as Kaimana, Dolak and Aru where the shrimp trawl operators land their catch, a kilogram of fish ranging from 1,400 to 3,000 rupiah (1 US$= 9,192.46 rupiah) which is twenty times lower than the one of shrimp. The price of brown tiger shrimp higher than other prices, is 55,000 to 60,000 rupiah, while other shrimp such as banana shrimp, endeavour shrimp and rainbow shrimp can be sold at 43,000 – 57,000 rupiah. Therefore, even if the by-catch species could be sold, the investment made in sorting, processing, storing and transporting them to market may not be recouped.

A lot of the by catch from shrimp trawling is discarded. The vessels retain and land more and more edible the by-catch species for the domestic markets but the discard rates of small fish (juveniles) are still high. Most of the by catch was dead when it was discarded, and a high proportion of it was taken by birds and dolphin. It is unlikely that much of it re-enters the benthic ecosystem at low tropic levels as result of degradation by microbial action. The trawlers are so numerous that whole population of fish can quickly disappear from the sea as they indiscriminately scoop up all matters of marine life, not just shrimp but purpose to collect biomass as much as possible. This is a serious danger to the sustainability of fish stock (EJF, 2003).

Ironically, by catch problem has been occurred in Arafura Sea, a part of Papua Province, where most of people living there are backward community with limited nutrition intake. The fact that Arafura Sea provides high nutritious food source has been neglected by discard practice of by catch from shrimp trawling fishery during this time. If this resource is properly managed, it could be significantly advantage for increasing national foreign exchange, especially for income and wealth of Papua people's.

3.2. Ecological damage

Even though the research on the impact of trawl to the benthic ecosystem in Arafura Sea is limited, however the general researches have been showing that the trawl gear affects the environment in both direct and indirect ways. Direct effects include scraping and ploughing of the substrate, sediment re-suspension, destruction of the benthic organisms, and dumping of processing waste. Indirect effects include post-fishing mortality and changes to the benthos which is induced by trawl in long term (Sheppard C., 2006; EFJ, 2003).

There are few studies related to trawl that observe environmental changes since it is difficult to isolate the cause. However, permanent faunal changes brought about by trawling have been recorded. Researches has established shown that the degree of environmental damage from bottom trawling activities is related to the weight of the gear on the seabed, the towing speed, the nature of the bottom sediments, and the strength of the tides and currents. The greater the frequency of gear impacts on an area, the greater the likelihood of permanent change (Jones, 1992).

Numerous studies have investigated the ecological impact of trawl parts (tickler chain, otter boards, net) and different types of trawls on the sea floor. A review of this type of literature and further communication with scientists and fishermen estimated the maximum cutting depth for otter trawl doors and beam trawls to range between 0.05 and 0.3 m when used in depths over 30 m (Stephan et al, 2000). The various values such as gear weight, bottom hardness, and towing warp (force on gear) attributes to depth ratio. Trawl doors were found to penetrate the surface more than the rest of the gear. In estuarine waters, a study of lobster trawling gearin Long Island Sound found trawl door penetration values of approximately 0.05-0.15 m (Smith and Stewart, 1985).

Shrimp trawling frequently takes place in shallow coastal waters beyond the 10 m isobath line, where it acts as nursery grounds and spawning grounds for many commercial fish species (Monintja, 2006). The trawl works in pairs to smash coral first, as coral in the seabed could damage net. The pair drag steel roller between them to break up the coral and then come back over the same area to trawl the fish. Such operation has been affecting species composition and size composition of crustacean and demersal fishes. Declining fish stock as an impact of shrimp trawl is shown by (1) decreasing catch rates (2) decreasing other crustacean species (blue crab) (3) changing of target shrimp and decreasing captured shrimp. Moreover, it is considered that fishing using rigged trawl will change microbenthic structure in the waters.

Trawling also removes vast numbers of juvenile fish that are needed to sustain fish stocks. In addition, by dragging large, heavy nets along the seabed, habitats that support marine life are damaged. In heavily-trawled areas, habitats have little chance to recover and in some cases may be permanently altered (EFJ, 2003)

The replacement from shrimp trawl to shrimp trawl net (*pukat udang*) as a consequence of its restriction by Indonesian Government still leave all problems made by common trawl behind, since both rig structure and operating ways remain unchanged, it giving relatively same negative impacts on ecosystem. According to DG of Capture Fisheries (2001), the bottom habitats in the Arafura Sea have hardly been studied, both after and before the utilisation of the shrimp trawl. Research activities concerning bottom sediments, biological oceanography or coastal ecosystems such as mangrove were carried out at Benton Bay, Sele Strait and the Aru Islands. However, due to the inconsistency of time and space the information now available is very limited making it difficult to analyze the impact of shrimp trawl on the seabed and habitat conditions.

Ecologically, discard of by-catch can pollute sea environment when its amount is over the environment carrying capacity. This is because of the decay process are no more be able either to be decomposed by decomposing bacteria or to be consumed by other predators such as carnivore fish, dolphins and sea birds around Arafura Sea.

3.3. Conflicts

Large numbers of small scale non-trawl fishers have been set against a comparative handful of trawl operators since they generally exploit the same resource and often compete to access the same fishing ground. Because trawl operators are attracted to the water with penaeid shrimp presence, which mostly concentrate shallow coastal water, the competition between trawler operators and small-scale fisheries has led to widespread conflict in Indonesia (Bailey, 1997). In that competition, small scale fishers are frequently in disadvantage. In some cases, according to Bailey (2007) the large trawl vessels often operate at night without lights and crash into smaller vessel and damaged gill nets or other. Many conflicts were often violent and commercial trawling was prohibited in waters adjacent to Java from September 1980 and in those adjacent to southeast Sumatra from January 1981 (Sardjono, 1980). Although there have been no official reports on conflict casualties or boat damages in Arafura Sea, unofficial reports however, suggest that open conflicts occurred.

In this respect, reference is made to the Ministry of Agriculture Decree No. 02/Kpts/Um/1/1975 concerning the sustainability of fishery resources development in the Irian Jaya waters which states that all trawling activities are prohibited in less than 10 meters depth. However, shrimp trawlers often operate closely to the coast (where the trawl are restricted) even estuarine, first of all because the depth steeply increases in certain areas, even in certain estuaries. There are frequent conflicts between local small-scale fishing communities and shrimp trawlers operating outside legal fishing zones.

IV. FISHERIES MANAGEMENT OF SHRIMP TRAWLING

Management of shrimp trawling in Arafura Sea is involved developing sets of appropriate operational plans to guide the shrimp trawling activities, in keeping with overall strategic fishery goals and policy directions. This is implemented through monitoring to shrimp resource, setting management objectives and strategies, applying fisheries regulation by placing some limitations on catches (output controls), restrictions applied to the amount of fishing effort (input controls) and limitation on some technical measures.

The fisheries resources management was established under Law No. 9 of 1985 on Fisheries. It states that fisheries resources management refers to all the measures taken to sustain and utilize the fisheries resources in an optimal manner. It includes measures for controlling fishing efforts to a level sustainable for fisheries resources, fishing practices acceptable for environments and assessment of other activities which impact fisheries resources and its environments.

The main legal product issued by Indonesian government, the Presidential Decree no 39 year 1980, had eliminated trawl operation in Indonesian waters excluded Arafura Sea which was abundant for shrimp resources and still underexploited. This had been implemented through following several phases.

The first implementation phase is description of banned trawl models through Ministry of Agriculture Decree No. 503/Kpts/Um/7/1980. This decree defines structure of banned trawl which is a pouch-like shaped net with a beam or an otter board pulled by a vessel or more. Furthermore, it also explained common local name of trawl such as *pukat harimau, pukat tarik , jaring tarik* etc.

Second phase of trawling restriction implementation was reduction of total trawl vessel amount become 1000 units through Ministry of Agriculture Decree No. 542/Kpts/Um/6 of 1981. This regulation had been executed during one year, from July 1st 1980 to July 1st 1981.

The next phase for reducing trawling operations is Presidential Decree No. 85 of 1982 which allows shrimp trawls operate in Arafura waters beyond 10 meters isobath line. And the last phase is Presidential Instruction No. 11 of 1982 on Implementation of Presidential Decree No. 39 of 1980 which banned trawling totally in all Indonesian waters, except for those of the Arafura Sea.

The fisheries management of the shrimp trawling are consist of some measures include input controls, output controls, technical measures and community as well.

1. Input control

Input control is regulating what fisheries bring into the fishing process (Charles, 2001) or controlling fishing effort take places. There are some input controls applied in shrimp trawling fishery in Arafura Sea.

1.1 License System

The fishing licenses of national companies, are issued by local government, while for Arafura Sea, it must get licenses issued by both Directorates general of Fisheries and Capital Investment Cooperating Agent (CICA/BKPM) as well as fisheries businesses that have foreign or domestic capital investment. MOMAF (2007) estimated among 7000 issued domestic licenses, 70% of which are involved in illegal fishing and abuse licensing. In order to obtain a license a trawler owner has to enter into joint venture or “rental” agreement with Indonesian company. This joint venture should provide economic benefit for Indonesia.

The fishing activities in the Indonesian water either by national fishing companies or by ex chartered fishing vessels, in which all the crews were from original countries (mainly Thailand), were almost uncontrolled. The catch obtained by these vessels was usually unrecorded/ unreported because these catches were directly transhipped and transported to the original countries and no records from the Indonesian side (Fegan, 2003). These practices will undoubtedly caused big losses to Indonesia, due to the fact that not only the index of abundance will certainly decreased, but also the context of stock assessment carried out by Indonesian will lead to inappropriate results. Thus, the outputs of these assessments will be misleading. Nevertheless, since July 16th 2007, there are no foreign fishing vessels permitted in all Indonesian waters includes Arafura Sea.

Before Law No. 9 of 1985 on Fisheries, Government Regulation (PP) No. 15 of 1990 on Fisheries Business and Ministry of Agriculture Decree No. 815 of 1990 on The Authority of Fisheries Business License in the certain scale are under a responsibility of the Local Government (Provincial Fisheries Service), that refers to Government Regulation No. 64 of 1957. License for fishing vessels of foreign companies are issued by the Directorate General of Fisheries. If capital investment is available, the license is authorized by the Capital Investment Coordinating Agency (CICA).

Trawling license by national companies is issued by the local government within some limitation established by the regulations in Indonesia. Trawling licenses of the Arafura Sea are issued by both the Directorate General of Fisheries and CICA, particularly for fisheries businesses that have a facility of capital investment of Foreign Capital Investment and Domestic Capital Investment (DG of Fisheries Capture, 2001).

1.2 Fishing Zones

Establishing fishing zones is necessary as basis in fisheries management in Arafura Sea oriented in environmental sustainability and equity. It is also necessary for fight against Illegal, Unreported and Unregulated (IUU) fishing by strengthen cooperation between stakeholders and neighbor countries whose bilateral agreement with Indonesia ion capture fisheries.

As many negative impacts arose in shrimp fishery such as conflict with small scale inshore traditional fishermen, government set some regulations regarding zone of trawling. The fishing zones are established to avoid social conflicts happening among fishers, to protect small-scale fisheries from large-scale operations in their fishing grounds and to protect resources damaging. The Ministry of Agriculture Decree No. 392 year 1999 regulates fishing ground by dividing it into 3 zones according to permission of certain size vessels to operate there. The following Table 6 shows summary of fishing zone regulation.

