BIO-ECONOMIC MODEL AND TECHNICAL EFICIENCY ANALYSIS FOR FAD-ASSOCIATED TUNA FISHERY IN KENDARI FISHING PORT - INDONESIA

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ABSTRACT

The tuna fishery is the most important and by far the predominant fishery in Indonesia. In 2013, total harvests amounted to 1.2 million tons, with a total value of 1.8 billion US dollars. One of the biggest tuna fisheries landing is Kendari fishing port which is in South East Sulawesi – Indonesia with yearly average tuna production of more than 20 thousand tons. The tuna fishing fleet in Kendari use FAD (Fish Aggregating Devices) as an auxiliary fishing gear. FAD management is major issues in Indonesian tuna fisheries, extensive investment on FAD has led to increase of the juvenile and by catch and social problems because of the competition. Two analyses were done during this study, bio-economic and technical efficiency analysis. Bio economic analysis result show that the FAD associated tuna fishery still on a good shape around the MEY level and profitable, this explain the reason behind the extensive investment in new FAD. Mean value technical efficiency was 0.534. Purse seine show the highest mean value compare to other fishing gear. All the variables input show positive relationship to the catch except the days at sea variables, this is a signal that the increasing the number of FAD has made the fisherman spend more time at sea it will decrease the technical efficiency. The results support the FAD regulation done by the government of Indonesia, there is need for strong regulation to regulate the FAD, so the fisheries continue to provide the optimum benefit from the resources.

Keywords: FAD fishery, regulation, extensive investment

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LIST OF ABBREVIATIONS

ACIAR – Australian Centre for International Agricultural Research
CCSBT – Commission for the Conservation of Southern Bluefin Tuna
CPUE – Catch per Unit of Effort
DEA – Data Envelopment Analysis
DGCF – Directorate General of Capture Fisheries
FAD – Fish Aggregating Devices
FMA – Fisheries Management Area
GRT – Gross Registered Tons
IOTC – Indian Ocean Tuna Commissions
MEY – Maximum Economic Yield
MMAF – Ministry of Marine Affairs and Fisheries – Republic of Indonesia
MSY – Maximum Sustainable Yield
OAY – Open Access Yield
RCFMC – Research Centre for Fisheries Management and Conservation
RFMO – Regional Fisheries Management Organization
SFA – Stochastic Frontier Analysis
SFPF – Stochastic Frontier Production Function
SPC. – Secretariat of the Pacific Community
USD – United State Dollar
WCPFC – Western & Central Pacific Fisheries Commission

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1 INTRODUCTION

Indonesia is an archipelagic nation consisting of 13,427 islands, with 95,181 km coastline, located right on the equator between the Indian Ocean and the Western Central Pacific Ocean. It is the second largest fishing nation in the world, with the capture marine fisheries in 2013 totalling 5.7 million tons worth more than 9 billion US dollars (Directorate General of Capture Fisheries, 2013). Indonesia's total capture fisheries production include the inland capture fisheries has increased steadily in recent years, from 4.6 million tons in 2003 to 6.1 million tons in 2013 (Figure 1). More than 93% of the capture fisheries production comes from marine capture fisheries which are dominated by three species' groups; big pelagic (including tuna), small pelagic and demersal fish.

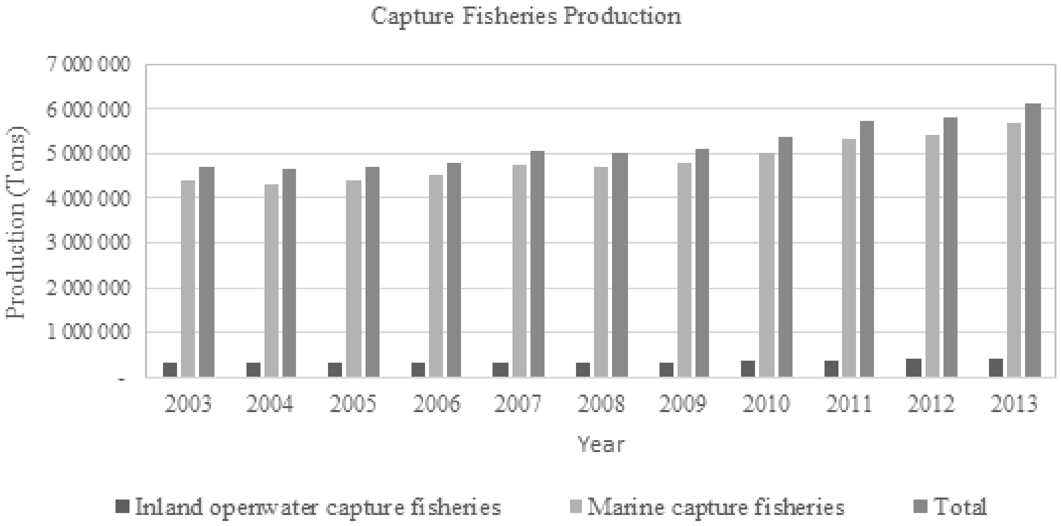

Figure 1. Indonesia's capture fisheries production (Source: DGCF, 2013.)

Indonesia's territorial waters adjoin two of the world's most important fishing grounds for tuna and other large pelagic species, and the nation has been able to take advantage of this position. Currently, six major tuna species are harvested in Indonesia; Southern Bluefin tuna (*Thunnus maccoyii*), Yellowfin tuna (*Thunnus albacares*), Bigeye tuna (*Thunnus obesus*), Skipjack tuna (*Katsuwonus pelamis*), Mackerel tuna (*Euthynnus affinis*) and Albacore (*Thunnus alalunga*). The tuna fishery is the most important and by far the predominant fishery in Indonesia, with total harvests in 2013 amounting to 1.2 million tons, representing 21.7% of the total harvests. Most of the tuna is exported (Directorate General of Capture Fisheries, 2013).

Tuna are highly migratory species and can be found all over the Indian Ocean, from the shores of Africa to the waters off Australia Indonesian tuna resources management is coordinated with those RFMOs (Regional Fisheries Management Organization), the Indian Ocean Tuna Commissions (IOTC), the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) and the Western & Central Pacific Fisheries Commission (WCPFC).

In 2014, total harvests of tuna (yellowfin tuna, big eye tuna and skipjack) in the WCPFC area amounted to 2.7 million tons, with Indonesian WCPFC area catch accounting for 494,503 tons, about 18% of total production (Figure 2).

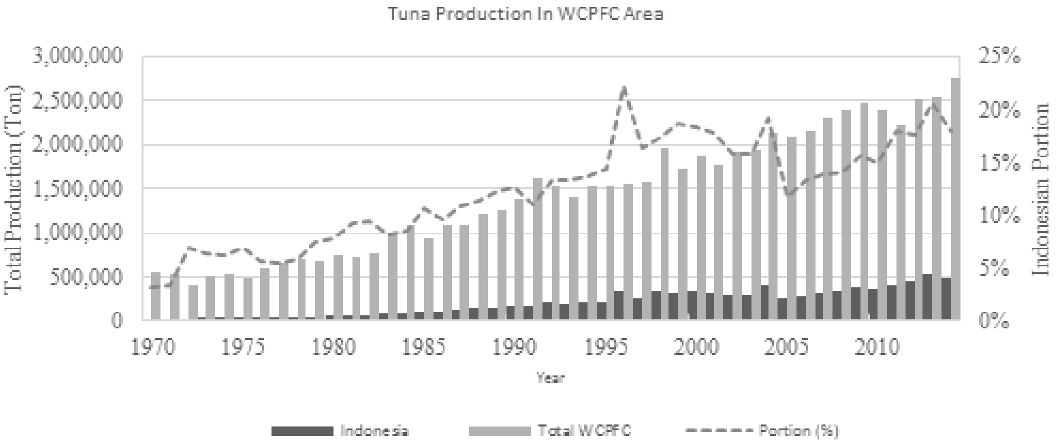

Figure 2. **Tuna catches in WCPFC area share of Indonesia. Source: Western and Central Pacific Fisheries Commission, 2015.**

The tuna fishery in Indonesia is a semi-open access fishery (limited entry) and has been developing over the years. Fishing gear improvements have made the fishing more efficient, the boats have become bigger, with a larger engine and many purse seiners are now equipped with power blocks and deep-freezing technology. Collecting vessel are also used to collect catches from smaller boats, especially those fishing with pole and line, thus enabling them to stay out longer. Anchored FADs (rumpon) have been a significant feature in Indonesia's pelagic fisheries, including tuna, since the 1980s. FAD construction varies regionally, with significant differences between western and eastern Indonesia. The FAD-based fisheries include purse-seine, pole and line, troll-line and hand-line. The increase of the fishing capacity and un-controlled use of the FADs have significantly improved catches, leading in many cases to overexploitation. This is certainly the case for the Indonesian tuna stocks, where juvenile catches have increased considerably. The amount of juvenile tuna caught around FADs, has become an environmental issue and also led to social conflicts. WCPFC has encouraged Indonesia to apply environmentally friendly measures within Indonesia’s archipelagic water (WCPFC, 2011). The government of Indonesia has tried to regulate the FAD through several ministerial regulations (MMAF, 2004; MMAF, 2011; MMAF, 2014), but these have not been fully successful. As a coastal developing state and a member of the RFMOs, Indonesia has to indicate its willingness to cooperate with the tuna RFMOs and ensure compliance to avoid overfishing of its fisheries (Sunoko & Huang, 2014).

Located in South East Sulawesi, Kendari is one of the six biggest fishing ports in Indonesia together with Jakarta and Cilacap in Java, Bitung in Sulawesi, Belawan and Bungus in Sumatera (Figure 3). Average total fish landing in Kendari fishing port for last 5 years from 2010-2014 amounted to 20 thousand tons, whereof average FAD associated tuna fishing fleets landing was 19,5 thousand tons or more than 95% of total catches. The port is an important fishing centre for the more than 77.000 fishers in South East Sulawesi.

The Kendari tuna fishing fleet is dominated by three types of fishing gears; purse seine, pole and line, and troll line. In all cases, FADs are used as an auxiliary fishing gear. Vessels range in size from smaller than 5 gross registered tons (GRT) to 150-200 GRT, and trips lengths vary from 1-day fishing to 2 – 3 weeks. In some fishing regions, transhipment to collecting vessels are common and collaboration of smallholder's partnership scheme (i.e. mitra kolaborasi) is also frequent. FADs are often provided to fishers through Provincial and Regency government assistance programs, but there are also many that are privately installed and privately owned (Natsir & Proctor, 2011).

Figure 3. Location of major fishing ports of Indonesian and a more detailed map of Kendari. Source: DGCF, 2009.

1.1 The Scope of the Project

This project focuses on the FAD associated tuna fishery based in Kendari in South East Sulawesi, Indonesia. The primary aims are two. First, to use a bio-economics model to compare the current semi-open access management (competitive fisheries) to policies that either maximise yield (maximum sustainable yield, MSY) or the economic benefit of the resources rent (maximum economic yield, MEY), as well as to open access equilibrium. Different harvest policies can then be analysed and their effect on fishing effort and profits compared. A bio-economic approach could increase stakeholder awareness and provide guidance to the Indonesian management authorities. The result could also be used as a stepping stone to campaign for better fisheries management at regional level and could therefore increase the role of Indonesian government at RFMO level.

Second, to use stochastic frontier analysis to assess the technical efficiency of the Kendari tuna fishing fleet. To this effect, the Battese and Coelli (1995) model will be used but this model assumes technical efficiency can be directly related to certain explanatory variables and that the efficiency therefore varies between vessels.

This project is important as it will analyze in detail the tuna fishery in Kendari, and the study should also provide useful results for management authorities. The bio-economic model is useful for comparing the profits and catches of the current level of effort with the level that could be attained by a more prudent utilization of the tuna stocks, while the efficiency analysis can be used to determine which boats are most productive.

The results from this study provide detail pictures to support management options for FAD associated tuna fisheries, not only in Indonesia but also in other parts of the WCPFC. Although Kendari is just one of the monitoring areas of the WCPFC, this study results could be presented during FAD working group discussion during the scientific meeting of the RFMO. Thus, it is hoped that the results can be used as inputs from Indonesia during the discussion.

1.2 Goal and Objectives

1.2.1 Goal

Develop a bio-economic model and estimate technical efficiency for the FAD associated tuna fisheries and provide recommendation about fisheries management options and efficiency improvement that maximizes total fishing rents and support sustainable FAD-associated tuna fisheries

1.2.2 Objectives

In order to achieve the goal of this project, five objectives were identified:

1. understanding the status of the FAD associated tuna fishery in Kendari port,
2. understanding socio and economic of the FAD associated tuna fisheries,
3. investigate how the bio-economic models performs for the Kendari tuna fishery,
4. investigate the technical efficiency of the Kendari tuna fishery,

5. develop management options according to biological parameter, level of exploitation, economic model and efficiency improvement for tuna fishery management that maximizes total fishing rents and supports sustainable tuna fisheries in the long term.

There is urgent need for well-constructed and understandable recommendations and strategies related to FAD associated tuna fisheries management in Indonesia to overcome the problems of overexploitation, increasing juvenile tuna catches and the un-controlled use of the FAD. These management options should support sustainable fisheries management and maximize the economic benefit of the resources rent. Constructing bio-economic model that provide a better characterization of the real situation of the fisheries would be an important step to that direction. Further, understanding the difference in the technical efficiency of individual vessels would allow authorities to come up with measures to increase the efficiency of the tuna fishing fleet

2 LITERATURE REVIEW

2.1 Bio economic models

Bio-economic optimization models have been widely used in fisheries policy analysis for more than half a century (Schaefer, 1957, Clark, 1979, Clark & Munro, 1975) This approach constitutes an integrated analysis of biological and ecological aspect of the resources with the economic properties of fishers behaviour, considering space, time and uncertainty dimensions (Anderson & Seijo, 2010), and takes into account the dynamic nature of the exploitation of the renewable resources involved (Clark, 1979). As such, bio-economic models are powerful tools to understand the impact of exogenous factors, natural or economic, on the fisheries dynamics and to aid decision making in fisheries management (Chaboud, 1998). The models can therefore be used as a fisheries and policy analysis tool and to describe the effect changes in fishery condition may have on the biological resources and economic performance of the fleets (Mardle, 2000).
Bio-economic models can be used to compare static open access solutions to both maximum sustainable yield (MSY) and maximum economic yield (MEY), as well as optimal dynamic utilisation. While the earliest models were simple one-fleet models that did not allow for migratory species that travelled across international boundaries, later developments have taken into account the fact that stocks may be exploited by several fishing fleets and nations (Anderson & Seijo, 2010).

