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Factors Contributing to the Decline of the Anchovy Fisheries in Krueng Raya Bay, Aceh, Indonesia

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ABSTRACT

Anchovy fisheries in Indonesia faces an imminent collapse in the next decade. This research explores some crucial factors contributing to the overfishing or depletion of anchovy resources. It was conducted in Krueng Raya Bay during September - October 2012. Survey, focus group discussion and interviews were implemented to explore the state of anchovy and coastal ecosystem degradation. It was shown that 52% of the total production was caught by lift net boats during the west monsoon season of 2012. Simple regression analysis resulted to different models of MSY either before or after the tsunami in 2004 which were shown as y = 0.8696 – 0.00008x and y=0.1138 – 0.00002x, respectively. Model 1 recommended reducing the number of lift net boat to 43 units for optimization of yield. On the other hand, Model 2 suggested that only 23 units could be operated for optimal effort each year. Average recent catch in MSY showed 53.9% (less abundant) before the tsunami and 5.5% (depletion) after that. These conditions was led by increasing effort, un-friendly, destructive fishing gears, and degradation of coral reef and mangrove. Such a tragedy was accelerated by anthropogenic factors and compounded by the tsunami factor. The tsunami impact on anchovy fishery depletion may be lesser than the combined effects of destructive fishing and anthropogenic factors.

Keywords: Anchovy fisheries, factors contributing, maximum sustainable yield, anchovy depletion

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INTRODUCTION

Anchovies contribute greatly to capture fisheries in Indonesia wherein they are utilized for human consumption and as bait fish. Fish consumption gradually increased from 23 kg/capita/year in 2003 to 38.4 kg/capita/year in 2010 (Ministry of Marine Affair and Fisheries-MMAF, 2011), although there are few records showing human consumption of anchovy. Various species of anchovy are used for bait fish, such as *Stolephorus devisi* and *S. heterolobus* in Western Sumatera, Southern Java, and Southern Nusa Tenggara (Indian Ocean Tuna Tagging Program, 2000); *Encrasicholina heteroloba* in Ambon Bay (Ongkers, 2011), and *Stolephorus commersonii* in Krueng Raya Bay. Indeed, salted and dried anchovy is widely produced by small-scale processing plants which are located along the coastlines of Aceh.

Increasing demand for anchovy has resulted from both increased human consumption and need for bait fish in Indonesia. As a result, anchovy production has fluctuated, decreased during the period 2001-2007 (average growth -1.1%) and increased again in the period 2008-2011 (average growth 4.4%), with an average annual growth reaching 1.4% (MMAF, 2012). However, over the past 14 years production has shown a decline in several anchovy fisheries centers including Aceh Province. Anchovy production declined to 5,516 tons (2004) from 7,062 tons (2001), being a -21.9% decrease. It gradually dropped from 2005 to 2010, with an average decline of -3.4% (Aceh Province Marine Affair and Fisheries (APMAF), 2001-2011).

There were several factors contributing to anchovy production decrease in Aceh Province. The most decisive factor is the rapid increase of lift net boats. The number of these boats increased from 593 units in 1994 to 607 units in 2004. After the 2004 tsunami, lift net boats dramatically dropped to 194 units, but again increased gradually to 224 units in 2012. Another factor was environmental degradation that affected anchovy resources. Nowadays, overfishing, mangrove and coral reef destruction, and waste pollution, have become worse and they would expectedly impact on anchovy fisheries in the near future. Moreover, the tsunami indirectly influenced the declining anchovy production during the period 2005-2012.

Overfishing of anchovy resources has also occurred in Krueng Raya Bay. Unfortunately, there is no scientific report on anchovy stock for this semi close ecosystem in relation to anchovy fisheries management, but those focusing only on social and economics aspect do exist (Muchlisin *et al*., 2012; Lisna and Sofyan, 2012; Miftachuddin, 2007). Our study in 2012 found that anchovy production showed a sharp decrease from 2,072 tons in 1999 to 1,050 tons in 2004 and dramatically declined further to 171 tons an aftermath of the tsunami (Imran and Yamao, 2014). Anchovy production showed fluctuation in the period 2005-2009. It was less than its pre-tsunami production that reached 126.57 tons in 2012. On the contrary, the number of lift net boats increased from 8 units in 2005 to 31 units in 2009. In-depth interviews with the Panglima Laot Lhok (sea commander, hereinafter called PLL) in 2012 indicated that both coral reef and mangrove ecosystem degradation were decisive factors in reducing anchovy catch before and after the 2004 tsunami.

Several researches identified that major factors of the depletion of anchovy resources around the world were overfishing (Clark, 1977), and El Niño in the 1970s and during 1982-1983 (Clark, 1977; Hilborn and Walters, 2001). Daskalov and Mamedov (2007) reported that the combination of competitive pressure with jellyfish (*Mnemiopsis ledyi*) and environmental condition led to the depletion of anchovy kilka (*Clupeonella engrauliformis*) in the Caspian Sea during the period 2001-2005. However, not many researches paid attention on what natural disasters can directly and indirectly do to the anchovy fisheries.

