Responsible grouper fisheries in Weh Island, Aceh Province, Indonesia

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Abstract The reef fish known as ‘Grouper’ from the Family Serranidae is a favoured food in seafood restaurants around the world, especially in the Asian region. High grouper demand directly leads to increased fishing efforts around Indonesian’s coral reefs. Weh Island is located in the most western part of Aceh Province, Indonesia, and is characterised by a high diversity of corals and reef fish. Reef fisheries are important sources of protein and income on Weh Island, and a main target group are reef fishes in the Family Serranidae. The objectives of this study were (1) to examine the current ecological status of groupers, (2) to identify the fishing gear used in grouper fisheries, and (3) to determine and quantify the fishing gear that is used sustainably in the grouper fishery of Weh Island. We used fish catch surveys, underwater visual censuses, and focus group discussions to collect information on the grouper fishery. Fish catch surveys were conducted at five fish landing sites, and underwater visual censuses were conducted at 20 sites around Weh Island. The data from the visual censuses were analysed using multi criteria analyses and linear goal programming. The input variables used in multi criteria analyses were the number of boat crews, fishing methods, social impact, and fish. Twenty five species of grouper were caught by six types of fishing gear; gillnets, encircling gillnets, handlines, purse seines, spearguns and troll lines.

Keywords Grouper, Weh Island, Responsible Fishing gear

Introduction

Fish is a global commodity that provides food security and jobs for millions of people in the world. Fisheries resources are often considered to be ‘a gift from nature’ or an infinite resource by many coastal communities in Indonesia. Globally, there is a recognition and increasing consensus that fishery resources are not infinite, and that sustainable management is needed in order to reverse global declines in fisheries around the world.

Since the Convention on International Maritime Law was declared in 1982, there was a paradigm shift in fisheries management. The convention gave mandate to the states to manage their coasts and islands, including their exclusive economic zones. The convention encourages coastal and island countries to develop plans for natural resource utilisation in their territorial waters; one of which is fishery resources. After ratification of the UN convention, each country began to take advantage of the opportunities which were provided by the convention. Each country built large-scale fishing industries which accelerated the widespread exploitation of fisheries re-
sources without regard to their carrying capacities.

Based on these conditions, the International Fisheries Committee under the Food and Agricultural Organization (FAO), developed a new concept of responsible fisheries management for the sustainability of fisheries resources at a meeting in 1991. After the FAO meeting, several conferences related to fisheries management were conducted which also provided similar recommendations regarding responsible fisheries management. In October 1995 the FAO published the Code of Conduct for Responsible Fisheries (CCRF), which encouraged each country to implement actions to prevent excessive exploitation of fisheries and to adopt responsible and sustainable use of fishing gear.

The group of reef fishes commonly known as the ‘Grouper’ is a favourite food in many restaurants around the world, especially in the Asian region and high grouper demand directly influences fishing practices and efforts. Weh Island is located in the most western part of Aceh Province, Indonesia, has good coral reef conditions and is rich in reef fish, therefore reef fisheries are prominent. One of the reef fish targeted was the grouper. To ensure sustainability of groupers at both local and national levels, there should be more developed responsible grouper fisheries. There are very limited studies concerning grouper status in Indonesia, thus, this study is very important to be conducted in Indonesia in order to achieve sustainable fisheries management of the grouper.

The objectives of this study were (1) to examine the current ecological status of the grouper, (2) to identify the fishing gear which is used in grouper fisheries, and (3) to determine and quantify the fishing gear that is used sustainably in the grouper fishery of Weh Island.

Materials and methods

This study was conducted in Weh Island, Sabang, Aceh Province from January to August 2009. Underwater visual censuses and fish catch surveys were conducted to collect the data.

Underwater visual census

Underwater Visual Census (UVC) with belt transect method is the identification and counting of fish that observed in a particular area. UVC was conducted to estimate the quantity and size of each fish species. An underwater visual census was carried out in 20 stations with 50 metre transects and six replications at each station.

