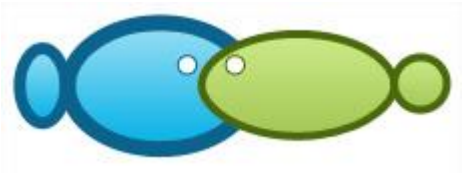

Bycatch biodiversity of blue swimming crab (*Portunus pelagicus*) fisheries in Kolono Bay, Southeast Sulawesi, Indonesia

Abdul Hamid, Syamsul Kamri

Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, Indonesia. Corresponding Author: A. Hamid, abdhamid_lamun@yahoo.com

Abstract. Bycatch biodiversity data are needed in ecosystem-based management and certification of *Portunus pelagicus* (Linnaeus, 1758) fisheries. This study aims to explain the bycatch biodiversity of *P. pelagicus* fisheries in Kolono Bay, Indonesia. Bycatch sampling was carried out purposively by *P. pelagicus* fishermen using traps. The bycatch data obtained were divided into 4 groups, namely: fish, crustaceans, echinoderms and molluscs. They were analyzed based on the fishing habitat and sampling period. The ecological status of bycatch biodiversity was determined based on the Shannon-Wiener diversity index, evenness index, and Simpson dominance index. The bycatch biodiversity of crab fisheries found in Kolono Bay indicated 55 species consisting of 27 fish species, 20 crustacean species, 7 molluscs species, and 1 echinoderm species. The biodiversity and number of individuals of crab fisheries bycatch in Kolono Bay varied with the fishing habitat and sampling period. However, the highest biodiversity and number of individuals was found in seagrass beds. The number of species and individual crabs fishery bycatch retained was higher than the discarded number. The ecological status of the bycatch biodiversity of *P. pelagicus* fisheries in Kolono Bay based on the fishing habitat and sampling period is classified in the low diversity category, with moderate evenness and low to moderate dominance. Similarity of bycatch biodiversity and economic status of bycatch in *P. pelagicus* fisheries were also discussed. The obtained bycatch data are expected to support ecosystem-based *P. pelagicus* fisheries management in Southeast Sulawesi.

Key Words: ecology status, habitat**,** Portunidae, small fisheries, species number.

Introduction. The blue swimming crab, *Portunus pelagicus* (Linnaeus, 1758) is one of the main export commodities of Indonesian fisheries, ranking third after shrimp and tuna (MMAF 2016). However, all of them still come from capture fisheries. The fishing of *P. pelagicus* in Indonesia has been carried out intensively and the stock is mostly overfished (Suman et al 2016). Thus, a good management model is needed to support the sustainability of the crab resources. The crab fisheries management model in Indonesia refers to the Management Plan for Blue Swimming Crab Fisheries 2016, which is ecosystem-based (MMAF 2016).

In fishing *P. pelagicus*, other aquatic biota are usually captured as bycatch. Generally, bycatch of fisheries consists of several species of fish, crustaceans, molluscs and echinoderms (Batista et al 2009; Pillai et al 2014; Fazrul et al 2015; Samanta et al 2018), and is divided into two categories: economically valuable (retained) and discarded (Alverson et al 1994; FAO 2019). Several previous studies (Campbell & Sumpton 2009; Shester & Micheli 2011; Leland et al 2013; Broadhurst et al 2014; Kalayci & Yeşilçiçek 2014; Fazrul et al 2015; Hamid & Kamri 2019; Hamid et al 2020) reported that the biodiversity and abundance of bycatch of the crab fisheries is influenced by habitat, season, and type and design of fishing gear used.

Bycatch data are needed in developing ecosystem-based management strategies for *P. pelagicus* fisheries (Kalayci & Yeşilçiçek 2014; Budiarto et al 2015; Fazrul et al 2015). Bycatch data of *P. pelagicus* fisheries are also needed as one of the requirements in the assessment of the Marine Stewardship Council certification for *P. pelagicus* fisheries (Sai Global 2014). Crab is one of the sea food commodities which needs urgent

Marine Stewardship Council certification (Kembaren et al 2012), being currently in the process of certification.

Research on bycatch of *P. pelagicus* traps and gillnet fisheries has been conducted by Campbell & Sumpton (2009), Leland et al (2013), Kumar et al (2013), Fazrul et al (2015), Kunsook & Dumrongrojwatthana (2017), Prakosa et al (2017), Hamid & Wardiatno (2018), Hamid & Kamri (2019), Mardhan et al (2019), and Hamid et al (2020). Campbell & Sumpton (2009), Leland et al (2013) and Prokosa et al (2017) examined trap construction in relation to bycatch of crab fisheries. Hamid & Kamri (2019) examined the biodiversity of fish bycatch in the crab trap and gillnet fisheries, and Hamid et al (2020) examined the biodiversity of crustacean bycatch in *P. pelagicus* trap fisheries. Research on the impact of small-scale lobster trap fisheries on habitat and bycatch was carried out by Shester & Micheli (2011). So far, research on bycatch biodiversity of *P. pelagicus* fisheries based on fishing habitat has not been carried out in Indonesia, to our knowledge, this being the focus of this study.

