Multispecies selectivity of line fishing towards sustainability

B.G. Hutubessy

Faculty of Fisheries and Marine Science, Pattimura University

email: gracehutubessy@gmail.com

Abstract. Understanding the selectivity of demersal fish towards different fishing methods is an important contribution to generate fisheries management plan. The purpose of this study is to examine the selectivity of line fishing on reef fishes based on multispecies approach. Coral fishes were caught by hand lines, longlines and trolled lines by fishers from Kotania bay, Maluku-Indonesia. The species and size of fish catch from January 2013 to December 2014 was filled in logbooks. Multispecies selectivity was estimated by the abundance size spectrum according to methods of fishing: handline, longline and trolled line. In total, 30886 reef fishes were collected, representing 147 species and 37 families. By grouping into genus, longline captured 55 genus which selective to genus Epinephelus, Handline caught 54 genus targeting on genus Lethrinus and trolled line caught 24 genus which selective to genus Plectropomus. Size distribution by hook sizes were not normally distributed (P<0.001). Multispecies approach from multi-gear selectivity analysis resulted that trolled line was the high selective method especially for grouper family. Handline showed equal selectivity among species captured while the selectivity of longline was varied among fish. Fishing method, hook sizes and biodiversity are the important factors affecting multispecies selectivity. Knowledge of multispecies selectivity is important for fisheries management and fishing allocation in supporting balance fishery is recommended to maintain fisheries sustainability.

1. Introduction

Fishing amplifies oscillation in the abundances of fish stock, more variable in population dynamics due to truncated the age and size structure the fish population [1][2]. Large individual exploitation changes the basic dynamics of harvested populations and destructive fishing methods such explosion and poison might collapse the stock ultimately. If selective fishing destabilize population dynamics, could community trophic dynamics stability be affected? Certainly, every fishing gear is selective at the community level: targeting on valuable species; large-sized species; prefers on large size classes within species meanwhile minimum size limits are established as management tools [3][4]. Since various amounts of unwanted size classes or species have been captured by the most of fisheries [5][6], the different of catch composition and the fish population or community in the fishing ground is called selective fishing [7]: escaping many animals is depend on their size or behavior. In general, it is considered that the more selective the better (e.g. [8]), and "perfect gear selectivity" became the goal of gear technologists [9].

Recently, consideration has been taken to the idea that selective fishing might alter biodiversity and ecosystem function [10]. By directly removing large fish, not all sizes are targeted, so fishing affect the size structure of communities [11] and indirectly increasing the abundance of smaller fish released from predation [12]. Selective fishing is ecologically disturbing, however unselective fishing might be benefit economically. In prawn fisheries, for instance, small fish removal and discarding probably increases prawn production because small fish is considered as prawn predators and competitor [13]. Within species, it is now well established that size-selective fishing creates an evolutionary selective pressure that drives generally counter-productive genetic changes in populations [14]; for example, targeting large individuals induces evolution towards smaller sizes and slower growth [15].
In marine ecological processes, size is recognized as an important feature [16]. Due to fishing being size-selective, the size distribution of marine populations and assemblages is often used to monitor fishing impacts [17]. The ‘size-spectrum theory’ has been developed for marine ecosystems [18]. Size spectrum is the distribution of biomass or abundance across body size classes, where each individual is defined by size regardless of species. The shape of the size spectrum is known to be sensitive to fishing intensity and selectivity, especially when large fish are targeted [17]. Naturally, selective fishing might generate gaps that would disturb the biomass flow and potentially alter oscillatory dynamics, creating temporal variations in biomass and catch. As size is related to many life-history traits and largely determines ecological role in trophic chains [19], size diversity provides a substitution for functional diversity. This study results imply that both fishing methods and selectivity affect biodiversity components of conservation interest.