Several studies have applied bio-economic models to tuna fisheries. The earliest is probably Schaefer (1957) on the yellowfin tuna off the west coast of the Americas, while later contributions include Clark & Mangel (1979), Sinan & Whitmarsh (2010) and Barclay (2010). Clark and Mangel (1979) describes mathematical models of exploited fish stocks under the assumption that a certain portion of the stock becomes available through a dynamic aggregation process, using as an example the surface tuna fishery in the eastern tropical Pacific Ocean.

Sinan and Whitmarsh (2010) employ bio-economic models to analyse the economic value of the Maldives marine fisheries. As skipjack tuna (*Katsuwonus pelamis*) makes up about 70% of the catches, with yellowfin tuna (*Thunnus albacores*) and a variety of reef fish making up the rest, their analysis can up to a point be regarded as a study on the resource rent in the tuna fisheries. The authors employed threshold and CYP surplus production functions and showed that harvesting was above the MEY level but still slightly below the open access equilibrium level. The paper points out that the 7th National Development Plan (NDP) for the Maldives sets out sectoral economic policies, one of which is to 'ensure sustainable management of marine resources for the benefit of present and future generations'. It is argued that a wealth-based approach to fisheries management, such as that outlined in the study, is the best way of achieving that goal. The paper thus contains useful and good policy recommendations.

Barclay (2010) studies the impacts of tuna industries on the coastal communities in Pacific Island countries and examines the aspirations of coastal communities towards tuna industries and traces actual experiences of their operations. Although no bio-economic models are used in the analysis, she provides valuable insights into the positive and negative effects the tuna fisheries have on local communities.

The first bio-economic studies on Indonesia fisheries date from the 1980s (Bailey *et al.*, 1987) They studied the socio and economic aspect of the Indoneisan capture fisheries and employed a surplus production model based on available data. Since then, several other papers have been published on various biological, economic and social aspects of the fisheries. (Fauzi, 1998) develop bio-economic model for small pelagic fisheries in the North Java Sea, while Anna (2007) developed bio-economic models for the Jakarta Bay fishery to estimate the loss from pollution. Sulistioanto (2013) conducted bio-economic analysis of the snapper fisheries in Borneo waters and showed that the stock was over-fished. Purwanto (2013) provided an advanced bio-economic model for the shrimp fishery in Arafura.

Bio-economic models for small pelagic multispecies and multifleet fishery in the Bali strait have also been done and compiled by Zulbainarni (2012) and Purwaningsih *et al.*, (2012), while Setiono *et al.*, (2014) conducted a bio-economic study on the sardines in Madura strait which revealed that the fishery was over exploited.

Several bio-economic studies have also been undertaken on the tuna fisheries in Indonesia. Rihi (2013) analyzed the tuna fishery in Kupang waters while Hulaifi (2011) and Fanani & Jamil (2013) modelled the tuna fishery in Sendang Biru. Both of these studies showed that tuna fishery in Sendang Biru in eastern Java was over exploited both biologically and economically, and the fishery was not profitable.

Nahib (2013) provides a recent bio-economic study on the FAD tuna fishery in Pelabuhan Ratu, Indonesia, which clearly shows that the use of FADs has increased yield and reduced effort.

Wailerunya *et al.,* (2014) conducted a bio economic analysis of the skipjack fishery in Maluku water. They combined data from questionnaire with economic data to undertake a biological analysis which was based on the Gordon-Schaefer's method and Fox algorithm.

Zulbainarni (2014) developed a bio economic model for the tuna fisheries in the IOTC area that allowed for multispecies interaction. She concluded that the level of exploitation in Palabuhan Ratu was still below the maximum and recommended that effort be increased. None of the Indonesian studies on the tuna fisheries have considered the highly migratory and transboundary nature of the tuna stocks.

2.2 Technical Efficiency

Stochastic frontier analysis (SFA) is a method used to estimate the efficiency of individual production units. The theory was introduced simultaneously by (Meeusen & van den Broeck, 1977) and (Aigner *et al.*, 1977), but since then more complex models have been developed. The technical efficiency (TE) of a firm or another production unit is defined as the ratio of observed output to maximum feasible output. In cases where the observed TE of firm *i* takes on a value of unit, the *i*-th firm is said to be fully technical efficient, while TEi < 1 indicates the firm is experiencing a shortfall of the observed output from maximum feasible output. In the former case, the firm may be said to lie on the production frontier, while in the second case it would find itself below the frontier. In SFA, the random component of an ordinary regression is split into a one-sided stochastic component, that captures the inefficiency, and a pure white noise component. The stochastic component describes random shocks that may affect the production process but are not directly attributable to the producer or the underlying technology. Typically, these shocks could be brought about through changes in weather, economic adversities or plain luck.

SFA has frequently been applied to the in fisheries sector, both aquaculture and capture fisheries. Early studies on efficiency in the harvesting sector include Kirkley *et al.*, (1995, 1998), Coglan *et al.*, (1999), Sharma & Leung (1999), Squires and Kirkley (1999), Pascoe *et al.*, (2001) and Pascoe & Coglan (2002). The model developed by Battese & Coelli (1995) has been employed by Fousekis & Klonaris, (2003) to investigate the technical efficiency of the trammel net fishery in Greece while Ghee-Thean *et al.*, (2012) use stochastic frontier analysis to analyze how technology and other determinants have affected the fishing efficiency of a trawl fishery in Malaysia.

In aquaculture the study by Iinuma *et al.*, (1999) on the technical efficiency of carp pond culture in Malaysia gives a good description of how the stochastic frontier production analysis can be used to estimate the production efficiencies and what variables effect the inefficiencies of the production. A recent study done by Islam *et al.*, (2014) on shrimp farming in Malaysia also use the stochastic frontier production function approach to estimates the technical efficiency and the averages efficiencies.

SFA study for purse seine fishery in Java Sea Indonesia has done by Jeon *et al.*, 2006, it discusses stochastic production frontier in developing country fishery and the effect of seasonality, boat ownership, captain schooling experience, location of the landing and the dimension of the boat on technical efficiency.

In term of policy and management inefficiency analysis in fisheries is important to maximize the benefit from the resources and also provide good technical improvement to increase the technical efficiency in harvesting the fish resources.

3 METHODOLOGY

3.1 Bio-economic Analysis

Bio economic modelling analysis for this project will be a simplified aggregated model for multispecies and multi-fleets fishery. Biological analysis will be done using surplus production model developed by Schaefer (1957).

Cost, revenue and profit functions will be estimated from the primary data and bio-economic models then compiled that will yield estimates of static reference points (open access equilibrium, MSY, MEY). A comparison will then be made between the existing level and fishing and associated profits and the level of fishing corresponding to maximum sustainable yield (MSY) and maximum economic yield (MEY). The bio-economic data analysis design can be seen on Figure 4.

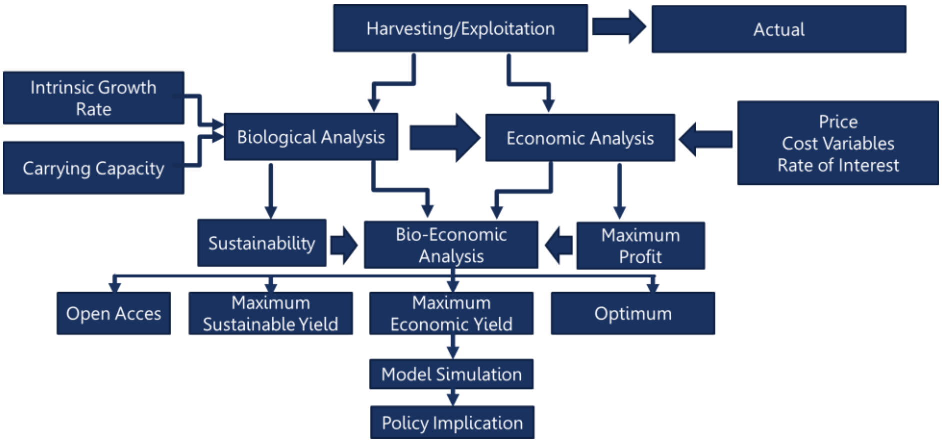

Figure 4. Bio-economic data analysis design. Source: Adopted from Zulbainarni N. , 2012.

3.1.1 Biological Analysis

Following Schaefer (1957) we postulate that change in the stock of Eastern Tropical Pacific Ocean tuna fishery can be described as

$$\frac{dx}{dt} = G(x) - h(x, E) \qquad (1)$$

where *x* represents the biomass of fish population, *t* equals time, *G(x)* represents the biological net growth rate, *h* represents harvests and *E* fishing “effort”.

The biological growth function model *G(x)* is defined as the logistic from

$$G(x) = rx\,(1 - \frac{x}{K}) \qquad (2)$$

where *r* and *K* are positive parameter called the “intrinsic growth rate” and “carrying capacity”.

Harvest is defined as

$$h = qEx \qquad (3)$$

where q = catchability coefficient.

From equation (3) it follows that catch per unit of effort (*CPUE*) may be defined as

$$CPUE = U = \frac{h}{E} = qx \qquad (4)$$

In long-term equilibrium harvests equal natural growth, i.e.

$$h = qxE = rx(1 - \frac{x}{K}) \qquad (5)$$

Rewriting (5) yields

$$x = K(1 - \frac{qE}{r}) \qquad (6)$$

Substituting (6) into (4) yields then the sustainable yield function

$$h = qEK(1 - \frac{qE}{r}) \qquad (7)$$

The yield function may also be written as written

$$\frac{h}{E} = qK(1 - \frac{q}{r}E) \qquad (8)$$

Equation (8) may also be written as the linear regression

$$Y = \propto + \beta X + \varepsilon \qquad (9)$$

where $Y = \frac{h}{E}$, $\propto = qK$, $\beta = \frac{Kq^2}{r}$, $X = E$, $\varepsilon = error.$

Provided data on CPUE and effort are available, it is therefore possible to estimate the linear regression in equation (9). However, as the two equations $\propto = qK$, and $\beta = \frac{Kq^2}{r}$ contain three unknown variables *q*, *K* and *r*, and only two equations it is only possible to obtain values for two of those three variables by assuming that the value of the third one is fixed. By, for instance, that *q* equals a fixed parameter it is therefore possible to obtain values for *r* and *K*.

3.1.2 Economic Analysis

The total cost function is specified as:

$$TC = C(h, E) + fk = a\,p\,h + b\,E + fk \qquad (10)$$

Where *TC* is total cost, *a* is a measure of the crew share of the revenues, *p* is the price of landings and *b* is the marginal cost of effort

The profit from the fishery are defined as the total revenues ($R = p\,h$) less total cost define above, i.e.:

$$\pi = p(1-a)h - fk - b\,E \tag{11}$$

Substituting in for *h* yields

$$\pi = p(1-a)\;q\;e\;x - fk - b\,E \tag{12}$$

3.1.3 Static reference points

Using the-economic model outlined above it is possible to find the stock biomass, harvest and effort level that correspond to maximum sustainable yield (MSY), maximum economic yield (MEY) and open access yield (OAY) (see Figure 5).

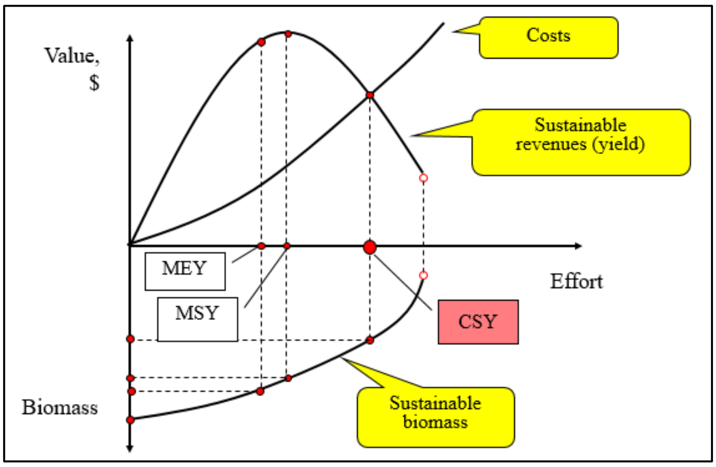

Figure 5. Bio-economic static reference points diagram. Source: Adapted from lecture notes UNU-FTP 2015 by Ragnar Arnason.

For MSY these are defined as:

$$h_{MSY} = \frac{Kr}{4} \tag{13}$$
$$x_{MSY} = \frac{K}{2} \tag{14}$$
$$E_{MSY} = \frac{r}{2q} \tag{15}$$

The corresponding values for MEY are defined as:

$$x_{MEY} = \frac{K}{2}(1+\frac{c}{Kpq}) \tag{16}$$
$$E_{MEY} = \frac{r}{2q}(1-\frac{c}{Kpq}) \tag{17}$$
$$h_{MEY} = qx_{MEY}\;E_{MEY} \tag{18}$$

Finally, the OAY values defined as:

$$x_{OA} = (\frac{c}{pq}) \tag{19}$$
$$h_{OA} = \frac{rc}{pq}(1-\frac{c}{Kpq}) \tag{20}$$
$$E_{OA} = h_{OA}/qx_{OA} \tag{21}$$

3.2 Stochastic frontier analysis

In applied microeconomics, efficiency may be calculated using either parametric or non-parametric methods. Here, we take the former approach and calculate technical efficiency (TE) using a model developed Battesse & Coelli (1995).

Consider the stochastic production function for panel data,

$$Y_{it} = exp\ (x_{it}\,\beta + V_{it} - U_{it}) \qquad (22)$$

or taking logs

$$\ln(Y_{it}) = x_{it}\,\beta + V_{it} - U_{it} \qquad (23)$$

Here, Y_{it}denotes the production of firm *i* at time *t* x_{it} is a (1 x k) vector values of inputs and other explanatory variables, while V_{it} is a random error term and U_{it} are non-negative random variables, associated with technical inefficiency of production.

The technical inefficiency effect, U_{it} in the stochastic frontier model is specified as

$$U_{it} = z_{it}\delta + W_{it} \qquad (24)$$

where z_{it} is a vector of explanatory variables associated with technical inefficiency, and δ are unknown coefficients. The random variable, W_{it},, is defined by the truncation of the normal distribution with zero mean and variance, σ^2, such that the point of truncation is $-z_{it}\delta$, i.e., W_{it}, > $-z_{it}\delta$. These assumptions are consistent with U_{it} being a non-negative truncation of the $N(z_{it}\delta, \sigma^2)$-distribution.

