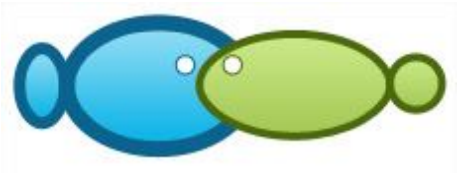

Diversity of Mullidae as by-catch of Plotosidae fishery in the waters of Southeast Sulawesi, Indonesia

[1,2]Asriyana Asriyana, [1]Halili Halili

[1] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kampus Bumi Tridharma Anduonohu, Kendari 93232, Southeast Sulawesi, Indonesia; [2] The Indonesian Ichthyological Society (IIS), Bogor, Indonesia. Corresponding author: A. Asriyana, asriyana@uho.ac.id

Abstract. By-catch from coastal fisheries is widely reported in Southeast Asia. However, several by-catch fish species such as Mullidae have been understudied due to the high variability of by-catch species. This study aimed to determine the diversity of Mullidae caught as by-catch of Plotosidae fishery. Tanjung Tiram and Kolono Bay waters of Southeast Sulawesi were selected as the target sites to represent the exploitation level of Mullidae in Indonesia. Mullidae by-catch was estimated using gillnets with different mesh sizes simulating Plotosidae fishing practice. Twelve species of Mullidae caught from June 2019 to May 2020. The relative abundance of Mullidae was spatially and temporally uniform ($p > 0.05$; $\alpha = 5\%$). The dominant by-catch species of Mullidae in both sites were *Parupeneus barberinus*, *Upeneus tragula*, and *Upeneus sulphureus*. The calculated ecological index showed that Mullidae community in both locations was considered stable ($0.75 < E \leq 1$) except in February and March ($0.5 < E \leq 0.75$). This study concludes that Plotosidae fishery has not caused a significant change in the community structure of Mullidae in the Southeast Sulawesi coastal waters and most likely the same with the other coastal areas in Indonesia. Yet, Mullidae by-catch needs to be regularly monitored to ensure the conservation and sustainable use of the fish resource.

Key Words: by-catch, ecological index, Mullidae, Southeast Sulawesi.

Introduction. Mullidae, known locally in Indonesia as 'Kuniran', is a family of tropical demersal fish distributed in shallow muddy sand coastal waters of the western Indo-Pacific (Peristiwady 2006). The fish family is characterized by elongated and slender body shape and has two long unbranched appendages on the front jaw with length size reaching up to 23 cm (Riede 2004). The fish is categorized as oceanodromous fish whose life stage and schooling behavior are permanently in the ocean (Riede 2004). The species diversity of Mullidae in Indonesia and specifically in the South Konawe waters was relatively varied (Muhajirah et al 2017; Asriyana et al 2020a) due to the heterogeneity of coastal ecosystems in Indonesia ranging from coral reef, seagrass bed, to dense mangrove vegetation (UHO-Research Center 2011).

Currently, the fish family has experienced a consistent pressure primarily being caught as by-catch from fishing activities targetting several highly valued species in Indonesia. In general, certain fishing activities and fishing gears, particularly gillnets have captured by-catch not only sea mammals, sea birds, turtles (Reeves et al 2013; Žydelis et al 2013; Benavides 2018) but also non-targeted fish resources such as Mullidae family. By-catch has been regarded as a persistent problem in capture fishery and a threat to coastal resource sustainable use and conservation, primarily if the fishing activities use non-selective fishing gear (Hutchings & Lamberth 2002; Rainaldi et al 2017). In several countries such as the USA (Williams et al 2006), Hurghada, Egypt (Sabrah 2015) and Brazil (Soares et al 2020), Mullidae is the main target fish species in demersal fishery. On the contrary, in South Konawe of Southeast Sulawesi, Indonesia, Mullidae is the main by-catch of Plotosidae fishery (Asriyana et al 2020a).

The Plotosidae fishery is classified as a small-scale fishing activity carried out primarily by the local fishermen in the area as well as many regions in Indonesia and other developing countries such as Bangladesh, Malaysia, and Thailand (Ahmed & Haque 2007; Usman et al 2016; Amornsakun et al 2018). The current high rates of number and species of Mullidae caught as by-catch in the area have raised some concerns that the pressure could destabilize the fish community and reduce its wild population leading to the extinction of the species. The imbalance of a fish community can be observed from certain indicators such as changes in abundance, productivity, and community structure (i.e., size spectrum, species dominance, and community index). For example, excessive fishing pressure to Mullidae has caused a significant decrease in abundance, landing volume and frequency, length and weight in various fishing areas such as Central Pacific (Friedlander & DeMartini 2002), Mediterranean (Labropoulou & Papaconstantinou 2004), and Hawai (Williams et al 2006). From the ecological point of view, Mullidae has a vital function in the food web, for example, serving as the trophic level 2.8 (Sano et al 1984). The fish family has also been used as the indicator species for fishing pressure, habitat modification (Friedlander & DeMartini 2002; Goren & Galil 2005; Uiblein 2007). The fish is the main food for local coastal communities and contains protein and fat, ranging between 20.79 and 22.16% and 1.43 and 3.78%, respectively. The fish also has essential amino acids and fatty acids (Doğan & Ertan 2017) and myofibril proteins, which are considered as nutritious food ingredients (Subagio et al 2004). Providing these critical functions, excessive by-catch of the Mullidae family could lead to the loss of its ecological and economic services.