Selective fishing aims to reduce or limited unwanted by-catch as well. In demersal line fishing, unwanted by-catch such as dolphins, sharks, turtles and other endangered megafauna species were rarely occurred compared than pelagic line fishing [20][21]. However, low-valued species and sizes by-catch are the most occasion during the operation of lines fisheries, especially in the coral reef as the most diverse community habitat [22][23]. Line fishing which generally use baits or artificial baits during the practices, most of the catches consisted of high trophic level species. Piscivores fishes was the most species caught but species from other trophic guilds were captured as well. By studying the selectivity of line fishing which is commonly operated to catch coral fish community, analysis on the catches may figure susceptibility of by-catches remain in the community.

In overall, the aim of this study is to measure the selectivity of line fishing on reef fishes based on multispecies approached. Abundance size-spectrum which grouped by genus of fish was used to visualized species and size selectivity of line fishing.

2. Materials and Method
2.1. Field work
Line fishing operated by fishers from Kotania Bay (Fig. 1) was observed from logbooks. Fishers filled the logbook since January 2013 to December 2014.

![Figure 1. The map of Kotania Bay and the distribution of important supporting habitats to the fishery](image)

Three types of line fishing: handlines, trolled lines and longlines were used to catch reef fishes at various depths. Handline, a monofilament line with 1 to 4 hooks was deployed at various depths ranged...
from 2 to 60m. Hooks #7, #8, #11, #12 and #14 with fish as baits were occupied by fishers to catch from reefs to pelagic sandy bottoms. Trolled line consists of a monofilament line connected to 1m wire and an artificial bait attached to a hook #7 or #8. The line was located at 6 to 9m above the reefs and towed from a boat at a slow and steady speed closed to a drop off. Longline is a monofilament line with 100-200 hooks which is deployed for 2 hours. Hooks #7-#14 were occupied during this study.

Every single catch was identified following [26], and measured its fork length (cm). Maturity size for each species was obtained from fishbase.org [27]. If size maturity was not available for a particular species, other species within genus will be used.

2.2. Data Analysis
First, catch by gear was standardized based on duration of fishing for each gear. Data of fishing duration and number of catches were log-transformed and the slope (b) of their linear relationship was used in the catch standardized equations below (Hutubesy 2015, unpub. Data):

- Handline: \( C_{std} = C_{act} \times 0.97 \times (7/\text{hour fishing})^{0.33} \)
- Trolled line: \( C_{std} = C_{act} \times 0.97 \times (7/\text{hour fishing})^{0.73} \)
- Longline: \( C_{std} = C_{act} \)

A \( C_{std} \) is standardized catch, \( C_{act} \) is an actual catch, 0.79 is the probability of catch by gear and 0.33 and 0.73 were the coefficient regressions between hour fishing and CPUE. Standardized catch of longline is equal to actual catch due to fishing duration for all operations of longlines is almost similar.

Normality test using Kolmogorov-Smirnov test (SAS 1.2) was applied for fork length of fish caught by various hook numbers and gear type.

Abundance size spectrum was set as relationship between the number of individuals in a body size class and the average size in that body size class. By grouping into genus, 8cm size class was occupied to produce abundance size spectrum for handline, longline and trolled line. Only genus represented by more than 100 individuals were included in the spectrum. For each size spectrum, relationship of log transformed of length and CPUE was analyzed to produce a regression line of size spectrum. The line slope is -1 if number of small and large fish captured is balanced.

3. Result and Discussion

3.1. Catch of line fishing
Total of 30886 reef fishes was captured by lines fishers at Kotania Bay from January 2013 to December 2014 and represented 147 species from 33 Families (Table 1). The catch of longlines was the biggest in numbers (18574 fish) belongs to 113 species and 31 families. Handlines caught 9824 fishes from 104 species and 24 families. Trolled line captured 2485 fishes represented 49 species from 13 families. The most family caught by trolled lines was Serranidae which consisted of 18 species, 2169 individual of fish and composed 87.2% of the total catch. Dominated species caught by trolled line were coral trout which were 793 individuals of Plectropomus oligocanthus and 711 individual of P. leopardus.