The method of maximum likelihood is used to simultaneously estimate the parameters of the stochastic frontier and the model for the technical inefficiency effects. The technical efficiency of production for the *i-th* firm at the *t-th* observation may then be defined by

$$TE_{it} = \exp(-U_{it}) = exp\ (\delta_0 - z_{it}\delta - W_{it}). \qquad (25)$$

4 THE KENDARI FISHERIES

4.1 Kendari Fisheries Characteristic

4.1.1 The Importance of fisheries sector in Kendari

Kendari fishing port is the major port for fish landings in the Province of Southeast Sulawesi. During the period 2010-2014, annual landings averaged 20.4 thousand tons with an average value of more than 20 million USD (Table 1).

Table 1. Total fish landing in Kendari Fishing Port

Year	Number of Landing	Total Landing (tons)
2010	4,438	21,554
2011	3,557	18,680
2012	3,542	19,519
2013	4,151	22,851
2014	3,193	19,727

Source: Landing monitoring report from Kendari fishing port.

4.1.2 Fleet Structure

The Kendari fishing port fleet varies in size and fishing gear. Most of the vessels employ purse seine, hand line and troll line or pole and line, with carrier vessels often accompanying boats using pole and line. In 2012 (Figure 6), there were 1129 vessel registered in Kendari fishing port. Most of the boats use FADs. Although the pole and line fishing fleet is quite small - only 5% of the registered vessels employ this gear - it constitutes a very important fleet since the fishing trips these boats make are quite long. The vessels do, however, not stay at sea for long time, but run their operations from an island near the fishing ground. Carrier vessels make regular collections and bring the catches to Kendari fishing port. There are two types of carrier vessels, vessels that support the pole and line fleet and vessels that accompany purse seine vessels, with the latter being much larger than the pole and line carrier vessels.

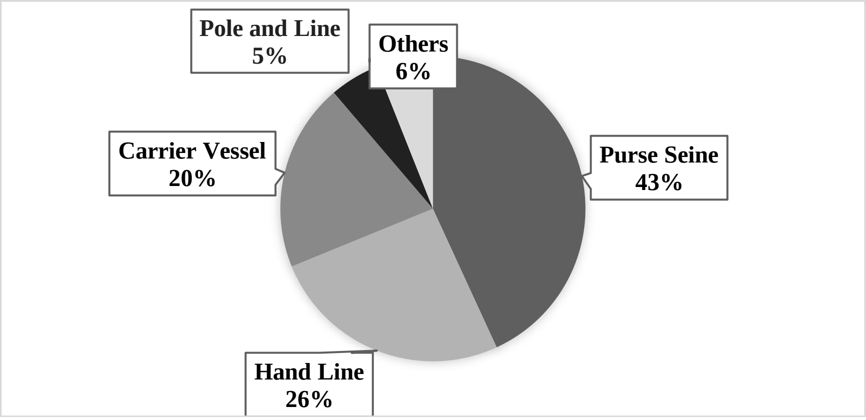

Figure 6. Fleet composition in Kendari fishing port in the year 2012. Source: Landing monitoring report from Kendari fishing port.

Tuna vessels vary in size and engine power, both between fleet segments and within each vessel group (Table 2 and Figure 7). Hand line and troll line vessels are generally smallest but the pole and line boats largest on average. The biggest vessels in the Kendari fishing fleet are though purse seiners. The number of crew also vary, different number of crew for each fishing fleet, this average number of crew will be use during the income shares for each crew. Purse seine fishing fleet has the highest crew numbers follow by pole and line, hand and troll line has the smallest number of crew with 7 crew members.

Table 2. Fishing fleet characteristic in Kendari fishing port.

Fleet		GT	Length	Width	Depth	Engine (HP)	Crew
Troll line and hand line	Average	4.50	12.12	2.33	0.91	33.63	7
	Maximum	30.00	17.00	3.70	1.90	270.00	13
	Minimum	2.00	9.00	1.00	0.35	16.00	3
Pole and line	Average	27.96	19.01	4.70	1.54	189.88	15
	Maximum	30.00	23.85	5.30	1.90	370.00	26
	Minimum	17.00	14.20	3.55	1.00	30.00	11
Purse seine	Average	14.29	16.65	3.48	1.19	121.81	15
	Maximum	51.00	25.30	14.15	2.50	360.00	27
	Minimum	5.00	10.00	2.00	0.50	14.00	6
Carrier	Average	25.83	16.04	3.64	1.28	81.10	6
	Maximum	148.00	27.98	8.68	2.89	380.00	17
	Minimum	3.00	9.21	2.00	0.62	15.00	3

Sources: Landing monitoring report from Kendari fishing port.

Pole and Line

Hand line and Troll line

Purse

Figure 7. Typical boats in the Kendari tuna fishing fleet.

4.1.3 Catch Composition

Mackerel tuna and scads are the dominant catches in the purse seine fishery and account together for more than 86% of the total catch, followed by skipjack, yellowfin tuna, big eye tuna and other species. Boats employing hand and troll line catch mainly skipjack with (68% of catches) (and yellowfin tuna (22%). For pole and line boats the corresponding catch shares of skipjack and yellowfin tuna are 77% and 23%. Pole and line can therefore be regarded as the most selective fishing gear (Table 3).

Table 3. Catch composition of the FAD associated tuna fishery in Kendari fishing

Common Name	Purse Seine	Pole and Line	Hand and Troll Line
Skipjack	11%	77%	68%
Yellowfin tuna	2%	23%	22%
Scads	40%		2%
Mackerel tuna	46%		3%
Bigeye tuna	0%		1%

Sources: Landing monitoring report from Kendari fishing port.

4.2 FAD Tuna Fishery

FAD Tuna fishery has been developed in Indonesia since the 1980's. A FAD is an auxiliary fish aggregating device that uses a variety of shapes of solid attractor or rope to attract fish which then may aggregate close to these devices. FADs can therefore improve the efficiency and effectiveness of fishing operations. FADs play an important role in tuna fishery operations; indeed the use of these devices has changed the fishing strategy of many tuna fishing fleet from hunting the fish across open seas into searching for the fish in more "semi-permanent" fishing grounds since FADs could create a kind of "mini ecosystem" for tuna and other pelagic species. In large scale industrial tuna fishery FADs have become more modern and technical in recent years and some of them are now equipped with sophisticated equipment such as radio buoy and intelligent FAD buoy monitoring device with many censors.

4.2.1 FAD Design and cost

FADs used in the Kendari tuna fisheries usually consist of four components (Figure 8). The float itself is made from styrofoam, bamboo raft or steel (called pontoon). A rope then ties the float to the sinker which is made from cement concrete cast on a drum or tied stones. The length of the rope depends on how deep the waters are where the FAD is located, but depths of up to 7,500 metres have been encountered. To attract the fish and encourage the tuna to aggregate, coconut leaves are then suspended from the float. Earlier designs sometimes used plastic instead of coconut leaves, but the use of plastic has since been banned.

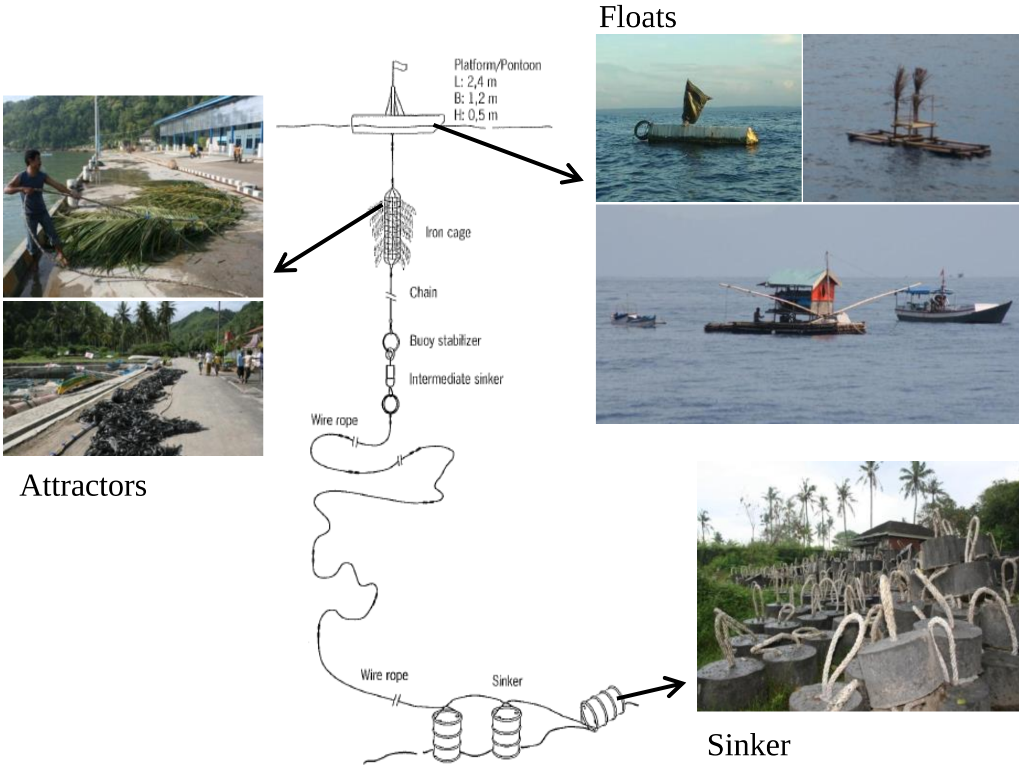

Figure 8. FAD design and construction. Source: Monintja and Mathews, 1999.

According to a survey undertaken among boat owners and captains in 2014 and 2015, the average cost of FADs was 1,180 USD (Table 4). The cost of building a FAD depends very much on the length of the rope, with rope costs typically more than 70% of total costs. The average depth of the ocean where the FADs of the Kendari fleet are located is 3,500 metres.

Table 4. **FAD component and cost.**

FAD Component	Quantity	Price (USD)	Total Cost (USD)	Average Cost (USD)
Attractor (coconut leaf)	5 – 45 leaf	0.15 – 0.37	0.75 – 16.83	2.78
Rope	500 – 7500 m	0.16 – 0.49	82.27 – 2,393.42	1,381.68
Ponton/Raft (Float)	1 – 5 Rafts	7.85 – 14.96	37.40 – 635.75	98.28
Sinker	7 – 35	7.48 – 25.58	52.36 – 224.38	266.57
Labour	3 – 7	14.96 – 37.40	44.88 – 261.78	130.89
Total FAD Cost			217.65 – 3,532.16	1,880.19

Source: Interviews with boat owners and captains in 2014 and 2015.

4.2.2 FAD Ownership and Management

FAD ownership in Kendari has many variations. Most FADs were built and are owned by boat owners. This is especially true for pole and line and purse seine vessels. Some FADs are though owned by the individuals who do not operate fishing vessels, but they just invested in FADs in order to collect shares from vessels that utilise their FADs. There are also several government FADs. These were usually built as part of the government boat assistances to small boat owners who mainly use hand line and troll line.

Privately owned FADs are managed by the owners themselves who enjoy the benefits of the FADs but also shoulder the costs. Government-owned FADs are maintained by cooperatives or group of fishers called “mitra kolaborasi” that utilise the FAD. This fishers group will not only repair “their” FAD from damages caused by nature but also from vandalism by the other fishers.

4.2.3 FAD Operational Arrangement

During operations, informal agreement will be made between owners of the FADs about the utilization of FADs by other vessel or other companies. As shown in Table 5, similar arrangements are in place for the purse seine and pole and line fishing fleets, while the hand line or troll line fleet has different arrangements. Hand line or troll line vessels are free to utilise the FAD as shelter, but in return they should play as a “watcher” for the owner of the FAD in question and report to the FAD owner if some other vessels are fishing from the FAD and support the claims of owner for utilisation fees.

Table 5. **Operational arrangement for the use FADs.**

	Purse Seine	**Pole and Line**	**Hand line/Troll line**
FAD sharing arrangement with other companies /vessels	yes, with acknowledgment to the other companies /vessel	yes, with acknowledgment to the other companies /vessel	no, free to use the FAD but if the owner wants to use it they should leave
Arrangement of the operation	after the revenues is subtract by the logistic cost then profit divided by 3 (2 for the boat 1 for the FAD owner)	after the revenues is subtract by the logistic cost then profit divided by 3, 2 for the boat 1 for the FAD owner	no
'Rolling system' for your FADs to make sure they are guarded from use/abuse by other vessels?	no, just watch each other FADs	no, just watch each other FADs, catching and guarding the FADs at the same time	help the FADs owner to watch their FADs

Source: Interviews with boat owners and captains in 2014 and 2015.

4.2.4 FAD issues and problems

Since the introduction of FADs use in the early 1980s, there has been a corresponding expansion of the purse seine fishery, resulting in the predominance of purse seine caught tuna. The use of FADs, however, has also led to significant amount of juvenile Yellowfin and Bigeye tuna being caught on FAD associated purse seine and ring net sets.

The widespread use of FADs appears to have disturbed the migratory pattern of the tuna, leading it to spend more time in Indonesian waters. This has led to regional disputes over the utilisation of the resource.

The use of FADs can cause social problems because fishermen will try to put their FADs in the most favourable locations and this competition can lead to conflicts.

Because fish will aggregate near the FADs, the average aggregation may become smaller as the number of FADs increases. The smaller schools will increase harvesting costs. In addition, fishermen will have to spend more time travelling between FADs in search of a suitable aggregation. This will also increase costs and may lengthen time each trip takes. As the quality of the ice used to chill the catches decreases with the length of the fishing trip, longer trips may reduce the overall quality of the catch. Thus, increasing the number of FADs can both increase costs and reduce revenue. It may therefore be desirable to limit the number of FADs to a certain optimal level.

4.2.5 Socio economic aspect of FAD tuna fishery

No formal education is needed for the young men to become good fishers or captains, as their knowledge is developed through the "autodidact" educational system. Young boys become fishermen at very young age, normally when they have finished elementary school at the age of 12 and became trained fishermen after the age of 20 years, although that does depend on the learning skills of each individual. Formal education is only required when fishermen want to undertake the training necessary before applying for the captain or engineer certificate. Fishermen generally have no clear path to follow. Some of them may became a successful captain and boat owner, while others remain as crew members for the rest of their live until they are become old and cannot continue fishing anymore.