Several studies have discussed some of the bio-ecological characteristics of this fish family which included their biology and ecology aspects (Widodo 1980; Kembaren & Ernawati 2011; Asriyana & Irawati 2018). However, studies on the diversity of the Mullidae family as by-catch have not yet widely available in the literature. Therefore, this recent study aimed to determine the diversity of the Mullidae family caught as by-catch of Plotosidae fishery in the coastal waters of Southeast Sulawesi, Indonesia. This research is expected to provide one of the first information regarding the effect of by-catch to Mullidae. Findings from this research were expected to provide the extent as well as lesson learning regarding Plotosidae fishing pressure to the Mullidae fish community not only for Indonesia but also other areas where Mullidae faces similar by-catch fishing pressure.

Material and Method

Research site. This research was carried out in Tanjung Tiram and Kolono Bay coastal waters of South Konawe, Southeast Sulawesi, Indonesia (Figure 1) for 12 months, starting from June 2019 to May 2020. The sample collection was performed monthly on three sampling sites, which were previously identified as the Plotosidae fishing grounds. The overlap between the sampling sites and the fishing grounds of Plotosidae was intentional to simulate the capture of Mullidae as by-catch by Plotosidae fishery. The characteristics of each location were presented in Table 1.

Fish collection. The fishing activities targetting Plotosidae were carried out using bottom gillnets sized 30 m in length, 1 m in height, and 1¼, 1¾, 2, and 3 inches in mesh size. The fishing gears were set during high tide and lifted during low tide. Captured Mullidae from both locations were sorted and separated from the main target fish (Plotoside family). The samples were placed into coolboxes and then transported to the Laboratory of Faculty of Fisheries and Marine Science of Halu Oleo University for further sorting and analyses. In the laboratory, fish samples were identified and grouped according to their species using the fish identification method suggested by White et al (2013), Froese & Pauly (2019). Afterward, the fish samples were measured for their total length using a scale with 0.1 cm accuracy and their weight using an analytic weight scale with 0.1 g accuracy.

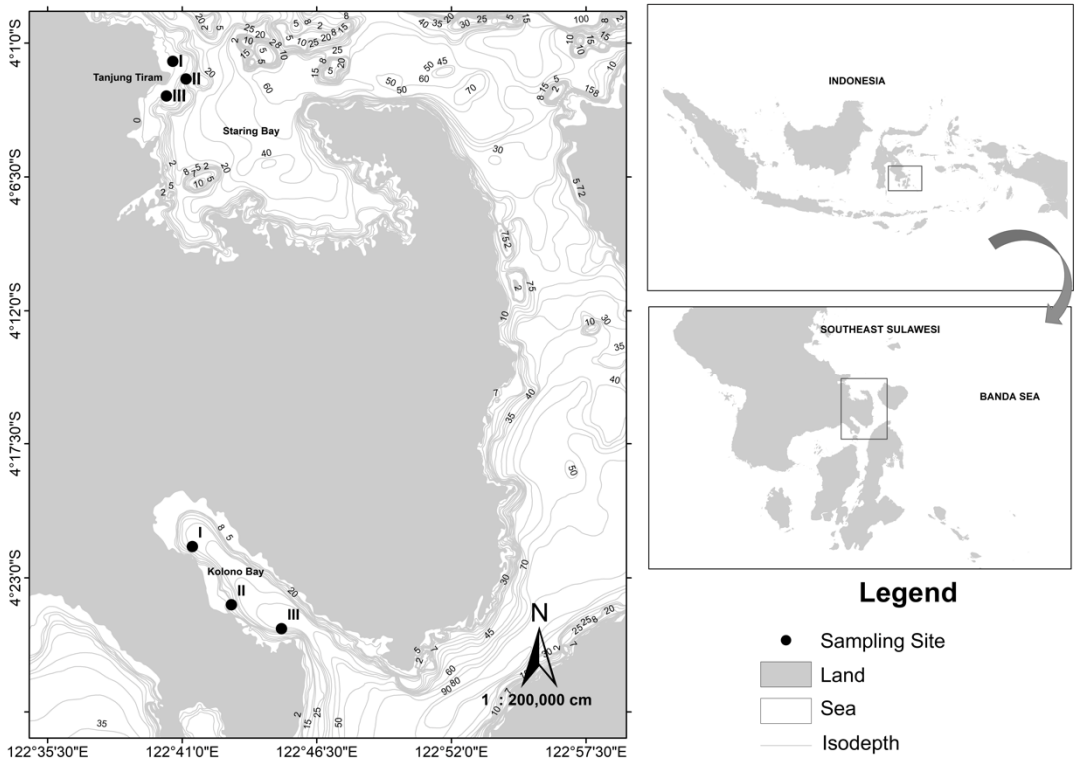

Figure 1. Sampling sites on the coastal waters of South Konawe, Southeast Sulawesi.