3.2. Size Distribution by hook
Size of fish caught (FLcm) by various hook numbers was not normally distributed, neither the logarithm (Log_{10}) transformed fork length data (P<0.001), except for hook #11 belonged to handline (P>0.15). Distribution of transformed fork length data for each gear (Fig. 2) showed overlapping of sizes from different hook numbers. Therefore, for further selectivity analysis, multispecies from multihook were combined to produce a size spectrum for each gear type.
Table 1. Family and species of fish caught by line fishing at Kotania Bay

| Family            | Species                  | Handline | Longline | Trolling |
|-------------------|--------------------------|----------|----------|----------|
| Ariidae           | Arius arius              | 1        | 60       | 1        |
| Balistidae        | Balistapus sp            | 4        | 1        |          |
|                   | Balistapus undulatus     | 40       | 9        | 2        |
|                   | Balistoides viridescens  | 65       | 138      |          |
|                   | Naso brevirostris        | 1        |          |          |
|                   | Pseudobalistes fuscus    | 99       | 1        |          |
|                   | Rhinecanthus verrucosus  | 1        |          |          |
|                   | Sufflamen chrysopterus   | 2        | 2        |          |
|                   | Sufflamen frenatus       | 59       | 64       |          |
| Belonidae         | Tylosurus crocodilus     | 1        | 325      |          |
|                   | Tylosurus sp             |          | 65       |          |
| Bothidae          | Pseudorhombus sp         |          |          | 242      |
| Caesionidae       | Caesio cunning           | 79       | 16       |          |
|                   | Caesio erythrogaster     | 7        |          |          |
|                   | Caesio pisang            | 96       |          |          |
|                   | Pterocaesio diagramma    | 3        |          |          |
|                   | Pterocaesio pisang       | 6        |          |          |
|                   | Pterocaesio tile         | 23       |          |          |
|                   | Alectes ciliaris         | 31       | 31       |          |
| Carangidae        | Carangoides chrysophrys  |          |          | 32       |
|                   | Carangoides malabaricus  | 77       | 6        | 4        |
|                   | Carangoides orthogrammus | 2        |          |          |
|                   | Carangoides sp           | 13       | 10       |          |
|                   | Caranx bucculentus       | 18       | 91       |          |
|                   | Caranx melampygus        | 105      | 1288     | 91       |
|                   | Caranx sexfasciatus      | 8        |          |          |
|                   | Caranx sp                | 50       |          |          |
|                   | Decapterus russelli      | 5        |          |          |
|                   | Gnathanodon specious    | 19       | 3        |          |
|                   | Magalaspis Cordyla       | 484      |          |          |
|                   | Ulua mentalis           |          | 5        |          |
| Carcharhinidae    | Carcharhinus plumbeus    |          | 29       |          |
|                   | Carcharhinus sp          |          | 43       |          |
| Chirocentridae    | Chirocentrus dorab       |          | 6        |          |
| Dasyatidae        | Dasyatis imbricata       |          | 30       |          |
|                   | Dasyatis sp              |          | 90       |          |
|                   | Taeniura lymma           | 1        | 17       |          |
|                   | Taeniura meyeni          |          | 164      |          |
| Diodontidae       | Diodon liturosus         | 14       | 137      |          |
| Fistularidae      | Fistularia petimba       |          | 142      |          |
| Haemulidae        | Plectorhynchus celebicus | 153      |          |          |
|                   | Plectorhynchus gibbosus  | 43       | 39       |          |
Table 1. cont.