Table 6. Summary of Ministry of Agriculture Decree No. 392 year 1999 regarding to fishing zone

Zone	Allowed vessels	Allowed gears
Fishing Zone Ia Lowest point of low tide – 3 mile	Non-powered canoes	Static gear Unmodified mobile gear
Fishing Zone Ib 3 – 6 miles	Boats with outboard engine vessel ≤ 5GT	Modified mobile gear Purse seine ≤ 150 m Drift gill net ≤1000 m
Fishing Zone II 6 – 12 mile	Boats with inboard engine ≤ 60 GT	Purse seine ≤ 600 m Drift gill net ≤ 2,500 m
Fishing Zone III Beyond 12 mile – outer of ZEEI	Indonesian vessel ≤ 200 GT	

(Source: MOMAF, 2007)

In Fishing Zone III, the allowable vessels are all Indonesian flag wavered vessels except for purse seine for large pelagic fish in Maluku Sea, Seram Sea Banda Sea and Flores Sea. ZEEI areas are allowable for all Indonesian and foreign vessel less than 350 GT and purse seine vessel 350 – 800 GT in size.

By this regulation, Fishing Zone I which extends from 3 – 6 miles from the lowest point of low tide is the most potential area for shrimp trawling, since the Catch per Unit Area (CPUA) in this zone is relatively high. The area with high shrimp density or high catch per unit area is valuable asset for economically sustainable production. This is supported by Gordon (1954) that economic aspect should be a priority for optimal development, when output (benefit) is higher than input (cost), since the main objective of fishing activity is a profit.

2. Output Control

This control is focus on what is taken from fish stock or catches (Charles, 2001) or controlling fishing effort take places. Fisheries resources allocation basically concerns the fishing effort being authorized in given areas, including for shrimp trawling. It is issued by means of Ministry of Agriculture Decree No. 995/Kpts/IK.120/9 of 1999. This Decree estimates the TAC for shrimp to 17,200 tonnes (while for demersal fishes, a total of 197,400 tonnes). Therefore, if the average CPUE for shrimp trawl net is around 10 ton/year (with fishing vessels 150-200 GT) then the number of shrimp trawl net to be operated in the Arafura Sea would be 156. Considering that the number of shrimp trawl net operated in the Arafura Sea is now 453 for a production amounting to approximately 49,830 tonnes, the conclusion is that shrimp is being over-fished in the Arafura Sea (DG of Capture Fisheries, 2001)

3. Technical measures

Technical measures is aim to limit the "how, when and where" of fishing are historically the most widely implemented management tools which are restrictions or constraints to regulate the output which can be obtained from a specified amount of effort, for example gear restrictions, closed seasons and closed areas. In terms of the above regulations, these measures generally attempt to influence the efficiency of the fishing gear (FAO, 1997).

3.1 Utilizing By-catch Reduction Device

In attempting to reduce by-catch in shrimp fisheries, Presidential Decree No. 085/1982 control that each unit should be equipped with a BRD (By-catch Reduction Device) which is a modified form of TED (Turtle Excluder Device). The BRD has been developed by adding grating frame in board part between body and cod end whose function to escape and to sort the capture. The shrimp trawl basically consists of cod end, body, wing, otter board and warp. The principle design of is actually same with other trawl, but the only difference is equipped with BRD (Purbayanto, 2004).

In general, the inclined grids (such as the TED shown in Figure 7) are best for the exclusion of larger animals (such as turtles) whereas small escape devices are more effective at allowing fish and sea snakes to leave the net (Blaber, *et al.*, 2000). These improve the selectivity of shrimp trawlers, so they catch shrimp in more proportion to other organisms.

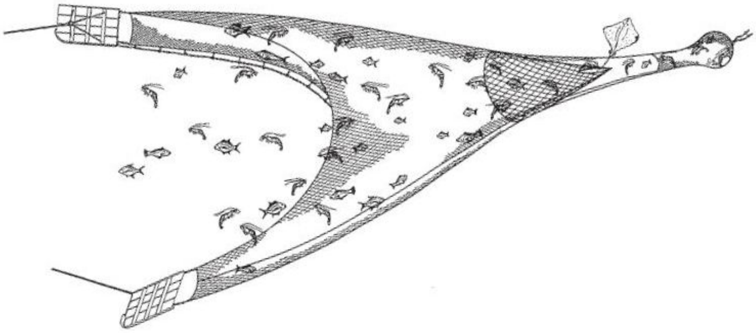


Figure 7. Characteristic of installation of BRD in a shrimp trawl codend. (illustrated by G. Day NORMAC, 2002 *in* EJF, 2003)

Regulation on utilisation of by-catch species is included in the Presidential Decree No. 85 of 1982 and Ministry of Agriculture Decree No. 930/Kpts/UM/12 of 1982 and the Directorate General Fisheries Decree No. IK 010/S3.8063/82. It is stated that the fishery companies that have licenses to use shrimp trawl net have to hand over the by-catch to the Fisheries/Cooperatives State owned Company. While the optimal fish by-catch utilization is in line with the principles of responsible fisheries (FAO, 1997), such stated requirement of keeping the by-catch on board is practically not easy to implement because of time and storage limitation to handle this portion of by-catch species.

3.2 Mesh Size Regulation

According to Ministry of Agriculture Decree no.1 year 1975, the minimal mesh size requirement is 25 millimeters or 1 inch as it is applied for all Indonesian waters, include Arafura Sea (Indonesian DG Capture Fisheries, 2001).

3.3 Fishing Vessels Size

Indonesian or foreign fishing vessels are authorized to operate in Indonesian Economic Exclusive Zones (IEEZ) except in Malacca Strait using vessels not more than 350 GT (regardless fishing gear used). Furthermore, shrimp trawler in Arafura Sea is authorized for vessels less than 350 GT.

3.4 Utilization of By-catch Species

By catch utilization depends on whether or not a market for a particular size or fish species is available. Very small fish (juveniles), which are inedible or damaged, is likely to be discarded. Even if shrimp trawlers catch adult commercial fish species, several factors complicate their utilisation. Informal and opportunistic systems of by-catch utilisation have been playing important role in shrimp trawl fisheries, since the local fishers taking advantage of the 'unwanted' fish resources.

Regulation on utilization of by-catch species is stated in the Presidential Decree No. 85 of 1982 and Ministry of Agriculture Decree No. 930/Kpts/UM/12 of 1982 and the Directorate General Fisheries Decree No. IK 010/S3.8063/82K. It is asserted that trawler operator companies that have licenses for shrimp trawl net should hand over the by-catch species to the local fisheries cooperatives under National Company. However, the optimal by-catch utilization along the line with responsible fisheries principles (FAO, 1997), requiring to preserve the by-catch species on board is, practically, not easy to be applied because of space limitation in the fish storage. In addition, the trawl operators are objected to spend the time and effort for handling a portion of the catch considered as trash.

In onshore area of Arafura Sea, trawl operators work very close to shore where the small canoe can reach them easily. Artisanal fishers, who used to make a living from fishing, often rely on by-catch species from shrimp trawlers. EJF (2003) commented on the utilization of by-catch species, "it is ironic, perhaps, that the use of shrimp trawlers in coastal waters has sometimes been blamed for the disruption of traditional fishing pattern, yet that same activity may be alleviating some of the problems it has created by giving fishermen alternative income-generating opportunities". Nevertheless these incomes -generating opportunities may not be ecologically or socially sustainable solutions.

4. Community-based Fisheries Management

The Indonesian government has taken measures in monitoring and controlling the suitable protection of fisheries resources and environment, the sustainability of fisheries as well as the development. This system is based on the designation of authority given in this respect to regional governments, especially regarding fishing activities carried out by small fishing units, less than 30 GT and 90 HP. The application for this management system is conducted through a

Coordination Forum of Fisheries Resources Utilization (*Forum Koordinasi Pengendalian dan Pemanfaatan Sumberdaya Ikan/FKPPS*) which holds an annual meeting. The status of FKPPS is described in Ministry of Agriculture Decree No. 994/Kpts/Kp.150/9 dated 1999. Nine FKPPS have been established for the various areas of the countries and The Arafura Sea is included in the FKPPS for area VI.

The coordination forum has discussed interests and the related matters such as fishery regulation, in general, resources allocation, fisheries operation, both industrial and small-scale, fisheries monitoring and control, etc. The above matters are applied particularly to the Arafura Sea. However, the limitation of the number of shrimp trawlers has been authorized in the area (based on the issue of Fishing Permit (UP) for operation in the Arafura Sea).

Many meetings and conference between the coordination forums from 6 areas have been held to encourage community participatory on fisheries management. However there is still a problem with this solution that is the community institutions do not have authority to exclude outside fishing vessels from their water since Indonesia law does not recognize coastal marine incumbency by communities (Purbayanto, 2004).

A technical report (DG Capture Fisheries, 2001) describes some perceptions by community concerning shrimp trawling in Arafura Sea, such as industrial groups, non-shrimp fishermen, officials, shrimp trader and exporters, scientists and etc, should be responded in the process of decision making. They consider that shrimp resource is decreasing and reach an equilibrium point and although trawl is the most proper fishing gear to be used in shrimp fishery, they also suggest that number of trawlers in the area should be reduced and shrimp fishing industry should not be developed more, but kept as present. Regarding to by catch problem they assert that by catch reducing device should be always used. In term of management for the conservation of shrimp, they agree that certain fishing ground and certain fishing season should be closed to reduce the potential negative impact. They consider that shrimp resource is decreasing and reach an equilibrium point and although trawl is the most proper fishing gear to be used in shrimp fishery, they also suggest that number of trawlers in the area should be reduced and shrimp fishing industry should not be developed more, but kept as present or reduce the fishing effort.

V. THE PROBLEMS OF SHRIMP TRAWLING MANAGEMENT AND BIO-ECONOMIC ANALYSIS

The Fisheries law no 9 of 1985 is apparently intended to perform as reference to the measures taken for maintaining and utilizing the fisheries resource in an optimum behavior. Moreover, the law also includes management principles and regulations which are implemented in the Ministry of Agriculture Decree. These regulations of fisheries resource management includes some measures such as TAC, minimum permitted mesh sizes by gear type, prohibited species, season closures during spawning seasons in certain areas and minimum size of fish to be caught. In fact, now the Government of Indonesia is coping with economic crisis which is necessary to create extra economic sources. The evidences shows that most of Indonesia's capture fisheries are fully or overexploited, nevertheless the capture fishery is expected still to contribute in increasing Indonesia's Gross National Product (GNP) by raising total catches (Mous *et al.*, 2005).

As a consequence, one of the government programs in fisheries sectors is poverty alleviation of coastal rural community under which shrimp commodity has been one of the potential fishery products for program's accomplishment. Thus, legal framework governing fisheries still lacks coherence and the compliance of regulations in shrimp trawl fishery is also questionable. The problems of small scale and industrial fisheries management have hardly been touched, despite recognizing an overfishing problem.

As opposed to the open access system, the license regulation is given to limit in which a limited number of boats or boat owners are given licenses (King, 1995). However, in case of the shrimp trawl fishery (other marine fisheries in Indonesia as well), these regulations have been applied ineffectively. In the implementation of shrimp trawling management, there are some drawbacks faced by government as fishery manager.