Table 1

Ecological characteristics of coastal waters of Tanjung Tiram and Kolono Bay

Location	*Ecological characteristics*	
	Tanjung Tiram	*Kolono Bay*
I	Adjacent to seagrass, coral reef, and mangrove areas. The site close to a small river mouth. The substrate was primarily muddy sand.	Adjacent to coral reef and mangrove areas and close to a small river mouth. The substrate was rocky and reef fragments.
II	Adjacent to seagrass and coral reef areas. The substrate was primarily sand.	Adjacent to seagrass, coral reef, and mangrove areas. The site was influenced by freshwater mass from a nearby river. The substrate was muddy sand.
III	Adjacent to seagrass, coral reef, and mangrove areas. The substrate was sand.	Adjacent to coral reef and mangrove areas. The site was located near the mouth of the bay

Data analysis. Weight and length sizes of sampled fish were tabulated, and the dominant species of Mullidae were categorized based on their size range following the protocol of Sturges (1926). The relative temporal abundance and frequency of occurrence of the fish family were calculated using the formula suggested by Brower et al (1998). The ecological category was determined based on the migration behavior and habitat preference according to the guidelines of Kuiter & Tonozuka (2001), Allen & Erdmann (2012), Froese & Pauly (2019). The juvenile and adult sizes of the family were determined based on the results of the total length measurement compared to the referenced maximum total length (TLmax.) and minimum size of the mature gonad (Lm) of Mullidae of other studies. The ecological indexes were determined using the Shannon-Wiener diversity index, Simpson dominant index, and species evenness index according to the suggestion of Brower et al (1998). Data analysis was performed using MS Excel Office. Variations of the relative abundance of Mullidae fish were spatially and temporally

analyzed using the non-parametric Kruskal-Wallis statistical test with a 95% confidence interval (Sokal & Rohlf 1981) using the IBM SPSS software ver. 23.0.

Results

Size distribution. The total number of Mullidae fish caught during the period of the study was 214 individual fish consisted of 65 individual fish caught in the coastal area of Tanjung Tiram and 149 fish caught in Kolono Bay. There were 12 fish species from three genera (Table 2). *Parupeneus barberinus* (Tanjung Tiram) and *Upeneus tragula* (Kolono Bay) had the highest length and weight mean sizes. From the 12 species of Mullidae found in both locations, *P. barberinus* and *Upeneus sulphureus* had the highest abundance. The distribution of weight and length of the two species is presented in Figure 2.

Table 2

Distribution of weight and length sizes of Mullidae family in the waters of South Konawe

Species	Tanjung Tiram			Kolono Bay		
	N	TL (cm)	W (g)	N	TL (cm)	W (g)
Mulloidichthys flavolineatus	1	22.0	105.1	6	12.2-21.3	24.0-81.7
Mulloidichthys vanicolensis	5	10.6-14.0	12.0-32.4	7	14.1-17.0	25.3-49.7
Parupeneus barberinus	28	9.0-23.8	4.9-166.5	7	11.4-22.0	14.6-140.7
Parupeneus heptacanthus	-	-	-	1	14.4	33.5
Parupeneus indicus	-	-	-	3	15.9-16.5	57.7-65.9
Parupeneus multifasciatus	5	13.3-21.1	32.4-132.5	17	9.8-16.4	11.5-57.9
Upeneus asymmetricus	1	18.7	73.1	-	-	-
Upeneus moluccensis	1	10.0	8.7	11	10.8-18.3	11.7-63.3
Upeneus sulphureus	3	10.1-14.9	9.53-32.8	75	9.4-19.9	10.0-91.4
Upeneus sundaicus	-	-	-	1	10.9	11.3
Upeneus tragula	21	11.2-23.8	14.3-131.6	18	9.6-23.5	7.1-148.7
Upeneus vittatus	-	-	-	3	19.3-19.4	79.3-89.8
Number of fish	65			149		
Species	8			11		
Genera	3			3		

N = individual; TL = total length; W = weight.

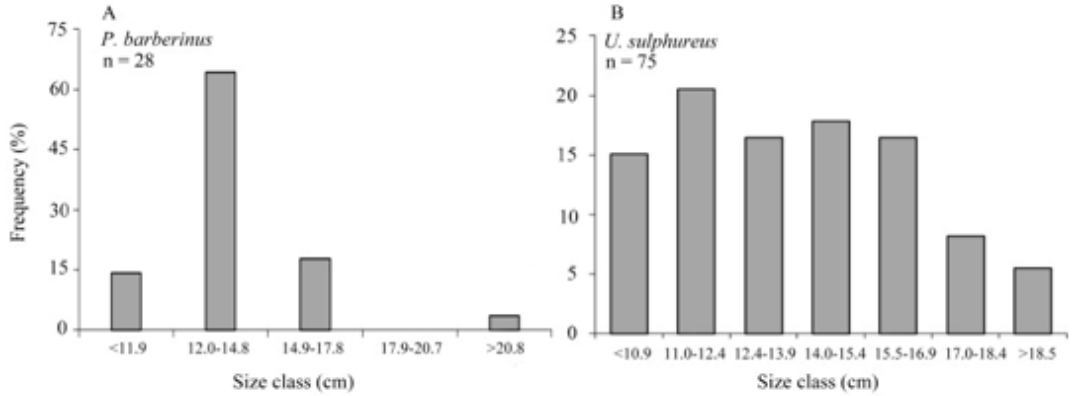

Figure 2. Length size distribution of dominant Mullidae species in the waters of South Konawe: A) Tanjung Tiram, B) Kolono Bay.

