Bycatch from seagrass fisheries: implication for conservation

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Abstract. Fishing activities conducted on seagrass bed to capture fishes and other seagrass associated fauna are very massive especially in the Pacific regions and undeveloped countries. This is due to the high abundance of economically important species associated to seagrasses, and additionally, seagrass area is the most accessible fishing ground throughout the year and with low capital. Seagrass meadows are importance habitat to support an abundance and diverse fish assemblages that form the basis for artisanal fisheries, which are vital in maintaining food security of coastal community in the regions. The seagrass fishery is considered a small-scale, multi-species and multi-gear fisheries. One of the fishing gear used in this fishery is traditional permanent fish trap called "*sero*". Bycatch from some small-scale fisheries have been reported such as from trawls, traps, gill nets, and longline fisheries. This study aimed to identify bycatch species from "*sero*", a type of seagrass fisheries which is in the form of fish fences with nets positioned on intertidal area of seagrass bed to the subtidal for approximately 200m. The result shown the bycatch from this fisheries was dominated by either low value fishes or invaluable and even toxic fishes for consumption, such as the puffers (Tetraodontidae and Diodontidae), juveniles of Apogonidae and Chaetodontidae. Additionally, sharks, turtles, and rays were also found in the bycatch. This result should be put into consideration as the bycatch would have an ecological consequences on the population, predator-prey relationship, and ecosystem resilience to stressor in general. Information from this study will be important for sustainable small-scale fisheries management and seagrass conservation, and therefore, further research into bycatch reduction in this fishery would be desirable.

1. Introduction

Bycatch in fisheries was referred to the unintended catch or unobserved mortalities due to encounters with fishing gear and the discard of all forms of marine life by fisheries [1,2]. The definition then revised into new term that all unused or unmanaged catch is referred to bycatch [3]. Bycatch in fisheries is a critical issue for marine conservation and resource management due to a high proportion (40.4%) of this catch of global marine catch [3]. The bycatch shoud be minimized to unsignificant level because the unused or unmanaged catch is unacceptable waste of natural resources, and have a big consequences to the populations, food webs, and ecosystems, for example, through the effect on

altering the relative abundance of species leads to changing trophic interactions [4]. The issue of bycatch became more strategic as increasing report on a high profile species and/or threatened species in the bycatch, such as sharks, sea turtles, marine mammals, seabirds, seahorses [5–9].

So far, research on bycatch was mainly conducted on industrial fisheries until report on high bycatch of threatened species and/or non-target species from artisanal fisheries emerging [10–12]. Some fisheries and gear types have been reported to capture threatened or non-target species referred to bycatch, such as artisanal longline and gillnet fisheries that captures loggerhead turtle [13], shrimp trawl fishery that captures seahorses [5] and 411 fish species as bycatch [14], coral reef fish trap have a high baycatch of non-target species and juveniles including of key herbivorous fishes [15,16], prawn trap fishery that captures the juvenile of rockfish [17], African basket traps that capture butterflyfish and other low value fishes [18], shrimp trawl operating in seagrass bed had captured 50 species bycatch including fishes which serve as linkages between primary and secondary production in seagrass ecosystems [19].

Seagrass fishery is referred to fishing activities conducted on seagrass bed to capture fishes and invertebrates from seagrass meadows [20–23]. This fishery is considered a small-scale, multi-species and multi-gear fisheries, with different kind of fishing gears used in this fisheries, including gill nets, crab traps, traditional permanent fish trap called "*sero*", gleaning, fishing rods, spearfishing [23]. Small-scale fisheries use many different relatively small boats (if any), relatively small capital, making short fishing trips, close to shore, and mainly for local consumption [24]. Bycatch from small-scale fisheries have been reported from only a certain fishing gears, such as trawls, traps, gill nets, and longline [5,13,14,16–19].

This study aimed to identify bycatch species from "*sero*", a type of seagrass fisheries which is in the form of fish fences with fyke nets; this is a semi permanent structures positioned on intertidal area of seagrass bed to the subtidal for approximately 200m [23,25]. This gear is commonly used in South America, West Africa, East Africa, the Persian Gulf, and the Indo-Pacific and Pacific Islands [26]. We have no data exist on bycatch from this kind of fisheries, and therefore making this study crucial and important for sustainable small scale fisheries management and seagrass conservation.

2. Methodology

Bycatch data was collected by direct observation of fishermen who landed the catch from "*sero*"fisheries in Selayar Island, South Sulawesi, Indonesia. Data records was conducted 2 to 3 times a month from October 2015 to April 2016. Data that we collected including what kind of bycatch, how much, and measurement on total length was also done for some specimens. Additionally, we asked four "sero" fishers to record all bycatch they had during the catch collection in "sero" for the period of two months (August-September 2020). We also asked them to weight the bycatch everytime they had them in their catch. All captured animals that considered as bycatch were identified to the lowest possible taxon.