| Family            | Species                        | Total | Guttenberger |
|-------------------|-------------------------------|-------|--------------|
| **Plectorhynchus**| *Plectorhynchus lineatus*     | 46    | 245          |
|                   | *Plectorhynchus sp*           | 1     | 18           |
| **Holocentridae** | *Myripristis hexagonatus*     | 158   |              |
|                   | *Myripristis kuntee*          | 1     | 42           |
|                   | *Myripristis violacea*        |       | 71           |
|                   | *Ostichthys kaianus*          | 68    |              |
|                   | *Sargocentron rubrum*         | 127   |              |
|                   | *Sargocentron violaceum*      | 51    |              |
| **Labridae**      | *Cheilinus chlorurus*         |       | 260          |
|                   | *Cheilinus fasciatus*         | 22    | 102          |
|                   | *Cheilinus tribolatus*        | 11    | 2            |
|                   | *Cheilinus tribolatus*        | 3     | 1            |
|                   | *Cheilinus undulatus*         | 4     | 14           |
|                   | *Choerodon anchorago*         | 210   |              |
|                   | *Choerodon cephalotes*        | 1     | 108          |
|                   | *Halichoeres scapularis*      | 8     | 8            |
|                   | *Halichoeres sp*              |       | 14           |
| **Latidae**       | *Psammoperca waigiensis*      |       | 599          |
| **Lethrinidae**   | *Gymnocranius elongatus*      | 214   | 816          |
|                   | *Lethrinus erythropterus*     | 11    | 728          |
|                   | *Lethrinus laticaudis*        | 97    | 60           |
|                   | *Lethrinus lentjan*           | 893   | 1238         |
|                   | *Lethrinus microdon*          | 60    |              |
|                   | *Lethrinus miniatus*          | 909   | 127          |
|                   | *Lethrinus nebulosus*         | 87    | 2            |
|                   | *Lethrinus ornatus*           | 142   |              |
|                   | *Lethrinus semicinctus*       |       | 25           |
|                   | *Lethrinus sp*                | 49    | 94           |
|                   | *Lethrinus xanthatceilus*     | 11    | 1            |
|                   | *Monotaxis grandoculis*       | 50    |              |
| **Lutjanidae**    | *Aprion virescens*            |       | 67           |
|                   | *Epinephelus sp*              |       | 2            |
|                   | *Etelis carbonculus*          | 9     | 32           |
|                   | *Lutjanus argentus*           | 121   | 49           |
|                   | *Lutjanus bohar*              | 121   | 1558         |
|                   | *Lutjanus carponotatus*       |       | 2            |
|                   | *Lutjanus decussatus*         |       | 24           |
|                   | *Lutjanus fulviflamma*        | 369   | 341          |
|                   | *Lutjanus fulvas*             | 29    | 49           |
|                   | *Lutjanus gibbus*             |       | 2            |
|                   | *Lutjanus malabaricus*        |       | 17           |
|                   | *Lutjanus russelli*           | 365   | 27           |
|                   | *Lutjanus sebae*              | 14    | 446          |
|                   | *Lutjanus semicintus*         | 40    |              |
Table 1. cont.

| Family         | Species                        | Count | Length |
|----------------|--------------------------------|-------|--------|
| Lutjanidae     | Lutjanus sp                    | 7     | 505    |
|                | Lutjanus vitta                 | 129   | 57     | 2     |
|                | Pristipomoides multidens      | 4     | 1      |
|                | Pristipomoides typus          | 191   | 2      |
| Monocanthidae  | Monocanthis sp                 | 50    |        |
| Mullidae       | Parupeneus barberinus         | 8     |        |
|                | Parupeneus chrysopleurion     | 35    | 185    |
|                | Parupeneus multifasciatus     | 39    | 24     |
| Murraenidae    | Gymnothorax buroensis         | 14    | 7      |
|                | Gymnothorax pictus            | 2     | 6      |
| Myliobatidae   | Aetomileus maculatus          | 4     |        |
| Nemipteridae   | Nemipterus nematophorus       | 98    | 309    |
|                | Nemipterus zyson              | 170   | 40     |
|                | Pentapodus caninus            | 267   | 5      |
|                | Pentapodus trivittatus        | 143   |        |
|                | Scolopsis bineatatus          | 2     | 4      |
|                | Scolopsis temporalis          | 17    | 152    |
| Pomacentridae  | Neoglyphidodon oxyodon        | 2     |        |
| Priacanthidae  | Priacanthus hamrur            | 201   |        |
|                | Priacanthus macracanthus      | 160   | 4      |
|                | Priacanthus sp                | 1     |        |
| Scaridae       | Chlorurus blekeeri            | 6     |        |
| Scianidae      | Johnius sp                    | 26    |        |
| Scombridae     | Euthinnus affinis             | 49    | 3      |
|                | Grammatorcynus bineatatus     | 12    |        |
|                | Gymnosarda sp                 | 78    |        |
|                | Rastreliger kanagurta         | 4     | 501    |
|                | Scomberomerus commersoni      | 9     | 6      | 6    |
|                | Scombroides tala              | 6     |        |
| Serranidae     | Anyperodon leucogrammicus     | 54    |        |
|                | Centrogenys vaigiensis        | 21    | 27     |
|                | Cephalopolis boenack          | 602   | 69     | 9    |
|                | Cephalopolis cyanostigma     | 16    | 14     |
|                | Cephalopolis miniata         | 196   |        |
|                | Cephalopolis polleni         | 10    |        |
|                | Cephalopolis sonnerati       | 394   | 11     | 18   |
|                | Cephalopolis sp              | 3     |        |
|                | Cromileptes altivalis        | 2     | 224    | 8    |
|                | Epinephelus aerolatus        | 20    |        |
|                | Epinephelus caeruleopunctatus| 16    | 2      | 16   |
|                | Epinephelus coioides         | 25    | 17     | 28   |
|                | Epinephelus fuscoguttatus     | 33    | 970    | 50   |
|                | Epinephelus latifasciatus     | 15    | 1      |
Table 1. cont.