Relative abundance. The relative abundance of the Mullidae family on the coast of South Konawe is presented in Figure 3. Spatially and temporally, the relative abundance of Mulliade in the waters of Tanjung Tiram and Kolono Bay had a probability value of 0.671 ($p > 0.05$; $\alpha = 5\%$). This value indicates that Mullidae has a relatively uniform

abundance in both locations during the study period, although it has been caught as by-catch from Plotosidae fishery.

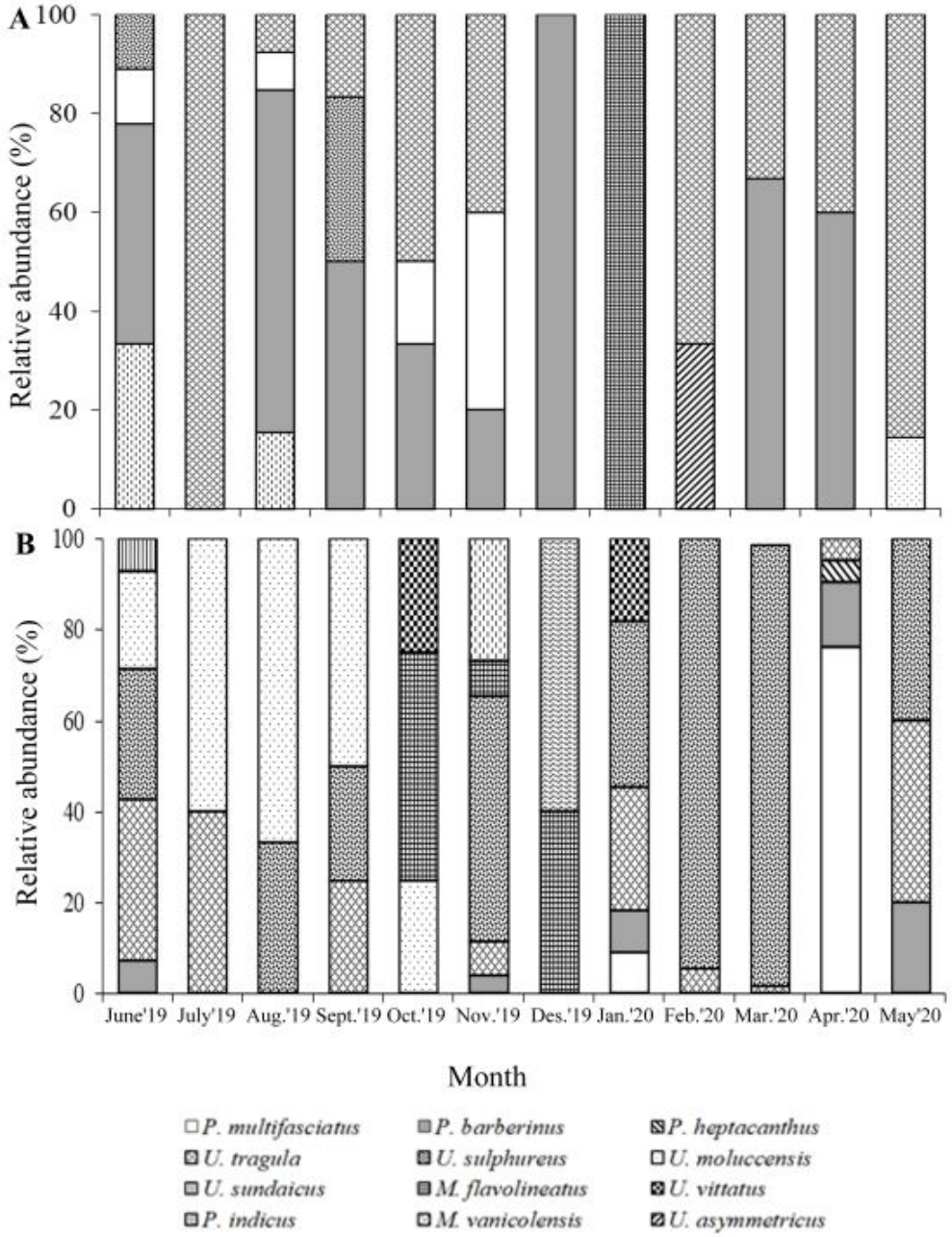

Figure 3. Spatial and temporal distribution of the relative abundance of Mullidae family in the waters of South Konawe: A. Tanjung Tiram, B. Kolono Bay.