Past data were not appropriate to fully account for the anchovies' state and condition. Scientific data are also limited to reveal whether anchovy fisheries are subjected to either overfishing or depletion in Krueng Raya Bay. Therefore, this study aims to explore some crucial factors contributing to overfishing or depletion of anchovy resources in Krueng Raya Bay. The specific objectives of this research are to identify the characteristics of anchovy resources; to examine the maximum sustainable yield (MSY) of anchovy before and after the tsunami; and, to examine the state of anchovy stock categories.

MATERIALS AND METHODS

The research was conducted in Krueng Raya Bay which is located on the edge of Malacca Strait and North Sea waters (Figure 1). It is strategically positioned for anchovy fisheries center. Intensive data collection was conducted in four villages (desas), i.e., Ruyung, Meunasah Keudee, Meunasah Kulam and Meunasah Mon. Primary data of some biological aspect of anchovy were collected through sampling survey in the period Sept-Oct 2012 using lift net fishing gears which are commonly operated in Krueng Raya Bay. Anchovies were randomly sampled from eight areas (Figure 1) that were marked by global position system (Garmin *etrex* VISTA Cx). For body length and weight, anchovy samples were taken at random until they represent 10% of the total catch and amounted to 188.

This research selected 83 respondents who answered structured and semi-structured questionnaires to obtain specific information about monsoon season, anchovy catch, size of anchovy, fishing gear, fishing ground, factor affecting the decline of anchovy catch, coral reef and mangrove conditions, and lift net fisheries. Interviews and Focus Group Discussions (FGD) were also carried out to explore deeper information on why anchovy resource has continually declined. Secondary data and information, in particular about the production of anchovy, number of lift net boats, and coral reef condition, were obtained from APMAF. Production of anchovy and the number of lift net boat series data in period 1999-2012 were analyzed to assess MSY and production trend. Other secondary data, such as fisheries and ecosystem data, were sourced from available reports.

Several data analyses were conducted to document the state of anchovy fishery (Table 1), as follow: (1) anchovy's MSY was estimated using surplus production model (SPM), which is widely used in fisheries related applications (Gaertner *et al.*, 2001), to explore the state of anchovy production; (2) length-weight relationship (LWR) and t test were determined to assess the relationship between weight and length, and growth categories; (3) descriptive statistics, comparative and fish stock classification analysis were also used to determine the state of anchovy fisheries; (4) ecosystem condition and tsunami impacts were assessed to clarify their effect on anchovy fisheries; and (5) fish identification was conducted using FAO Species Catalogue Volume 7.

A modified version of the previous study of Mohammed *et al*. (2007) was also inferred in this research. The percent average catch for the last two to three years in relation to the historical maximum value was used to define the state of fish stock. This study applied the percent average catch in relation to the MSY before the tsunami to determine the state of anchovy stock (Table 2).