| Species                  | Occurrence | Length (mm) | Weight (g) |
|-------------------------|------------|-------------|------------|
| Epinephelus merra       | 10         | 435         | 3          |
| Epinephelus morrhua     | 9          |             | 2          |
| Epinephelus quoyanus    | 299        |             | 2          |
| Epinephelus sexfasciatus| 155        | 1127        | 5          |
| Epinephelus sp          | 560        | 146         | 165        |
| Epinephelus suillus     | 78         | 1010        |            |
| Plectropomus areolatus  |            |             | 10         |
| Plectropomus leopardus  | 118        | 557         | 711        |
| Plectropomus maculatus  |            |             | 2          | 37         |
| Plectropomus oligocanthus| 118           | 94         | 791        |
| Plectropomus sp         | 6          | 10          | 2          |
| Variola albimarginata   | 837        | 126         | 301        |
| Variola louti           |            |             | 2          |
| Anyperodon leucogrammicus|          |             | 3          |
| Siganidae               |            |             |            |
| Siganus canaliculatus   |            |             | 3          |
| Sparidae                |            |             |            |
| Acanthopagrus berda     | 30         |             | 1          |
| Dentex blochii          |            |             | 2          |
| Sphyraenidae            |            |             |            |
| Sphyraena jello         | 38         | 412         | 5          |
| Teraponidae             |            |             |            |
| Therapon jarbua         | 24         | 101         |            |
| Toxotidae               |            |             |            |
| Toxotes jaculator       |            |             | 12         |
| Total fish              | 10073      | 18561       | 2477       |
| Total Families          | 33         | 24          | 31         | 13         |
| Total Species           | 150        | 104         | 110        | 49         |
Figure 2. Box plot of size distribution of fish caught by longline (A), handline (B) and trolled line (C).
3.2. Selectivity of longline
Genus of fish captured by longline was dominated by *Epinephelus*, consisted of 10 species. The size ranged from 6cm to 68cm with modus on 28.1cm-36.0cm length class. The second genus was *Lutjanus* with 9 species. Size ranged from 7cm to 71cm and the modus was on 20.1-28.0cm length class (Fig. 2). Other genus which abundantly captured by longline were *Lethrinus*, *Caranx*, and *Gymnocranius*. Genus *Caranx* consisted of 4 species, *Lethrinus* with 8 species and *Gymnocranius* with one species. Most of these genus were caught under 30cm fork length.

![Abundance size spectrum of longline catch based on genus. The regression line was obtained from the relationship between log transformed of the total catch and maximum size of the length class.](image)

**Figure 3.** Abundance size spectrum of longline catch based on genus. The regression line was obtained from the relationship between log transformed of the total catch and maximum size of the length class.

Almost all species caught are edible for the locals, but some genus are not economically valuable. Less value genus were included stingrays (*Taeniura* and *Dasyatis*), floutmouth (*Fistularia*), porcupinefish (*Diodon*), grunter (*Terapon*), monocle bream (*Scolopsis*) and shark (*Carcharinus*). The catch of longline was also pelagic species such as *Rastrelliger* (indian mackerel) and *Megalaspis* (scad).