Fish catch survey

The grouper fish catch survey was conducted in five sites representing the northern, western, southern and eastern parts of Weh Island. Survey locations were Lhok Meulee Ie, Lhok Anoi Itam, Lhok Pasiran, Lhok Kenekai, and Lhok Paya. The data which was collected were based on the catch of each species of each fishing gear in the five sites during the 14 days on the west and east monsoon.

Data analysis

The methods used in data analyses were the Biomass Analysis, Maximum Sustainability Yield, Multi-criteria Analysis, and Linear Goal Programming.

Biomass analysis

The length of the fish from UVC was converted into weight by the equation:

$$W = aL^b$$

where; $W$ : Weight

$L$ : Total Length

$a, b$ : L-W relationship.

The L-W relationship of each fish was obtained from metadata of the fish-base online at http://www.fishbase.org (Froese and Pauly, 2008). Fish biomass was calculated by dividing the total weight of fish with the survey area.

Maximum Sustainability Yield (MSY)

MSY was calculated by the following equation (Garcia et al., 1989):

$$MSY = \frac{\bar{B} M^2}{2M - F}$$

where, $B$ is the average biomass, $M$ is natural mortality and $F$ is fishing mortality. The natural mortality of each species was obtained from the existing data on the fishbase online at www.fishbase.org (Froese and Pauly, 2008). Fishing mortality was obtained from the equation of exploitation rate; $E = F / (F + M)$, where $E$ is the level of exploitation. Several references indicated the $F_{msy}$ value
occurred when the value of $E$ was 0.5 (Gulland, 1971 and Samoilys, 1997).

**Multi-criteria Analysis**

Multi Criteria Analysis is an analysis of several parameters that have various values. The first step in this analysis was scoring each parameter. The parameters included fish caught, the impact on the target species, the impact on non-target species, fishing methods, the social impact of the operation of fishing gear, and number of crew of each fishing gear. Scores of each parameter were presented in Table 1. After scoring, we performed the standardization of each parameter as modified from Briguglio (1995).

\[
SV_{ij} = \left[ \left( \frac{X_{ij} - \text{Min } X_{ij}}{\text{Max } X_{ij} - \text{Min } X_{ij}} \right) \times 2 \right] + 1
\]

where; $SV_{ij}$ : Standard value of each indicator for each fishing gear

$X_{ij}$ : Each indicator value for each fishing gear

Min $X_{ij}$ : Minimum value of each indicator for each fishing gear

Max $X_{ij}$: Maximum value of each indicator for each fishing gear

The average score of each fishing gear was measured by the formula;

\[
S_i = \frac{\sum_{j=1}^{l} SV_{ij}}{m_i}
\]

where; $S_i$ : Fishing gear score

$SV_{ij}$ : Standard value of each indicator for each fishing gear

$m_i$ : Number of indicator each fishing gear

**Linear Goal Programming**

Linear goal programming was used to determine the optimum number of fishing gear based on MSY of each species. The equations of Linear Goal Programming are,

Objective: $\min Z = \sum_{k=0}^{l} \sum_{j=1}^{m} P_k (dB_i + dA_i)$

Subject to: $\sum_{j=1}^{n} a_{ij} X_j + dB_i - dA_i = b_i$

Where; $P_k$ : Priority

$dB_i$ : Slack

$dA_i$ : Surplus

$a_{ij}$ : Coefficient

$X_j$ : Decision variable

Decision variables used in the constraint function was MSY reef fish resources and the average catch of each fishing gear in one year.

**Result and discussion**

**Grouper status**

Based on the fish-catch survey, twenty five groupers were caught by fishermen in Weh Island. However, UVC only found 18 species from 25 species. Species which had the highest biomass was *Cephalopholis argus* with biomass values of 10.5 kg / ha or 28%, followed by the biomass of *C. sexmaculata* (20%), *C. sonnerati* (7%), *C. leopardus* (7%) and *C. spiloparaea* (6%). There were three grouper species which had low biomass and high catch. The three grouper species were *Cephalopholis miniata*, *Epinephelus caeruleopunctatus* and *Variola louti*. The composition of all species and the comparison of biomass and catch were presented in Figure 1 and Figure 2.