1. Reluctance against By-catch Reduction Device (BRD)

The use of by-catch reduction/excluder devices is obligatory for all trawlers on board in the Arafura Sea. This regulation creates problems for fishing operations and generates some loss of shrimp. In general, the fishing operators have still not perceived the benefit from using such devices (DG Capture Fisheries, 2001). Unfortunately, neither BRDs nor Turtle Excluder Devices (TEDs) are used extensively in shrimp fisheries in Arafura Sea, mainly because most shrimp fishermen either do not have access to this technology or are concerned that these devices reduce their shrimp catch.

Regulations requiring the use of BRD on trawls are ineffective since they are flaunted by fishermen. Even though the trawl banning has been applied for 28 years, the illegal use of trawl still can be seen in a great deal. A research by Evans and Wahju (1996) used data from followed trawler in February 1992, it operated without applying BRD. According to the crew, it is common practice not to use the device since it reduces the shrimp catch.

Traditionally, most effort to reduce by-catch in tropical shrimp-trawl fisheries has focused on the development of TEDs, but attention is increasingly being directed toward reducing catches of small fish and other by-catch. However, for ensuring sustainability of oceanic resources, we need to have a preventive approach which envisages by-catch rather than efforts to fully utilize the by-catch.

2. Obscurity of Fishing Zone Boundary

Setting fishing zone is a necessary as a basis in fisheries management in Arafura Sea. This zone is an instrument to bring effective and sustainable management of fisheries resource. The zone should be set along with the National development of fisheries namely to optimize the management of fish resource, to reach optimum utilization level of fisheries resource and to ensure the sustainability of the resources. The fishing zone setting in Arafura Sea is important to eradicate Illegal, Unreported and Unregulated (IUU) fishing by increasing collaboration between stake holders and other countries whose bilateral agreement on capture fisheries with Indonesia.

The law enforcement needs basic reference and management tools supporting quick and accurate decision on suspect fishing operator who violates the fishing regulation. In another hand, the fishing operator should have the same understanding of the regulation with the regulation enforcer.

Some regulations in the establishment of fishing zone has limitations such as the distance of fishing zone measured from coastal line is debatable as coast line is always dynamic, especially in the area with high tidal range, flat coastal slope and active sedimentation-erosion. In addition, there is a possibility that the referred sea map is unreliable anymore with the last condition.

According to Monintja (2006), establishment of boundary line using isobath line has disadvantages. The 10 depth is not always found in a narrow line form, but it could be a large ground field, such exist in Dolak waters of Arafura Sea. Moreover, the position of isobaths line in a map could be different from another map according to the scale and author. The measurement of sea depth in the field could be different from the existing map, thus the measurement of sea depth in the should be calibrated with the data of tidal range.

3. Problems on Trawl Nomenclature

The President Instruction no 1980 has been implemented ineffectively since trawl has been still existed and even developed both in small scale and industrial scale. The following development tends to manipulate the nomenclature of fishing gear name, which is technically included as trawl category. For instance, some fishing gear use term *pukat hela*(fish trawl), *pukat ikan*(fish trawl), etc.

This policy then created confusion due to the lack of clear understanding of what the trawl definition is, and what a modified trawl should look like. Trawl has been translated into Indonesian language as *pukat harimau*, which was incorrect meaning and inconsistent with the international standard. An opportunity to modify trawl had led to a race of technology inventions to trawl. There are various local names and modifications for trawl, such as *arad berpalang*, and *arad berpapan* in north coast of Java, mini beam trawl in Probolinggo, *cantrang* in South Sulawesi and *lampara dasar berpalang*, *lampara dasar berpapan* in South and Central Kalimantan (Purbayanto, 2004).

There was big waves of modified trawls flooded the waters in various parts of the Indonesian coasts while fisheries depletion was still becoming worse and worse. These nomenclatures were understood only by some local fishing communities, whilst not recognized by some others. They did it as an effort to get a formal legality. The implementation of regulation is remain unclear which led in illegal fishing, which if it let to be continued, it is assured will damage fisheries resources and led a horizontal conflict among the fishermen. It then became a source of fishermen conflicts because the first community could get legal permit for their gears, while for some others in different areas, these gears were still prohibited. It went to show the name was not recognized nationally.

The fishermen do neither use gear that would lessen the environmental damage of the nets nor use large mesh net nor use equipment that would prevent the net from dragging alone seabed. However, trawl prohibition policy failed to recognize Government's role in addressing such fishery and resources depletion. Government could have provided an opportunity for trawl users to modify their trawls to meet the legal fishing gear requirements. Technical constraints and lack of law enforcement remained as classic case.

4. Bio-economic Analysis for Shrimp Trawling

The general purpose fisheries management of shrimp trawling is to make sure that shrimp resource is exploited in an optimal manner. The biological models can provide an estimation of MSY and effort level related to the catch. Surplus production models are applied with considering data availability. Thus, 5 bioeconomic models employed to analyze the shrimp trawling fishery in Arafura Sea are including three logistic growth models (1) Schaefer (1957) model, (2) Schnute (1977) model and (3) Walters and Hilborn (1976) model and two exponential growth models, (4) Fox (1970) model, and (5) Clark, Yoshimoto and Pooley (1992) model (Pyo, 2001). The difference between the two is that growth function is parabolic or symmetrical in 3 logistic models, implying the possibility of stock extinction in an extreme case while two exponential models are asymmetrical. Both are related to the intrinsic growth rate of the stock (*r*), the biomass (*B*) and the environmental carrying capacity (*k*), which is the maximum stock level are:

- Logistic growth model $G = rB(1-B/k)$
- Exponential growth model $G = rB\ ln(k/B)$

Using catch (C) assumption of $C = qBE$ where E is the rate of fishing effort, q is the catchability coefficient and Catch Per Unit Effort (CPUE) is defined by $U = qB = C/E$, current biomass is given by $B = U/q$. The effort level in sustainable manner (E_{MSY}) and can be estimated as follow

Table 7. Equations of logistic and exponential growth models

Level	**Parameter**	**Logistic growth model**	**Exponential growth model**
Catch		$qkE(1-qE/r)$	$qkE\ exp^{-(q/r)E}$
MSY	Effort Catch	$r/2q$ $kr/4$	r/q $qkE_{MSY}\ exp^{-(q/r)E}$

In data formulation, based on catch and effort data, CPUE or (U) or its approximation and the associated level of effort were then calculated. All these models relate stock size, fishing effort and yield to another (Pyo, 2001)

Schaefer model
$$\frac{\overline{U}_{t+1}-\overline{U}_{t-1}}{2\overline{U}_t}=r-\frac{r}{qk}\overline{U}_t-q\overline{E}_t$$

Schnute model
$$\ln\left[\frac{\overline{U}_{t+1}}{\overline{U}_t}\right]=r-\frac{r}{qk}\left[\frac{\overline{U}_t+\overline{U}_{t+1}}{2}\right]-q\left[\frac{\overline{E}_t+\overline{E}_{t+1}}{2}\right]$$

Walter&Hilborn model
$$\frac{\overline{U}_{t+1}}{\overline{U}_t}-1=r-\frac{r}{qk}\overline{U}_t-q\overline{E}_t$$

Fox model
$$\frac{\overline{U}_{t+1}-\overline{U}_{t-1}}{2\overline{U}_t}=r\ln(qk)-r\ln\overline{U}_t-q\overline{E}_t$$

Clarke, Yoshimoto & Pooley
$$\ln\overline{U}_{t+1}=\frac{2r}{2+r}\ln(qk)+\frac{2-r}{2+r}\ln\overline{U}_t-\frac{q}{2+r}\left(\overline{E}_t+\overline{E}_{t+1}\right)$$

Where,

$\overline{U}$ = Average catch per unit effort for a given year

$\overline{E}$ = Total effort expended in year t

r = intrinsic growth rate

q= catchability coefficient

k= carrying capacity of the environment

In all these models, the dependent variable is a certain form of catch per unit effort, and independent variables are the other form of catch per unit effort and the level of effort. Therefore, these 5 equations can be estimated using Ordinary Least Square (OLS) regression method based on catch per unit effort and the level of effort.

Annual catch is obtained from Annual Statistic Book of Indonesian Capture Fisheries published by MOMAF (2007) and effort data should include the size and type of boat, the amount and type of gear used, the time spent on fishing as well as the time spent in searching, the level of search technology employed and the skill of the skipper and crew. However, collecting data for shrimp trawling effort which is limited in Arafura Sea is not a simple job, since this area still has poor report system, thus the available data for fishing effort for this study is amount of trawl operating in Arafura Sea. As demonstrated in Chapter 3, the fishing effort, the duration of fishing trip for trawl vessels is from 40 to 60 days and the average of fishing days at the sea is approximately 280 days in a year with 7 – 9 hauls in a day (DG Capture Fisheries, 2001). While according to Monintja et al (2006), the tonnage average of shrimp trawl operating in Arafura sea in 2004 - 2006 is 139 - 142 GT.

In this study, the trawl vessel tonnage is assumed as 140 GT. This number also represents all kinds of trawl rig, including single rig, double rig, with BRD and without BRD. Thus, Catch Per Unit Effort (CPUE) in a certain year is annual catch divided by unit trawl in that year. The summary of data is shown at the Table 8.

Table 8. Catch Per Unit Effort of shrimp trawling in Arafura Sea

Year	Volume (ton)	Fishing Effort (Unit trawl)	CPUE (ton/unit)
1994	14,634	342	42.79
1995	18,581	375	49.55
1996	17,750	381	46.59
1997	25,418	323	78.69
1998	21,625	542	39.90
1999	21,026	741	28.38
2000	25,023	744	33.63
2001	24,832	772	32.17
2002	20,193	765	26.40
2003	21,045	775	27.15
2004	22,731	819	27.75
2005	21,150	912	23.19
2006	20,528	1066	19.26
Average	21,118	658	36.57

5. Result of Bio-economic Analysis

The Schaefer, Schnute, Fox, W&H and CY&P production models are estimated using regression analysis with catch and effort data from year 1994 – 2006.