P. pelagicus fisheries in Southeast Sulawesi are small-scale fisheries using traps and gillnets. The fishing ground extends 35 m from the intertidal section (Madduppa et al 2016; Hamid et al 2017). Kolono Bay is one of the *P. pelagicus* fishing grounds in Southeast Sulawesi, where fishermen use traps. *P. pelagicus* in Kolono Bay has been fished for a long time, but information on the biodiversity of bycatch was not found. This study aims to present the bycatch biodiversity of *P. pelagicus* fisheries in Kolono Bay, Southeast Sulawesi, Indonesia.

Material and Method

Location and time of study. This research was conducted in Kolono Bay, Puupi Village, South Konawe Regency, Southeast Sulawesi, Indonesia (Figure 1). The fishing ground of *P. pelagicus* in this village covers almost the entire waters of Kolono Bay, including the intertidal part, the river estuary, to a depth of 27 m using traps. In Kolono Bay, there are several river estuaries, including the Kolono River estuary, Awonia River estuary, Meletumbo River estuary, and Roda River estuary. This research was conducted five months, starting in February 2020, stopping because of the Covid-19 epidemic, resuming and continuing from July to October 2020.

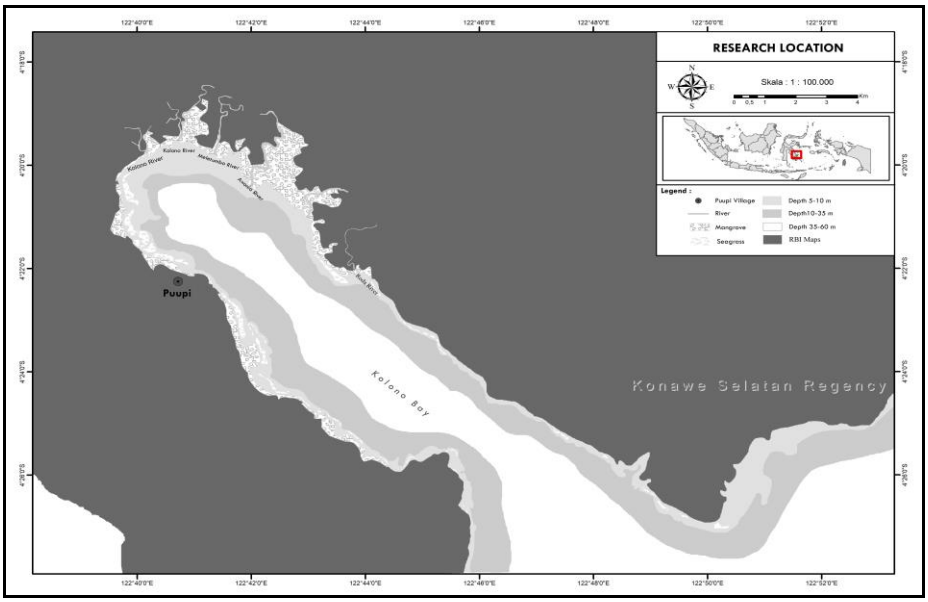

Figure 1. Map of research and location of the fish landing of *Portunus pelagicus* fisheries (black circles) in Kolono Bay, Southeast Sulawesi, Indonesia.

Sampling protocols and data analysis. Bycatch samples of *P. pelagicus* fisheries were obtained from the catch of crab fishermen using traps. The traps used were folding dome

traps with a diameter of 50 cm, a height of 19 cm and a mesh size of 20 mm. Bycatch sampling was conducted purposively twice a month at 4 locations (habitats). Samples of bycatch crustaceans were identified after Wee & Ng (1995), Ng (1998), Ng et al (2008) and Khvorov (2012); fish bycatch was identified after Kuiter & Tonozuko (2001) and White et al (2013); and molluscs were identified by Wilson & Gillett (1979).

The data of crab fisheries bycatch in each sampling period were divided into 4 groups: fish, crustaceans, echinoderms and molluscs. Each group was further divided into 2 categories: bycatch of economic value or retained, and non-valuable or discarded, based on the perceptions of local fishermen (Alverson et al 1994). Bycatch data were analyzed and presented based on the fishing habitat of crabs - river estuaries, seagrass beds, depths of 5-10 m (D5-10), and depths of 11-27 m (D11-27) - and on the sampling period. The ecological status of crab fisheries bycatch biodiversity was determined by the Shannon-Wiener diversity index, evenness index, and Simpson dominance index (Brower et al 1990), using combined data of the 4 bycatch groups. The ecological status of fish and crustacean bycatch biodiversity was analyzed. The similarity of bycatch biodiversity between fishing habitats and sampling periods was determined by the Sorensen similarity index (Brower et al 1990).