Revenue from the fisheries are split between crew and FAD owners according to fixed rules and arrangement (see Table 6). First 10% of the revenue is deducted as investment costs. Then some of the catch is set aside for the crew. If the vessel has utilised the FAD of others 33% of those catches must be paid to the FAD owners. The rest is shared between the boat owner on the one hand and captain and the crew on the other, according to the shares of each individual, with some 2% also set aside for certain fees which include costs associated with unloading the catches. The captain gets the highest share of the crew, 3.64, with ordinary deck hands only getting a share of 1.0.

Table 6. Share arrangement of the 3 different tuna fleets

Shares	unit	Purse Seine	Pole and Line	Hand line/ Troll line
Before Subtracted by the cost				
Investor and investment	percentage	10%	10%	11%
Free Fish for the Crew	Kg	176.25	30.00	19.44
After Subtracted by the cost				
Boat Owner (True Benefit)	percentage	49%	49%	49%
FAD (if utilized other vessel or companies FAD)	percentage	33%	33%	
Captain + Crew	percentage	49%	49%	49%
Fees (include unloading)	percentage	2%	2%	2%
Shares base on the position				
Captain	Shares allocation	3.64	2.54	2.15
Engineer	Shares allocation	2.08	1.96	1.50
Fishing Master	Shares allocation	1.50	2.31	
Boy-boy	Shares allocation		1.85	
Net Thrower	Shares allocation	1.50		
Diver	Shares allocation	1.50		
Crew	Shares allocation	1.00	1.00	1.00

Source: Interviews with boat owners and captains in 2014 and 2015.

5 DATA

5.1 Bio-economic model

5.1.1 Catch and effort data

Data on annual catches and effort for the years 2010-2014 was compiled from Kendari fishing port which collects daily data on the fisheries. As shown in Table 7, catch per unit effort (CPUE) is on average highest for pole and line vessels, or 6.17 tons per tip, and lowest for the vessels using hand line and troll line, or 2.75 tons per trip. Most of the catches were registered by purse seiners, or almost 14,700 tons on average, while average catches of boats using hand line and troll line only amounted to 870 tons.

Table 7. Catch, Effort and CPUE for Kendari FAD associated tuna fisheries

Year	Purse seine			Pole and line			Hand line & troll line		
	Effort (trip)	Catch (ton)	CPUE (ton/trip)	Effort (trip)	Catch (ton)	CPUE (ton/trip)	Effort (trip)	Catch (ton)	CPUE (ton/trip)
2010	3,075	15,544.95	5.06	940	5,032.41	5.35	387	826.85	2.14
2011	2,538	13,856.39	5.46	673	3,805.29	5.65	293	861.26	2.94
2012	2,606	14,450.96	5.55	485	3,419.24	7.05	290	856.42	2.95
2013	2,465	14,904.77	6.05	522	3,561.86	6.82	380	961.60	2.53
2014	2,178	14,589.88	6.70	683	4,083.78	5.98	267	847.25	3.17
Average	**2,572**	**14,669.39**	**5.76**	**661**	**3,980.52**	**6.17**	**323**	**870.68**	**2.75**

Sources: Landing monitoring report from Kendari fishing port.

5.1.2 Cost and revenue

Information on cost and revenue of each vessel was obtained through 60 intensive interviews undertaken in 2014 and 2015. Data was collected from three different fleets; purse seine, pole and line and troll line and included information on fishing cost, the characteristics of the vessel (size, engine type), fishing gear, crew size, catches, social aspects (level of education etc.), various aspects of FADs, fish prices, average revenue and the share-system in operation.

Using this information, cost functions were constructed for each vessel type that included investment costs (vessel and FAD), fixed costs and variable costs. As shown in Table 8, total costs are highest for pole and line vessels, or USD 97,300, with costs for purse seiners only slightly lower. Costs associated with investing in and operating hand line and troll line boats is much lower, or only USD 15,200.

5.2 Stochastic frontier

Stochastic frontier model for the FAD associated tuna fisheries in Kendari was done using data for the year 2015. This includes observations on of catches per trip, as well as information on vessel size, number of crew, days at sea, the amount of ice and water used on each trip, as well as information on the captain, fishing ground and gear used. Total 2598 data from 2015 landing monitoring being used during the technical efficiency analysis, Summary statistics are shown in Table 9.

Table 8. Cost Variables of the tuna fishing fleets.

Cost variables	Unit	Purse seine	Pole and line	Hand and troll line
Total Cost (Capital+Fixed+Variables)	USD	**86,846.1**	**97,284.8**	**15,250.7**
Capital investment		**79,856.1**	**88,242.6**	**12,509.3**
Boat	USD	48,881.5	74,794.3	8,601.3
Engine	USD	9,844.8	10,512.0	2,842.2
Auxiliary 1	USD	792.5	804.0	828.1
Auxiliary 2	USD	544.0	-	-
Fishing gear	USD	17,763.6	102.4	88.1
Permit	USD	149.6	149.6	149.6
FAD	USD	1,880.2	1,880.2	-
Fix cost		**5,357.7**	**7,127.3**	**1,904.2**
Maintenances				
Boat	USD	2,508.7	4,038.9	448.8
Main Engines	USD	1,656.8	2,772.4	568.4
Auxiliary	USD	586.4	284.2	56.1
Fishing gear	USD	605.8	31.8	224.4
Variable cost		**1,632.3**	**1,914.9**	**837.1**
Fuel	USD	642.9	472.7	349.2
Lubricant	USD	40.6	88.3	33.1
Bait	USD	-	56.1	22.7
Ice	USD	203.5	113.7	95.2
Logistic	USD	696.7	558.7	278.8
Wages	USD	-	-	15.0
Spare part	USD	48.6	74.8	43.2

Source: Interviews with boat owners and captains in 2014 and 2015.

There are four dummy variables indicating how many fishing grips each captain made during the year 2015. DumCap1 takes a value of 1 if the captain made less than 2 trips a year, and zero otherwise. DumCap2 takes a value of 1 if the captain made 2-6 trips a year, and zero otherwise. DumCap3 takes a value of 1 if the captain made 6-12 trips a year, and zero otherwise. DumCap4 takes a value of 1 if the captain made more than 12 trips a year, and zero otherwise. As shown in Table 9, the average values of the four captain dummy variables were in the 0.19-0.29 range, indicating that each captain category contained 19-29% of all observations. The captain dummy variables are used as a proxy variable for experience.

In all, it was possible to identify 29 different fishing grounds where the vessels fished in 2015. The identification was done on the basis of 1x1 degree grids, but finer grips of 0.5x0.5 degrees were also used. Most of the fishing, or over 80%, took place in a single grid, which is represented by the dummy variable Dum4B.

Table 9. Summary statistics for variables included in stochastic production frontier and technical efficiency models for FAD Associated tuna fisheries

			summary statistics			
Variables	**Description**	**Measurement**	**Mean**	**Stad dev**	**Min**	**Max**
n = 2598						
Output and input variables						
Y(Catch)	Catches	Kg	3,632.8	2,640.6	204	23,256
Crew	Number of crew	person	14.3	5.2	3.0	30.0
Dim	Size of boat (length x wide x depth)	m^3	83.31	63.13	7.7	270.46
DAS	Day spent at sea	days	5.4	2.7	1.0	45.0
Ice	Quantity of ice	ice block	84.5	49.6	11.0	900.0
Water	Quantity of water	1000 litres	1.3	0.7	0.1	7.5
Fuel	Quantity of fuel	litre	674.0	427.3	30.0	15,000
Boat specific variables						
DumCap1	2 trips or fewer	dummy	0.19	0.39	0	1
DumCap2	2 - 6 trips a year	dummy	0.25	0.43	0	1
DumCap3	6 - 12 trips a year	dummy	0.27	0.44	0	1
DumCap4	More than 12 trips a year	dummy	0.29	0.45	0	1
Dum1	Fishing ground grid 1	dummy	0.02	0.15	0	1
Dum2	Fishing ground grid 2	dummy	0.06	0.24	0	1
Dum6	Fishing ground grid 6	dummy	0.09	0.29	0	1
Dum8	Fishing ground grid 8	dummy	0.02	0.16	0	1
Dum4B	Fishing ground Grid 4B	dummy	0.80	0.40	0	1
DumFG1	Hand line and Troll Line	dummy	0.18	0.38	0	1
DumFG2	Pole and line	dummy	0.01	0.10	0	1
DumFG3	Purse seine	dummy	0.81	0.39	0	1
DSoff	Off season period (Oct, Nov, Dec, Jan, Feb)	dummy	0.43	0.49	0	1
DSpeak	Peak season period (March, April, May)	dummy	0.33	0.47	0	1
DStrans	Transition period (June, July, Aug, Sep)	dummy	0.24	0.43	0	1

Three dummy variables were defined for the fishing gear used in the Kendari tuna fishery; DumFG1 takes a value of unity if the vessel used hand or troll line, and zero otherwise. DumFG2 takes a value of unity if the vessel used pole and line, and zero otherwise. DumFG3 takes a value of unity if the boat employed purse seine, and zero otherwise. Just over 80% of the boats in the sample used purse seine.

Three variables were also used to indicate whether the boats were operating during the peak season or off season, or during a transition period. DSoff takes a value of unity if the fishing trip was made during the off season (October-February), and zero otherwise. DSpeak takes a value of unity if the trip was made during the peak season (March-May), and zero otherwise. DStrans takes a value of unity if the trip was made during the transition period (June-September).

6 RESULTS

6.1 Bio-economic model

6.1.1 Harvest function

The bio-economic model outlined in Section 3.1 using the data discussed in Section 5.1. In particular, ordinary least squares were used to estimate equation (9) and data on costs and revenue outlined in Section 5.1.2 to construct cost, revenue and profit functions. The data on catches and effort for the years 2010-2014 was aggregated to annual data and harvests expressed as catch per unit effort then estimated as a function of effort.

The estimated harvest function is defined as

$$\frac{h}{E} = \propto + \beta E + \varepsilon \qquad \text{(9a)}$$

where h denotes harvest and E effort, α and β are parameter to be estimated and ε a random error term. The ratio $\frac{h}{E}$ is also defined as catch per unit effort.

The results for the estimated harvest function for each fleet segment (purse seine, pole and line, hand and troll line) are shown in Table 10. These results should though be taken with considerable care as they are obtained using only five observations, and the number of degrees of freedom was thus very small, or only three. The R^2 from the regression of this data set varies from 0.84 for the pole and line and 0.91 for the hand and troll line data, indicating that the model explains a considerable amount of the variation of CPUE.

Table 10. Harvest function from 3 fishing gears type

Gear	b_0	t stat	P-value	b_1	t stat	P-value	R square
Purse Seine	10.3456	8.8874	0.0030	0.0018	-3.9634	0.0287	0.8396
Pole and Line	8.6545	13.3348	0.0009	0.0038	-3.9361	0.0292	0.8378
Hand Line & Troll line	5.0251	11.9529	0.0013	0.0070	-5.4840	0.0119	0.9093
Accumulated Model	9.8459	10.4725	0.0005	0.0012	-3.9590	0.0167	0.7967

Multiplying through both sides of equation (9a) by the effort variable yields the following harvest function

$$h = \propto E + \beta E^2 \qquad \text{(9a)}$$

The plots of the resultant harvest function for each fleet segment are presented in Figures 9-11. As shown in Figure 9, actual effort in the purse seine tuna fishery was less in 2013 and 2014 than in 2010 and 2011.

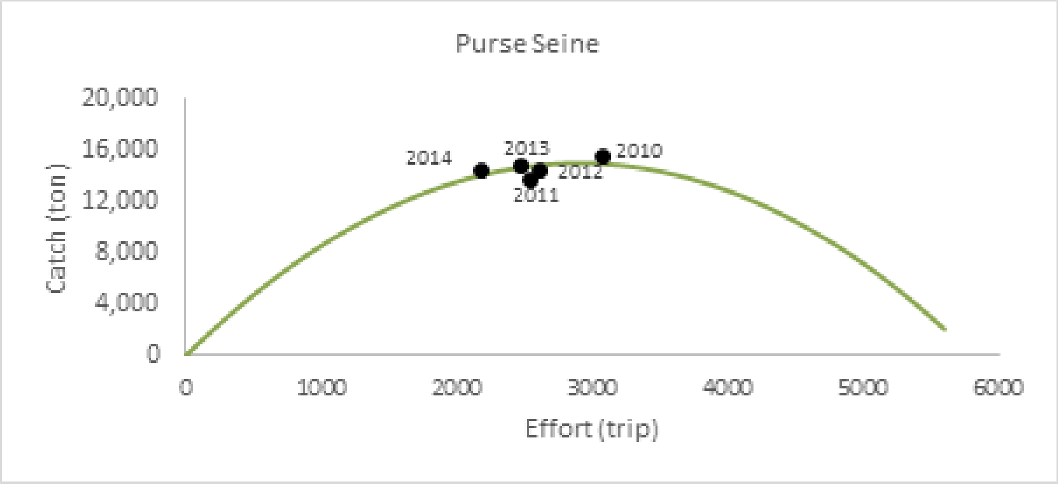

Figure 9. Actual purse seine catch effort in 2010-2014.

Actual catch effort for the pole and line fishery was highest in 2010 but reduced significantly in 2011 and 2012, before then increasing again during 2013 and 2014. Effort is though still less than at the maximum point (Figure 10).

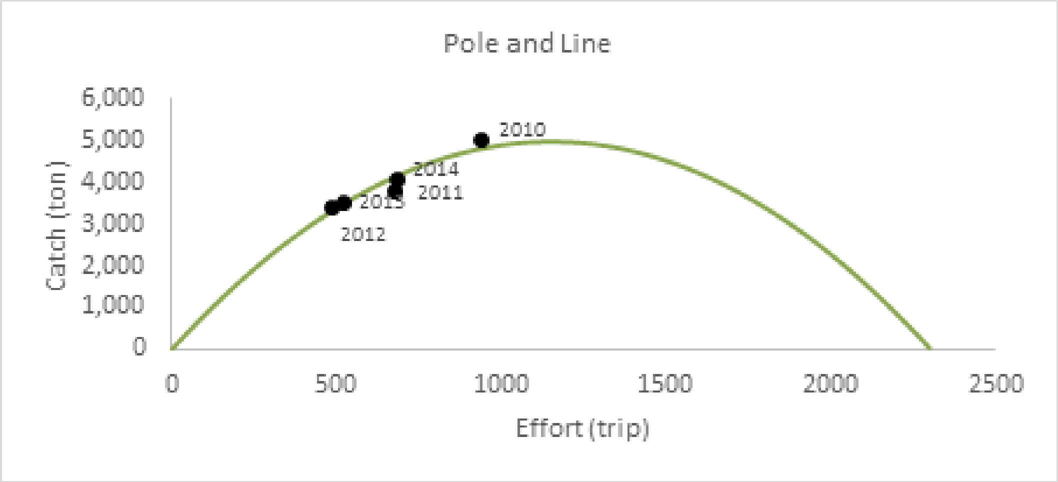

Figure 10. Actual pole and line catch effort in 2010-2014.