- Schaefer model

Independent variables	Coefficient	R^2	t-statistic	P value
Constant	0.25648440	0.0500635	0.28661	0.78169348
$\overline{U}_t$	-0.002169		-0.20857	0.83999557
$\overline{E}_t$	-0.000383		-0.47189	0.64961078

$$\frac{\overline{U}_{t+1} - \overline{U}_{t-1}}{2\overline{U}_t} = 0.2564 + 0.0022\overline{U}_t + 0.00038\overline{E}_t$$

- Schnute model

Independent variables	Coefficient	R^2	t-statistic	P value
Constant	0.803710917	0.062652	0.563071	0.58713788
$\left[\frac{\overline{U}_t + \overline{U}_{t+1}}{2}\right]$	-0.0093578		-0.50275	0.627212
$\left[\frac{\overline{E}_t + \overline{E}_{t+1}}{2}\right]$	-0.00080022		-0.68748	0.50910435

$$\ln\left[\frac{\overline{U}_{t+1}}{\overline{U}_t}\right] = 0.80371 + 0.00936\left[\frac{\overline{U}_t + \overline{U}_{t+1}}{2}\right] + 0.0008\left[\frac{\overline{E}_t + \overline{E}_{t+1}}{2}\right]$$

- Walter&Hilborn (WH) model

Independent variables	Coefficient	R^2	t-statistic	P value
Constant	1.90031305	0.477454	2.805193	0.02053767*
$\overline{U}_t$	-0.0237426		-2.793571	0.02093134*
$\overline{E}_t$	-0.0016404		-2.701063	0.02435126*

$$\frac{\overline{U}_{t+1}}{\overline{U}_t} - 1 = 1.90031305 + 0.0237426\overline{U}_t + 0.0016404\overline{E}_t$$

Note: * = significant at 5% level

- Fox model

Independent variables	Coefficient	R^2	t-statistic	P value
Constant	0.951106491	0.055641	0.327245	0.75188098
$\overline{U}_t$	-0.1887918		-0.3017	0.77059047
$\overline{E}_t$	-0.00054276		-0.4965	0.63290911

$$\frac{\overline{U}_{t+1} - \overline{U}_{t-1}}{2\overline{U}_t} = 0.9511\ln(qk) + 0.1888\ln\overline{U}_t + 0.00054\overline{E}_t$$

- Clarke, Yoshimoto & Pooley (CYP) model

Independent variables	Coefficient	R^2	t-statistic	P value
Constant	6.314539995	0.871172	0.000338	0.00033757
$\overline{U}_t$	-0.39255345		0.152294	0.15229429
$\overline{E}_t + \overline{E}_{t+1}$	-0.00106938		0.000457	0.00045677

$$\ln\overline{U}_{t+1} = 6.3145\ln(qk) - 0.3925\ln\overline{U}_t + 0.00107\left(\overline{E}_t + \overline{E}_{t+1}\right)$$

In this regression analysis, Schaefer, Schnute and Fox model do not fit well for the data since they have low R^2 and the variables are not statistically significant at 5% level for all models except the WH model. In WH model, P value of all independent variables is significant at 5% level and R^2 level is somewhat lower (R^2 = 0.48). CY&P model has the best fit for the data (R^2 = 0.87) and good P value for coefficient of constant and fishing effort. However, P value of CPUE variable in CYP model is high (P-value= 0.1523), shows that coefficient of CPUE is not significant. The insignificant coefficient of CPUE variable in CYP model, the parameters estimated are quite unrealistic.

From the regression result, it is possible to make such summary as following Table 9 which shows the calculated parameters and sustainable values for Effort (E_{MSY}) and Catch (C_{MSY}).

Table 9. Values of parameters estimated by production models

Parameter	Schaefer	Schnute	WH	Fox	CY&P
Constanta	0.2565	0.8037	1.900	0.9511	6.3145
CPUE	-0.022	-0.0094	-0.0237	-0.1888	-0.3925
Effort	-0.00038	-0.0008	-0.00164	-0.00054	-0.00107
Collinearity	ToL=0.219	ToL=0.141	ToL=0.291	ToL=0.120	ToL=0.278
VIF	4.574	7.116	3.431	8.349	3.596
DW stat	1.897	2.682	2.396	1.905	2.05
R^2	0.0506	0.063	0.4774	0.0556	0.87
Adjusted R^2	-0.187	-0.145	0.3613	-0.18	0.842
R	0.256	0.804	1.9003	0.189	4.589
q	$3,8x10^{-4}$	$8x10^{-4}$	$1.6x10^{-4}$	$5.4x10^{-4}$	$70x10^{-4}$
k	308823.5	107328.90	48792.68	283981.38	13198.31
E_{MSY}	334.86	502.18	579.23	347.83	651.31
MSY	19,802.10	21,565.36	23,180.34	19,723.25	22,284.99

As shown in the Table 9, the effort and the catch on MSY level by the Walter & Hilborn model, 579 units (E_{MSY}) of trawl and 23,180.34 ton of catch, is likely to be quite suitable compared with the average of actual effort and catch, 658 units of trawl and 20,118 ton of catch (shown in Table 4).

However, WH model has coefficient with the proper signs and t-statistic that statistically significant at the 5% levels. In addition, Durbin Watson test to indicate autocorrelation shows the correlation between variables in WH model (DW=2.396) as shown in Table 9. Multi-collinearity statistic test in WH model results on Tolerance value of 0.291 and Variance Inflation Factor (VIF) value is 3.431 which show multi-collinearity between the variables. In conclusion, autocorrelation and multi-collinearity problems are not occurred in WH model. Nevertheless, CYP model can also be referred as the second most suitable model for estimating Effort (E_{MSY}) and Catch (C_{MSY}) of shrimp trawling fishery in Arafura Sea. It has coefficient with the proper signs and t-statistics that statistically significant at the 5% levels except for CPUE variable (t-stat=0.152). Autocorrelation test using Durbin Watson test shows that there is correlation between variables in CYP model (DW=2.05) as shown in Table 9. Multi-collinearity statistic in CYP model results on Tolerance value of 0.28 and VIF value is 3.596 which show multi-collinearity between the variables. In conclusion, autocorrelation and multi-collinearity problems are not occurred in CYP model as well. The completed analysis is provided in Appendix 2 to 8.

Comparing to estimation by Indonesia Institute of Science in 2004 (shown in Table 1), the MSY level of penaeid shrimp in Arafura Sea estimated by this study almost a half of estimation by Indonesia Institute of Science which is 43.100 MT/year. This big difference could be as result of different model application when estimate MSY level; different parameters used in the estimation and a conditional change as a matter of time. Besides, by looking at shrimp catch data (shown in Table 5), the MSY level estimated by Indonesia Institute of Science is somewhat over beyond the average catch. The catch parameter applied for MSY estimation in this study is using shrimp production of Mollucas province and Papua province where the shrimp trawlers land the catch in fishing port of both provinces. Unfortunately, the shrimp production data and MSY estimation method used by Indonesia Institute of Science does not clearly define both the scope area of Arafura Sea and the limitation of penaeid species.

Figure 8 and 9 below demonstrate the comparison between successively CPUE and catch of WH model, CYP model and actual CPUE which shows the suitability of both model to the actual data. The catch estimation by WH model is equal to the equation of $qkE(1-qE/r)$ as WH model is one of the logistic growth model (as shown in Table 7). CYP model estimation of catch is equal to $qkE\ exp^{-(q/r)E}$ as CYP model includes in the exponential growth model. Completed table sources are shown in Appendix 10 and 11.

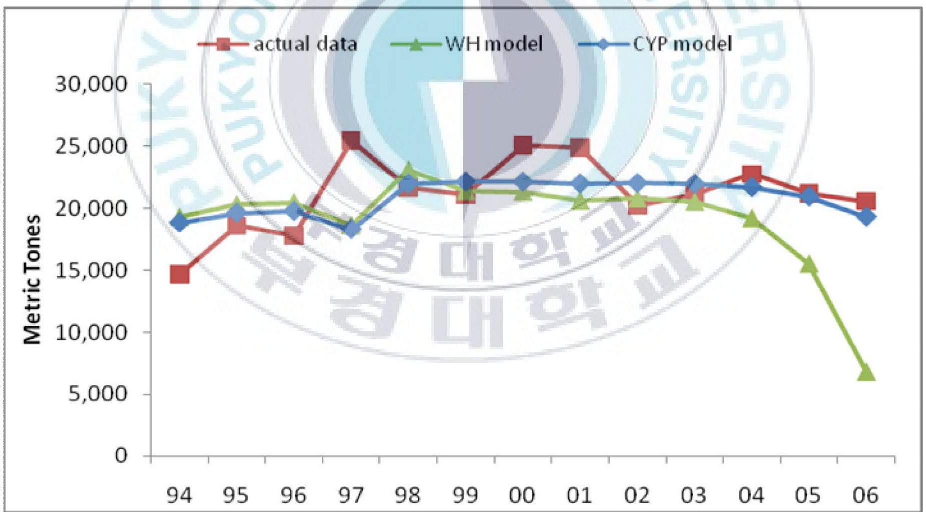


Figure 8. Comparison between actual catch WH-model catch and CYP-model catch

Figure 8 demonstrates that CYP model and WH model are suitable to the actual data. During year 2003-2006, CYP model is more appropriate to the actual data than WH model.

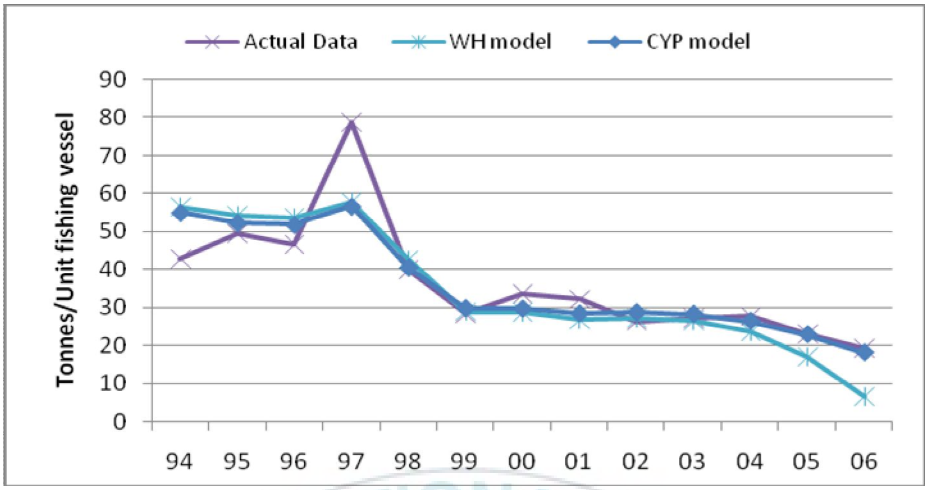


Figure 9. Comparison between actual CPUE, WH-model CPUE and CYP-model CPUE

VI CONCLUSION AND RECOMMENDATIONS

1. Conclussion

Based on the conditions above, MOMAF through Directorate General of Capture Fisheries has been making serious effort to solve the problems. One of the solutions is establishing cooperation with world's organizations such as Food Agricultural Organization to solve local and international issues of fisheries. The approach is including sustainable capture fishing, complexity of capture fishing, fisher wealth, equitable exploitation, and community management on fisheries resources with empowerment of local wisdoms.

This study is identifying effective measures for implementing as well as managing shrimp trawl activity in Arafura Sea. The main goal for implementing and managing shrimp trawling in Arafura Sea is to increase the standard of living of small scale fishermen, to increase availability and consumption of fish protein resources, to reach optimum exploitation level of fisheries resource as well as ensure its sustainability. Therefore, the priority should be focused on productivity and biodiversity. Some recommendation as a tool in the management of shrimp trawl fisheries includes in following sections.

Given the drawbacks of shrimp trawling management are identified, here are some alternative measures to answer them and build the more effective fisheries management for trawling activities. The management plans for sustainable fisheries mangament on shrimp trawling in Arafura Sea focuses on following criterias: (1) Limiting fishing effort (2) Reducing by catch and (3) Supporting Monitoring Control and Surveillance System.

1.1. Limiting Fishing Effort

The surplus production models are useful in situation where the fisheries managers have limited research fund and they have to make management decision based on relatively limited biological and economic data. The reason is that these models require relatively limited data, although some question their applicability (Clarke, et al., 1992).

Although WH model tested for shrimp trawling in Arafura Sea demonstrates that the yield of all kind of shrimp was not excess the MSY level, but the trawl amount should be adjusted downward to half of the amount of trawl in year 2006. As showed in the previous chapter, the shrimp trawling fishery has been placed in the state fully exploited. Thus, this section aims at suggesting management plans for sustainable fisheries of shrimp trawling in Arafura Sea. Limiting fishing effort on the level 579 units of trawl and increasing yield to the level 23,180 ton is a sustainable manner to maintain the shrimp stock.

