Bycatch assessment for fusilier gillnet to support ecosystem approach fisheries management

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Abstract. Fusilier (Pisces: Caesionidae) gillnet, called jaring lalosi, have been used since decades by fishers from Assilulu village, meanwhile its scientific information is limited. The aim of this study is to learn the reef fish species selectivity of jaring lalosi and to assess its bycatch using productivity and susceptibility assessment (PSA). This study was conducted at Pulau Tiga waters, Central Maluku Regency, for 3 months observation: October 2017, February and April 2018. Jaring lalosi which means fusilier gillnet, caught dark-banded fusilier, Pterocaesio tile, 94.4% of the total catch. The rest of the catch we represented as bycatch of jaring lalosi. As a high resilience and low vulnerability species, the sustainability of dark-banded fusilier fisheries is unlikely to be fully concerned. As high mobility schooling species, dark-banded fusilier was caught at different communities of reef fishes. MDS analysis showed discrepancy of species selectivity of fusilier gillnet by monthly catch rate. The PSA for bycatch resulted 2 reef species are least likely to be sustainable, 12 reef species are most likely to be sustainable on the criteria of recovery axis and 3 pelagic species are the most sustainable species. We concluded that the practiced of jaring lalosi has low impacts on reef fish community and tendency to overfishing is almost none as long as there is no increasing on fishing pressure. For the implementation of fisheries management based on ecosystem approach (EAFM), bycatch assessment should be applied to other fishing gears.

1. Introduction
Ecosystem approaches to fisheries management have been developed in Indonesia since 2010 following the worldwide awareness of evidence that fishing activities adversely affect populations of non-target species (i.e. bycatch) and physical damage to habitats [1]. These impacts can lead to changes to biodiversity and ultimately change the overall ecosystem function [2, 3]. Although broad management policies and objectives exist for ecosystem-based management [4], translating them into action is difficult. Fishery scientists and managers often do not have the information required to properly assess fishery impacts on non-target species and communities, and to develop management measures to ensure the fishery operates in an ecologically sustainable manner. Close moving to fulfil the broad objectives of ecosystem-based fisheries management, approaches need to be developed that can cope with the high species diversity and limited data that is typical of many fisheries worldwide, especially in tropical regions.

Bycatch, the unintentional capture of nontarget species, is mostly resulted by less selective fishing methods. Fisheries bycatch threatens populations of many marine vertebrate taxa worldwide, including marine endangered species [5, 6, 7]. In most fishing methods, the weight of bycatch is greater than the weight of commercially or target species, for instance, bycatch of trawls [8, 9] as well as in fish traps [10, 11]. Although mitigation efforts have successfully reduced some threats (e.g., 12, 13, 14), difficulties and high cost of mitigation implementation [13, 15, 16], result in fewer use of best practices for minimizing the fishing damage on marine ecosystems. Even though trawls are known brought massive damage on marine bottom ecosystem, study on the threats of bycatch from other
fishing gears is necessitated to minimize the damage, also to increase the fisheries sustainability.

Consolidation resolution to reduce incidence of bycatch have been conducted and produced some potential methods. Productivity and susceptibility assessment (PSA) was one of those methods which have been originally developed to classify differences in bycatch sustainability in Australian prawn fishery [17]. The PSA evaluates an arrangement of productivity and susceptibility criteria for a stock, from which index scores for productivity and susceptibility are computed and graphically displayed. The PSA was capable of broadly distinguishing between stocks based on fishing pressure, as stocks that were known to be overfished or undergoing overfishing in the past [18]. PSA has been also used in other fisheries [19, 20]. The PSA was applied to six U.S. fisheries, containing 162 stocks that exhibited varying degrees of productivity, susceptibility, and data quality. This application was also recently employed among fisheries scientists in Indonesia [e.g., 21, 22].

Fusilier net is a bottom gillnets targeting on a species of fusilier fish (Caesionidae) with local term jaring lalosi. Fusilier fishes become the target of gillnet fishery due to its biological features. Fusilier fishes usually can be found in lagoon and on the reef flats at depths to 60 [23]. These fishes frequently form several hundred individual schooling that feed on plankton in the mid-water [24]. Fusilier fishery has been operated for decades in Ambon island with different types of net targeting different species of fusilier fishes. The practice of fusilier gillnet to capture schooling actively swimming fish depend on in-situ current movement. The net is deployed encircled the fishes if the current is slow, however, if the current is strong, the net is set as bottom gillnet with additional sinkers and anchors. The catch rates of targeting fusilier species varied and produced bycatch. Statistically, this fishery is reported annually. For management purposes, however, fewer studied have been performed.