Actual catch effort for hand and troll line fishery was lower in 2011 and 2012 than in 2010 but at a similar level in 2013 as in 2010. In 2014, effort was significantly reduced (Figure 11).

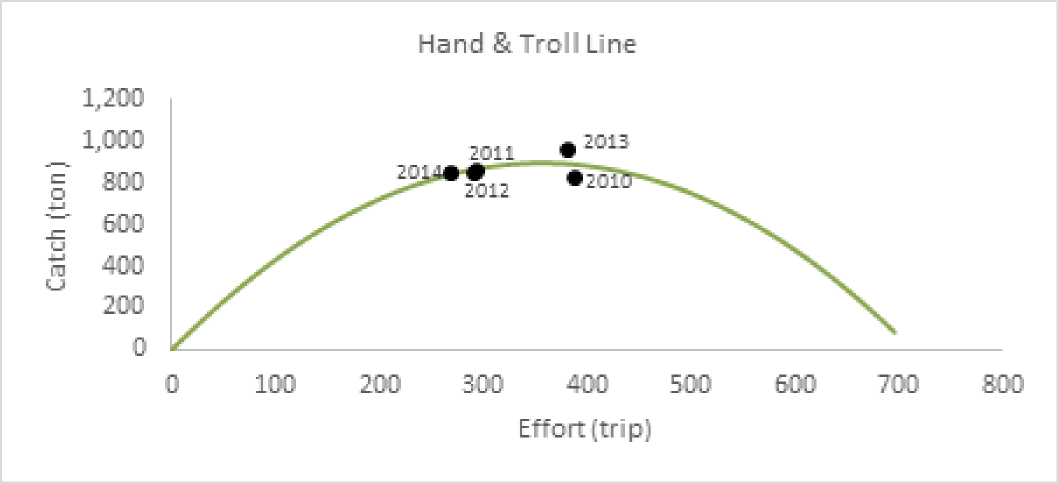

Figure 11. Actual hand and troll line catch effort in 2010-2014.

6.1.2 Cost variables and function

Cost functions were developed using the data presented in Section 5.1.2. For each fleet segment, - purse seine, pole and line and hand and troll line – total costs were constructed from individual vessel data. The total cost function was then used to estimate profits. The total cost function is the sum of capital costs, fixed cost, cost of free fish and variable cost. Capital cost is defined as the part of revenue accruing to the vessel as the revenue is shared between the vessel, vessel owner, crew and other owners of FAD used for fishing (see Section 4.2.5 on share arrangements). For the purse seine fleet, the capital cost is defined as 10.4% of catches and this value is multiplied by harvests (h) and average price of the harvests (p). Fixed costs are defined as maintenance of the boat, engine and fishing gear. The cost of free fish is the costs of giving part of the harvest free of charge to the crew. For the purse seine vessels this amount equals 176.25 kg per trip and the opportunity cost per trip thus equals the amount given freely times the average price of the catches (p). Annual costs associated with the free fish are calculated as costs per trip multiplied by the number of trips (f). Variable cost per trips is defined as the sum of fuel, ice, water and other logistics. In the case of hand and troll line boats variable costs also include wages paid to crew over and above what the crew gets through the share system. These additional wages are low. For the purse seine vessels, variable costs average USD 1632.3. Total costs are defined as the sum of fixed costs, free fish costs, capital costs and variable costs. Total costs are calculated both for vessels which are completely inactive, in which case the number of trips (f) equals zero, and for active vessels in which case the number of trips is greater than zero. In the latter case, the fixed cost is divided by the number of trips undertaken per year, 43 for the purse seine fleet, 20 for the pole and line, and 30 for the hand and troll line boats.
The cost functions thus developed are as follows:

Purse seine:
$C(f) = (5357.7) + (176.25 * p) * f + (0.104 * h * p) + (1632.3 * f)$, for $f = 0$
$C(f) = 5357.7/n_{trip/year}*f + (176.25 * p) * f + (0.104 * h * p) + (1632.3 * f)$, for $f = 1 \ldots N$

Pole and line:
$C(f) = (7127.3) + (30 * p) * f + (0.10 * h * p) + (1914.9 * f) +$ for $f = 0$
$C(f) = (7127.3/ n_{trip/year})*f + (30 * p) * f + (0.10 * h * p) + (1914.9 * f) +$, for $f = 1 \ldots N$

Hand and troll line:
C (f) = (1904.2) + (19.44 * p) * f + (0.1078 * h * p) + (837.1 * f), for f = 0
C (f) = (1904.2/ $n_{trip/year}$)*f + (19.44 p) * f + (0.1078 * h * p) + (837.1 * f),for f = 1... N

Where:
C = cost (USD)
p = fish price (USD/kg)
f = effort (trip)
h = harvest/catch

6.1.3 Fish price and revenues function

Revenues function for each fishing gear type was developed from the fish price and catch composition (see Section 4.1.3 for the catch composition). Average fish prices for the year 2015 data are presented in Table 11, where prices are broken down into fish groups similar to the catch composition of each gear type. Three are differences price between each fishing fleet for the same fish group, i.e. Skipjack tuna caught by hand and troll line vessels has a higher price than tuna caught by purse seiners and pole and line boats. This information is then used to calculate total revenues functions for each fishing fleet. As shown in Table 11, the calculated average revenue is highest for the hand and troll line boats and pole and line boats, or USD 936 and USD 913 respectively, but significantly lower for the purse seiners, or USD 796.

Table 11. Average fish price and estimated revenues for 3 different tuna fishing fleets. USD per ton.

Species	Purse seine	Pole and line	Hand and troll line
Skip Jack	924.58	907.85	938.34
Yellowfin Tuna	957.83	924.43	993.63
Scads	897.84		897.53
Mackerel tuna	663.15		698.31
Big Eye Tuna	1,009.52		1,095.87
Others	1,128.83		782.79
Estimated revenues*	**795.53**	**912.59**	**936.14**

Sources: 2015 landing monitoring data, *after accommodating the catch composition

6.1.4 Static Equilibrium

Results from estimating the harvest function outlined in Section 6.1.6 above were used to find the effort (number of trips) corresponding to maximum sustainable yield. Letting b0 and b1 represent the intercept and slope coefficient in the harvesting equation, the MSY level of effort may be defined as

$$E_{MSY} = \frac{b_0}{2b_1}$$

Effort levels corresponding to maximum economic yield and open access yield were calculated using the goal solver in MS Excel. In the former case the solver was set to maximise profits, while in the latter case the solver was set for zero profits. Revenue was calculated on the catch composition and average prices for each fleet segment discussed in Section 6.1.3 and costs using the total cost function set forth in Section 6.1.2.

The result from the biological and economic analysis for the static equilibrium for thee three different fleets is presented in Table 12 and Figures 12-14. The level of effort currently applied to the tuna fisheries is in all three cases very close to the effort level corresponding to maximum economic yield. For the purse seiners, the level is slightly above MEY, but for the pole and line boats and hand and troll line boats the level is just below that corresponding to MEY. This indicates that the tuna fishery is a present enjoying considerable profits, but at the same time that because of these good profits there is a risk that investments in the fisheries – both FADs and boats – could increase in the coming years. Prudent management would try to curb those likely increases. It should be noted that the profits shown in Table 12 refer to nett profits, the true benefit for the boat owner i.e. Profits after the shares, benefit after the revenues is subtract with the cost function subtracted by the shares (total 51 % for the crews and the fee).

Table 12. Static equilibrium for the FAD associated tuna fishery in Kendari

	Effort (trip)	Catch (Ton)	Revenues USD	Benefit USD	Benefit/ effort
Purse Seine					
Maximum economic (MEY)	2,147	13,996	11,134,593	2,868,934	1,336
Maximum sustainable (MSY)	2,902	15,014	11,944,145	2,513,509	866
Open access (OAY)	4,294	11,565	9,200,070	6	0
Existing condition	2,178	14,079	11,199,976	2,868,330	1,317
Pole and Line					
Maximum economic (MEY)	779	4,461	4,066,478	916,205	1,176
Maximum sustainable (MSY)	1,152	4,983	4,542,491	706,283	613
Open access (OAY)	1,558	4,364	3,977,832	0	-
Existing condition	683	4,158	3,790,444	902,347	1,321
Hand and Troll Line					
Maximum economic (MEY)	278	852	797,734	222,374	801
Maximum sustainable (MSY)	357	896	838,805	204,418	573
Open access (OAY)	555	618	578,153	0	-
Existing condition	267	839	785,831	222,043	832

As shown in Figure 12, MEY for the purse seiners is equal to USD 2.9 million which is only slightly above the current profits. The optimal number of trips is 2,147 but the number of actual trips undertaken in 2015 was 2,178 effort (trip). Profits per trip would at the maximum point equal USD 1,336 USD. The OAY level for the purse seiners is reached wen the level of effort equals 4.294 trips. Total revenue would then equal USD 9.2 million, but profits would be almost zero profit. These results indicate that the purse seine fishery is still in good conditions and still provide high benefits.

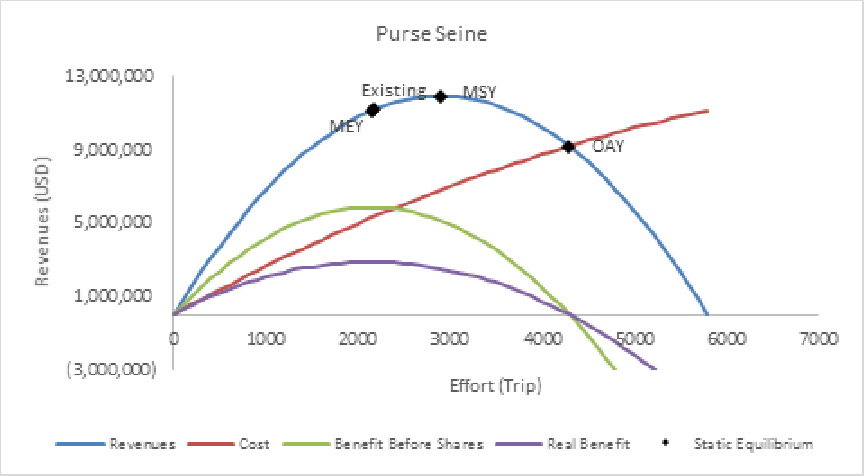

Figure 12. Static equilibrium of the bio economic model for purse seine fishery

For the pole and line fishery maximum economic yield is obtained when effort equals 779 trips. Profits are then USD 916 thousand. Effort is presently lower than this, or only 683 trips per year. The effort level corresponding to MSY is reached at 1.152 number of effort with total revenues USD 4.5 million. The OAY level for the pole and line will be reached if the level of effort is 1,558 trips with total revenues 3,977,832 and zero profit. Pole and line fishery is also still in the good shape and still provide high benefits.

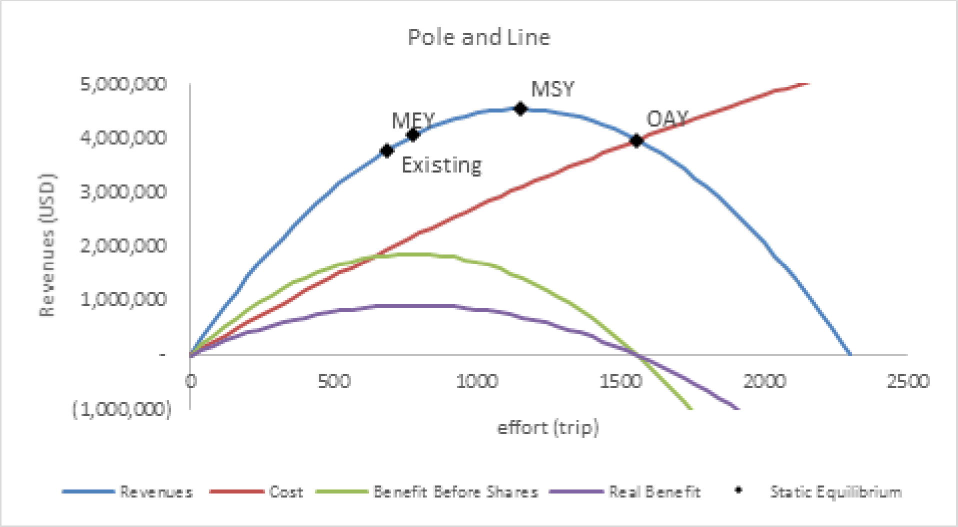

Figure 13. Static equilibrium of the bio economic model for pole and line fishery

In the hand and troll line fishery maximum economic yield will be reached with effort levels corresponding to 278 trips. Profits at this level total USD 800 thousand. This is slightly above the current level of exploitation. MSY is obtained at effort levels equalling 357 trips and total revenues of USD 840 thousand while the OAY level will be reached when level of effort equals 555 trips. Total revenues will then amount to USD 580 thousand but there will be no profits. The hand and troll line fishery is also still in the good shape and still provide high benefits.

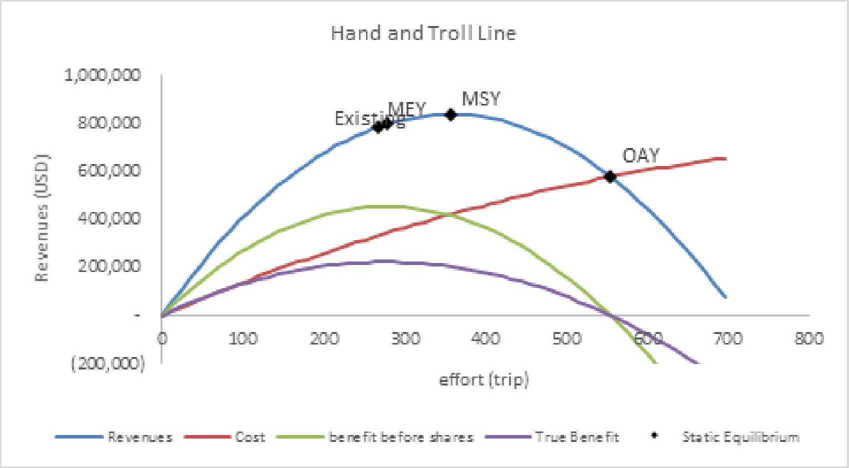

Figure 14. Static equilibrium of the bio economic model hand and troll line fishery

These results indicate that the present level of effort is similar to that expected to hold when maximum economic yield is obtained. There are good profits to be enjoyed in all three tuna fisheries and there are therefore strong incentives for further investment, both in FADs and boats, but also in auxiliary gear like GPS or echo sounders. Such investments could push the fishery towards the open access point (OAY), where there are no profits to be had. Management authorities should therefore keep a close watch on investments in the tuna fisheries.