Reducing amount of fishing vessel in Arafura Sea as well as optimizing shrimp catch could be implemented in 2 options:

1.2. License Control

In managing fisheries, the sustainability of resource should be main priority, and followed by economic and social value. Based on estimation of fishing capacity, fishing activity in Arafura Sea especially shrimp trawling has not been efficient anymore. Therefore, one of strategies to solve this problem is reducing amount of vessels. The limitation on trawling license should be based on availability of shrimp stock which is derived from catch data through trend analysis of catch per unit effort. The catch data are obtained from continuous monitoring activity in Papua and Maluku Province.

Barani report (Monintja, 2006) illustrate that increasing of capture amount per haul occurred by vessel that had been operated less than 10 years, vice versa, regardless the vessel size. Besides, during the research period, Barani also concluded that the effective vessel size to be operated in shrimp trawling fisheries is 100 – 200 GT. While vessel with GT more than 300 will cause lost about US$ 25.5 million annually. Besides, the recent development of trawl fishing using small vessels of 20–30 GT based in the Aru Islands contributed to the decline of the shrimp stock in the western part of the Arafura Sea. Government technical policy should reduce the number of trawl to a half amount of the existing trawl vessel in this time.

1.3. Closure Season and Closure Area

The management of fishing activity can be improved by introducing area or seasonal closures, particularly in locations that are nursery grounds for juvenile fish and other animals. Once the closure is in place and fishing is prohibited no by-catch will be (legally) caught. Closures also afford total protection to all by-catch while they remain within closed areas; it is unlikely that BRDs will ever achieve an equal level of protection. Closure systems have been commonly used option in many countries because it is immediately effective. Since the systems are effective in protecting by-catch, their use as a management tool will be increasingly common.

Given that the spawning ground and nursery ground are clearly recognized, the closure area system or restriction on shrimp trawling season can be applied. Grafton et al (2006) mentioned that some states in Australia has been imposing closure area for shrimp trawling activities in order to let the shrimp juveniles grow to the marketable size. The same system could be imposed in Arafura Sea as well. The spawning seasons of shrimp have been researched by fisheries biologists, where mostly in the area within 12 miles from coastline, then in those seasons the areas are temporarily prohibited for fishing activities and allowed to be fished after the spawning season is elapsed.

Considering the existing fishing zone in Arafura Sea regulated by Ministry of Agriculture Decree No. 392 year 1999, the Fishing Zone I and Fishing Zone II, identified as shallow waters that are mostly spawning ground and nursery ground, are not allowed for trawl vessel. However, this requires effective Monitoring, Control and Surveillance (MCS) as a guarantee in protection of the long-term health of the fishery and ecosystem.

1.4. Environmentally Friendly Trawl Net (optimum BRD)

In most cases, as reported by Eayrs (2007), trawl deployment will not be affected by a TED or BRD and the time taken to shoot the trawl away should not change. However, fishermen must be careful to ensure that the codend is not twisted when the trawl is deployed. This may prevent the passage of shrimp through the codend and they may be lost through the escape openings of the device. By watching the device and visible floats as the trawl is being deployed, a fisherman can see if the codend is twisted and rectify the problem without wasting a tow. Increasing vessel speed before deployment may cause the device to sit up higher in the water and better indicate if the codend is twisted. It may also flop to one side but will usually correct itself once the trawl has been deployed. Care must be taken to ensure that turbulent wash generated by the trawler at higher speeds does not cause the TED or BRD to flip over (Eayrs, 2007).

Table 10. A summary of the important tips to optimize BRD performance (Eayrs, 2007)

BRD Component	**Improvement Tips**
BRD Size	A large BRD will allow large escape openings to be used. The number of escape openings may also be increased.
Location and attachment	If located in the codend, the BRD must be close enough to the accumulated catch for fish to escape, but not too close that shrimp loss is high. The BRD should be securely attached to the trawl and correctly orientated
Escape opening	The size of the escape opening(s) determines the size of the by-catch that can escape.
Guiding panel or funnel	They are used to guide shrimp away from the escape openings as they pass throughthe codend. They must not block the escape openings of the BRD.
Flotation	Floats assist BRD stability and orientation. They must not block the escape openings of the BRD.
Backwash funnel	These funnels prevent shrimp loss as the trawl is hauled, particularly in bad weather. They must not be located in a position where they can block the escape openings of a BRD.

The development of effective BRDs is also required to further reduce by-catch. In the near future improvements will be made as fishermen gain more experience in the use and operation of current

BRD designs. This will include better selection of a device to suit the fishing ground and improved positioning in the codend[2]. The selection of appropriately sized escape openings and good maintenance will also go a long way to optimizing the performance of these devices. However, research has found that TED performance is not consistent in all areas of a fishery and that performance can deteriorate with time. This has made the task of optimizing TED performance difficult, and highlights the need to seek expert assistance until experience and knowledge is gained.

The Southeast Asian Fisheries Development Centre (SEAFDEC), an inter-governmental organization who has developed and tested several TED and BRD designs, has improved a Juvenile and Trash Excluder Device (JTED) and has tested it widely throughout the region with good success. They have also developed a specialized TED to better suit local fishing conditions called a Thai Turtle Free Device (TTFD). Several countries in Southeast Asia, including Indonesia has been working toward the mandatory introduction of TEDs into their shrimp trawl fisheries to reduce turtle capture. This TTFD has been proven as the most effective BRD using in Malaysia, Brunei and Philippine.

A well-designed and maintained BRD should ensure that fish and other by-catch is rapidly excluded from the trawl and that shrimp loss is minimal or non-existent. This technology development should

---

2 The first steps in reducing by-catch is to identify the type of by-catch to be excluded. This is followed by selection of an appropriate by-catch reduction device. Some are less common option used to reduce a particular type of by-catch. Further reading, see Eayrs, 2007

be publicly informed so that the community recognizes that the improved design of BRD do not affect the trawl operations.

The environmentally friendly fishing by trawl operation should be based on the study of trawl selectivity especially when it is conducted in highly exploited areas. Thus, a technically and biologically effective trawl is able to be invented

Negative impact of by-catch discard as explained above can be reduced by implementation of management policy which planned well and supported by all stakeholders. The management needs to be considered and fully power-driven by government as its responsibility on sustainable fisheries in Arafura Sea as well as world's pressure to follow the code of conduct for responsible fisheries, namely minimize the discards and maximize the utilizing of by-catch

1.5. Obvious Fishing Zone Boundaries

Given the consideration on boundary delimitation above, the fishing zone should have clear boundaries in unambiguous geographical position so that the trawl operators have same perception and the MCS system can be more effectively taken place. Therefore, regarding the regulation of fishing zone in Arafura Sea based on 10 m isobaths line and the reference of 12 miles of coastline, trawlable area is suggested to be referred on these 2 rules:

1. In case of 10 m isobaths line is exist beyond 12 miles from the coastline, thus the area less than 10 m in depth is closed for shrimp trawling

2. In case of 10 m isobaths line is exist within 12 miles from the coastline, thus the area within 12 miles line is closed for shrimp trawling

The management of shrimp trawling in Arafura Sea includes delimitation on shrimp trawling boundary which remain unclear for some stakeholders as well as the trawl operators. To diminish the impact of obscurity in trawling boundary, that frequently result a conflict between trawl operators, there is a need to provide comprehensible boundary such as the line linear to longitude and latitude line such shown in Figure 11. However, this delimitation needs more research involving the related stakeholders.

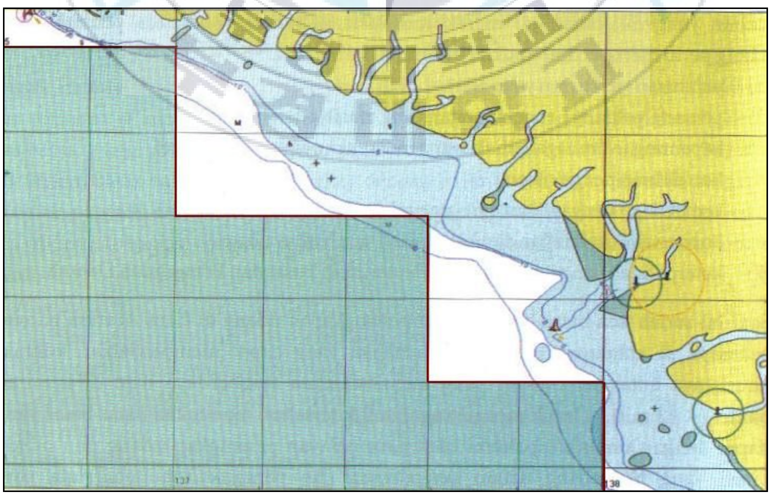


Figure 11. The illustration of trawling management area in Arafura Sea: Trawls are allowable in green area. The south and north boundaries are linear to longitude and latitude line.

1.6. Enforcing Regulation through Co-management System

The Indonesian government has taken measures in monitoring and controlling in Indonesia waters regarding the suitable preservation of fisheries resources and environment, the sustainability of fisheries as well as the development. However, all parties related to fishing activities in Arafura Sea are important to play roles correctly in the fisheries management as well.

The MOMAF, as a National Fisheries Manager should keep giving support for the management initiative taken by local community such as Coordination Forum of Fisheries Resources Utilization, Agency for Fisheries Resource in Arafura Sea, etc. The national managers should prepare the law, which in principle does not allow groups of fishers to se catch limits. They, through the local communities, will also help the fishers design the detail of management measures. This system does not simply depend on the fishers, indeed in many ways the national authorities, MOMAF, will determine whether or not the local system will be succeed.

1.7. Monitoring, Controlling, Surveillance (MCS) System in Fisheries Management of Shrimp Trawling

The application of shrimp trawling technology both traditionally and modernly results on negative impacts towards fisheries resources and environment if the technology is not properly operated. Monitoring, controlling and surveillance program should be continuously and sustainably imposed. This is because community is lack of awareness toward the sustainability of existing fisheries resources and environment, so that there should be strict control toward shrimp trawling activity is necessary for resource sustainability.

1. Institution

Institution function to manage flowing work in each division of a system, thus it can prevent overlapping within internal parts of the system. Institution plays important role in fisheries management system, so that needs to be set appropriately to accommodate interests of all parts in the system.

Ministry of Marine Affairs and Fisheries has main role of policy maker in setting strategy management of fisheries resource, accommodating the needs of all parties based on community aspiration and participatory. The manager of MCS system is the parties who are compulsory to run the management of fisheries resource responsibly. In the field, the manager is Directorate of Monitoring under MOMAF should employ Surveillance Community, Surveillance Inspection, apply remote sensing supported by aircraft, inspection vessel, communicating radio and so on.

One of the problems faced by fisheries management of shrimp trawling in Arafura Sea is low enforcement of regulation. Illegal fishing which take places in many parts of Indonesia waters is an indicator that the country is lack of legal enforcement.

Therefore, it is necessary to prepare law enforcer with good capability and high dedication to law enforcement in Indonesian waters.