Results and Discussion

Bycatch fish biodiversity. The biodiversity of bycatch fish from *P. pelagicus* fisheries in Kolono Bay consists of 27 species of 21 families, with a total of 260 individuals (Table 1).

Table 1

The biodiversity of fish bycatch of *Portunus pelagicus* fisheries based on fishing habitat in Kolono Bay, Southeast Sulawesi, Indonesia

No	*Family*	*Species*	*Number of individuals/habitat*				*Status*
			Estuary	*Seagrass*	*D5-10*	*D11-27*	
1	Apogonidae	*Apogonichthyoides melas*	-	3	-	-	D
		Ostorhinchus chrysopomus	-	2	-	-	D
2	Batrachoididae	*Allenbatrachus grunniens*	-	6	1	-	R
3	Centrogenyidae	*Centrogenys vaigiensis*	-	4	-	-	D
4	Gerreidae	*Gerres shima*	-	-	2	-	R
5	Gobiidae	*Exyrias puntang*	-	1	-	-	D
6	Haemulidae	*Pomadasys argyreus*	2	2		8	R
7	Leiognathidae	*Eubleekeria splendens*	-	11	-	-	D
8	Lethrinidae	*Lethrinus lentjan*	-	2	-	-	R
9	Lutjanidae	*Lutjanus fulviflamma*	-	1	-	-	R
		Lutjanus malabaricus	-	1	-	-	R
10	Monacanthidae	*Acreichthys tomentosus*	10	94	8	1	D
11	Mullidae	*Upeneus subvittatus*	-	-	1	1	R
12	Muraenesocidae	*Muraenesox bagio*	-	2	-	-	R
13	Nemipteridae	*Nemipterus* sp.	-	-	4	28	R
		Pentapodus bifasciatus	-	1	-	-	R
14	Platycephalidae	*Sunagocia otaitensis*	-	1	-	-	D
15	Pristigasteridae	*Ilisha striatula*	-	1	-	-	R
16	Seranidae	*Epinephelus malabaricus*	3	1	-	-	R
		Cephalopholis argus	-	-	-	3	R
17	Siganidae	*Siganus canaliculatus*	-	1	-	-	R
18	Sillaginidae	*Sillago sihama*	-	-	1	-	R
19	Synodontidae	*Saurida nebulosa*	-	-	-	3	D
20	Tentraodontidae	*Arothron manilensis*	-	7	-	-	D
		Chelonodon patoca	2	15	2	2	D
		Lagocephalus lunaris	1	11	-	-	D
21	Terapontidae	*Terapon theraps*	-	1	9	-	R
Number of species			5	20	8	7	
Number of individuals			18	168	28	46	260
Shannon-Wiener index			0.553	0.768	0.753	0.552	
Evennes index			0.792	0.599	0.834	0.653	
Simpson's dominance index			0.327	0.330	0.190	0.399	

Note: R - retained (with economic value); D - discarded (non-valuable economically); D5-10 - depth of 5-10 m; D11-27 - depth of 11-27 m.

The highest bycatch fish biodiversity was found in seagrass habitats and the lowest was found in river estuaries. Fish bycatch of crab fisheries retained (with economic value) was comprised of 15 species, and 12 species were discarded (non-valuable). *Acreichthys tomentosus* and *Chelonodon patoca* were found in all fishing habitats of *P. pelagicus* in Kolono Bay.

The ecological status of fish bycatch biodiversity of crab fisheries in each fishing habitat is classified as low, with the Shannon-Wiener diversity index ranging from 0.552-0.768. The evenness status of bycatch fish in each habitat was moderate to high, with an evenness index ranging from 0.599-0.834. Dominance was low, with the Simpson dominance index ranging from 0.190-0.399 (Table 1).

Biodiversity of crustaceans bycatch. The biodiversity crustacean bycatch of *P. pelagicus* fisheries found in all fishing habitats in Kolono Bay consisted of 20 species from 11 families with a total number of 3829 individuals, each fishing habitat hosting 11 to 15 species (Table 2). Crustacean bycatch of crab fisheries with economic value comprised 11 species and there were 8 species with no economic value (Table 2). Bycatch crustaceans found in all fishing habitats were *Dardanus* sp., *Myomenippe hardwickii*, *Eucrate* sp., *Charybdis anisodon*, *C. hellerii*, *Podophthalmus vigil, Portunus sanguinolentus,* and *Thalamita crenata.*

Table 2

The biodiversity of crustaceans bycatch of *Portunus pelagicus* fisheries based on fishing habitat in Kolono Bay, Southeast Sulawesi, Indonesia