In MEY level in Table 12 we could see that the actual boat owner benefit portion from the total revenues is consider low, only 22% for the pole and line fishery (USD 916,205 from USD 4,066,478 total revenues), 25% for the purse seine fishery (USD 2,868,934 from the USD 11,134,593 total revenues) and 27% for the hand and troll line (USD 222,374 from USD 797,734 total revenues). Most of the portion is going to the sharing and cost, the average 10% portion goes to the investment for the boat, engine, fishing gear and FAD. This also explains the reason behind the extensive investment in fishing fleet and auxiliary gear

6.2 Stochastic production function

Following Battese and Coelli (1995), the model used for estimating the stochastic production frontier is given by:

$$\ln Catch_i = \beta_0 + \beta_1 \ln(Dim)_i + \beta_2 ln\,(Crew)_i + \beta_3 ln\,(DAS)_i + \beta_4 ln\,(Ice)_i + \beta_5 ln\,(Water)_i + V_i - U_i$$

where the technical inefficiency effects are defined as a function of dummy variables:

$$U_i = \delta_0 + \delta_1 DumCap2 + \delta_2 DumCap3 + \delta_3 DumCap4 + \delta_4 Dum4B + \delta_5\, DumfFG3 + \delta_6\, DSoff + \delta_7\, DSpeak + W_i$$

Here, the β's and δ's are parameters to be estimated, while V_i and W_i are well-behave random error terms and i indicates individual vessels.

The model was estimated using maximum likelihood. For this purpose, the frontier R package developed by Coelli & Henningsen, (2013) was employed. Use was also made of the plm R package developed by Croissant & Millo (2008).

The results from estimating the model are presented in Table 13. As all variables are in logarithmic form, the parameter estimates can be interpreted as elasticities which show by how many percentages catches will increase if the use of each input is increased by 1%. All the parameters in the model are statistically significant at the 1% level or better, with the exception of the parameter relating to the variable days at sea (DAS). This parameter takes a negative value, indicating that lengthening the fishing trip will lead to reduced catches. As mentioned in Section 4.2.4, the increased utilisation of FADs can lead to boats spending more time sailing between platforms in search of suitable fish aggregations, thus reducing the time actually spent fishing. The negative value of the DAS-parameter appears to be picking up this effect. All the other variables have a significant positive impact on catches.

All the dummy variables in the inefficiency equation have a negative effect on inefficiency – and thus increase the efficiency of the vessels – as can be seen from the fact that all the estimated parameters in the inefficiency equation take a negative value. However, three of the parameters are not statistically significant from zero, those related to DumCap2, DumCap4 and Dum4B. The DumCap2 and DumCap4 variables refer to instances where the captain of the vessel went 2-6 fishing trips or more than 12 fishing trips in 2015. The results therefore indicate that the efficiency of vessels with such captains was no different from the efficiency of captains who went 1 or 2 fishing trips in that year. To avoid multicollinearity the dummy variable pertaining to cases where the captain went fewer than 1or 2 trips per year (DumCap1) was not included in the regression model. However, having captains that went 6-12 trips a year has a positive effect on efficiency.

The choice of fishing grounds does not appear to matter much for efficiency, but boats equipped with purse seine are more efficient. Efficiency is also higher both in the off-peak season and the peak season, than in the transitory period.

In Table 14, estimated technical efficiency is calculated across fleet segments. Technical efficiency is highest for purse seiners or 0.58 on average, but significantly lower for both pole and line vessels and boats using hand and troll line. The least efficient vessels have a similar efficiency score for all three fleet segments, but the most efficient purse seiners and boats using hand and troll line are much more efficient than boats using pole and line.

Table 13. Estimation results, output elasticities, and technical inefficiencies

Item	Estimate	Std.	Error	z-value	Pr(>|z|)
Stochastic frontier model					
(Intercept)	6.0487	0.2109	28.6785	< 2.20E-16	***
log(Crew)	0.2349	0.0411	5.7179	1.08E-08	***
log(Dim)	0.0685	0.0140	4.9060	9.30E-07	***
log(DAS)	-0.0804	0.0373	-2.1558	0.0311	*
log(Ice)	0.4275	0.0297	14.4009	< 2.20E-16	***
log(Water)	0.2001	0.0194	10.2966	< 2.20E-16	***
Ineffieciency fator					
(Intercept)	1.2583	0.1284	9.7983	< 2.20E-16	***
DumCap2	-0.0810	0.0788	-1.0284	0.30374	
DumCap3	-0.2005	0.0949	-2.1132	0.03458	*
DumCap4	-0.0254	0.0916	-0.2768	0.78192	
Dum4B	-0.0240	0.0688	-0.3485	0.72748	
DumFG3	-0.4924	0.0875	-5.6263	1.84E-08	***
DSoff	-0.2693	0.0622	-4.3315	1.48E-05	***
DSpeak	-0.4152	0.0896	-4.6361	3.55E-06	***
sigmaSq	0.4473	0.0534	8.3776	< 2.20E-16	***
gamma	0.7070	0.0247	28.6620	< 2.20E-16	***

Significance codes: 0 (***), 0.001 (**), 0.01 (*), 0.05 (.), 0.1 ( ), 1

Table 14. Summary statistic of the efficiency

Parameter	All	Purse seine	Pole and line	Hand and troll line
n	2598	2107	26	466
Average	0.5431	0.5764	0.3707	0.4018
Min	0.0934	0.0989	0.0994	0.0934
Max	0.9061	0.9061	0.7165	0.8718
Stdev	0.1737	0.1653	0.1378	0.1308

Efficiency distribution of the tuna fishing fleet in Kendari is skewed to the right evident from Figure 15 which shows that the estimated technical efficiency of 40% of the boats is below the average. The estimated efficiency of 20% of the boats is in the 0.7-0.8 range while the efficiency of more than 21% of the fleets is estimated as greater than 0.8.

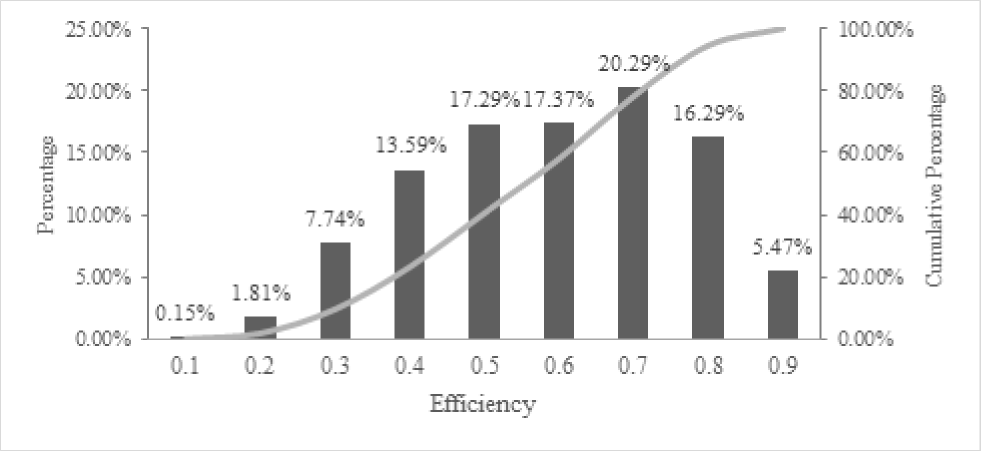

Figure 15. Frequency distribution of the estimated technical efficiency.

In Figure 16 and Table 14 the seasonality of the estimated technical efficiency is analysed in more detail. The dark black line in Figure 16 represents the estimated technical efficiency of boats active during the peak season (March-May) while the grey line represents the efficiency of vessels during the off season (October-February). The dotted line shows estimated efficiency of vessels in the transitory season (June-September). Estimated efficiency is highest during the peak season, but overall there is not a great difference between the technical efficiency of boats operating during the peak season and off season. The frequency distribution during three different periods also shows different patterns, with the distribution of the peak season more skewed to the right than the distribution of the other season.

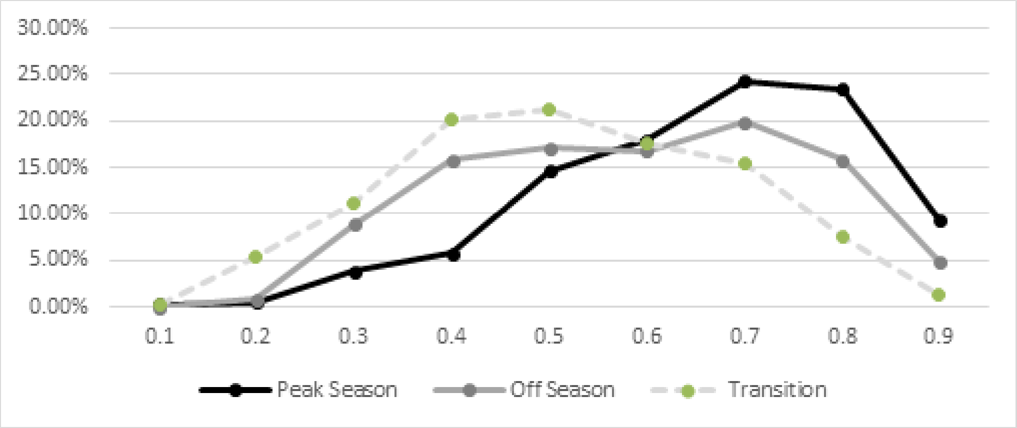

Figure 16. Efficiency frequency distribution for different seasons.

From Table 15 tabulation it is clear that average efficiency is highest during the peak season and the standard deviation lower. However, the difference between the peak and off seasons is not large. This is rather surprising, as one would expect efficiency to be higher during the peak season when the fish is more abundant and catches better.

Table 15. Efficiency distribution and summary for 3 different seasons

Efficiency	Peak Season		Off Season		Transition	
[0.0, 0.1)	3	0.35%	0	0%	2	0%
[0.1, 0.2)	5	0.58%	9	1%	34	5%
[0.2, 0.3)	33	3.85%	98	9%	70	11%
[0.3, 0.4)	49	5.71%	176	16%	128	20%
[0.4, 0.5)	125	14.57%	190	17%	134	21%
[0.5, 0.6)	154	17.95%	186	17%	111	18%
[0.6, 0.7)	209	24.36%	221	20%	98	16%
[0.7, 0.8)	200	23.31%	176	16%	47	7%
[0.8, 0.9)	80	9.32%	54	5%	8	1%
Average	0.6068		0.5383		0.4652	
Min	0.0989		0.1020		0.0934	
Max	0.9061		0.8733		0.8723	
Stdev	0.1562		0.1715		0.1667	

Results from estimating the stochastic production frontier indicated that the length of the trip as measured by days at sea had a negative, but statistically insignificant, effect on catches. In Figure 17 the relationship between trip length and estimated efficiency is analysed in more detail. The Figure clearly reveals that boats that spend many days at sea tend to have rather lower efficiency. Indeed, most of the points corresponding to those long trips lie below the average level.

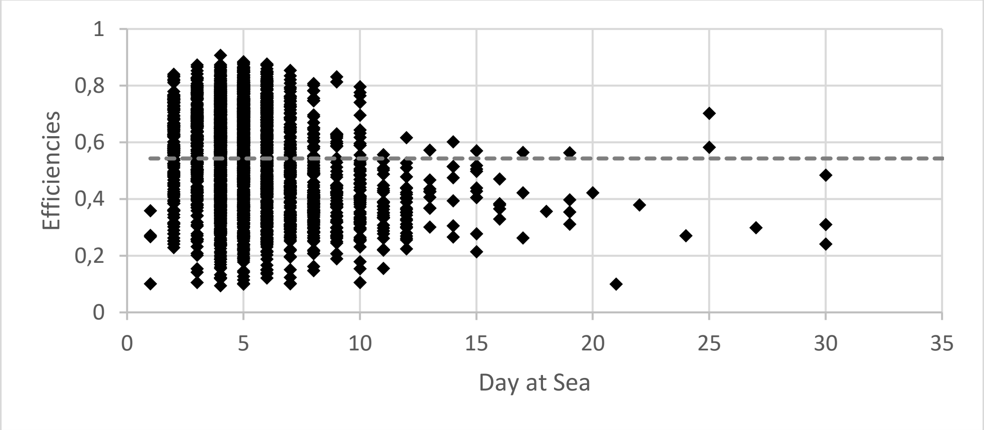

Figure 17. Technical efficiency according to length of fishing trip.

Figures 22 and 23 in the Appendix show the efficiency plot by vessel dimension and crew size. Here, there is no clear pattern and the relationship between the vessel dimensions and crew size on the one hand and technical efficiency level on the other hand is unclear. As Figure 18 indicates, there does though appear to be a non-linear relationship between crew size and estimated efficiency. Technical efficiency is low for vessels with small crews and large crews, but larger for boats with crews of 10-20 individuals.

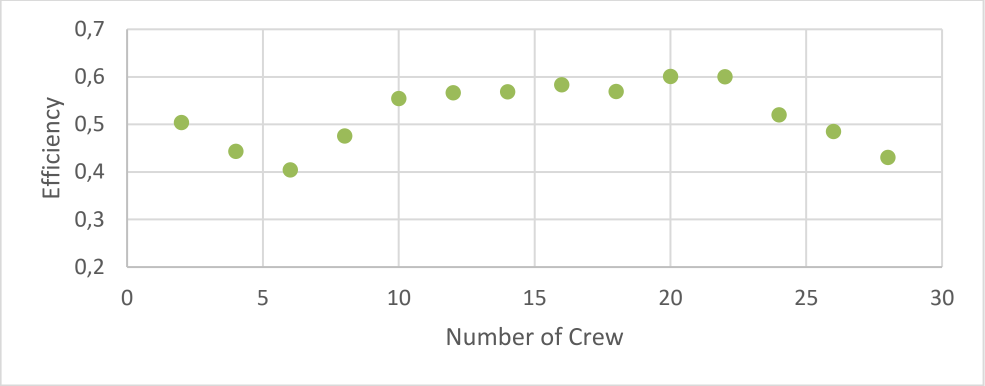

Figure 18. Average technical efficiency according to the size of boat crew.