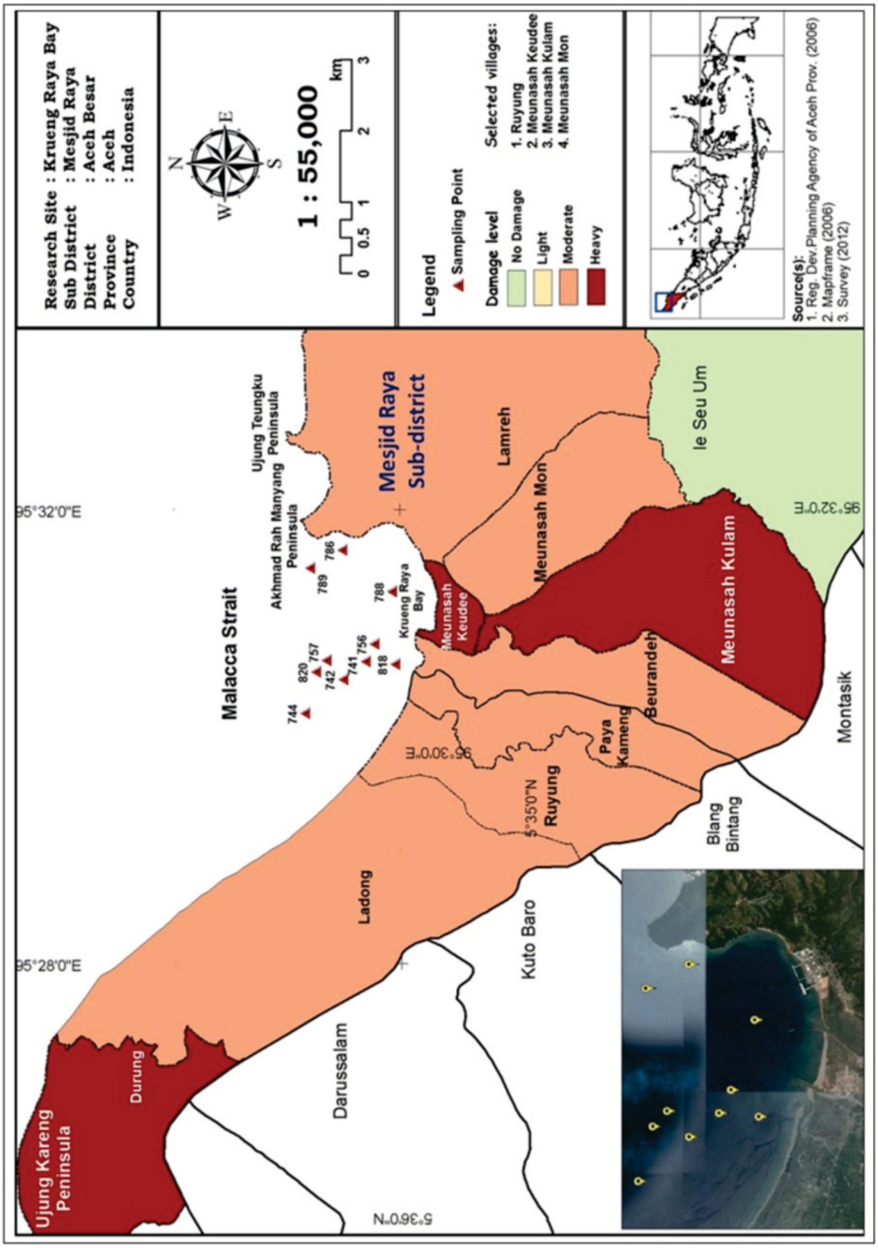

Figure 1. Research site of Krueng Raya Bay, Aceh Besar District-Indonesia
Source: Regional Development Planning Agency of Aceh Province (2006) and Mapframe (2006) and Field Survey (2012)

Table 1. Length-weight relationship, length size classification, and MSY analysis

No.	Data Analysis	Equation	Remark
1.	Length and weight		
	- Length and weight relationship[1]	$W = aL^b$ To estimate a and b parameter using Log W = Log a + b Log L	W = total weight (gram) L = total length (mm) a = constant b = coefficient estimator
	- t test	$t_{test} = \|b - 3\|/Sb$ with the hypothesis: $H_0 = 3$, weight growth is *isometric* H_1 ≠ 3, weight growth is *allometric* (allomatric growth can be positive (b > 3) or negative (b < 3)	b = regression coefficient Sb = standard error of b H_0 = hypothesis null H_1 = hypothesis one Reject H_0 if $t_{test} > t_{table}$ Accept H_0 if $t_{test} < t_{table}$
2.	Length size classification[2]	K = 1 + 3.3 Log N $r = (X_{max} - X_{min})/K$	K = a number of class W = interval/range r = wide of interval X_{max} = maximum value X_{min} = minimum value
3.	Maximum Sustainable Yield[1]	Y = a + b X Where $MSY = a^2/4b$, and $f_{opt} = a/2b$	Y = catch per unit effort X = effort (unit/trip/years) a = constant b = coefficient estimator f_{opt} = effort optimal (unit/trip/years
	Vessel optimal[3]	$V_{opt} = f\,opt/\bar{e}$	V_{opt} = vessel optimal (unit) $\bar{e}$ = average trip in certain period (trip/years)

Sources: [1]Gayanilo and Pauly (1997), [2]Walpole (1995) and [3]modified from Gayanilo and Pauly (1997)

Table 2. Equation and criteria for fish stock classification

Equation	Stock classification	Recent average catch in MSY (%)
% of recent catch in MSY = $[\bar{y}/MSY]$ X 100%	Abundant	> 80
where:	Less Abundant	50-80
$\bar{y}$: average catch last three years before or after tsunami;	Declining	26-49
MSY : MSY during the period before disaster.	Depleted	6-25
	Collapsed	< 5

Sources: Modified from Mohammed et al. (2010)

RESULTS AND DISCUSSIONS

Identification and characteristics of anchovy

In Indonesia, anchovies are generally called "Ikan Teri", but it is known as "ikan bileh" in Aceh. Anchovies sampled in this study belonged to *Stolephorus commersonii* Lacepède, 1803 (Figure 2b). Fishermen in Krueng Raya Bay divide anchovies into small, medium, and big sizes. This research identified that these samples of anchovies have size ranges of 6.8

– 9.9 cm standard length (medium-big size), 5.3-8.3 g weight, a silver stripe line in the compressed body, and a little rounded belly. Commonly, *S. commersonii* is used for daily consumption and fish bait. Therefore, it can become a commercial species for the fishing communities to earn income and sustain their livelihood.

(a) (b)

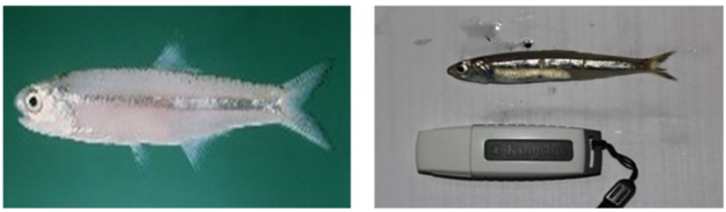

Figure 2. *Stolephorus commersonnii* (Randall, J.E. 1995) (a), *Stolephorus commorsonii* (Doc. Imran 2012)(b)

A regression was calculated for all the length and weight of anchovy sample. The regression formula found was $W = 0.0556\ L^{1.0809}$ ($r^2 = 0.9625$). These computations did not consider: (1) the LWR of the juvenile; and (2) the separation of male and female samples. Regarding t test to coefficient estimator (b), it revealed that t test (123) was more than t table $_{(0.05,\ 187)}$ (1.972), and it means in this case to reject the null hypothesis (H_0 = 3). Logarithmic transformation analysis performed has revealed that b (1.0809) was less than 3. Therefore, anchovy growth could be subjected to a negative allometric growth, meaning length growth is faster than weight growth (Gayanilo and Pauly, 1997).