The aim of this study is to assess the bycatch of fusilier net by two approaches. First, to evaluate the species selectivity of jaring lalosi which are described by the amount and the composition of bycatch. PSA is subsequently applied to measure the sustainability of this fishery. Concerning the ecological impact of bycatch has required for EAFM [4].

2. Material and Methods

Research was conducted at three islands called Pulau Tiga. The islands are located at the western part of Ambon island, Eastern Indonesia (Figure 1). The study sites were sheltered by fringing reefs and contained beautiful patch reefs, and included one of the tour dive destinations in Ambon Island. Observation for three months: October 2017, February and April 2018 went along with fishers’ from Assilulu village using encircling gillnets.

Fusilier gillnet specifically designed to catch dark-banded fusilier is 1.25inch meshed, 37.5% hanging ratio and 100m long. Fishers travelled 45 – 60 minutes from Assilulu village to the fishing grounds around Pulau Tiga in the morning and afternoon. After searching for the schooling of fusilier, fishers deployed the nets either encircling the school or set as bottom gillnet depending on the water current. Twenty-one (21) fishing sites have been visited covering 0.99km² of coral reefs.

The species caught was identified based on Allen (1999)[24] and measured the total length (cm). Species selectivity of fusilier gillnet was analyzed using Multi-Dimensional Scaling (MDS) which measured on Bray-Curtis similarity [25]. Catch rate data on monthly basis was square root transformed.

Bycatch was assessed based on biological and ecological information which was collated from literature for each species. This information was then used to rank the species along two axes that described the overriding characteristics that would determine the sustainability in bycatch. Axes 1 indicate susceptibility of species to capture and mortality due to fusilier netting (susceptibility). Axes 2 indicate the capacity of species to recover after the population is depleted (recovery). Following Stobutzki et al. (2001)[17], we made slightly change for maximum depth and survival rate criteria for gillnet. We change the maximum depth down to 10 meters (instead of 40m for trawls). Survival rate is obtained by reversing the value of vulnerability of each species (collated from fishbase.org).
3. Result and discussion

Sixteen species from 9 families have been recorded in the catch from fusilier gillnet. The numbers of species within families were up to 3 species for the Caesionidae, Balistidae and Holocentridae, 2 species for Serranidae and Carangidae. Individual fishes of 3690 were captured during this study. Dark-banded fusilier, *Pterocaesio tile* (Caesionidae), composed 94.4% of total catch together with other 16 species which then we categorized as bycatch (Figure 2). Since fusilier fishes often school in mixed species aggregations [26], blue and gold fusilier (*Caesio caerulaurea*) and red-belted fusilier (*Caesio cuning*) composed more than 35% of total bycatch. According to fishermen at Assilulu, red-belted fusilier and blue and gold fusilier are also target species for other fusilier gillnets using 1.5inch and 2.25inch mesh sizes, respectively.

Dark-banded fusilier, *Pterocaesio tile*, is the most species captured, however, it is not proved that the fusilier gillnet is selective to catch this species as the target species. Heterogenity $\chi^2$ analysis resulted the most minimum value of 129.6 (df = 17) which was obtained from the 1:1 ratio between dark-banded fusilier and the bycatch. This minimum result implied that although this fusilier gillnet is exclusively designed to catch dark-banded fusilier, the gear selectivity is low for the target species. The catch rate of dark-banded fusilier varied during 21 trips of observation. The results showed that dark-banded fusilier was classified as high resilient and low vulnerability fish (fishbase.org) so this fish population would not be overexploited. Conversely, the resulting bycatch needs to be evaluated to find out whether this fusilier gillnet has an impact on other reef fish communities.

The MDS 2-dimensional plot showed 4 groups of temporal catch rate of bycatch based on monthly sampling. One fish of *Myripristis pralina* represented the bycatch of October (Figure 3). Group of February consisted of 6 species and 4 species represented April sampling. The most occurrence of bycatch during sampling are *Caesio cuning* (16), *Mulloidichthys vanicolensis* (15), *Sargocentron tieraoides* (12), *Neoniphon samara* (9) and *Decapterus russelli* (4). This result expressed the occurrence of temporal diversity changes of reef fishes caused by the occupation of small meshed...
such fusilier gillnet [27]. For fisheries management purpose based on ecosystem approach, however, temporal changing on fishing mortality give a good sign of break or rest from fishing pressure rather than high fishing mortality on a particular target species. During the break or rest, fish might grow or reproduce.