Frequency of occurrence. The frequency of occurrence, ecological category, and habitat of the Mullidae family in the waters of South Konawe is presented in Table 3. There were two Mullidae species in the waters of Tanjung Tiram, which had the highest frequency of occurrence, i.e., *P. barberinus* and *U. tragula* (FO = 66.67%). In Kolono Bay, *U. sulphureus* and *U. tragula* had the highest frequency of occurrence of 66.67% and 83.33%, respectively. The highest occurrence of these three species possibly indicates that they have the highest tolerance and adaptability to the existing condition of both sites.

Table 3

Frequency of occurrence of (FO); ecological category (EC): resident (R), migratory visitor (MV), and occasional visitor (OV); habitat: associated with coral reef (C), associated with coral reef and estuary (CB), associated only with estuary (B), and associated with aquatic plant (W); life cycle (LC): juvenile (J), mature (M)

Species	Tanjung Tiram				Kolono Bay			
	FO (%)	EC	Habitat	LC	FO (%)	EC	Habitat	LC
M. flavolineatus	8.33	OV	C	J	25.00	OV	C	J
M. vanicolensis	16.67	OV	C	J	0.08	OV	C	J
P. barberinus	66.67	R	C	J, M	33.33	OV	C	J
P. heptacanthus	-	-	-	-	8.33	OV	CB	J
P. indicus	-	-	-	-	8.33	OV	CB	J
P. multifasciatus	41.67	MV	C	M	16.67	OV	C	J, M
U. asymmetricus	8.33	OV	W	J	-	-	-	-
U. moluccensis	8.33	OV	CB	J	41.67	MV	CB	J
U. sulphureus	16.67	OV	B	J	66.67	R	B	J, M
U. sundaicus	-	-	-	-	8.33	OV	B	J
U. tragula	66.67	R	CB	J, M	83.33	R	CB	J, M
U. vittatus	-	-	-	-	8.33	OV	CB	J, M

Ecological index. Monthly indexes of diversity, dominancy, and evenness in both study sites are described in Figure 4. Spatially, the diversity index of Mullidae in Tanjung Tiram and Kolono Bay ranged between 0.41-1.21 and 0.14-1.47, respectively. *U. sulphureus* caught in Kolono Bay had a higher dominancy index (0.27-0.94) compared to that of *U. sulphureus* in Tanjung Tiram (0.33-0.76) (Table 2). In Tanjung Tiram, the distribution of the number of individual fish was relatively even with the value of evenness between 0.60 and 0.97. In contrast, Mullidae fish in Kolono Bay has a relatively uneven distribution of the number of individual fish within a species signaled by the range of evenness index values between 0.20-0.97.

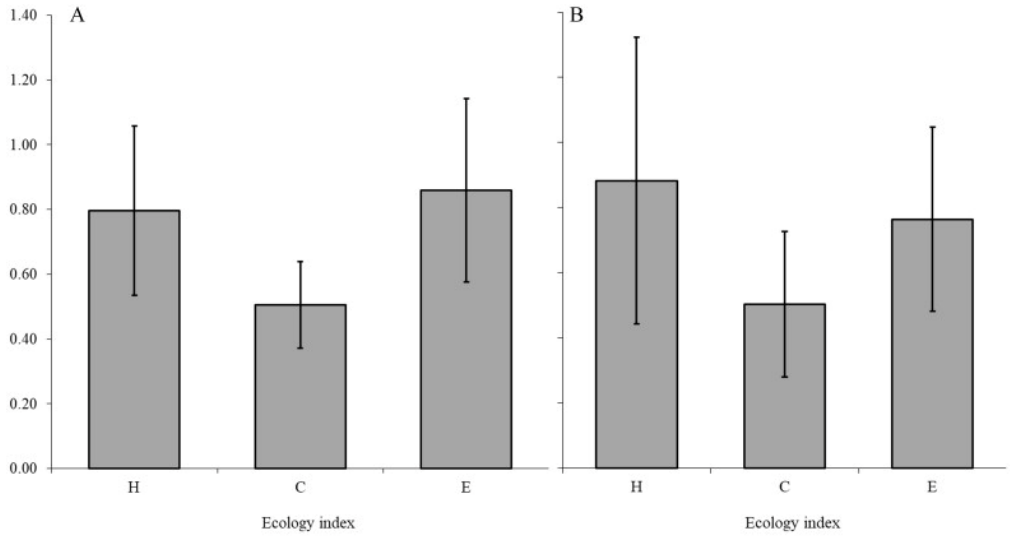

Figure 4. Spatial distribution of ecological index (H: diversity; C: dominance; E: evenness) of Mullidae as by-catch in the waters of South Konawe: A) Tanjung Tiram; B) Kolono Bay.