Production trend

As regards production change in Krueng Raya Bay, the anchovy fisheries can be categorized into three distinct periods, namely: (i) before the tsunami disaster (1999-2004), (ii) after the tsunami (2005-2006), and (iii) the recovery process period (2007-2012). Before the tsunami, anchovy production showed a decreasing trend (Figure 3). Anchovy catch dropped to 1,050 tons in 2004 and it sharply plummeted to 171 tons in 2005 after the tsunami. Eventually, it fluctuated between 126 and 279 tons in the period 2006-2012. Figure 3 also point out that actual production has been less than the result of production surplus model recommendation (Figure 3).

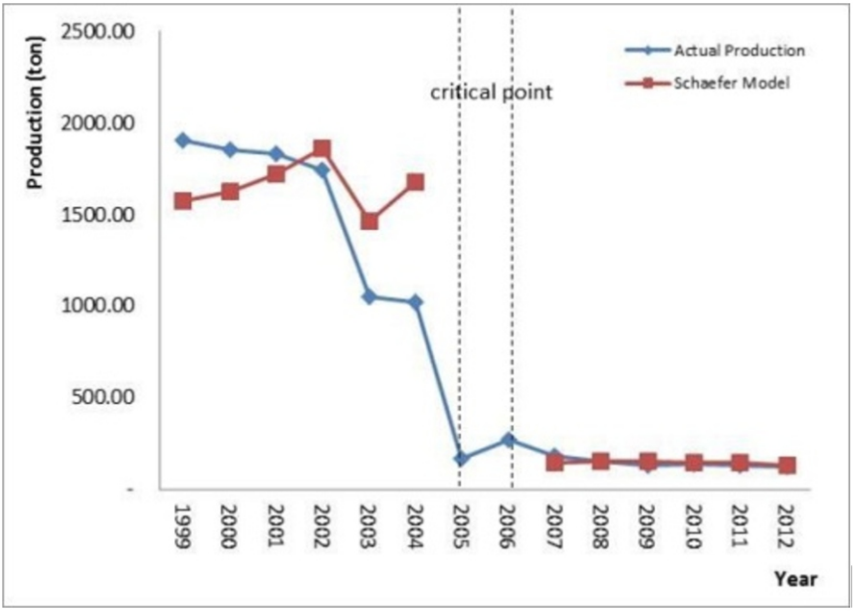

Figure 3. Comparison of actual production of anchovy and Surplus Production Model recommendation in the period 1999-2012, Sources: APMAF (2000-2012) and Data Analysis (2013)

During the field survey on September-October 2012, anchovy catch was very low in the east monsoon season. With the operation of 7-29 units of lift net boats, anchovy production was 7.8 tons. Average catch per unit effort (CPUE) reached 13.5 kg/day or total catch of 100-425 kg/day. During this operation, anchovy catch composition was 52% of the total catch. Other small pelagic fish catch composition were sardines (*Sardinella* sp., 25%), pony fishes (*Leiognathus* sp., 14%), yellow tail trevally (*Caranx* sp., 6%) and mackerels (*Decapterus* sp., 3%).

Fishing operation in the monsoon seasons

As a typical fishing gear operated only in the coastal water zone, lift net boats can catch various small pelagic fishes including anchovy throughout the year. Fishing operation starts at 0430H and finishes the following morning at 0700H. Various pelagic fish species were caught and total volume of catch differs between west (October-March) and east monsoon season (April-September).

The size of anchovy caught is diversed during the east and west monsoon seasons. The change in anchovy size occurs as follow: first, small anchovy was caught in the beginning of the east monsoon season (June-July) and the west monsoon season (October-November) when wind and waves were calm. Second, both medium and big sized anchovies were usually harvested from August to September and from February to April (at the end of west and east monsoon seasons, respectively) when wind and waves were gradually changing from moderate to strong. Third, other small pelagic species such as sardines, pony fishes, mackerels and yellow tail trevallies were harvested in the same season when medium and big anchovies are caught. This research found that 23% and 15% of anchovy size were distributed within intervals of 84.4-88.4 mm and 88.5-92.5 mm during the period September-October 2012, respectively (Figure 4). The mean of total length value was 84 ± 0.02 mm; thus, it can be classified as adult stage.