![Graph showing bycatch composition](image)

**Figure 2.** Ranked bycatch composition of fusilier gillnet, *jaring lalosi.*

![Graph showing MDS plot](image)

**Figure 3.** MDS plot for temporary bycatch species and the list of species

| List of species: |
|------------------|
| 1. *Balistapus undulatus* | 7. *Melichthys vidua* |
| 2. *Caesio caerulea* | 8. *Myripristis pralinia* |
| 3. *Cephalopholis urodeta* | 9. *Neoniphon samara* |
| 4. *Decapterus russelli* | 10. *Priacanthus tayenus* |
| 5. *Epinephelus merra* | 11. *Rastrelliger kanagurta* |
| 6. *Melichthys niger* | 12. *Sargocentron tie roides* |
| 13. *Selar boops* | 14. *Synodus dermatogenys* |
| 15. *Mulloidichthys vanicolensis* | 16. *Caesio cuning* |
Productivity and susceptibility analysis which is delineated into 6 contours of sustainability level showed that *Decapterus russelli* (Carangidae) is on the most sustainable contour together with other two pelagic species *Rastrelliger kanagurta* (Scombridae) and *Selar boops* (Carangidae) (Figure 4). These small pelagic species have primary habitat lies outside the coral reef and water column outside the fusilier gillnet ground even though they also form an active schooling. Probability of breeding of these pelagic species are more than 50% which means they had spawned before were captured. Pelagic species is also the most likely to be sustainable species as bycatch of trawl [17].

Two species Balistidae, *Melichthys niger* and *Melichthys vidua*, are the least likely to be sustainable species (on the third contour). They have lower survival rate and mortality index compared than other species. Reproductive strategy of guarding their nest leads them to produce few eggs which reduce their recovery capacity in comparison to broadcast spawners. These species had high recovery ranks but they also had higher susceptibility, so influences the sensitivity of species to overfishing and the probably of extinction [28].

Positioned on the fourth and fifth sustainability level, 12 species of bycatch are most likely to be sustainable on the criteria on recovery axis. They are benthopelagic and demersal and closely associated with the coral reef where fusilier gillnets fish. Their diets are mostly benthos and fish for the family Serranidae. Except for the juveniles, adult fish live in the broader depth range than that exploited by gillnet. Most of these species are dioecious except the Serranids are protogyny species (fishbase.org). Most of these species were little information available especially for the maturity size ($L_{mat}$) and the mortality index (only 1 fish captured). So, its characteristic ranked it in the lower sustainability group than the pelagic species.

In EAFM, the function of species in their community must not be disturbed by fishing activities [29]. The trophic guilds of bycatch fusilier gillnet consist of benthiwores, planktivorous and two piscivorous species. This composition of trophic guild is likely to be proportional to the natural trophic level of the reef fish community [30]. Compared to line fishing, the catch is dominated by piscivorous species. Non-baited trap fishing mostly captures herbivores species. Therefore, we might say that the practice of fusilier gillnet did not disturb the balance of the reef fish ecosystem.

**Figure 4.** The ranking of 16 species bycatch based on the criteria which reflecting susceptibility to capture and recover capacity. The contour lines group species with a similar sustainability. Labels numbers explain the fish species.
4. Conclusion
Fusilier gillnet is specifically designed to catch dark-banded fusilier, *Pterocaesio tile* (Caesionidae). The selectivity of this gillnet is low for the target species. Therefore, the bycatch should be analyzed to evaluate the impact of fusilier gillnet on the reef fish community.

The selectivity of fusilier gillnet changed temporarily. There was shifting species of bycatch based on monthly catch rate assessment. These results imply expected conditions where there are opportunities for certain fish may grow or spawn without interruption.

There are only 2 species from Balistidae family identified as least likely to be sustainable, the other bycatch species are categorized as the most likely to be sustainable. Concerning the population of these two species of not being overfished, temporarily closing the fishing ground, especially during fish spawning and guarding the nest is urgently needed.

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