3. Results and discussion

3.1. Bycatch species in "sero" fisheries

There were 16 species found as bycatches from "*sero*" fisheries in Selayar Island, South Sulawesi, Indonesia (Table 1 and Figure 1). They were dominated by Class Actinopterygii, especially from Order Tetraodontiformes (Figure 1) and Perciformes (Figure 2). The last ordo was specifically dominated by Apogonidae (cardinalfishes) and Chaetodontidae (butterflyfishes).

We found the bycatch from this fisheries was dominated by either low value fishes or invaluable and even toxic fishes for consumption, such as the puffers (Tetraodontidae and Diodontidae), eventhough the boxfishes and the filefishes are the popular fishes for human consumption, but the size of the fishes incidentally catch in this net were very small (see Table 2 for more information on the size of the fishes as bycatch in this fisheries). Trap fishing in the Caribbean had been also reported that Tetraodontiformes particularly very susceptible to trapping, and therefore have a high proportion in

the bycatch from this fisheries, as well as the butterflyfishes (Family Chaetodontidae, Perciformes) [27].

Table 1. List of species found as bycatch in "*sero*" fisheries in Selayar Island, Indonesia.

Class	Ordo	Family	Common names	Species
Actinopterygii	Tetraodontiformes	Tetraodontidae	Puffers	*Arothron manilensis*
				A. hispidus
				A. stellatus
				Canthigaster amboinensis
		Diodontidae	Puffers (burrfishes)	*Diodon liturosus*
		Ostraciidae	Boxfishes	*Ostracion cubicus*
		Monacanthidae	Filefishes	*Aluterus scriptus*
				Chaetodermis penicilligerus
	Perciformes	Apogonidae	Cardinalfishes	*Pristiapogon kollapterus*
				Ostorhinchus fleurieu
				O. aureus
				O. fasciatus
				Taeniamia fucata
		Pomacentridae	Damselfishes	*Abudefduf vaigiensis*
		Chaetodontidae	Butterflyfishes	*Chaetodon lunula*
				C. trifasciatus
				C. vagabundus
				C. citrinellus
				C. kleinii
				C. auriga
		Zanclidae	Moorish Idol	*Zanclus cornutus*
		Lobotidae	Tripletails	*Lobotes surinamensis*
	Atheriniformes	Atherinidae	Silversides	*Hypoatherina sp.*
				H. temmnckii
	Aulopiformes	Synodontidae	Lizardfishes	*Saurida elongata*
	Siluriformes	Plotosidae	Catfishes	*Plotosus lineatus*
	Pleuronectiformes	Bothidae	Flatfishes	*Asterorhombus intermedius*
	Syngnathiformes	Syngnathidae	Pipefishes	*Hippichthys cyanospilos*
Elasmobranchii	Myliobatiformes	Dasyatidae	Stingrays	*Taeniura lymma*
	Carcharhiniformes	Scyliorhinidae	Cat sharks	*Atelomycterus marmoratus*
		Carcharhinidae	Blacktip Reef Shark	*Carcharhinus melanopterus*
Reptilia	Testudines	Chelonidae	Turtles	*Chelonia mydas*

Figure 1. Different type of fishes from Class Tetraodonthiformes frequently found in the bycatch from "*sero*" fisheries in Selayar Island, South Sulawesi, Indonesia.

Family Chaetodontidae (butterflyfishes) is also found in a high percentage bycatch from coral reef trap fisheries [16]. These fishes are a highly specialized coral fishes that feed mainly on live corals, as a result, this fish population will decline as the destruction or loss of coral reef habitat increase [28,29]. Whereas, Family Apogonidae was also listed as a susceptible species to trawling, along with other benthic or demersal species such as Diodonthidae, Labridae, Plotosidae, Tetraodontidae [14]. Some apogonids were also found in the gut content of predatory bottom-dwelling species [30,31]. Apogonidae (cardinalfishes) is a small size fishes (mostly less than 10 cm) estimated has about 358 species, distribute in a wide range of marine ecosystem such as coral reefs, rocky reefs, seagrasses, coralline algae beds, and other soft bottom communities, in the warm temperate to tropical areas [32,33]. However, despite their wide distribution, some species of cardinalfishes were found have fidelity to a certain coral species, e.g. scleractinian corals, for resting and making them using overlapping microhabitat leads to their susceptible condition to even the single coral species destruction [34]. More apogonid species have been reported as a bycatch from deep water fisheries, for example from commercial trawler operated between 90m and 100m depth [35]; and from drift gill net operated from traditional fishing craft at 30m to 50m depth [36].

Figure 2. Different type of fishes from Class Perciformes dominated by cardinalfishes and butterflyfishes frequently found in the bycatch from "*sero*" fisheries in Selayar Island, South Sulawesi, Indonesia.