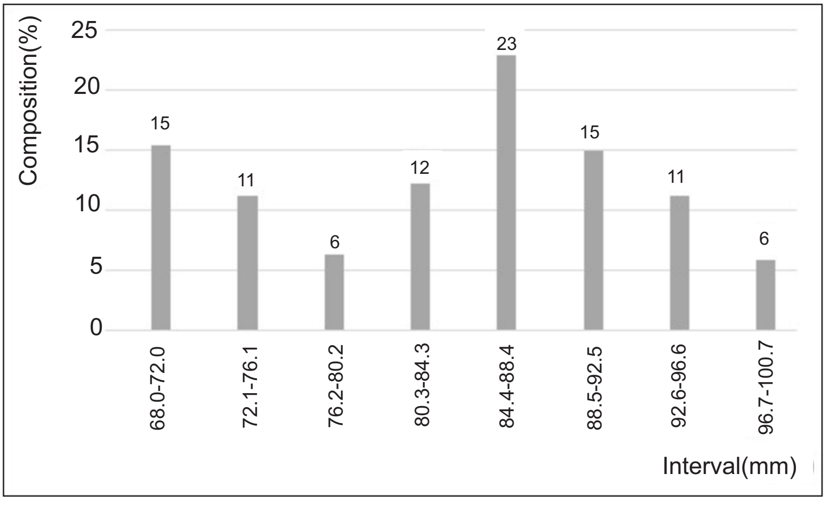

Figure 4. The size class of anchovy's distribution in the period September-October 2012
Sources: Data Analysis (2013)

Maximum Sustainable Yield (MSY) and the State of Anchovy Stock

MSY computation was divided to the period 1999-2004 and 2007-2012. Two point data were excluded to estimate MSY in both these periods because those data showed an extreme decline in anchovy production in 2005 and 2006. These points can be called as an out liner point (in statistical terms it can be classified as biased data) or critical year for anchovy for stock recovery and equilibrium.

Anchovy production is significantly correlated with effort as indicated in the data for the period 1999-2012 (Table 3). When the effort reached 9,344 trips in 1999, anchovy catch was 1,905.58 tons. Afterward, catch volume fluctuated and fell sharply in 2003. This fact indicated that the critical point of anchovy fisheries occurred after the 2004 tsunami. Production dropped extremely down to 166.94 tons in 2005 using 432 trips. Even though the fishing effort was three times than that in 2005, anchovy production only went up almost twice in 2006. Simultaneously, the total effort gradually increased during the recovery process, but anchovy catch continued to show constant decline.

Table 3. Anchovy production, effort, and catch per unit effort from 1999-2012 in Krueng Raya Bay

Period	Year	Production (ton)[1]	Number of vessel[2]	Effort (unit/trip/years)[2]	CPUE
Before Tsunami	1999	1,905.58	73	9,344	0.2039
	2000	1,855.47	72	9,216	0.2013
	2001	1,833.11	71	8,946	0.2049
	2002	1,743.29	68	8,568	0.2035
	2003	1,053.47	76	9,576	0.1100
	2004	1,024.18	73	9,198	0.1113
After Tsunami	2005	166.94	6	432	0.3864
	2006	272.12	18	3,067	0.1575
Recovery Process	2007	182.32	24	2,715	0.059
	2008	156.79	22	2,839	0.055
	2009	129.82	23	3,086	0.048
	2010	136.28	24	3,150	0.044
	2011	129.87	26	3,325	0.039
	2012	126.57	29	3,654	0.035

Sources: 1APMAF (2000-2012) and 2Field Survey (2012)

A lift net boat operated from 18 to 22 days each month for a total of six months per year. PLL (2012) mentioned that these boats were not operated to maximum capacity, but only around 60-80% of the total capacity were used for fishing anchovies both before and after the tsunami. As a consequence, the number of vessels, total efforts, and anchovy catch fluctuated during the period 1999-2012 (Table 3).

Data revealed that CPUE in both the period 1999-2004 and 2007-2012 tend to decrease with increasing efforts (Figure 5). Correlation between CPUE as a dependent variable (y) and effort as an independent variable (x) was computed using SRA. According to SRA, we can propose two distinguishable models of anchovy MSY in Krueng Raya Bay. Model 1 represented the period before the tsunami with equation $y= 0.8696 – 0.00008x$ and Model 2 addressed the period 2007-2012 with equation y= 0.1138 – 0.00002x. Both models recommended the MSY of anchovy fisheries and the optimum effort to be spent in a managed area of Krueng Raya Bay (Table 4). To sustain the anchovy fisheries for each period, models 1 and 2 also performed the optimum number of 43 units and 23 units of lift net boats, respectively.