2. Technology

MCS system on fisheries resources needs support from many components which one of them is a technology support. The technology for field ground monitoring should be new innovative technology and easy to handle in the field. The technology can be applied for monitoring in Arafura waters such as Vessel Monitoring System (VMS), a new technology applied for fisheries monitoring. It works based on principle of Global Positioning System (GPS) by identifying the position of vessel through a transmitter sending a signal to satellite. By employing VMS, the vessel movement can be detected in a screen in the Monitoring Centre. Another technology development is Integrated System of Information and Database, under which MCS can be carried on by collecting information from local fisheries agency reports at Fish Unloading Site, fishing license, harbour and other institutions.

3. Funding

Without enough funding support, MCS system can not be run optimally, thus funding source for MCS implementation should be considered. In this term, Indonesia government needs to spend big amount of budget for this program.

The implementation of MCS system in fisheries management in Arafura Sea basically aims to guarantee the sustainability of fisheries resources and the ecosystem. Although there are many regulation imposed in the management of shrimp trawling by provincial government and central government, but obedience of fishery industrialists and trawl vessel crews to follow the regulation is very low. Therefore, the MCS system should be continued more structurally.

For its success, the synergic cooperation between related stakeholders involves MOMAF, Indonesian Navy Army, related institutions (harbor master, sea police, community groups, and so on) is necessary. In the field practice, enough monitoring tools and budgets are needed so the MCS program can be well prolonged.

From government budget through MOMAF, some monitoring vessels have been operated for monitoring fishing activities in Arafura Sea. However, amount of the monitoring vessel and the personnel are very limited compare to the area of Arafura Sea. Nevertheless, the monitoring activity can be collaborated with the monitoring program by Navy Army whose equipments for supporting the implementation of MCS in the field. By collaborating two activities, operational cost can be reduced and the effectiveness of MCS implementation can be increased.

By attaching an observer in each fishery company operating shrimp trawl in Arafura Sea, the MCS is expected to be more effective. However, the success of MCS implementation badly depends on a commitment from all stakeholders to be seriously and responsibly run the program. Financial support from government and wholehearted awareness of shrimp trawl operators in Arafura Sea is absolutely needed.

Strengthen MCS system is proven to be the effective way to reduce pressure from illegal fishing, moreover this also a reason in increasing non-tax income of Indonesian Government fisheries during 2001 – 2003 when MCS started to be employed in fisheries management.

2. Recommendations

Management of fisheries resource is growingly needed nowadays and getting more attention. Fisheries as an uncertain resource since its biological characteristic and the exploitation manner that is tend to be "open access" and "common properties" is a challenge. Here is proposed some recommendations for but not limited to fisheries management of shrimp trawling in Arafura Sea which is possible to be applied in many fisheries as well.

1. Reconsider the existence of resource rights. This right has historical root in coastal community tradition, although many of them are less powerful or disappear because of various national policies. In the colonial time, Dutch strengthened these traditional rights in a law of 1939 which aimed to protect fishermen and conservation of fisheries resources. In the first president periode, the president also strengthened the existence

of traditional rights through Basic Agrarian Law in 1960. The current regional autonomy of decentralization system is a significant opportunity to reconsider the traditional rights to be involved in setting fisheries management.

2. An incentive for conservation and rehabilitation of fisheries resource through stock enhancement and habitat rehabilitation. Mass production of fries is a key to enhance the stock and to develop aquaculture industries. The program of enhancing stock is limited and habitat rehabilitation gets more attention for example by holding Coral Reef Rehabilitation and Management Program (COREMAP)[3] supported by international funds.

3. Scarcity of fisheries resource will complicate fishermen to improve their quality of life and the fragility of environment is going along with poverty. While fisheries development is oriented solely to achieve its target, the group based enterprises such as aquaculture, fish processing, tourism, as well as woman based enterprises become a social capital to integrate fisheries into rural development thoroughly. Indeed, there are many methods and concepts in fisheries management which need to be developed and improved. Sense of urgency and political will especially from Government of Indonesia to sustainably build the industries is one of the keys.

---

[3] COREMAP is a long-term program initiated by the Government of Indonesia with the objectives to protect, rehabilitate, and achieve sustainable use of the Indonesian coral reefs and their associated ecosystems which, in turn, enhance the welfare of the coastal communities

3. Limitations of this study and future suggestions

In the process of developing bioeconomic models for the shrimp trawling in Arafura Sea, flawed data has disturbed the analysis. Fishing effort data are insufficient; the MOMAF census are not included detailed fishing effort data of trawl such as fishing days, haul numbers for each engine power classes but only for simple number of trawl vessel, total tonnage of all fishing vessel and total fishing trip data are only available from year 2002. In addition, there is a possibility of misreporting in catch data, since it obtained from a trade repot at fishing ports and fishing villages, but there is lack of data contribution from industrial fishing vessels. In addition, Illegal, Unreported and Unregulated (IUU) fishing activity make the data more invalid.

This study focused on single species stock; however, in marine ecosystem, all species has each function within, and they are dependent on each other, communities of differing complexity in terms of the number of species. Therefore, harvesting a single species has impacts on others, either through technological interactions such as the incidental capture of other species during fishing, or through food chain effects such as reducing the abundance of a predator, prey or competitor of other species through fishing. The impact on ecological linkages between species, may lead to changes in species dominance and affect the dynamic equilibriums of the resource system, potentially affecting future options. These multi species effects need to be considered in bio-economic analysis.

AKNOWLEDGEMENT

I would like to express my gratitude to all those who gave me the possibility to complete this thesis, especially to my advisor, Dr. Sang-Go Lee for his advice and encouragement throughout my study.

I had good opportunity to learn surplus production models with Dr. Hee-Dong Pyo and got helpful remarks from Dr. Jong-Hwa Choi as well. My special thanks extended to Dr Song-Yun Hong (Professor Emeritus from Department of Marine Biology) for the much-needed advice and encouragement since I met him in August 2005.

I want to thank to Ms. Min-ji Kim, Ms. Chun-Bong Jang, Mr. Jin-Ho Jung, Ms. Chun-Yeong Choi, Ms. Jin-Hee Yoo, Ms. Ji-Eun An, Mr. Joo-Nam Seo, Mr. Hyeok-Joon Kwon, Ms. Kyeong-Hwa Lee, Ms. Jeong-Ah Park, the member of graduate student office of Marine Business and Economic Division, for their support during my study in PKNU. I am also indebted to all members of Aquaculture Engineering Laboratory, Lilik Teguh Pambudi, Dicky Harwanto, Sang-Jun Choi and Ho-June Min, who always being like my family.

Finally, I would like to dedicate this effort to my parents who love me eternally and always pray for me.

REFERENCES

Allsopp, W.H.L. "Use of fish by-catch from shrimp trawling: future development. In: Fish by-catch bonus from the sea". Report of the technical consultation on shrimp by-catch utilization. Georgetown, Guyana, 27–30 October 1981, IDRC-198e, IDRC, Ottawa (1982), pp. 29–36. 1982.

Alverson, D.L., Freeberg, M.H., Pope, J.G. and Murawski, S.A. "A Global Assessment of Fisheries By-catch and Discards". FAO Fisheries Technical Papers T339, Rome, 233 p. 1994.

Badrudin dan Karyana,. "The composition of shrimp trawl by-catch in Moluccas – Irian waters (in Indonesian)". Journal of Marine Fisheries Research No. 79. Balitkanlut, Jakarta:14-23. 1993.

Bailey, C. "Lesson's from Indonesia's 1980 trawler ban". Marine policy Vol 21. No. 3. Elsevier Science Ltd. 1997

Blaber, S. J. M., D. P. Cyrus, J.-J. Albaret, Chong Ving Ching, J. W. Day, M. Elliott, M. S. Fonseca, D. E. Hoss, J. Orensanz, I. C. Potter and W. Silvert.. "Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems". ICES Journal of Marine Science57 pp 590-602. 2000.

DG (Directorate General) Capture Fisheries. "Reducing the impact of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices in the Arafura Sea, Indonesia". Technical report on Tropical shrimp fisheries and their impacts on living resources. Food and Agriculture Organisation of the United Nations, Rome. 2001.

Charles, A.T. “Sustainable Fishery System. Blackwell Science”. London, UK. 2001

Clarke, R.P., Yoshimoto, S.S. and Pooley, S.G. “A Bioeconomic Analysis of the Northwestern Hawaiian Islands Lobster Fishery”. Marine Resource Economic vol. 7 pp115-140.1992.

Curtis, H.C. and Myers, M. “Economic comparison of single-rig and twin-rig trawl for Nephrops. Seafish Economics”. Edinburgh, UK. 2006.

Dwiponggo, A. “Indonesia’s Marine Fisheries Resources” In Indonesian Marine Capture Fisheries [Bailey, Dwiponggo and Marahudin Eds]. International Center for Living Aquatic Resources management, Directorat General of Fisheries, Ministry of Agriculture, Indonesia.1991.

Eayrs. “A Guide to by catch reduction in tropical shrimp fisheries”. FAO, Rome. 2007.

EJF (Environmental Justice Foundation). “Squandering The Seas, How shrimp trawling is threatening ecological integrity and food security around the world”. Environmental Justice Foundation. London, UK. 2003.

Evans, S.M., Wahju, R.I. “The Shrimp Fishery of the Arafura Sea (eastern Indonesia)”. Fisheries Research 26.pp 365 – 371. 1996.

FAO, “FAO Techincal Guidelines for Responsible Fisheries”. FAO, Rome. 1997.

Fegan, B. Plundering the Sea. “Regulating trawling companies is difficult when the navy is in business with them”. Inside Indonesia 73rd edition. January – March 2003. http://insideindonesia.org/content/view/339/29/

Gordon, H.S. “The economic theory of a common property resource: the fishery”. J. Polit. Econ. 62, pp. 124–142.1954.

Grafton, R. Quentin, Kirkley, J., Kompas T., Squires D. “Economic for Fisheries Management”. Ashgate Publishing Ltd. Hampshire, England. 2006.

Iskandar, B., Sumiono, B. and Sarjana. Study on Shrimp Potency and By-catch species in Mollucas and Papua water (unpublished). 1993.

Jones J.B.. Environmental Effect of Trawling on the Seabed: “A Review. New Zealand Journal of Marine and Water Research”. Volume 26: pp.59-67. 1992.

King, M. “Fisheries biology, assessment and management”. Oxford, Fish News Books. Blackwell publishing. 1995

Martosubroto, P. “Implementing of the Code of Conduct for Responsible Fisheries in the Marine Fisheries Sector”. International Law Institute, Jakarta, International Law Journal, Vol 2, No. 3, April 2005.

Monintja, D., Sularso, A., Sondita, M. F. A., Purbayanto, A. (eds). “A Perspective of Capture Fisheries Resource in Arafura Sea (in Indonesian)”. Departemen Sumberdaya Perikanan-Institut Pertanian Bogor. Bogor, Indonesia. 2006.

MOMAF. Indonesian Fisheries Book. MOMAF and JICA. Jakarta. 2007.

Mous, P.J., Pet, J.S., Arifin, Z., Djohani, R., Erdmann, M.V., Halim, A., Knight, M., Pet-Soede, L. and Wiadnya G. Policy needs to improve marine capture fisheries management and to define a role for marine protected areas in Indonesia. Fisheries Ecology and Management Vol. 12: pp. 259. 2005.