The size-spectrum of longline which resulted slope of -1.79 indicates that longline selectively captured more large species than small fish. Five genus were captured as large sizes including *Lutjanus*, *Caranx*, and *Plectropomus* and was categorised as target species. Other large fish captured such *Dasyatis*, *Taeniura*, *Tylosurus*, *Sphyraena*, and *Carcharinus* were included as non-target species. The last two genus are predator for juveniles of some target species.

Since longline was deployed vertically, the fishing area was wider, from bottom to mid water layer. Some pelagic species was attracted to the bait, and some predators might come closed to the hooked preys.

Based on the length of fish caught, the catch of longline comprised of 35% above the maturity size. It implied that more than half of the catch were immature or under legal size.
3.3. Selectivity of handline

From 53 genus of fish captured by handline, *Lethrinus* was the most abundance genus represented 9 species. The length ranged from 11 to 66cm with mode of 20.1-28cm length class. Genus *Cephalopolis, Lutjanus* and *Epinephelus* have similar abundance and similar length mode, 20.1-28cm.

The size spectrum (Fig. 4) showed uniform pattern of size distribution for abundance genus, the optimum size was 28cm FL. Since size distribution of fish caught by handline showed similar pattern, the vulnerability of reef fish towards handline might be equal. The practise of handline in coral reef habitat was categorised as a passive method, expecting predators to overcome the bait provided. Consequently, predator species has equal opportunity to be hooked.

The slope of size spectrum was -0.707. Abundance of small fish caught was higher than large fish, and about 67% were categorized as unmature fish. This result indicates that fishing activities were conducted at shallow part of the reef, where abundance of small fish or juveniles was high [28] and diversity of species was also high [29]. Therefore, it should take into account for fisheries management the practice of selective fishing at shallow coastal reef to sustain the biodiversity.

![Figure 4. Abundance size spectrum of handline catch based on genus.](image-url)
3.4. Selectivity of trolled line

Compare than two other methods, trolled line is an active method of line fishing. Number of genus caught was 24 and only 5 genus were abundantly captured, cod *Plectropomus*, trout *Variola*, rockcod *Epinephelus*, trevally *Caranx* and rockcod *Cephalopolis*. Based on the most abundantly caught, trolled line was highly selective on genus *Plectropomus*. Size ranged from 7cm to 87cm, with length mode of 44cm. Cod, trout, and rockcod were including into grouper family which has biological features: hermaphroditism, long lived, and low fecundity [30]. High vulnerability towards trolled line might positioned these species in high risk rank of fish.

Size spectrum of trolled line catch showed flat slope line, -0.39 (Figure 5). Although the optimum size of fish captured, 44cm, was higher than two other methods, however, more small fish were caught than large fish. Percentage of mature fish was 0.24, means that immature fish were more vulnerable to trolled line.

\[
y = -0.3898x + 1.892
\]
\[R^2 = 0.0273\]

Figure 5. Abundance size spectrum of trolled line catch based on genus.

4. Conclusion

The catch of line fishing was categorized as predator species to other marine animals. Vulnerability of fish from trophic guild piscivores and benthivores was high towards handline and trolled line. Towards longline, the vulnerability to be captured was varied among species but it was equal towards handline. Vulnerability of family Serranidae towards trolled line was high and lead to population declined.

Based on the size spectrum slope line, selective fishing method will produce less steep slope of size spectra [31]. Varied selectivity of longline among species produced size spectrum with steep slope line.
(-1.8). Equal selectivity of handline among species produced less steep slope line (-0.7). High selectivity of trolled line on Serranids produced a flat slope line (-0.39).

To support sustainability of fisheries, handline fishery should be distributed to various depths to avoid capturing small size of fish. Practice of trolled line for demersal reef fish should be reduced otherwise the population of reef fishes especially groupers will be threatened.

Considering that this study is based on the filled logbook by fishers, fish length data are often based on memory rather than using provided measuring tools. Fish size was informed greater that published maximum size.

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