The data at hand also allows for comparison of technical efficiency of the same vessels between individual fishing trips. This is studied in more detail in Figure 19 which shows the spread of estimated technical efficiency of the tuna boats according to the number of trips undertaken by each boat. Boats with fewer than 12 trips a year were excluded from this comparison. Seven boats were identified has being very efficient. The efficiency of these boats was estimated much higher than the average and the spread of estimated efficiency as measured by the difference between maximum and minimum efficiency scores was quite narrow. As these vessels were not always captained by the same individual, the efficiency of the vessels must first and foremost be related to the boat specification and use of inputs. Other boats always perform poorly; the estimated efficiency is low and the variations of efficiency scores high. These boats might need more talented captains or try to operate more often during the peak fishing season and fish were catches can be expected to be better.

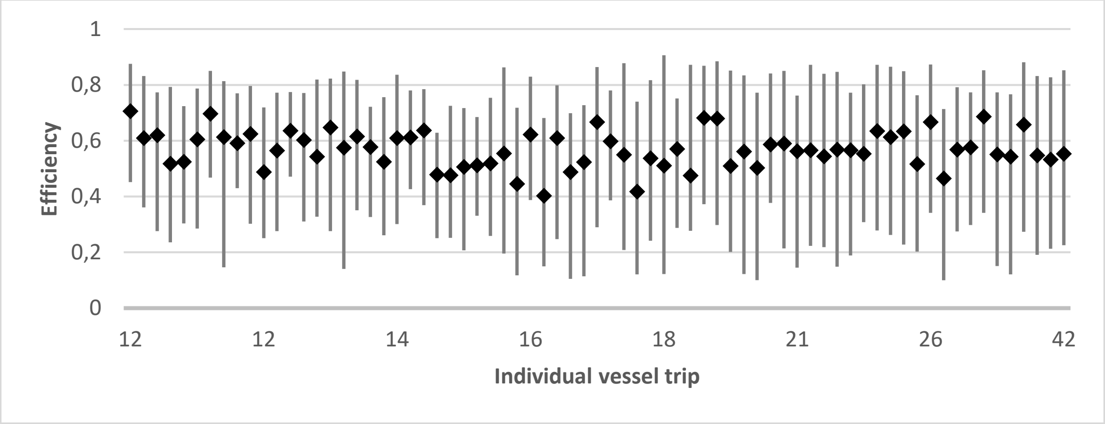

Figure 19. **Spread of technical efficiency of individual vessels.**

7 DISCUSSION

This study aimed to provide a socio-economic and bio-economic analysis of the FAD associated tuna fishery in Kendari-Indonesia and estimate the technical efficiency of the tuna fishing fleets. The main constrains during the project are the lack of long time series for catch and effort data and lack of complete biological parameter data to build robust biological analysis for the bio economic model. There is also need for detailed information about the fishing operation around the FAD to improve the technical efficiency analysis results. Better data would give many other possibilities on the analysis, such as deriving the long run dynamic equilibrium for the bio economic model, and also more detail stochastic production function frontier analysis. However, the results from this project are very useful to describe the FAD associated tuna fisheries in Kendari fishing port, Indonesia and revealed the possibilities of data analysis could be done and support the policy planning and implementation.

7.1 Socio Economic Aspect

The socio-economic aspect has been one of the biggest concern for both policymakers and researcher regarding fisheries management. Understanding the behaviour, social structure of the fishers will provide good policy recommendation to achieve successful fisheries management, in line with the Hilborn (2007) statement about managing fisheries is managing people. Most of the fishers engaged in the FAD associated tuna fisheries are highly dependent on the fisheries sector, only few of the captains or boat owners have the alternative income outside the fisheries sector. Some of the alternative livelihood is not even outside the fisheries sector because is connected with the fishing activities such as fishing equipment and spare part store, engine repairs workshop and fish catch transportation.

Using the average benefit per trip from the bio economic model and the share data from the socio economic we could estimate the individual income from the crews. On the existing condition point pole and line fleet offer the highest shares among the three fisheries, pole and line fishery offer amount of 1,321 USD per trip for the existing condition, the amount of the share for each crew is present on Table 17 in the appendix, each crew of the pole and line will receive 67 USD per trip and the average trip of the pole and line fishing fleet is 20 trip per year, in total the crew of the pole and line will earn USD 1,344 or USD 112 on monthly basis.

The revenue to be shared in the purse seine fishery is USD 1,317 per trip for the existing condition, if we use the same calculation as for the pole and line boats and assuming an average crew of 15 for the purse seiners and the average shares allocation for the purse seine fishery then the crew will receive USD 65 per trip. On average, purse seiners make 43 trips per year, so the total annual shares are USD 2,801, or USD 233 per month.

Hand and troll line fishing fleet shares the smallest amount from each trip, or presently only USD 832. By using the same calculation methods as above and assuming a crew of 7 persons per hand and troll line boat and the average shares allocation it can be estimated that the crew will receive USD 96 per trip. Hand and troll line boats make on average 30 trips per year so annual shares would amount of USD 2,886, or USD 240 per month. Hand and troll line crew received highest share amount compare to the other two fishing fleets while the pole and line crew received the smallest share amount. If we compare with (Bailey, Dwiponggo, & Marahudin, 1987) the crew shares for the hand line crew was only USD 87 per year (if we accommodate the changes of the gold price in 1985 and 2015 we could use the 3.98 as the correction factor) so it equal to USD 348 per year. For the payang net (almost similar to the purse seine) the crew shares were even smaller, as they only earned USD 73 or equal to USD 294 per year.

From the year 2015 Kendari in figures statistical book we could get the information about the labour income in Kendari city industry, in 2015 the minimum amount of salary for the labour was USD 134. This minimum salary is low compared with the monthly income from the purse seine and hand and troll fishing fleet but it still higher than the monthly income from the pole and line fishing fleet. Fisheries sector especially the FAD associated tuna fisheries in Kendari still offer higher income for the crew than the other sector. As it also requires intensive use of labour, some of the fishers come from other places outside the Kendari or Sulawesi Island. This also explains the reason why the extensive investment in FAD fisheries has occurred. The results here are very similar to those obtained by Gaffar (2015) on the contribution of the modernized fishing technology on socio-economic status in south Sulawesi – Indonesia. Gaffar (2015) states that the modernized of the fishing technology improve the socio-economic of the fishers.

In term of education of the fishers this fact is also revealed the reason why the fisherman starts to enter the fisheries and participate in fishing activity at very young age when they have only finished elementary school (12 years old). The income offered by the fisheries acts as a strong incentive for the young to quit school and start working as a fisherman at an early age in order to help provide for their family and also to prepare for starting their own family in the future. One of the main reason they only depend on their income in fisheries was they spend most of their time to go to fishing in the sea. They also think that the wealth offered by the fisheries sector will enough to support their life and they didn’t necessary need other source of income.

7.2 Static equilibrium of bio economic model

Bio-economic model for the FAD associates tuna fisheries in Kendari fishing port has been developed using the Schaefer (1957) surplus production model. From the static equilibrium estimates from the bio-economic model shows that the current exploitation level of still below the MSY level, and the profit per trip of all fishing gear is still high. Simulation was conducted to see the effect of the changes in fish price, fuel price and number of trip in a year. Result of this simulation present on Figure 16 and Table 15 in the appendix. In one scenario it was assumed that fuel would increase in price by 40%, fish prices decrease by 10% and effort (fishing tips per year) decrease by 20%. In all three cases, the point representing MEY shifted to a lower level of effort and profits were reduced for all three gear types. Pole and line vessel were most severely impacted by this change, as profits reduced by 34%. This can be explained by the fact the pole and line boats use a lot of fuel, much more than the other two boat types. The average number of trip per year for the pole and line is also less if compare to other fishing fleets, so the reducing of the number of trip per year will caused the increasing of their fix cost.

7.3 Technical efficiency

Result of technical efficiency analysis shows that the mean efficiency score is 0.5485, this technical efficiency is lower than the study done by Jeon *et al*. (2006) for the purse seine fishery in Java Sea Indonesia (mean value 0.61), Fousekis & Klonaris, (2003) for the Grece trammel net (mean value 0.717) and also lower than Malaysian trawl fishery mean efficiency from the studied done by Ghee-Thean *et al.*, (2012) (mean value 0.717 for the SPF and 0.56 for DEA). This show that the ability of the FAD associated tuna fishery in Kendari to convert the input variable into output (catch) is still lower if compare with the purse seine fishery in Java Sea. Both fishing fleets utilise FAD during their fishing operation.

Seasonality also contributed to the efficiency level in FAD associated tuna fishing fleet in Kendari. This is similar to the results obtained by Jeon *et al.*, (2006) who used different dummies for the different fishing season to see the effect of the seasonality on technical efficiency. Their study revealed that efficiency is highest during peak season than in the off season.

7.4 Policy implication

The focus of bio economic and technical efficiency analysis in open access fisheries is to describe the best form of sustainable development and management for the renewable resource stock, avoid the overcapacity and higher pressure to the fisheries. Bio economic will look into a broader area and also includes the sustainable resource stock and maximising economic resources rent from the fishing activity while the technical efficiency will more focus on detail explanation about the efficiency level for the individual vessel to analysed and avoid the overcapacity contributed by the fishing fleet.

Results from both analysis show there is strong need regarding the implementation of FAD regulation is to reduce the overinvestment in FAD installation and maintain the number of FAD at optimum level. This result supports the implementation of ministerial regulation no 26 year 2014 (The Maximum number of FAD for each boat/owner is 3 FADs)

Regulation regarding the FAD installation and utilisation is Ministerial Regulation No. 26/2014 concerning FAD on this regulation the installation of FAD should comply the requirements; the installation is not disturbing marine shipping/transportation routes, the minimum distance between FADs must be more than 10 nautical miles, and the installation must not in a zig-zag configuration to prevent a barrier effect. Licenses for FADs are granted by different government levels depending on distance of FAD installation from shore, FAD installation on the location between 2 to 4 nautical miles distance from the shore line the licences will be by regency government level, for distance 4 to 12 nautical mile the licence is under the provincial government, and for installation on more than 12 nautical miles to EEZ water the licence is under the central government by the Ministry of Marine and Fisheries Affairs.

There are some improvements about the FAD installation and utilisation if compared with previous regulation, most of the improvements are concerning on the sustainability of the fish resources and also ecological related species protection especially reducing the juveniles catch and unwanted bycatch, the control of the FAD investment and ownership and also the identification of the FAD such as the obligation to install the radar reflector, restriction about the use of used net as an attractor, and also obligation to report detail information about FAD specification including the technical design of the FAD, the geographical position of the FAD as the requirement of the licencing component. The ownership of the FAD is also regulating, maximum number of FAD for one boat/owner is 3 FADs.

This regulation is trying to overcome the uncontrolled investment in FAD installation, the increase of juvenile catch and unwanted catch so it will give better FAD fisheries management. The result from study need to be presenting in the RFMO level as one of the evidence that Indonesia has done something regarding the FAD associated tuna fisheries management.

8 CONCLUSIONS

Results of this project have described the socio-economic aspect, bio economic analysis, technical efficiency stochastic frontier analysis for the FAD Tuna fisheries. Schaefer surplus production model for the FAD associated tuna fisheries in Kendari fishing port has been estimates, the existing condition in the bio economic model FAD of the tuna fisheries indicates that the tuna fishery is still on a good shape and profitable, tuna fisheries still offer more benefit/profit if compare to other sector, the arrangement of the fishing operation also allows this profitable fisheries players to put more investment in the FAD, this results support the reason behind the over investment in the Tuna fisheries especially on increasing the number of new FAD deployment.

The increasing number of FAD tends to have impact on the technical efficiency, mean efficiency still on the low – medium level on 0.534, and if we see in more detail day at sea shows negative impact on the catch, this is one indication that the number of days at sea has been increased affect by the increasing in number of empty FAD. This over investment lead to inefficiency operation and the FAD function as the aggregating devices become less efficient.

9 RECOMMENDATION

The data set could be used for the bio economic analysis and the technical efficiency, need longer and detailed data series on catch landing, and further analysis to accommodate multi fleet and multi species analysis, the extent of the data scope could also provide better picture. Detailed data for technical efficiency, with additional information on FAD and the fishing operation to provide better explanation about the effect of FAD utilization (time series efficiency changes).

Recommendation for the implementation of FAD regulation is to reduce the number new FAD and maintain the number of FAD at optimum level. This recommendation supports the implementation of ministerial regulation no 26 year 2014. Effort to put the regulation in places for example are through socialization, dissemination, focus group discussion with the captain, boat and FAD owner and also law enforcement. However, it also need to do more detail FAD study in term of socio economic aspect, fishing operational aspect and level of exploitation on the FAD associated tuna fishing vessel. Another recommendation is also conduct detail research about the fish behaviour around the FAD to give the detail information and data about the FAD. One recommendation regarding the technical efficiency analysis is to increase the technical efficiency in sustainable way and keep the fisheries profitable.

The controlling of the FAD will reduce the uncontrolled of FAD investment and will prevent the negative impact such as: Reducing the Fish densities in every FAD, Increasing the time to catch the fish this will have negative consequences also to the increasing the cost for the fuel, and reducing the quality of the catch because of the poorer ice quality if the time is longer

The need to increase captain skill to increase the efficiency so the productivity (catch) and also the quality of the catch will be increasing, this could be done through training and workshops in related fields of study (Post Harvest losses reduction, better fishing skills etc.)