No	*Family*	*Species*	Number of individuals per habitat				*Status*
			Estuary	*Seagrass*	*D5-10*	*D11-27*	
1	Diogenidae	*Dardanus* sp.	81	92	8	19	D
2	Eriphiidae	*Myomenippe hardwickii*	45	22	25	40	R
3	Euryplacidae	*Eucrate* sp.	36	11	9	112	D
4	Grapsidae	*Grapsus* sp.	1	-	-	-	D
5	Leucosiidae	*Arcania* sp.	-	-	1	1	D
6	Majidae	*Schyzophrys aspera*	-	1	-	-	D
7	Matutidae	*Ashtoret lunaris*	1	7	-	-	D
8	Pilumnidae	*Pilumnus* sp.	-	1	-	-	D
9	Portunidae	*Charybdis anisodon*	460	549	248	951	R
		C. hellerii	14	12	5	16	R
		C. feriatus	1	-	-	5	R
		Gonioinfradens sp.	-	10	-	-	R
		Podophthalmus vigil	3	1	11	16	R
		Portunus sanguinolentus	12	5	4	4	R
		Scylla serrata	1	-	-	-	R
		Thalamita danae	1	32	-	-	R
		T. crenata	173	189	56	73	R
		T. sima	10	387	-	50	R
10	Squillidae	*Harpiosquilla raphidea*	1	-	4	9	R
11	Xanthidae	*Lophozozymus pictor*	-	9	-	-	D
	Number of species		15	15	11	12	
	Number of individuals		840	1322	371	1296	3829
	Shannon-Wiener index		0.618	0.648	0.533	0.471	
	Evennes index		0.525	0.551	0.512	0.436	
	Simpson's dominance index		0.356	0.230	0.471	0.552	

Note: R - retained (with economic value); D - discarded (non-valuable economically); D5-10 - depth of 5-10 m; D11-27 - depth of 11-27 m.

The ecological status of biodiversity of crustacean bycatch of *P. pelagicus* fisheries in each fishing habitat was low, with the Shannon-Wiener diversity index ranging from 0.471 to 0.648. The evenness status of the crustacean bycatch in each fishing habitat was classified as moderate, with an evenness index ranging from 0.436 to 0.451. The dominance was low to moderate, with the Simpson dominance index value ranging from 0.319 to 0.552 (Table 2).

Biodiversity of echinoderms and molluscs bycatch. The echinoderms bycatch of *P. pelagicus* fisheries in Kolono Bay contains only 1 species (*Protoreaster nodosus*), with 4 individuals. The biodiversity of molluscs bycatch of crab fisheries consists of 7 species from 5 families, with a total number of 400 individuals, 5 species of economic value and 2 species discarded. *Tritia* sp. was found in all fishing habitats. The highest number of individuals was found in seagrass beds and the lowest was at 11-27 m depth (Table 3).

Table 3

The biodiversity of echinoderm and mollusc bycatch of *Portunus pelagicus* fisheries based on fishing habitat in Kolono Bay, Southeast Sulawesi, Indonesia

No	*Group and family*	*Species*	*Number of individuals and habitat*				*Status*
			Estuary	*Seagrass*	*D5-10*	*D10-27*	
	Echinodermata						
1	Oreasteridae	*Protoreaster nodosus*	2	3			D
	Moluscs						
1	Arcidae	*Anadara antiquata*	1	-	-	-	R
2		*A. granosa*	-	-	-	2	R
3	Muricidae	*Chicoreus ramosus*	-	-	1	1	D
4		*Murex trapa*	1	-	-	6	D
5	Nassariidae	*Tritia* sp.	81	246	52	1	R
6	Tonnidae	*Tonna* sp.	-	2	-	-	R
7	Valutidae	*Cymbiola* sp.	-	2	-	-	R
	Number of species		4	3	2	4	
	Number of individuals		85	252	53	10	400

Note: R - retained (with economic value); D - discarded (non-valuable economically); D5-10 - depth of 5-10 m; D11-27 - depth of 11-27 m.

Biodiversity of bycatch based on habitat. The total biodiversity of bycatch of *P. pelagicus* fisheries found in all fishing habitats in Kolono Bay consists of 55 species with a total number of 4342 individuals. The highest biodiversity and number of crab fisheries bycatch was found in seagrass beds and the lowest was at a depth of 5-10 m. The ecological status of crab fishery bycatch biodiversity in each fishing habitat was classified as low, with the Shannon-Wiener diversity index ranging from 0.546 to 0.908. The status of bycatch evenness was moderate, with the evenness index ranging from 0.407 to 0.567. The dominance was low to moderate, with the Simpson dominance index ranging from 0.187 to 0.496 (Table 4).