MSY, which was obtained from the model of Garcia *et al.* (1989), was regressed with each grouper biomass, where the value of the biomass was as an independent variable. Biomass and MSY regression model was;

\[
\text{MSY} = 0.4219 \times \text{Biomass} + 0.1757
\]

The model showed the coefficient of determination ($R^2$) of 0.92 (CI: 95%, $p$-value = 0.000). The results indicated the average grouper MSY was 42% of the biomass of each grouper. Biomass and MSY regression model was presented in Figure 3.
Table 1  Score of each indicator of fishing gear

<table>
<thead>
<tr>
<th>Score</th>
<th>Grouper Species Catch¹</th>
<th>Impact to Targeted Species²</th>
<th>Impact to Non Targeted Species²</th>
<th>Fishing Gear Type</th>
<th>Social Conflict</th>
<th>Number of crew</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High risk species</td>
<td>High</td>
<td>High</td>
<td>Bottom operation and active fishing gear</td>
<td>High</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(species are recommended for zero exploitation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Moderate risk species</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Bottom operation and passive fishing gear</td>
<td>Moderate</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>(species with first priority to be protected/regulated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Low risk species</td>
<td>Some</td>
<td>Some</td>
<td>Pelagic operation</td>
<td>Low / None</td>
<td>3 or more than 3</td>
</tr>
<tr>
<td></td>
<td>(species with second priority to be protected/regulated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>None risk</td>
<td>Low</td>
<td>Low</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>


Fig. 1  Biomass composition of the grouper species in Weh Island
Six types of fishing gear were used by fishermen to catch grouper. There were handlines, purse seines, spear-guns, troll lines, gillnets, and encircling gillnets.

**Handlines**

Handlines were commonly used by fishermen in Weh Island. The size of the hook used was 9 to 12.

**Gillnets**

The Gillnets were 50 meters long monofilament nets with a mesh size of 1 inch. Gillnets were operated by fitted settle with the straight position for a night around the coral reefs area. This fishing gear caught fish by gilled.

**Purse seines**

Purse seines were 800–1200 meters long multifilament
nets with a mesh size of 1–3 inches. Purse seines were operated by encircled schooling fish. The main target of the fishing gear was pelagic fish, but fishermen in Weh Island operated purse seines near coral reefs so that grouper fish were caught.

**Spearguns**

Spearguns are a type of fishing gear that the arrow thrower made from wood are use as a weapon. This gear was operated by a fisherman when they dive and shoot the target fish.

**Encircling Gillnets**

Encircling Gillnets are gillnets which are operated by encircling schooling fish and placed in the bottom of the coral reef area. Encircling Gillnets were 100–300 meters long multifilament nets with a mesh size of 1–3 inches. Operation of this gear was assisted by a fisherman who herded fish into nets so that fish hit the net. This fishing gear caught fish by gilled.

**Trollines**

Trollines are fishing gear that are used as bait which are pulled by a boat. The size of the hook that was used was in the size of 4 to 6.

Based on the number of catches per trip, spearguns, encircling gillnets, and handlines were shown to be the most dominant fishing gear to catch the grouper. Spearguns were the most selective fishing gear as it could catch targeted species (grouper) with larger sizes. Encircling gillnets are a passive fishing gear, but because it was assisted by fishermen, the device seemed to be active. Handlines and trollines were used to attract the fish so that the fish were attracted to eat the bait. Gillnets are a passive fishing gear so that the amount caught was relatively less than with other fishing gear. Purseines are a pelagic fish fishing gear, but due to its operation close to the reef area, it caught fewer grouper and it was by catches. The composition of the amount caught by each fishing gear was presented in Figure 4 and Figure 5.

**Sustainable Fishing Gear**

Based on the scoring to all fishing gears, the average results showed the handline was the most sustainable fishing gear for grouper fisheries because the handline had the highest score. The assessment result of each fishing gear was presented in Table 2.

The optimum number of fishing gears showed different results with sustainable fishing gear rank. Linear goal programming showed the optimum numbers of handlines were less than the number of gillnet. If it compared with the number of fishing gear that operated in Weh Island waters, it was necessary to reduce the number of handline and gave incentives to increase the number of gillnet. These results suggested that even though the handline was the most responsible fishing gear, but the optimal number that could be operated was limited by the number of fish in nature. Table 3 showed the optimum number of fishing gear in three scenarios and the number of existing fishing gear.