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APPENDIX

Table 16. Summary statistic of the interview data

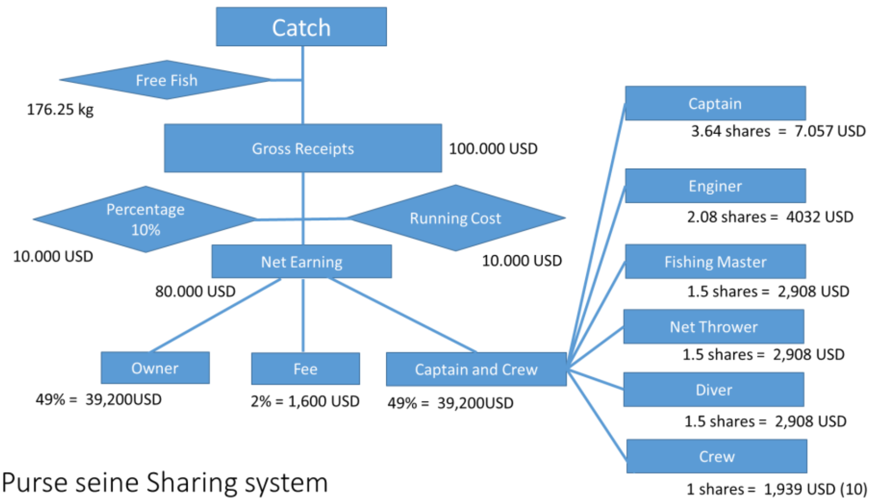
Items	**Purse Seine**			**Handline**			**Pole and Line**		
n total = 60	**31**			**17**			**12**		
	average	**Min**	**Max**	**average**	**Min**	**Max**	**average**	**Min**	**Max**
Operational information									
Fish Hold Capacity	13,320	5,000	35,000	4,182	2,000	6,000	4,200	3,600	5,000
Crew	18	12	25	5	4	6	17	17	18
FAD visited in 1 trip	5	2	30	11	2	30	9	5	12
Days at Sea	4	1	7	10	7	16	21	3	31
Duration skipper in this fishery?	15	2	25	14	10	20	20	16	23
Captain age	36	23	46	34	26	40	40	36	44
Duration skipper on this vessel?	6	1	20	7	1	14	7	0.3	16
Capital Price									
Boat	48,881.5	11,593.1	74,794.3	8,601.3	5,609.6	14,958.9	74,794.3	52,356.0	97,232.6
Engine	9,844.8	7,479.4	13,089.0	2,842.2	2,243.8	3,739.7	10,512.0	7,479.4	13,089.0
Auxillary 1	792.5	747.9	934.9	828.1	747.9	934.9	804.0	747.9	934.9
Auxillary 2	544.0	486.2	747.9	-	-	-	-	-	-
Fishing gear	17,763.6	13,089.0	22,438.3	88.1	72.9	112.2	102.4	59.1	268.5
Permit	149.6	-	-	149.6	-	-	149.6	-	-
FAD	1,880.2	217.7	3,532.2	-	-	-	1,880.2	217.7	3,532.2
	79,856.1	**33,613.3**	**115,536.6**	**12,509.3**	**8,674.3**	**19,745.7**	**88,242.6**	**60,860.1**	**115,057.2**
maintenances									
Boat	2,508.7	448.8	7,479.4	982.9	112.2	1,795.1	4,038.9	3,590.1	4,487.7
Main Engines	1,656.8	568.4	4,562.5	667.0	37.4	1,795.1	2,772.4	897.5	5,026.2
Auxiliary	586.4	56.1	1,795.1	206.9	121.2	350.0	284.2	134.6	448.8
Fishing gear	605.8	224.4	1,495.9	47.4	15.0	112.2	31.8	20.6	37.4
	5,357.7	**1,297.7**	**15,332.8**	**1,904.2**	**285.7**	**4,052.4**	**7,127.3**	**4,642.9**	**10,000.0**

Fuel	642.9	295.4	1,299.9	349.2	177.3	472.7	797.7	590.9	1,181.8
Lubricant	40.6	21.3	176.5	33.1	11.0	88.3	55.2	22.1	110.3
Bait	-	-	-	22.7	3.7	56.1	148.8	119.7	179.5
Ice	203.5	46.7	403.9	95.2	63.6	113.7	137.1	63.6	254.3
Logistic	696.7	196.0	1,062.1	278.8	149.6	558.7	708.8	555.7	972.3
Wages	-	-	-	15.0	-	-	-	-	-
Spare part	48.6	22.4	74.8	43.2	26.2	74.8	67.3	59.8	74.8
	1,632.3	**581.9**	**3,017.2**	**837.1**	**431.4**	**1,364.2**	**1,914.9**	**1,411.7**	**2,773.0**
Shares									
Before the Cost									
Investor and investment	10.40%	10.00%	12.00%	10.78%	10.00%	12.00%			
Unloading fee	1%								
Free Fish	11.75	1.00	30.00	2.78	1.00	5.00	2.0	1.0	2.5
Number of Crew	15.00	6.00	27.00	7.00	3.00	13.00	15	11	26
Total Fish	176.25	6.00	810.00	19.44	3.00	65.00	30.00	11.00	65.00
After the cost									
Boat Owner	49%			49%			49%		
FAD	33%			33%			33%		
Captain+Crew	49%			49%			49%		
Others fee	2%			2%			2%		

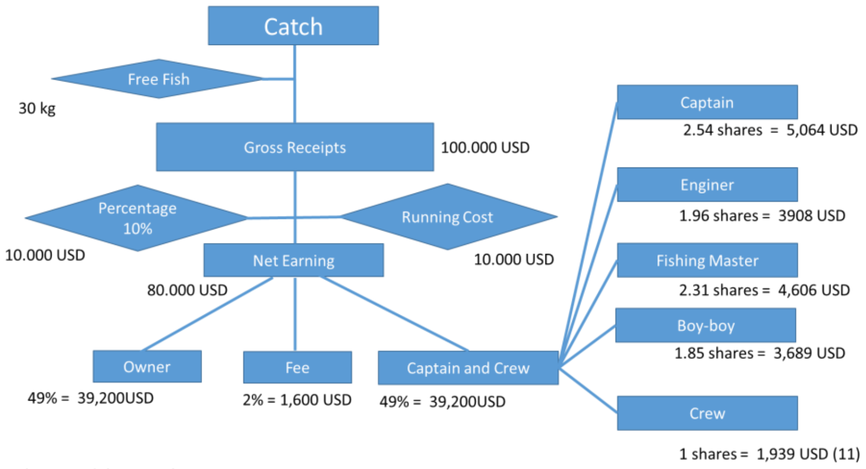
Table 17. Simulation of the shares for 3 fishing fleets

Position	Purse Seine	Pole and Line	Hand & Troll line	Purse Seine	Pole and Line	Hand & Troll line
Captain	3.64	2.54	2.15	237	171	207
Engineer	2.08	1.96	1.5	135	132	144
Fishing Master	1.5	2.31		98	155	
Boy-boy		1.85			124	
Net Thrower	1.5			98		
Diver	1.5			98		
Crew	1	1	1	65 (10)	67 (11)	96 (5)
TOTAL	20.22	19.66	8.65	731	649	447

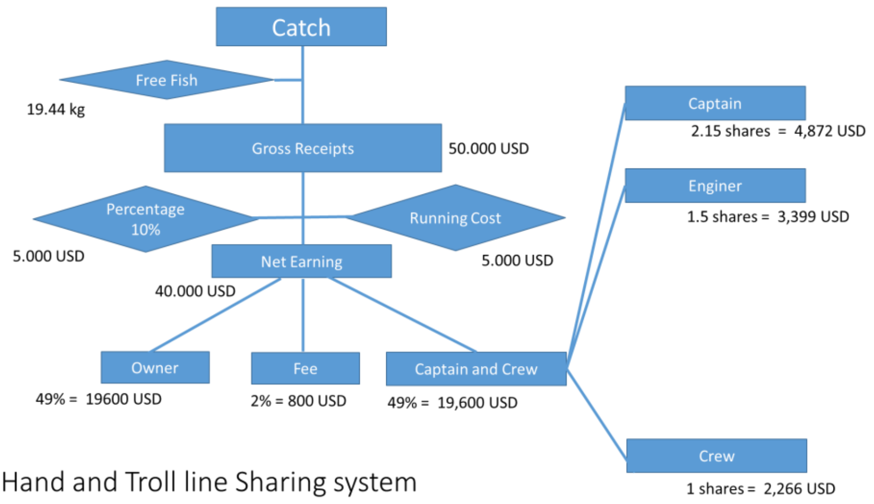
Total shares; PS = USD 1,317, PL = USD 1,321, HTL = USD 832, number of crew PS = 15, PL = 15, HTL = 7



Purse seine Sharing system



Pole and line Sharing system



Hand and Troll line Sharing system

Figure 20. **Sharing scheme of 3 different fishing gear**

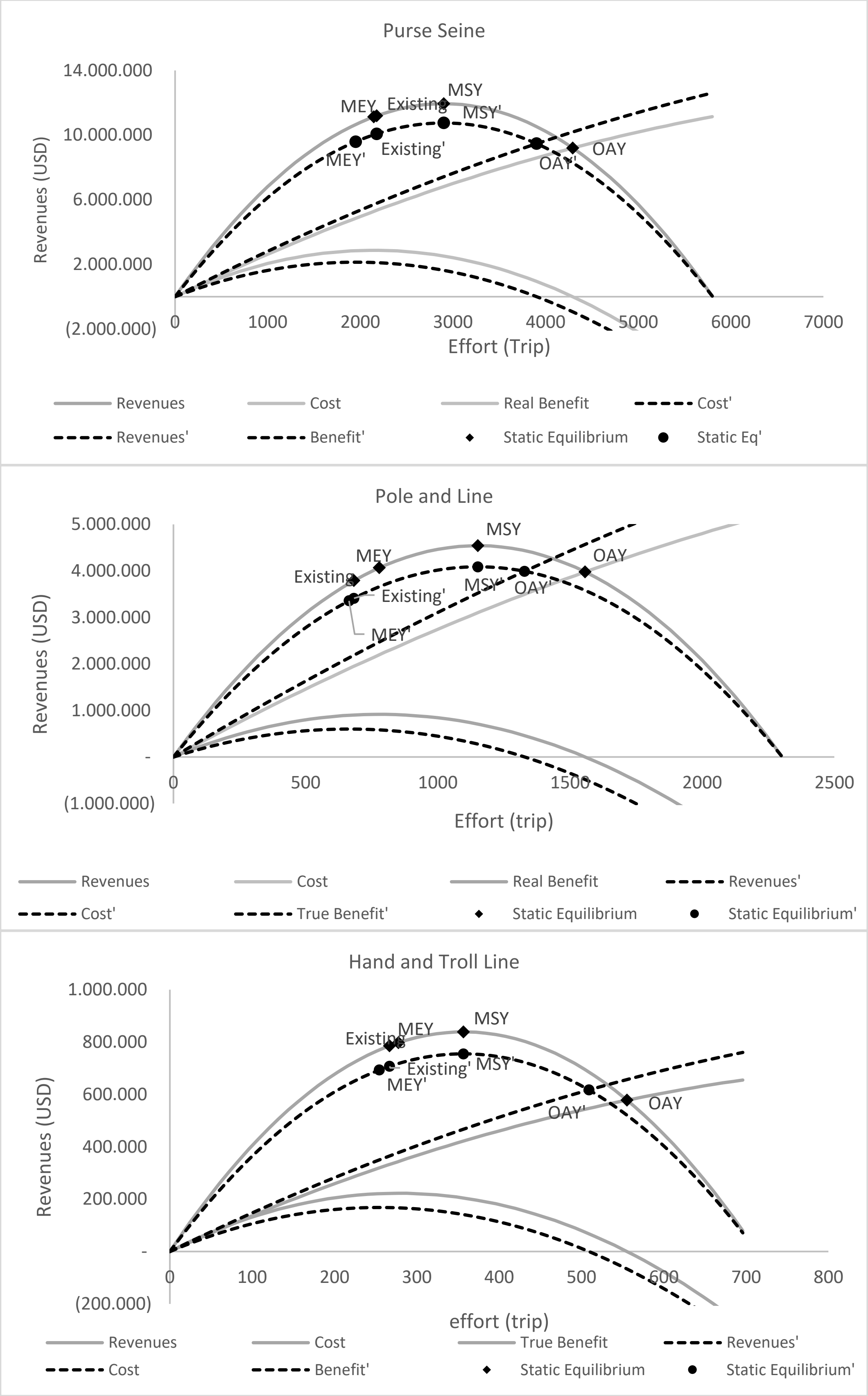


Figure 21. Bio-economic simulation for different scenarios

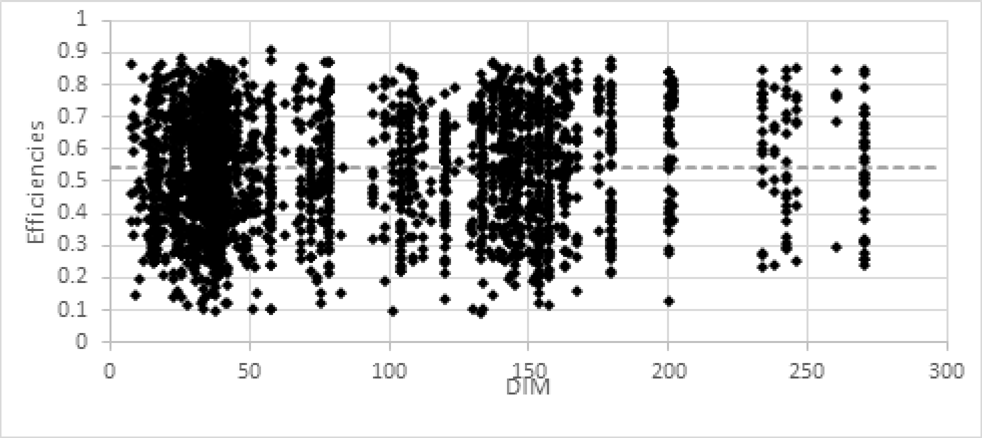


Figure 22. Efficiency plot by vessel dimension

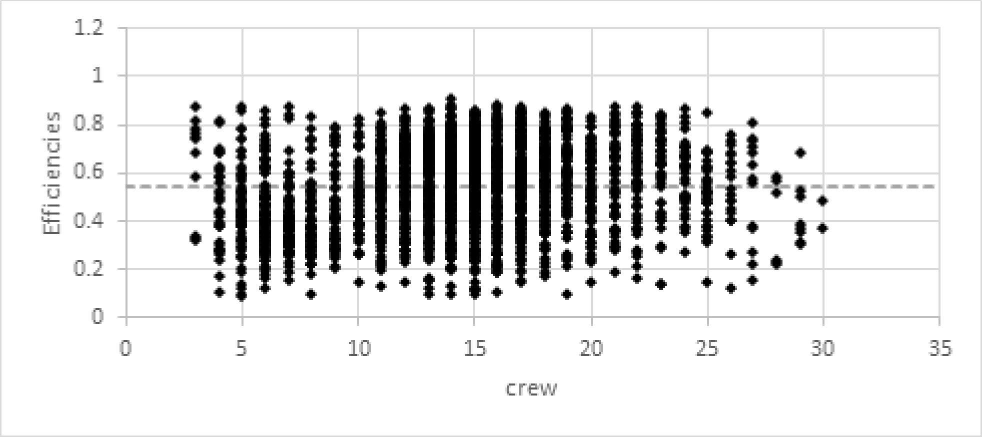


Figure 23. **Efficiency plot by crew size**