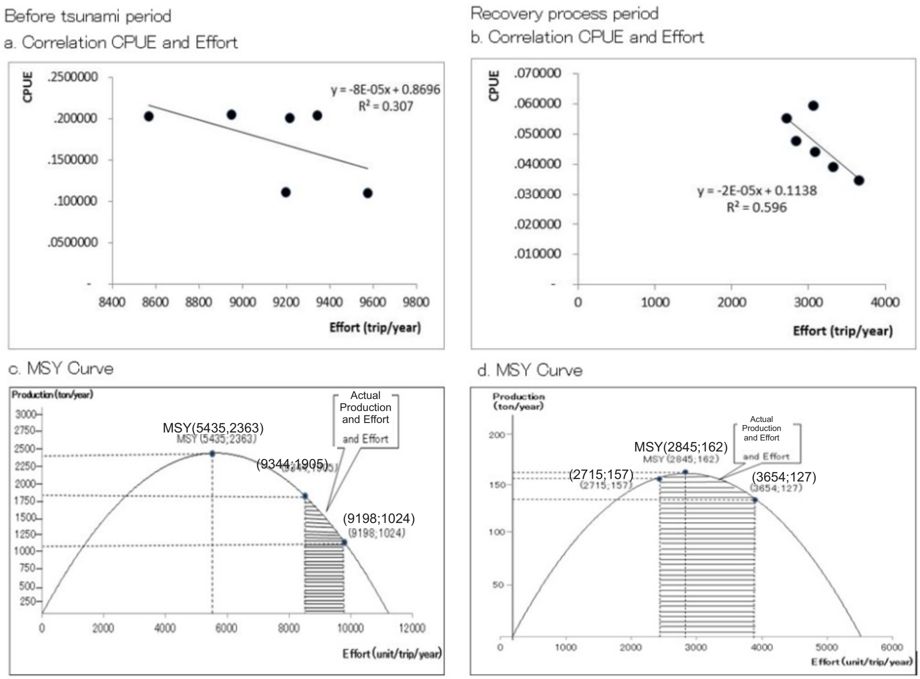

Figure 5. CPUE-effort correlation (a and b) and MSY curve (c and d) of achovy resources in the priod 1999-2012, Sorces: APMAF (2000-2012) and Data Analysis (2013)

Later on, anchovy's MSY curve can be directed using both constant (a) and coefficient (b) estimators (Figure 5). This research revealed that MSY in the period before tsunami (1999-2004) and recovery process (2008-2012) were 2,363.138 tons/year and 161.881 tons/year, respectively. Meanwhile, actual productions in the same period were in range of 1,024.18-1,905.58 ton and 126.57-156.79, respectively. According to Figures 4 actual production was less than anchovy's MSY, but the actual effort had already been over the optimum efforts as this model suggested for both periods. Interestingly the findings in this research were: (1) the fishery's MSY in the period of recovery process was 20 times less before the tsunami (Table 4); (2) the recent average catch in MSY was 53.9% of

MSY and it can be classified to the less abundant stock in before tsunami; and (3) the recent average catch in MSY went down to 5.5% of MSY, it means the stock faced imminent depletion.

Table 4. Surplus production model and its calculation to estimate MSY and Optimum effort

Period	Estimator		Model (Equation)	Result	
	Constant (a)	Coefficient (b)		MSY ($a^2/4b$) (ton/year)	Optimum Effort (a/2b)(trip)
Before Tsunami	0.8696	[illegible]	y= 0.8696 – 0.00008x	2,363.138	5,435
Recovery process	0.1138	[illegible]	y= 0.1138 – 0.00002x	161.881	2,845

Source: Data Analysis(2013)

Anchovy identification and its characteristic role in fisheries management

As an initial research, we started to identify anchovy species and its characteristics in Krueng Raya Bay which was established as one of anchovy centers in Aceh Province prior to the 2004 tsunami. The distribution of anchovy in Aceh Province had been known in coastal waters of the Malacca Strait and the Indian Ocean from our observation during the period 2005-2012. However, there is no previous research carried out to define the characteristics of anchovy. In this case, the identification of anchovy as *Stolephorus commersonii* Lacepède (1803) in Krueng Raya Bay was an interesting task to initiate anchovy fisheries management in the future. The species has had widespread distribution in the Indian Ocean and Western Pacific (Whitehead *et al.*, 1988), Ambon Bay (Sumadhiharga and Yulianto, 1987), Bima Bay-West Nusa Tenggara (Andamari *et al.*, 2002), and Kabuy Bay-Raja Ampat (Bailey *et al.*, 2007).

However, some characteristics of *S. commersonii* identification and its LWR analysis were inappropriate for the holistic determination of the stock concept in term of fisheries management purposes. Begg *et al.*, (1999) concluded that a fundamental of fisheries management requirement is to consider the full impact of management actions, including identification of the stock complexity of a fish species. As morphometric study, LWR in this research was a small part of fish stock identification. Nowadays, anchovy that has had a negative allometric growth pattern was not only found in Krueng Raya Bay, but also this similar pattern of LWR was identified for anchovy in Bima Bay-Ambon Province (Andamari *et al.*, 2002) and Cirebon's coastal water (Supriyadi, 2008). Samsun *et al.* (2004) also found that the anchovy functional regression was a negative allometric growth pattern ($b < 3$) in the Mid-black Sea.

Paraskevi and Stergiou (2012) noted that the allometric growth model was (1) the most appropriate in describing fish morphometric relationship; and (2) study on effect of feeding habit and habitat to morphological characteristics. They stated that anchovy, as small pelagic filter feeder which prey on small zooplankton (copepods), has small mouth and strong dentition in adaption of food habit. Our research predicted that seasonal migration of S. *commersonii* might have a relationship with food habit, monsoon season, enrichment of nutrient into water column regarding FGD with fishermen. Furthermore, oceanography and type of ecosystem; such as current, temperature, existence of mangrove and coral reef; might be contributed in establishment of anchovy population. For instance, the population strategies of European Anchovy to the seasonal upwelling ecosystem has relationship with the enrichment of coastal water and growth investment (Cubillos *et al*., 2001). Integration of anchovy identification, its characteristics and food habit, LWR, and factors contributing on seasonal migration should be paid attention on anchovy fisheries management in the future. Otherwise, these crucial factors might have influenced on un-sustainability of *S. commersonii* in Krueng Raya Bay.