Table 4

The biodiversity index of bycatch of *Portunus pelagicus* fisheries based on fishing habitat in Kolono Bay, Southeast Sulawesi, Indonesia

No	Biodiversity index	*Fishing habitat*			
		Estuary	*Seagrass*	*D5-10*	*D11-27*
1	Number of species	25	40	20	22
2	Number of individuals	943	1599	452	1348
3	Shannon-Wiener index	0.686	0.908	0.712	0.546
4	Evenness index	0.491	0.567	0.547	0.407
5	Simpson's dominance index	0.289	0.187	0.297	0.496
6	Total number of species		55		
7	Total number of individuals		4342		

Note: D5-10 - depth of 5-10 m; D11-27 - depth of 11-27 m.

The Sorensen similarity index of bycatch biodiversity between crab fishing habitats ranged from 0.427 to 0.667. The highest was found between depths of 5-10 m and depths of 11-27 m, and the lowest was found between seagrass beds and depths of 11-27 m (Table 5).

Table 5

The matrix of Sorensen similarity index of bycatch biodiversity of *Portunus pelagicus* fisheries of habitat basic in Kolono Bay, Southeast Sulawesi, Indonesia

Habitat	*Sorensen similarity index between habitats*			
	Estuary	*Seagrass bed*	*D5-10*	*D11-27*
Estuary	-	0.531	0.533	0.638
Seagrass bed		-	0.475	0.426
D5-10			-	0.667
D11-27				-

Biodiversity of bycatch based on sampling period. The biodiversity of bycatch of *P. pelagicus* fisheries found in Kolono Bay in each sampling period ranged from 17 to 24 species, with the number of individuals ranging from 382 to 853 (Tables 6 & 7). The biodiversity of fish bycatch of crab fisheries found in each sampling period ranged from 4 to 10 species, with the number of individuals ranging from 7 to 48. Crustaceans bycatch ranged from 8 to 14 species, with 246 to 792 individuals. The biodiversity of molluscs bycatch of crab fisheries in each sampling period ranged from 1 to 4 species, with 11 to 111 individuals. Echinoderms were only found in July, with 2 individuals (Table 6).

Table 6

Biodiversity and number of individuals of each group bycatch of *Portunus pelagicus* fisheries based on sampling period in Kolono Bay, Southeast Sulawesi, Indonesia

Sampling period	*Biodiversity and number of individuals of group bycatch*								*Total*	
	Fish		*Crustaceans*		*Echinodermata*		*Mollusca*			
	S	N	S	N	S	N	S	N	S	N
February	10	42	10	323			3	17	23	382
July_1	7	40	8	246	1	2	1	94	17	382
July_2	5	48	13	792	1	2	2	11	20	853
August_1	6	24	13	388			3	19	22	431
August_2	8	32	11	523			2	101	21	656
September_1	8	26	8	401			2	20	18	447
September_2	7	13	11	517			1	111	19	641
October_1	4	7	12	391			4	11	20	409
October_2	7	30	14	366	1	1	2	13	24	409

Note: S - number of species; N - number of individuals.

The ecological status of bycatch biodiversity of *P. pelagicus* fisheries in each sampling period was low, with the Shannon-Wiener index ranging from 0.652-0.88. The bycatch evenness of crab fisheries was moderate, with the evenness index ranging from 0.419-0.646. The dominance was low to moderate, with the Simpson dominance index ranging from 0.242-0.534 (Table 7).

Table 7

Bycatch biodiversity of *Pertunus pelagicus* fisheries based on sampling period in Kolono Bay, Southeast Sulawesi, Indonesia

Sampling period	*No of species*	*No of individuals*	*Biodiversity indices*		
			Diversity	*Evenness*	*Simpson's dominance*
February	23	382	0.880	0.646	0.242
July_1	17	382	0.749	0.609	0.254
July_2	21	853	0.722	0.546	0.413
August_1	22	431	0.562	0.419	0.534
August_2	21	656	0.718	0.543	0.314
September_1	18	447	0.760	0.606	0.268
September_2	19	641	0.749	0.609	0.254
October_1	20	409	0.658	0.505	0.344
October_2	24	356	0.868	0.629	0.213

The similarity index of biodiversity of bycatch of *P. pelagicus* fisheries between sampling periods ranged from 0.426 to 0.821. The highest was found between July_1 and August_1, and the lowest was found between October_1 and October_2 (Table 8). Bycatch biodiversity found in the sampling period July_1 was 17 species; in August_1, October_1 and October_2 were 22, 20 and 24 species, respectively. The number of the same bycatch species in July_1 and August_1 were 16 species, and in October_1 and October_2 were 10 species.