The temporal fluctuation of the ecological index of the Mullidae family is depicted in Figure 5. The highest diversity of Mullidae was observed in January (H' = 1.47), and the lowest was in March (H' = 0.39). The populations of Mullidae in the sites were considered to be in a stable state (E≈1) characterized by the relatively even distribution of among

the member of the Mullidae species, except that *U. sulphureus* was more dominant in number during February and March (C≈1), especially in Kolono Bay.

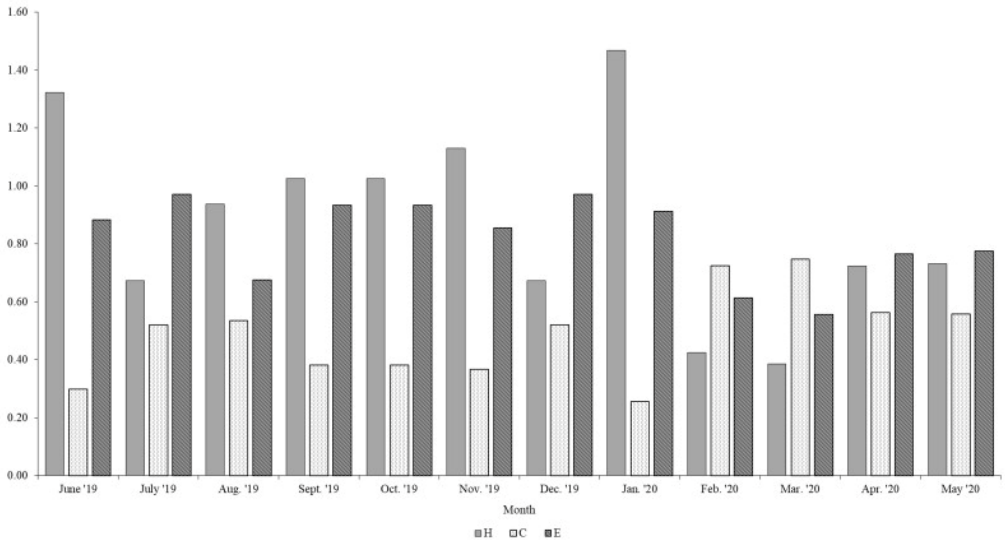

Figure 5. Temporal distribution of ecological index (H: diversity; C: dominance; E: evenness) of Mullidae as by-catch in the waters of South Konawe.

Discussion. This recent study has identified 8 and 11 species from the three genera of Mullidae in waters of Tanjung Tiram and Kolono Bay, respectively. The number of Mullidae species in these sites is higher than that of Hoga Island, which only consisted of 5 species from two genera (Sarisma et al 2018). Similarly, there were only 7 Mullidae species from two genera found in the Southern Red Sea, Hurghada, Egypt (Farrag et al 2018). However, the Islands of Andaman and Nicobar, India have a higher number of Mullidae species, which consisted of 14 species from three genera (Rajan et al 2012). The relatively high diversity of Mullidae species in the coastal waters of South Konawe is strongly related to the diversity of the fish habitat and condition (Table 1). Other referred locations mentioned previously, such as Hoga Island and the Southern Red Sea, had fewer species diversity due to less variation of the supporting coastal ecosystems (only one or two coastal ecosystems). The comparison between this study and other studies' findings reiterates that the more heterogeneous a physical environment of an aquatic system, the more complex the community of its constituents, which allows a higher diversity of the species and vice versa. Several researchers also reported such a relationship; for example, Teshima et al (2016), Protasov et al (2019), López-Delgado et al (2020).

Most of the members of the Mullidae family caught as the by-catch of Plotosidae fishery have smaller sizes of maximum length and minimum mature gonad, which are common in the coastal regions except for *P. multifasciatus, U. tragula,* and *U. vittatus* (Table 4). This finding indicates that the waters of Tanjung Tiram and Kolono Bay are used by most of the Mullidae species for nursery ground. Similarly, several studies also reported that the typical characteristics of nursery ground preferred by the juvenile of Mullidae are soft substrate coastal waters, seagrass area, and mangrove area (Gullström & Dahlberg 2004; Dorenbosch et al 2006).

By-catch of the juvenile stadia of some of Mullidae species might severely impact the overall fish family diversity, considering that their populations will not reach the adult sizes and have at least one spawning activity during their life period. A persistent and more prolonged period of pressure of by-catch to the fish family might lead to a diminishing population and, eventually, the extinction of the fish family, at least in the local region of South Konawe. A similar effect can be expected from the by-catch of the adult fish of the three Mullidae species: *P. multifasciatus, U. tragula, and U. vittatus*. These adult fish sizes will not have a chance to complete their life cycle through spawning

due to being caught as by-catch. As a result, their populations will also diminish over time.

Generally, coastal waters and bays have a relatively high primary productivity (Asriyana & Irawati 2019) due to the existence and interaction of three productive ecosystems i.e. mangrove, seagrass, and coral reef. Such habitat diversity attracts fish juveniles to use these waters as the feeding ground, grow-out area, and protection shelter. For the same reasons, the coastal waters of Tanjung Tiram and Kolono Bay are used by other fish families such as Plotosidae and Labridae (Asriyana et al 2020b, c). Several areas have been reported with the same mix functions such as the Northern waters of Mindanao Island, Philippines (Honda et al 2013), Swartkops Estuary, South Africa (Edworthy & Strydom 2016), Bontang coastal waters, Indonesia (Irawan et al 2018).