We also found an endangered species such as a stingray (*Taeniura lymma*) and a turtle (*Chelonia mydas*) as bycatch. Additionally, a group of shark was also found in a "*sero*" trap that still kept alive by the fishermen due to his inability to get rid of the shark from the trap, eventhough the shark has decreased the catch of target fishes due to the predation of the shark to the fish target. Moreover, we also found a cat shark in the bycatch of this fishery (Figure 3). The bluespotted fantail ray *Taeniura lymma* and the blacktip reef shark *Carcharhinus melanopterus* are listed as Near-Threatened species, whereas *the green turtle Chelonia mydas* is listed as Endangered species. The turtle and the shark are both declining in populations [37]. Some kind of artisanal fisheries have been reported to have endangered/threatened species of Elasmobranchii and turtles as bycatch [8,11,38,39]. This issue has been mitigated by developing some devices such as Bycatch Reduction Devices (BRDs) for sharks and Turtle Excluder Devices (TEDs) that mostly addressed this bycatch from tropical shrimp trawling [39]. Some successful implemention to mitigate bycatch problems have been reported including acoustic deterrent devices (pingers) to reduce bycatch of some small cetacean species in gillnets, appropriately designed exclusion devices which reduced pinniped bycatch in some trawl fisheries, and various pot/trap guard designs that reduced marine mammal entrapment [40].

Escape gaps in African basket traps is also the example of mitigation of baycatch problem, where the device has been reported to reduce baycatch from this fishery, which is mostly butterflyfishes and other low value species [18]. Whereas, bycatch in general is proposed to be reduced by implementing Ecosystem Approach to Fisheries Management (EAFM) in order to maintain a healthy, productive, and resilience ecosystem to support human livelihood in a sustainable manner [41].

Figure 3. Some Near-Threatened species: ray (*Taeniura lymma*), blacktip reef shark (*Carcharhinus melanopterus*), and juvenile of green turtle (*Chelonia mydas*) were among the bycatch of the "*sero*" fisheries in Selayar Island, South Sulawesi, Indonesia.

3.2. Bycatch size

As definition that bycatch is generally a non-target fishes in the catch, therefore, it could be that the bycatch is the undersized or juvenile of a target fishes. In this study, we measured total length of the bycatch spesies that can be seen in Table 2.

Table 2. Length of bycatch for each species found in "*sero*" fisheries of Selayar Island, South Sulawesi, Indonesia.

Species	Total length (cm)	Max Length (cm)
Arothron manilensis	17.5	31.0
Arothron hispidus	19.5 - 23.0	50.0
Arothron stellatus	26.0	120.0
Canthigaster amboinensis	7.5	15.0
Diodon liturosus	24.0 - 28.0	65.0
Ostracion cubicus	22.0 - 24.0	45.0
Aluterus scriptus	27.5	110.0
Chaetodermis penicilligerus	9.5	31.0
Pristiapogon kollapterus	6.5 - 11.0	15.5
Ostorhinchus fleurieu	6.0 - 11.0	12.5
Ostorhincus aureus	5.0	14.5
Ostorhincus fasciatus	5.5	12.6
Taeniamia fucata	6.0	10.0
Abudefduf vaigiensis	12.5 - 13.0	20.0
Chaetodon lunula	13.0	20.0
Chaetodon trifasciatus	13.0	15.0
Chaetodon vagabundus	11.0	23.0
Chaetodon citrinellus	12.0	13.0
Chaetodon kleinii	13.0	15.0
Chaetodon auriga	11.5 - 12.5	23.0
Zanclus cornutus	20.0	23.0
Lobotes surinamensis	13.0	110.0
Hypoatherina temmnckii	6.5 - 7.0	12.0
Hypoatherina sp.	5.5	12.0
Saurida elongata	7.0	50.0
Plotosus lineatus	9.0 - 15.0	32.0
Asterorhombus intermedius	7.0	20.0
Hippichthys cyanospilos	20.0 (total length)	16.0 (standard length)
Taeniura lymma	17.0 (widest diameter)	35.0 (widest diameter)
Atelomycterus marmoratus	50.0	70.0
Carcharhinus melanopterus	NA	200.0
Chelonia mydas	juvenile	NA

Note: data on fishes maximum length are taken from https://www.fishbase.org

The bycatch found from this seagrass fisheries was mostly considered in a juvenile stage, if we show the size of the fishes found in the catch which were half to one third of the maximum size reported (see Table 2). This is mostly related to the services of seagrass meadows as nursery grounds for the early life cycles of many marine organisms [42].

Discarded fishes (bycatch) from small-scale fisheries were low [27], however, incidental catch of some juveniles of species and non-target species is still a great concern because it became natural waste and have an ecological consequences to the population, community, and ecosystem. An increase activities that taken fauna associated to seagrass, both as target fish or bycatch, will reduce the

abundance of the fauna and especially making the rare species to be extincted, decrease diversity that leads to an impoverishment of potential functional roles within the seagrass ecosystem [43]. More concern should also be raised as we found an endangered or threatened species in the baycatch, this will contributes to the population declines of these threatened species. Most sharks and turtles are slow growing and slow to reproduce, making them highly vulnerable to overexploitation leading to a population decline [44]. Sharks are the top predator in the marine environment, and the declines of this marine top predator will have a trophic cascading effect to the whole marine communities due to a fundamental influence of this predator has to the structure and function of marine communities [45]. The ecological functional of rays as a bioturbator that important in marine biogeochemical cycles and infaunal communities would also diminish as a result of rays population decline [46]. Therefore, more research are needed to find a solution of the bycatch problem in different kind of artisanal fisheries, including the "*sero*" fisheries.

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