Table 8

Matrix of Sorensen similarity index of bycatch biodiversity of *Portunus pelagicus* fisheries based on the sampling period in Kolono Bay, Southeast Sulawesi, Indonesia

Sampling period	*Sorensen similarity index between sampling periods*								
	Feb	*Jul_1*	*Jul_2*	*Aug_1*	*Aug_2*	*Sep_1*	*Sep_2*	*Oct_1*	*Oct_2*
February	-	0.550	0.651	0.578	0.591	0.537	0.488	0.558	0.650
July_1		-	0.632	0.821	0.526	0.514	0.457	0.486	0.591
July_2			-	0.698	0.619	0.615	0.513	0.537	0.711
August_1				-	0.698	0.600	0.600	0.619	0.636
August_2					-	0.718	0.615	0.634	0.683
September_1						-	0.667	0.632	0.537
September_2							-	0.579	0.465
October_1								-	0.426
October_2									-

Biodiversity of bycatch. The bycatch biodiversity of *P. pelagicus* fisheries found in Kolono Bay presented 55 species with 4342 individuals. The bycatch biodiversity of crab fisheries found in this study was lower than that found in Lasongko and Kendari Bay, Indonesia (Hamid & Wardiatno 2018; Hamid & Kamri 2019; Hamid et al 2020), and that of Pantai and Pattani Bay, Thailand, in gillnet fisheries (Fazrul et al 2015). It was lower than in the Algarve, Portugal, where there are trawl fisheries (140 species) (Erzini et al 2002), but higher than the bycatch of lobster traps in Baja California, USA (Shester & Micheli 2011). The bycatch biodiversity of each group of crab fisheries in Kolono Bay was still the range found in several waters using traps and gillnets, namely fish ranging from 2 to 61 species, crustaceans 1 to 38 species and molluscs 1 to 25 species. The bycatch biodiversity of crab fisheries in Kolono Bay was relatively lower than that found in Lasongko Bay and Kendari, Indonesia (Table 9).

Table 9

Bycatch biodiversity of *Portunus pelagicus* fisheries in several waters

Location	*Bycatch biodiversity*			*Source*
	Fish	*Crustaceans*	*Molluscs*	
		Trap		
Moreton Bay, Australia	12	3	1	Campbell & Sumpton 2009
Wallis Lake, Australia	8	-	-	Leland et al 2013
Jepara, Indonesia	2	1	-	Prakosa et al 2017
Kung Kren Bay, Thailand	-	17	-	Kunsook & Dumrongrojwatthana 2017
Lasongko Bay, Indonesia	17	-	-	Hamid & Kamri 2019
Kendari Bay, Indonesia	23	37	-	Hamid & Kamri 2019; Hamid et al 2020
Kolono Bay, Indonesia	27	20	7	Current study
		Gillnet		
Pattani Bay, Thailand	61	26	8	Fazrul et al 2015
Pattani Coast, Thailand	33	29	25	
Thoothukudi Coast, India	7	6	3	Kumar et al 2013
Lasongko Bay, Indonesia	27	38	-	Hamid & Wardiatno 2018; Hamid & Kamri 2019
Kendari Bay, Indonesia	31	-	-	Hamid & Kamri 2019
Purirano Coast, Indonesia	18	6	4	Mardhan et al 2019

The bycatch biodiversity and number of individuals of *P. pelagicus* fisheries found in this study varied based on fishing habitat, sampling period, and bycatch groups. The bycatch biodiversity and abundance of crab fisheries in seagrass were higher than in the other three fishing habitats. The highest bycatch biodiversity was found in the February period and the highest bycatch number of individuals was found in the July_2 period. The lowest values were found in the July_1 period. The bycatch biodiversity and abundance of crab fisheries are influenced by habitat and season (Kalayci & Yeşilçiçek 2014; Fazrul et al 2015), fishing gear type and design (Campbell & Sumpton 2009; Shester & Micheli 2011; Leland et al 2013; Broadhurst et al 2014; Kalayci & Yeşilçiçek 2014, Hamid & Kamri 2019), as well as the frequency and coverage of sampling areas (Shester & Micheli 2011; Hamid et al 2020).

The bycatch biodiversity of *P. pelagicus* fisheries in Kolono Bay was higher than the other three bycatch groups, while the bycatch with the highest number was comprised of crustaceans. The biodiversity of fish bycatch in the crab trap fisheries in Kolono Bay was higher than that found in similar studies (Campbell & Sumpton 2009; Leland et al 2013; Prakosa et al 2017; Hamid & Kamri 2019), higher than that reported by Kumar et al (2013) and Mardhan et al (2019). However, it was lower than that reported by Fazrul et al (2015) and Hamid & Kamri (2019), using gillnets.

The number of individuals of each fish species bycatch caught in each habitat and sampling period was low, around 1-2 individuals, being similar to results reported in Lasongko and Kendari Bay, Indonesia (Hamid & Kamri 2019). Fish bycatch of crab fisheries in seagrass is generally still in the juvenile stage, indicating that seagrass beds are a nursery area for fish (Hanafi et al 2020).