Overfishing of anchovy fisheries prior to the tsunami disaster (1999-2004)

Overfishing of anchovy fisheries was shown by actual effort more than the optimum effort and actual production less than the MSY (see Figure 5c and Table 4). Indeed, anchovy stock could be considered into less abundant state, which is shown by the recent average catch in MSY (53.9%). There were several major factors that caused overfishing of anchovy fisheries prior to the tsunami disaster. *Firstly*, the number of lift net boats definitely increased in the 1980s and the 1990s. In the earlier stage of anchovy fisheries development in the 1970s, only 2 lift net boats had been put into operation for fishing anchovy, according to PLL . The number of lift net boats rapidly increased to 70 units in the 1980s, and reached 89 units in the 1990s. PLL mentioned that the number of fishing boats was 91 units just before the disaster in 2004.

Secondly, since the 1990s, equipment and materials used for fishing have become rapidly sophisticated with a sharp rise of productivity. In the earlier stage of development, the lift net boats used simple kerosene lamps in the 1970s and the 1980s; finally, they operated fluorescent lamps (capacity 10 watts) since the 1990s to attract phytoplankton and small schooling fish, including anchovy. Motorization of pull boats equipped with outboard engine was a decisive factor to increase catch effort. In the last two decades, generators were equipped on board as power plant for light fishing to increase productivity. Each lift net boat was equipped with 25-40 white fluorescent lamps and one green lamp. Light intensity and distribution have influenced fish harvesting. For example, Sudirman *et al*. (1992) reported that using light intensity of 6,000 watts by lift net boats in the South Sulawesi waters since 1987 resulted to higher fish catch than those using 5,000 and 4,000 watts lamps.

Thirdly, the mesh size of the lift net fishing gear is becoming smaller. Fishermen used the mesh size 0.95 cm on the bottom side, 1.27 cm in the middle side, and 2.54 cm on the top side to construct a set of lift net fishing gear with wide 18 m X 18 m and depth of around 15 – 20 m. This fishing net is not selective, targeting juvenile stage of anchovy (fishermen knew such fish as small anchovy or "Teri Medan"), and catching all kind of small pelagic fish. In fact, the design of lift net also harvested the small size of anchovy (10-15 mm) during east and west monsoon seasons. As a consequence, stock of anchovy faced pressured condition and declined year after year, because it has no chance to reach sexual maturity stage. There is no special record the interval length of first stage maturity for *S. commersonii*. However, Luther (1979) reported that minimum size of *S. commersonii* at first maturity is 110 mm in the southwest coast of India. Andamari *et al*. (2002) mentioned that the maturity stage of *S. commersonii* was identified in average length 109.9 ± 0.5 mm in Bima Bay.

Fourthly, anchovy is harvested throughout the year in both west and east monsoons. It might cause a decline of stock to support reproduction system of anchovy. In case of tropical anchovy, spawning season may have occurred throughout the year and reproductive seasons are often linked to the monsoon season (Tiews *et al.*, 1970).

Other factors to boost anchovy fisheries depletion during the recovery process (2005-2012)

Overfishing of anchovy fisheries continued during the period 2005-2012. Because the actual production and fishing efforts were more than MSY and optimum efforts in the same period (Table 3 and Table 4), means anchovy fisheries was in overcapacity condition. FAO (2008) noted that overcapacity might occur when the fishing fleet is larger than it needs to be to catch the available fish resources. Lift net fisheries was in overcapacity at around 16.7% by using the effort of 3,325 trips in 2011. Thus, the number of lift net boats had to be reduced by 23 units for sustainable anchovy fisheries. Otherwise, anchovy resources sustainability would be threatened and depleted due to the recent average catch in MSY (5.5% of MSY).

Besides the factors mentioned above, there are many other factors as to why anchovy fisheries showed depletion. Firstly, coral reef and mangrove ecosystem degradation might have contributed to anchovy depletion. There were no research activities conducted to analyze the state of this ecosystem in prior the tsunami in Krueng Raya Bay. According to the Center for Oceanography-Indonesia Research Institute (2005), coral reefs in the western part of Indonesia are in poor condition (35.7%), including the reef in this study area. As an aftermath of the tsunami, the area, length and average living cover of the coral reef ecosystem were 196.4 ha, 13 km and 10%, respectively (Long et al., 2006); and the live cover of hard coral was 36.9 % (Ocean Diving Club, 2011). Therefore, the coral reef ecosystem was in poor condition based on the classification developed by McAllister (1988). It is estimated that 62-90% of this ecosystem was in degraded condition. We also observed that the point of Akhmad Rahmanyang peninsula and Lhok Mee Beach are frequently used for harvesting the small anchovy during October-November in the west monsoon.