In Tanjung Tiram, *U. tragula* had the highest relative abundance (85.71%), which occurred in May. In Kolono Bay, *P. multifasciatus* and *U. sulphureus* had the highest relative abundance of 76.19% and 96.97%, respectively, which were occurred from April to March. The variations of relative abundance of these species were the result of the different number of individual fish from each species caught in each month. Despite the noticeable abundance of the three species, the overall abundance of Mullidae caught as by-catch in the waters of Tanjung Tiram, and Kolono Bay was relatively uniform ($p > 0.05$; $\alpha = 5\%$).

Based on the frequency of occurrence, the species of Mullidae found in the coastal waters of South Konawe can be categorized as resident (R), migratory visitor (MV), and occasional visitor (OV) (Table 3). Most of the Mullidae species caught as by-catch in Tanjung Tiram and Kolono Bay are occasional fish visitors (OV) that come periodically to the area to find shelter and food. This behavior pattern can be inferred from the fact that the juvenile population (J) is more dominant compared to the mature population (M). Habitat use by an organism is strongly correlated with its effort to find the best condition available for its survival. In other words, habitat preference is influenced by the primary objectives of the fish, which changes according to its life stage. The juveniles of Mullidae use the waters of South Konawe primarily as protection and feeding grounds. The dense mangrove root, seagrass coverage, and coral reef complex structure in the area provide the much-needed protection for younger fish from predation and consistent food supply. The use of habitat by fish juveniles for protective shelter and feeding grounds have been reported by various researchers such as Gristina et al (2017) in the Gulf of Taranto, Lee et al (2019) on Dongsha Island, South China Sea.

This recent study has also found both juvenile and mature stadia of Mullidae species of *P. barberinus, P. multifasciatus, U. sulphureus, U. tragula*, and *U. vittatus*. All species were determined to be both the resident (R) and occasional visitors of the study sites (Table 3). The mature fish of Mullidae species arguably choose these sites to find sufficient food for their gonadal development. In addition, seagrass in these sites also functions as the recruitment habitat for the species of this family. Similarly, Dorenbosch et al (2006) found that seagrass beds in the coastal areas of East Africa serve as the recruitment area for adult Mullidae fish.

P. barberius and *U. tragula* were the dominant by-catch in waters of Tanjung Tiram from Plotosidae fishery due to their highest frequency of occurrence. On the other hand, *U. sulphureus* and *U. tragula* were the dominant by-catch in Kolono Bay (Figure 4) owing to their highest frequency of occurrence. As a result, these three species can be categorized as the resident (R) of both Tanjung Tiram and Kolono Bay waters.

The coral reef and seagrass coverages of Tanjung Tiram waters were in medium (30%) and good (60-80%) conditions, respectively (UHO-Research Center 2011). Such habitat characteristics allow *P. barberinus*, a marine fish species primarily associated with coral reef (Allen & Erdmann 2012) and seagrass (Dorenbosch et al 2006; Uiblein 2007), to become the permanent resident of Tanjung Tiram waters. The strong relationship to its habitats allows the fish to reach higher population density and become the dominant by-catch of Plotosidae in the coastal waters. Similarly, *U. tragula* is also the other dominant fish in Tanjung Tiram waters due to its association with the coral reef and its ability to migrate to the brackish water system (Riede 2004).

Table 4

Ranges of maximum length and minimum mature gonad sizes of Mullidae family from the study compared to the results of other studies from various locations

Species	Total length (cm)		TL_{max} (cm)	L_m (cm)	Location	References
	Tanjung Tiram	Kolono Bay				
M. flavolineatus	22.0	12.2-21.3	23.0	20.8 TL* 19.8 TL**	Guiuan, Samar, Philippines	Sommer et al (1996)
M. vanicolensis	10.6-14.0	14.1-17.0	25.0	24.0 TL	Lagoon of Maurituis	Sommer et al (1996)
P. barberinus	9.0-23.8	11.4-22.0	27.0	19.2 FL* < 12.4 FL **	New Ireland Province, Papua New Guinea	Longenecker et al (2017)
P. heptacanthus	-	14.4	24.1	-	Visakhapatnam, India	Das & Rohit (2011)
P. indicus	-	15.9-16.5	35.0	-		Kuiter & Tonozuka (2001)
P. multifasciatus	13.3-21.1	9.8-16.4	14.5* 15.5**	11.0 TL* 10.0 TL**	Nha Trang Bay, Vietnam	Pavlov et al (2011)
U. asymmetricus	18.7	-	30.0	-		Allen & Swainston (1988)
U. moluccensis	10.0	10.8-18.3	21.9	12.4 TL* 12.0 TL**	Sunda Strait, Indonesia	Sarumaha et al (2016)
U. sulphureus	10.1-14.9	9.4-19.9	20.0	9.9 TL	Tegal, Central Java, Indonesia	Kembaren & Ernawati (2011)
U. sundaicus	-	10.9	14.0	-		Kumaran & Randall (1984)
U. tragula	11.2-23.8	9.6-23.5	18.7	9.3 FL	Nha Trang Bay, Vietnam	Pavlov et al (2014)
U. vittatus	-	19.3-19.4	19.8	11.0 TL	Gulf of Suez, Egypt	Sabrah & El-Ganainy (2009)

TL_{max} = total length maximum; TL = total length; FL = fork length; L_m = length maturity; * = female; ** = male.