The biodiversity and number of individuals of crustacean bycatch of *P. pelagicus* fisheries in Kolono Bay also tended to vary with respect to fishing habitat and sampling period, similar to situations in Lasongko and Kendari Bay (Hamid & Wardiatno 2018; Hamid et al 2020). The highest biodiversity of crustacean bycatch was found in seagrass beds and estuaries, and the highest number of individuals was found in seagrass beds. The lowest for both was found at a depth of 5-10 m (Table 2). The highest biodiversity and number of individuals of bycatch crustaceans of crab fisheries were found in the July_2 period, and the lowest in the July_1 period (Table 6). Bycatch biodiversity caught in seagrass beds was much lower than that found by other several studies of crustacean biodiversity in seagrass beds: 31-85 species (Moosa & Aswandy 1994; Pratiwi 2010, 2012; Anggorowati 2014). Bycatch biodiversity caught at a depth of 5-10 m and 11-27 m was also lower than the crustacean biodiversity study at a depth of 20-30 m with trawl: 50-66 species (Pratiwi & Wijaya 2013; Pratiwi & Elfidasari 2020).

The biodiversity of crustacean bycatch in this study was higher than that found by Campbell & Sumpton (2009), Prakosa et al (2017), Kunsook & Dumrongrojwatthana (2017), but lower than that found by Hamid et al (2020), with crab traps. The biodiversity of crustacean bycatch of crab fishery in Kolono Bay was also higher than that found on the Thoothukudi Coast, India (Kumar et al 2013) and Purirano Coast, Indonesia (Mardhan et al 2019), and lower than that found in the Pattani Coast and Bay, Thailand (Fazrul et al 2015), and Lasongko Bay (Hamid & Wardiatno 2018), all using gillnets.

The fish bycatch of crab fisheries found in each habitat and sampling period was *Chelonodon patoca*. *Tritia* sp. was the mollusc found in all habitats and sampling periods. *A. tomentosus* is the dominant fish species found in all fishing habitats, but was not found in the September_2 period. The crustaceans bycatch found in each fishing habitat and sampling period in Kolono Bay were *Dardanus* sp., *Myomenippe hardwickii*, *Eucrate* sp., *Charybdis anisodon*, and *T. crenata*, with a variable number of individuals. The biodiversity of crustacean bycatch of crab fisheries found was lower than that found in Lasongko Bay, Indonesia (10 species) (Hamid & Wardiatno 2018) and Kendari Bay, Indonesia (7 species) (Hamid et al 2020).

C. anisodon is the most dominant bycatch of *P. pelagicus* fisheries in each habitat and sampling period, and its percentage in each fishing habitat ranged from 35.65-70.79% of the total bycatch individuals. *C. anisodon* is the main bycatch species of crab fisheries in Kolono Bay, being similar to the situation in Lasongko and Kendari Bay, Indonesia (Hamid & Wardiatno 2018; Hamid et al 2020). Crustacean bycatch of crab trap

fisheries in Indonesia is generally dominated by *P. vigil* and *T. crenata*, while crab gillnet fisheries are dominated by *T. orientalis* (IMACS 2015). The crustacean bycatch of crab gillnet fishery in Pattani Coast and Bay, Thailand, was dominated by *Carcinoscorpius rotundicauda, S. serrata* and *Miyakea nepa* (Fazrul et al 2015).

Ecological status of bycatch biodiversity. The Shannon-Wiener diversity index bycatch of *P. pelagicus* fisheries in Kolono Bay varies with the fishing habitat, sampling period and bycatch groups (fish and crustaceans), and the ecological status of bycatch biodiversity was classified as low. The low diversity index of bycatch is thought to be due to the high fishing intensity of crabs. The Shannon-Wiener diversity index bycatch of crab fisheries in Kolono Bay was lower than that found in the Pattani Coast and Bay, Thailand, with 2.84-3.47 (Fazrul et al 2015).

The Shannon-Wiener diversity index of fish and crustacean bycatch of *P. pelagicus* fisheries in this study was lower than in Lasongko Bay and Kendari, Indonesia (Hamid & Wardiatno 2018; Hamid & Kamri 2019; Hamid et al 2020), as well as that of several studies on crustacean and fish biodiversity in seagrass beds (Pratiwi 2010; Anggorowati 2014; Marwati et al 2018; Hanafi et al 2020) and that of research on the biodiversity of crustaceans at a depth of 20-30 m (Wijaya & Pratiwi 2011; Pratiwi & Wijaya 2013). The difference in the Shannon-Wiener diversity index was related to differences in fishing intensity of crabs, number of species and abundance of each species of bycatch between locations (Brower et al 1990; Hamid et al 2020).

The evenness status of bycatch biodiversity of crab fisheries in Kolono Bay based on fishing habitat, sampling period and bycatch groups (fish and crustaceans) was moderate or unstable, with low to moderate dominance. This suggests that each bycatch species was evenly distributed, although the number of individuals of *C. anidoson* was prominent, affecting the variation of the two biodiversity indices. The highest bycatch dominance index of crab fisheries was found at a depth of 11-27 m, and in August_1 period. The percentage of *C. anisodon* at that depth and period were 69.6% and 72.6% of the total bycatch, respectively.