Commonly, coral reef damage in the study area has been caused by increasing intensity of line boat activities, anthropogenic factors, and tsunami impact. Increasing number of line boats to 31.3% before the tsunami might have contributed to the destruction of coral reef ecosystems because these boats captured reef fish as a target species. These boats also frequently dropped anchors on reefs that can cause severe damage to coral reef ecosystems.

Anthropogenic factors have simultaneously occurred toward contributing to anchovy depletion after the tsunami. Nowadays, potassium cyanide that can kill coral polyps, symbiotic algae, and other small organisms necessary for healthy reefs has been used to catch ornamental reef fish by some fishermen in the study area. Explosives, land-based pollution, destructive fishing, oil spills, sand mining and untreated human sewage might have exerted much stress towards coral reef degradation. Indeed, mangrove conversion, deforestation, agriculture, shipping and harbor construction have destroyed the coral reef ecosystem indirectly.

The tsunami also affected the mangrove ecosystems in Krueng Raya Bay. It is estimated that 77.1 ha of mangrove ecosystem is distributed along a 15.27 km stretch within the Aron Meudawa-Ujung Teungku Peninsula zone. The percentage cover of mangrove trees had remained at around 5% and it can be classified as under the severely damaged category according to the Ministry of Environment Classification (2004). In the 1980s, the mangrove area was estimated at around 300 ha in Krueng Raya Bay. The mangrove ecosystem has been converted into brackish water shrimp ponds which might be a major factor for the ecosystem degradation in this area. As a comparison, Wibisono and Suryadiputra (2005) reported that 26,823 ha mangrove ecosystem in Aceh Besar District was affected by the huge tsunami disaster. However, the tsunami's effect was less than the other anthropogenic impacts on the mangroves which are harvested for charcoal, housing and fire wood.

Secondly, rapid human population growth in Krueng Raya Bay after the tsunami disaster has urged fishing communities to depend more on fisheries resources (in particular anchovy) than before the 2004 tsunami. Before the disaster, around 69% of the population in this region had been dependent on capture fisheries and 31% on other livelihoods such as agriculture and livestock. After the tsunami disaster, those who were engaged in capture fishery and relied on it for their income increased to 78%. Lotze *et al*. (2006) stated that rapid human population growth caused an increasing demand, commercialization of resources, technology development, unselective and destructive fishing gears that caused a sharply upward trend on fish resources depletion. They added that human activities have impacted to more than 90% of important species depletion; and 60% sea grass and wetlands habitat destroyed, water quality degradation, and accelerated species invasion.

CONCLUSION

Anchovy, identified as *Stolephorus commersonii,* has a significant role to sustain livelihood for the fishing communities in Krueng Raya Bay. Increasing utilization and dependency of anchovy resources caused the decline of anchovy fisheries which is increasingly unable to support fisheries livelihood after the 2004 tsunami. As a consequence, anchovy fisheries was over exploited during the period 1999-2004 and became deplete in the period 2005-2012.

There are several factors that contributed to overfishing anchovy fisheries prior to the tsunami. The lack of anchovy characteristic knowledge, increasing effort, non-selective mesh size, unlimited use of lighting, harvesting throughout the monsoon season were direct factors contributing to anchovy overfishing. Anthropogenic factors definitely caused the degradation of coral reef and mangrove ecosystem and these factors could be indirect factors on the decline of anchovy fisheries prior to the tsunami.

Anchovy fisheries faced overfishing and depletion condition due to the actual production of anchovy and average recent catch in MSY. This anchovy fisheries depletion can lead to at least six scenarios, as follow: (1) anchovy resources suffered under extreme pressure during the critical years (2005-2006), (2) the direct factor continued contributing on anchovy resource declining during recovery process, (3) the destructive fishing operations threaten the coral reef ecosystem, (4) the anthropogenic factors lead to coral and mangrove ecosystem degradation, (5) tsunami impact compounds the degradation of coastal ecosystem; and (6) the population increase caused the increase of anthropogenic factors and dependency on anchovy resources. However, it is clear that the tsunami impact on anchovy resources depletion may be lesser than the combined effects of destructive fishing and anthropogenic factors.

On a positive note, anchovy depletion can be turned around to avert another anchovy fisheries collapse in the future. To prevent such a bigger “tragedy of the commons,” the Government of Aceh Province (GOAP) needs to prepare “Good Governance of Anchovy Fisheries Management, GGAFM” in the future. Within a short time (1-5 years), the GOAP should conduct research on the unit stock to generate new baseline data of anchovy resources, information dissemination for preventing destructive and ecologically un-friendly fishing gear utilization for anchovy catch, and the greater involvement of society in the management of coastal ecosystems for anchovy resources. The Zoning and Management Plan must be prepared to integrate multi-purpose uses of the coastal zone of Krueng Raya Bay for the next 5-10 years. The most interesting scenario is to keep anchovy fisheries sustainable by integrating the indigenous institution (Panglima Laot Lhok) and district governments in managing fisheries resources by using social ecological approach and establishing Marine Protected Areas in the long run (25 years). This recommendation will be useful to further conserve anchovy resources and the ecosystem, thus potentially contributing to an increase in income of fishing communities in Krueng Raya Bay.

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