Kolono Bay waters have relatively different ecological characteristics. The diverse habitats of the sites added with the existence of a river mouth in the bay (Table 1) have made *U. tragula* and *U. sulphureus* to be the dominant Mullidae species in Kolono Bay. *Upeneus* genus is one of the Mullidae genera known to be associated with brackish waters. These species occurrences in brackish, estuary, and coastal waters have been recorded by various researchers in other regions such as in The Northern coast of North Sulawesi, Indonesia (Bataragoa et al 2014), Gulf of Thailand, South China Sea (Pavlov & Emel'yanova 2018), and Moreton Bay, Australia (Wee et al 2018).

Species of Mullidae found in the South Konawe waters can be classified into four categories based on each species association with the existing ecosystems they live in (Table 3). In Tanjung Tiram waters, the number of species of Mullidae associated with coral reef (C) was more than the species associated with the other ecosystems due to the dominant coverage of the coral reef in the area. In Kolono Bay, on the other hand, Mullidae species were dominated by fish that have an association with coral reef (C) and brackish water (CB). The variation of the fish category is the response of Mullidae species preferences to the specific characteristics of both locations (Table 1).

Based on the ecological indexes, the diversity of Mullidae in the waters of Tanjung Tiram and Kolono Bay is classified from low to medium. In terms of spatial distribution, the species richness of Mullidae in Kolono Bay is higher than that of Tanjung Tiram waters. The existing ecosystem heterogeneity, such as mangrove, seagrass, coral reef, intertidal area, and river mouth in Kolono Bay, provides suitable and varied habitats for different life stages of Mullidae (Table 1). Brower et al (1998) argued that the variation of the number of species and individuals within a species occupying a habitat would determine the value of the diversity index. The relatively high number of species of Mullidae implies the critical role of the family fish to support the other fish communities in Kolono Bay. The distribution of individual numbers among Mullidae species was relatively even in Tanjung Tiram waters, indicating that the fish family was in a stable condition despite consistent pressure from Plotosidae fishery. In contrast, the Mullidae family in Kolono Bay was in an unstable state due to the possible effect of Plotosidae fishery. One of the telltale signs was the uneven distribution number of individuals among the species of Mullidae and the dominant occurrence of one Mullidae species (*U. sulphureus*).

Temporally, the diversity of Mullidae was higher in January, which is influenced by the Nothern monsoon compared to the other months. During the peak of the Northern monsoon period (December-January), the high intensity of rainfall does not only affect the salinity distribution in the waters but also influences the availability of food triggered by the increased nutrient flux in the system from land runoff and water turbulence. The decreased salinity during this period also invited euryhaline species to this site, one of which was *U. sulphureus* known to prefer a brackish water system. During the high rainy season, water input to the bay has considerably increased the inundated area where fish can access to find food. Several studies reported similar findings regarding higher fish diversity during the rainy season, for example, in Alagoas coastal waters, Brazil (Souza et al 2018), Sundak beach, Indonesia (Adharini et al 2020).

The domination of *U. sulphureus* due to fishing pressure to other Mullidae species described in this research was also observed on other Mullidae species such as *M. vanicolensis* in Central Pacific (Friedlander & DeMartini 2002), *Mullus barbatus* and *M. surmuletus* in Western Mediterranean and Northeast Mediterranean (Labropoulou & Papaconstantinou 2004; Maravelias & Papaconstantinou 2006). These similar findings show that fishing pressure does not only affect the distribution of inter-fish species, but also reduce fish diversity, abundance, biomass, and increase the dominance of a particular species. We acknowledge that this research has some limitations in terms of limited sampling sites and was conducted in a local, regional setting. Nevertheless, the research's findings provided one of the first evidence regarding Mullidae as the by-catch Plotosidae fisheries, which has been overlooked in the related literature.

Conclusions. The pressure of Plotosidae fishery in Tanjung Tiram waters has not reached a level that could affect the community structure of the Mullidae family. On the contrary, the Plotosidae fishery in Kolono Bay has, despite small, a noticeable effect on

the community structure of Mullidae. One of the visible signs is the uneven distribution of the number of individuals among species and the occurrence of a dominant species of Mullidae in the area.

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Authors:
Asriyana Asriyana, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kampus Bumi Tridharma Anduonohu, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: asriyana@uho.ac.id
Halili Halili, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kampus Bumi Tridharma Anduonohu, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: halili@uho.ac.id

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