NFSC(Northeast Fisheries Science Center). “Fisheries Technical Terms”. 2003. http://www.nefsc.noaa.gov/techniques/tech_terms.html

Naamin, N. dan Sumiono, B. “By-catch species of shrimp fishing in Arafura Sea and surrounding waters (In Indonesian”). Project Report. LPPL No. 24/1982. BPPL, Jakarta: pp. 45-55. 1983.

Purbayanto A. et al. “Technical guide in planning for management and utilization of shrimp trawl by catch in Arafura Sea”. Fisheries Agency of Papua Province and PT. SUCOFINDO, Jakarta. 68p. 2004.

Pyo, Hee-Dong. An Economic Valuation of Tidal Wetlands in Korea. PhD Dissertation. University of Portsmouth, UK. 2001.

Sardjono, I. “Trawlers banned in Indonesia”. ICLARM Newsletter 3(4):3. 1980.

Sheppard, C. “Trawling the sea bed”. Marine Pollution Bulletin 52 (2006) 831–835. 2006.

Smith, E.M., and L.L. Stewart. “A study of lobster fisheries in the Connecticut waters of Long Island Sound with special reference to the effects of trawling on lobsters”. Connecticut Department of Environmental Protection Marine Fisheries Program, University of Connecticut, Hartford, CT. 1985.

Stephan, C. et al. “Evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies”. ASMFC Habitat Management Series #5, ASMFC, Washington DC. 2000.

Widodo, J., By-catch assessment of the shrimp fishery in the Arafura Sea and its adjacent waters. Journal of Marine Fisheries Research No. 63/1991. Balitkanlut, Jakarta: pp. 43-49. 1991.

http://statistik.dkp.go.id/

http://dkp.go.id/

Appendix 1. Species caught by shrimp trawl in Arafura Sea

No	Family name	English name	Percent
1	Leighnathidae	Pony fish	44.39
2	Engraulidae	Anchovy	6.49
3	Haemulidae	Grunts	6.28
4	Dasyatididae	Stingray	5.55
5	Clupeoid	Sardines	4.16
6	Sciaenidae	Croaker, jewfish	4.19
7	Maullidae	Goat fish	2.19
8	Lactaridae	False trevallies	2.05
9	Synodontidae	Lizard fish	2
10	Trichiuridae	Hairtails	1.78
11	Drepanidae	Sicklefish	1.65
12	Shark		1.53
13	Ariidae	Cat fish	1.2
14	Polynemidae	Threadfin	1.19
15	Carangidae	Jack mackarels	1.12
16	Centropomidae	Gulper sharks	0.78
17	Crabs		0.73
18	Lutjanidae	Snapper	0.6
19	Soleidae	Flatfish	0.51
20	Sphyraenidae	Barracuda	0.48
21	Cuttle	Sepiidae	0.48
22	Harpadontidae	Nomei	0.42
23	Squids		0.29
24	Salangidae	Icefish/noodlefish	0.28
25	Scrombidae	Tuna/mackerel	0.26
26	Muraenesocidae	Conger	0.22
27	Theraponidae	Grunters	0.1
28	Platycelphalydae	Flathead	0.07
29	Nemipteridae	Threadfin breams	0.07
30	Gerreidae	Mojarra	0.04
31	Menidae	Moonfish	0.02
32	Chirocentridae	Herring	0.01
33	Rachycentridae	Cobia	0.01
34	Lobster		0.07
35	Snake		0.11
36	Invertebrate		0.05
37	Shrimp		7.27
38	Turtle		0.6

Source : Mahiswara & Widodo (2005) and fishbase.org

Appendix 2. Number of Shrimp and Other Crustacean Production

Year	Province	Shrimp					Other Crustacea		
		Endeavour shrimp	Spinny Lobster	Tiger Shrimp	White Shrimp	Others	Crab	Small Crab	Others
2006	Arafura Sea	2024	682	8353	5994	3475	784	241	64
2005	Maluku	-	95	328	263	244	238	207	31
	Papua	404	77	2,794	4,078	470	551	6	-
	Irian jaya	2,200	529	5,619	2,297	1,752	31	33	-
	Total	2,604	701	8,741	6,638	2,466	820	246	31
2004	Maluku	-	49	368	231	6,099	88	48	3
	Papua	2,572	605	5,827	4,798	2,182	563	37	-
	Total	2,572	654	6,195	5,029	8,281	651	85	3
2003	Maluku	-	22	10	-	5,718	74	78	4
	Papua	2,589	596	7,670	2,797	2,325	433	35	-
	Total	2,589	618	7,680	2,797	8,043	507	113	4
2002	Maluku	11	11	-	-	4,327	91	56	2
	Papua	2,612	592	7,667	2,711	2,265	210	34	-
	Total	2,623	603	7,667	2,711	6,592	301	90	2
2001	Maluku	1,041	2	1,020	2,066	1,055	102	89	58
	Papua	4,426	592	7,740	4,835	2,092	91	35	-
	Total	5,467	594	8,760	6,901	3,147	193	124	58
2000	Maluku	1,441	18	2,049	4,928	1,857	266	310	-
	Papua	2,287	267	7,788	2,900	1,469	80	25	-
	Total	3,728	285	9,837	7,828	3,326	346	335	
1999	Maluku	1,441	18	2,049	4,928	1,857	266	310	4
	Papua	2,248	257	3,372	2,938	1,719	134	63	83
	Total	3,689	275	5,421	7,866	3,576	400	373	87

Appendix 3. Number of Fishing Vessel according to the Gross Ton

Year	Province	Unmotorized Boat				Outboard Engine Vessel	Inboard Engine Vessel							
		Dug-out boat	Wooden boat				< 5 GT	5-10 GT	10-20 GT	20-30 GT	30-50 GT	50-100 GT	100-200 GT	>200 GT
			Small	Medium	Large									
2006	Papua	29854	5489	1652	425	1838	365	141	93	41	1	1	-	-
	Irian	8756	6574	3152	793	2964	244	240	191	57	3	8	2	-
	Total	38610	12063	4804	1218	4802	609	381	284	98	4	9	2	0
2005	Papua	30,884	6,285	1,609	627	3,251	418	266	99	41	2	1	2	-
	Irian	9,003	7,800	2,399	935	2,444	223	197	237	80	3	10	2	-
	Total	39,887	14,085	4,008	1,562	5,695	641	463	336	121	5	11	4	1
2004	Maluku	28,978	5,378	1,216	272	1,792	255	119	65	37	2	-	3	-
	Papua	12,953	10,283	3,286	1,555	4,091	308	376	431	224	3	24	3	1
	Total	41,931	15,661	4,502	1,827	5,883	563	495	496	261	5	24	6	1
2003	Maluku	29,372	5,762	1,162	321	1,738	245	134	75	40	30	170	45	5
	Papua	12,165	10,333	2,822	1,550	3,970	269	434	322	226	260	227	250	250
	Total	41,537	16,095	3,984	1,871	5,708	514	568	397	266	290	170	295	255
2002	Maluku	17,530	1,894	655	163	994	131	54	56	57	51	198	165	26
	Papua	11,547	10,258	2,761	1,542	3,748	255	380	291	207	234	257	239	168
	Total	29,077	12,152	3,416	1,705	4,742	386	434	347	264	285	455	404	194
2001	Maluku	20,709	1,621	1,033	117	968	146	66	113	66	2		5	6
	Papua	11,390	9,982	2,625	1,539	3,574	202	370	288	201	5	19	2	6
	Total	32,099	11,603	3,658	1,656	4,542	348	436	401	267	7	19	7	12

Appendix 4. Summary of Bio economic analysis

Model	R square	adjusted R square	F ratio	Significance F	D W Statistic	Collinearity Statistic	Indpndnt variables	Coefficient	t statistic	P value (5%)
Schaefer	0.05006	-0.18742	0.21081	0.814288399	1.897	T=0.219	Constant	0.2564844	0.28661	0.78169
						VIF=4.574	CPUE	-0.002169	-0.20857	0.84000
							Effort	-0.000383	-0.47189	0.64961
Fox	0.05564	-0.18045	0.23568	0.795331156	1.905	T=0.120	Constant	0.9511065	0.32725	0.75188
						VIF=8.349	CPUE	-0.188792	-0.30168	0.77059
							Effort	-0.000543	-0.49648	0.63291
Schnute	0.06265	-0.14565	0.30078	0.747400893	2.682	T=0.141	Constant	0.8037109	0.56307	0.58714
						VIF=7.116	CPUE	-0.009358	-0.50275	0.62721
							Effort	-0.0008	-0.68748	0.5091
WH	0.47745	0.36133	4.11168	0.053896444	2.396	T=0.291	Constant	1.900313	2.80519	0.02054*
						VIF=3.431	CPUE	-0.023743	-2.71979	0.02093*
							Effort	-0.00164	-2.70106	0.00243*
CYP	0.87117	0.84254	30.4304	9.8865E-05	2.05	T=0.278	Constant	6.31454	0.00034	0.00034*
						VIF=3.596	CPUE	-0.392553	0.15229	0.15229
							Effort	-0.001069	0.00046	0.00046*

Note: * = significant at 5% level

Summary of Bio economic analysis (continued)

Model	Independent variables	Coefficient	Std error	r	q	k	Emsy	Cmsy
Schaefer	Constant	0.2564844	0.89489	0.256484	0.000383	308823.5543	334.862	19,802.11
	CPUE	-0.002169	0.0104					
	Effort	-0.000383	0.00081					
Fox	Constant	0.9511065	2.9064	0.18879	0.00054	283391.0491	347.834	19,682.25
	CPUE	-0.188792	0.6258					
	Effort	-0.000543	0.00109					
Schnute	Constant	0.8037109	1.42737	0.80371	0.0008	1077328.9314	502.181	21,565.36
	CPUE	-0.009358	0.01861					
	Effort	-0.0008	0.00116					
WH	Constant	1.900313	0.67743	1.90031	0.00164	48792.6854	579.232	23,180.34
	CPUE	-0.023743	0.0085					
	Effort	-0.00164	0.00061					
CYP	Constant	6.31454	5.59234	4.589786	0.007047	13198.1911	651.313	22,284.99
	CPUE	-0.392553	-1.56384					
	Effort	-0.001069	-5.35924					

Appendix 5. Schaefer Model

Year	CPUE	Effort	Y	Un	En
95	49.55	375	0.03833001	49.55	375
96	46.59	381	0.31278667	46.59	381
97	78.69	323	-0.0425029	78.69	323
98	39.90	542	-0.6305788	39.90	542
99	28.38	741	-0.1104039	28.38	741
00	33.63	744	0.0563528	33.63	744
01	32.17	772	-0.112495	32.17	772
02	26.40	765	-0.0949187	26.40	765
03	27.15	775	0.02501396	27.15	775
04	27.75	819	-0.0714125	27.75	819
05	23.19	912	-0.1832094	23.19	912

$$Y = \frac{\overline{U}_{n+1} - \overline{U}_{n-1}}{2\overline{U}_n}$$

Regression Statistics	
Multiple R	0.223749
R Square	0.050064
Adjusted R2	-0.187421
Std Error	0.247282
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	Durbin Watson
Regression	2	0.0257811	0.01289055	0.2108079	0.8142884	1.89690907
Residual	8	0.4891866	0.06114832			
Total	10	0.5149677				