**Conclusions**

There were twenty five grouper species, which were caught by fishermen in Weh Island. During the underwater survey, 18 species of grouper were found that were dominated by the genus of *Cephalopholis*, with the highest biomass being *Cephalopholis argus* (28%). Maximum sustainable yields of grouper in Weh Island was 42% of the total biomass of each species.

Six types of fishing gear were used by fishermen to catch groupers, namely handlines, purse seines, spearguns, troll lines, gillnets, and encircling gillnets. Handlines, gillnets and trollines were the most sustainable fishing gear. The optimum number of fishing gear was handlines (57 units), gillnets (1737 units), and troll lines (8 units). In
Fig. 5  Fishing capacity of each fishing gear in Weh Island

Table 2  Score table of each fishing gear

<table>
<thead>
<tr>
<th>Fishing Gear</th>
<th>Type of fishing gear</th>
<th>Number of crew</th>
<th>Impact on target</th>
<th>Impact on non target</th>
<th>Social Impact</th>
<th>Species caught</th>
<th>Average Score</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnet</td>
<td>2.00</td>
<td>1.00</td>
<td>3.00</td>
<td>1.67</td>
<td>3.00</td>
<td>2.00</td>
<td>2.11</td>
<td>3</td>
</tr>
<tr>
<td>Encircling gillnet</td>
<td>1.00</td>
<td>3.00</td>
<td>2.33</td>
<td>2.33</td>
<td>1.00</td>
<td>1.33</td>
<td>1.83</td>
<td>6</td>
</tr>
<tr>
<td>Handline</td>
<td>3.00</td>
<td>2.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>1.78</td>
<td>2.63</td>
<td>1</td>
</tr>
<tr>
<td>Purse Seine</td>
<td>3.00</td>
<td>3.00</td>
<td>2.33</td>
<td>2.33</td>
<td>2.00</td>
<td>2.33</td>
<td>2.50</td>
<td>2</td>
</tr>
<tr>
<td>Spear Gun</td>
<td>2.00</td>
<td>1.00</td>
<td>3.00</td>
<td>3.00</td>
<td>2.00</td>
<td>1.53</td>
<td>2.09</td>
<td>5</td>
</tr>
<tr>
<td>Trollline</td>
<td>2.00</td>
<td>1.00</td>
<td>3.00</td>
<td>3.00</td>
<td>2.00</td>
<td>1.67</td>
<td>2.11</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3  Optimum number of fishing gear

<table>
<thead>
<tr>
<th>Fishing Gear</th>
<th>No Regulation</th>
<th>Fishing Gear Restriction</th>
<th>Fishing Gear and Species Restriction</th>
<th>Existing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnet</td>
<td>1321</td>
<td>1737</td>
<td>1737</td>
<td>3</td>
</tr>
<tr>
<td>Encircling gillnet</td>
<td>0</td>
<td>Restricted</td>
<td>Restricted</td>
<td>3</td>
</tr>
<tr>
<td>Handline</td>
<td>27</td>
<td>57</td>
<td>57</td>
<td>225</td>
</tr>
<tr>
<td>Purse Seine</td>
<td>386</td>
<td>Restricted</td>
<td>Restricted</td>
<td>14</td>
</tr>
<tr>
<td>Spear Gun</td>
<td>5</td>
<td>Restricted</td>
<td>Restricted</td>
<td>12</td>
</tr>
<tr>
<td>Trollline</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>153</td>
</tr>
<tr>
<td></td>
<td>No Species Restricted</td>
<td>No Species Restricted</td>
<td>3 Species Restricted*</td>
<td>No Species Restricted</td>
</tr>
</tbody>
</table>

Remark: *Three Species restricted: Cephalopholis miniata, Epinephelus caeruleopunctatus and Variola louti
order to achieve sustainable grouper fisheries, it needs a policy to reduce the number of hand lines and incentives to increase the number of gillnets. It also needs to restrict or regulate three grouper species; *Cephalopholis miniata*, *Epinephelus caeruleopunctatus*, and *Variola louti*.

**References**


Ⓒ Japanese Coral Reef Society