	Coefficients	*Std Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*	*beta*	*Collinearity*	
										Tolerance	VIF
Intercept	0.256484	0.8948896	0.28661011	0.78169348	-1.80713471	2.32010352	-1.8071347	2.32010352			
Un	-0.002169	0.0103976	-0.2085711	0.83999557	-0.02614543	0.02180817	-0.0261454	0.02180817	-0.15371	0.2186316	4.573903
En	-0.000383	0.0008116	-0.4718863	0.64961078	-0.00225446	0.00148852	-0.0022545	0.00148852	-0.34776	0.2186316	4.573903

Appendix 6. Fox Model

Year	CPUE	Y	ln Un
95	49.55	0.03833001	3.9029688
96	46.59	0.31278667	3.8413414
97	78.69	-0.0425029	4.3655605
98	39.90	-0.6305788	3.6863393
99	28.38	-0.1104039	3.3455144
00	33.63	0.0563528	3.5155096
01	32.17	-0.112495	3.4709039
02	26.40	-0.0949187	3.2732155
03	27.15	0.02501396	3.3015553
04	27.75	-0.0714125	3.3234008
05	23.19	-0.1832094	3.1437552

$$Y = \frac{\overline{U}_{n+1} - \overline{U}_{n-1}}{2\overline{U}_n}$$

Regression Statistics	
Multiple R	0.235884
R Square	0.0556413
Adjusted R2	-0.1804484
Std Error	0.2465548
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	Durbin Watson
Regression	2	0.02865346	0.0143267	0.2356785	0.79533116	1.9047969
Residual	8	0.48631421	0.0607893			
Total	10	0.51496767				

	Coefficients	*Std Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*	*beta*	*Collinearity* Tolerance	VIF
Intercept	0.9511065	2.90640154	0.3272454	0.751881	-5.75106746	7.65328044	-5.7510675	7.6532804			
ln Un	-0.1887918	0.62580478	-0.3016784	0.7705905	-1.6319002	1.2543166	-1.6319002	1.2543166	-0.29948	0.1197819	8.34851
En	-0.0005428	0.00109323	-0.4964793	0.6329091	-0.00306375	0.00197822	-0.0030637	0.0019782	-0.49287	0.1197819	8.34851

Appendix 7. Schnute Model

$$Y = \ln\left(\frac{\overline{U}_{n+1}}{\overline{U}_{n}}\right)$$

Year	CPUE	Effort	Y	(Un+(Un+1))/2	(En+(En+1))/2
94	42.79	342	0.1466767	46.1694035	358.5
95	49.55	375	-0.0616274	48.0686299	378
96	46.59	381	0.5242191	62.6407125	352
97	78.69	323	-0.6792212	59.2960112	432.5
98	39.90	542	-0.3408249	34.1368463	641.5
99	28.38	741	0.1699952	31.0041166	742.5
00	33.63	744	-0.0446058	32.8994338	758
01	32.17	772	-0.1976884	29.2809408	768.5
02	26.40	765	0.0283398	26.7754586	770
03	27.15	775	0.0218456	27.4547087	797
04	27.75	819	-0.1796456	25.4726841	865.5
05	23.19	912	-0.1858787	21.2239126	989

Regression Statistics	
Multiple R	0.25030405
R Square	0.06265212
Adjusted R2	-0.1456474
Std Error	0.31662525
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	Durbin Watson
Regression	2	0.060307113	0.0301536	0.30077897	0.74740089	2.681504397
Residual	9	0.902263915	0.1002515			
Total	11	0.962571028				

	Coefficients	*Std Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*	*beta*	*Collinearity*	
										Tolerance	VIF
Intercept	0.80371092	1.427371111	0.5630707	0.58713788	-2.42522686	4.032648694	-2.4252269	4.032648694			
(Un+(Un+1))/2	-0.0093578	0.01861324	-0.5027496	0.627212	-0.05146387	0.032748276	-0.0514639	0.032748276	-0.43281	0.14053	7.11591
(En+(En+1))/2	-0.0008002	0.001163982	-0.687485	0.50910435	-0.00343333	0.00183289	-0.0034333	0.00183289	-0.59184	0.14053	7.11591

Appendix 8. Walter & Hilborn Model

$$Y = \frac{\overline{U}_{n+1}}{\overline{U}_{n}} - 1$$

Year	CPUE	Y	Un
94	42.79	0.1579795	42.79
95	49.55	-0.059766835	49.55
96	46.59	0.689139319	46.59
97	78.69	-0.492988306	78.69
98	39.90	-0.288816581	39.90
99	28.38	0.185299192	28.38
00	33.63	-0.043625564	33.63
01	32.17	-0.179374495	32.17
02	26.40	0.02874519	26.40
03	27.15	0.022085937	27.15
04	27.75	-0.164433743	27.75
05	23.19	-0.169625697	23.19
06	19.26		19.26

Regression Statistics	
Multiple R	0.74640063
R Square	0.5571139
Adjusted R2	0.46853668
Std Error	0.28409313
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	Durbin Watson
Regression	2	1.015250985	0.5076255	6.289584448	0.0170396	2.396
Residual	10	0.80708908	0.0807089			
Total	12	1.822340065				

	Coefficients	*Std Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*	*beta*	*Collinearity*	
										Tolerance	VIF
Intercept	2.45367701	0.7709376	3.182718	0.009774235	0.735921	4.171433023	0.735921	4.171433			
Un	-0.0283547	0.010025617	-2.8282225	0.017906406	-0.0506931	-0.006016209	-0.0506931	-0.0060162	-1.247	0.291	3.431
En	-0.002306	0.000653272	-3.5298532	0.005448142	-0.0037615	-0.000850374	-0.0037615	-0.0008504	1.206	0.291	3.431

Appendix 9. Clark, Yoshimoto & Pooley (CYP) Model

$$Y = \ln \overline{U}_{n+1}$$

Year	CPUE	Effort	Y	ln Un	(En+(En+1))
94	42.79	342	3.90296881	3.7562921	717
95	49.55	375	3.84134142	3.9029688	756
96	46.59	381	4.36556054	3.8413414	704
97	78.69	323	3.68633933	4.3655605	865
98	39.90	542	3.34551442	3.6863393	1283
99	28.38	741	3.51550965	3.3455144	1485
00	33.63	744	3.47090387	3.5155096	1516
01	32.17	772	3.27321545	3.4709039	1537
02	26.40	765	3.30155525	3.2732155	1540
03	27.15	775	3.32340083	3.3015553	1594
04	27.75	819	3.14375519	3.3234008	1731
05	23.19	912	2.95803041	3.1437552	1978

Regression Statistics	
Multiple R	0.9333661
R Square	0.8711723
Adjusted R2	0.8425439
Std Error	0.1527116
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	Durbin Watson
Regression	2	1.4193235	0.70966177	30.430363	9.8865E-05	2.05
Residual	9	0.2098876	0.02332084			
Total	11	1.6292112				

	Coefficients	*Std Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*	*beta*	*Collinearity* Tolerance	VIF
Intercept	6.31454	1.1291419	5.59233524	0.0003376	3.76024358	8.86883641	3.7602436	8.8688364			
ln Un	-0.392553	0.2510197	-1.5638352	0.1522943	-0.9603995	0.17529257	-0.9603995	0.1752926	-0.3548	0.278099	3.5958451
(En+(En+1))	-0.001069	0.0001995	-5.3592398	0.0004568	-0.0015208	-0.000618	-0.0015208	-0.000618	-1.2159	0.278099	3.5958451

Appendix 10. Comparison between CYP model, WH-model catch and actual catch

Year	Fishing Effort	Actual catch	WH (catch)	CYP (catch)
94	342	14,634	19,292.04	18,814.73
95	375	18,581	20,298.56	19,610.96
96	381	17,750	20,465.40	19,742.03
97	323	25,418	18,644.26	18,295.47
98	542	21,625	23,084.57	21,933.68
99	741	21,026	21,372.33	22,092.13
00	744	25,023	21,304.65	22,079.64
01	772	24,832	20,612.98	21,946.54
02	765	20,193	20,796.06	21,982.53
03	775	21,045	20,532.45	21,930.58
04	819	22,731	19,208.44	21,661.73
05	912	21,150	15,529.68	20,911.82
06	1066	20,528	6,809.92	19,296.00

WH Catch = qkE(1-qE/r)

q= 0.001640374

k= 48792.6854

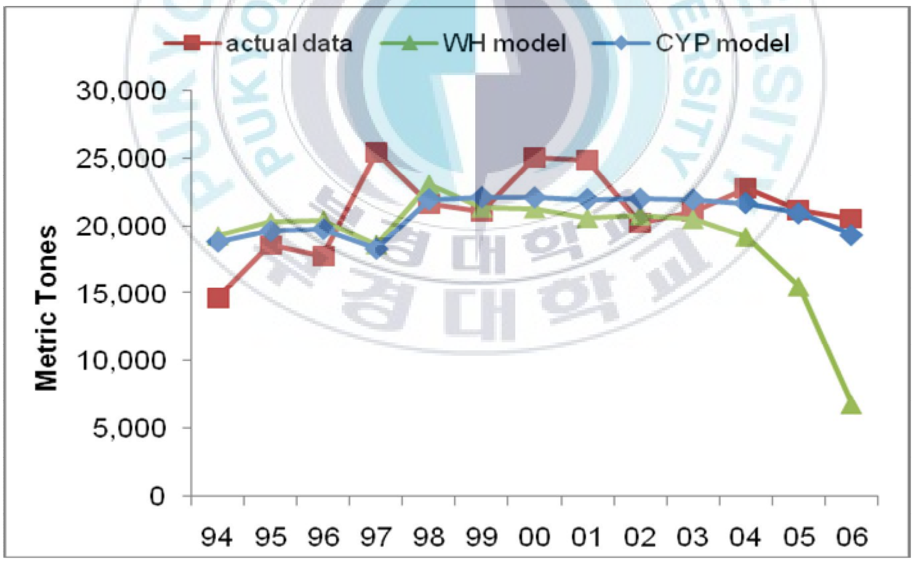
r= 1.90031305

CYP Catch = qkE exp-(q/r)E)

q= 0.007047

k= 13198.1911

r= 4.589786



Appendix 11. Comparison between CYP model, WH-model CPUE and actual CPUE

Year	Fishing Effort	Actual catch	WH (catch)	CYP (catch)	CPUE actual	WH CPUE	CYP CPUE
94	342	14,634	19292.04	18814.73	42.78947	56.40947	55.01384
95	375	18,581	20298.56	19610.96	49.54933	54.12949	52.2959
96	381	17,750	20465.4	19742.03	46.58793	53.71495	51.81635
97	323	25,418	18644.26	18295.47	78.6935	57.72218	56.64233
98	542	21,625	23084.57	21933.68	39.89852	42.59146	40.46805
99	741	21,026	21372.33	22092.13	28.37517	28.84255	29.81395
00	744	25,023	21304.65	22079.64	33.63306	28.63528	29.67694
01	772	24,832	20612.98	21946.54	32.1658	26.70076	28.42816
02	765	20,193	20796.06	21982.53	26.39608	27.18439	28.73534
03	775	21,045	20532.45	21930.58	27.15484	26.49349	28.29752
04	819	22,731	19208.44	21661.73	27.75458	23.45353	26.449
05	912	21,150	15529.68	20911.82	23.19079	17.02815	22.92963
06	1066	20,528	6809.917	19296	19.25704	6.38829	18.10131