The evenness indices of fish and crustacean bycatch found in this study were lower than in Lasongko and Kendari Bay, Indonesia (Hamid & Kamri 2019), lower than that of several studies on fish and crustacean biodiversity in seagrass beds (Pratiwi 2010; Anggorowati 2014; Marwati et al 2018; Hanafi et al 2020), and lower than results from the deep waters of Matasiri Islands, Indonesia (Wijaya & Pratiwi 2011; Pratiwi & Wijaya 2013). In contrast, the Simpson dominance index was higher than that obtained in the Lasongko and Kendari Bay (Hamid & Wardiatno 2018; Hamid et al 2020), and higher that that obtained by several studies on fish and crustacean biodiversity in seagrass beds (Pratiwi 2010; Anggorowati 2014; Marwati et al 2018; Hanafi et al 2020).

The Sorensen similarity index of the bycatch biodiversity of *P. pelagicus* fisheries based on the fishing habitat was lower than that in the sampling period, and similar to that found in Lasongko and Kendari Bay, Indonesia (Hamid & Wardiatno 2018; Hamid et al 2020). The similarity index of the bycatch biodiversity of crab fisheries in Kolono Bay based on the sampling period was higher than that found in Lasongko and Kendari Bay, Indonesia (Hamid & Wardiatno 2018; Hamid et al 2020), and higher than that of other studies (Anggorowati 2014). The contribution of the crustacean group bycatch in determining the similarity of bycatch biodiversity between the fishing habitats and the sampling period was greater than that of the other three bycatch groups, because several bycatch crustacean species were often found in the same habitat and period. The bycatch biodiversity of crab fisheries found in the same habitat and sampling period ranged from 9 to 16 species.

Bycatch economic status. The bycatch biodiversity of *P. pelagicus* fisheries in Kolono Bay that has economic value was comprised of 31 species (56.4%), while 24 species (43.6%) were discarded. The biodiversity of fish bycatch of crab fisheries, which has economic value was higher than the discarded, in contrast to that found in Lasongko and Kendari Bays, Indonesia (Hamid & Kamri 2019). The number of retained fish bycatch of crab fisheries was lower than the discarded one, being similar to the situation in

Lasongko and Kendari Bay, Indonesia (Hamid & Kamri 2019). The biodiversity and number of crustaceans and molluscs bycatch of *P. pelagicus* fisheries with economic value were higher than the discarded one, and crustacean bycatch was dominated by species of low economic value.

Fish bycatch biodiversity with high economic value consists of *L. lentjan, L. fulviflamma, L. malabaricus, E. malabaricus,* and for crustaceans, *C. argus,* and *S. serrata*. The number of individuals from each species of bycatch was classified as low, with 1-3 individuals per species. These conditions are similar to those found in Lasongko Bay Kendari, Indonesia (Hamid & Wardiatno 2018; Hamid & Kamri 2019; Hamid et al 2020). The biodiversity of high-value fish bycatch of crab fishery found in this study was lower than in Lasongko and Kendari Bay, with 12 species (Hamid & Kamri 2019), and lower than in in Pattani Beach, Thailand (Fazrul et al 2015). The high-value crustacean bycatch of crab fishery in Lasongko Bay consisted of 5 species (Hamid & Wardiatno 2018), there were 4 species in Kendari Bay (Hamid et al 2020), and 3 species in Pattani Beach, Thailand (Fazrul et al 2015).

There are three species of fish bycatch that were classified as poisonous fish: *Arothron manilensis*, *Chelonodon patoca*, and *Lagocephalus lunaris*. There was one poisonous crustacean bycatch, *Lophozozymus pictor*. The toxins in the three fish species are tetrodotoxins, which have very high toxicity (Pratama et al 2014). The toxins in the body of *L. pictor* are permanent and have high toxicity (Widyastuti 2003).

Conclusions. The bycatch biodiversity of *P. pelagicus* fisheries in Kolono Bay consists of 55 species, comprising 27 species of fish, 20 species of crustaceans, 1 species of echinoderms, and 7 species of molluscs. *C. anisodo*n was the main bycatch. The bycatch with economic value consisted of 31 species (56.4%), while 24 species (43.6%) had no economic value. The biodiversity and number of crab fishery bycatch in Kolono Bay varies with fishing habitat and sampling period. The highest values of both were found in seagrass bed habitats. The ecological status of the bycatch biodiversity of crab fisheries in Kolono Bay based on the fishing habitat and sampling period is classified as low, with moderate evenness, and low to moderate dominance. The obtained bycatch data are expected to support ecosystem-based *P. pelagicus* fisheries management in Southeast Sulawesi.

Acknowledgements. This article is part of a basic research grant in 2020 with contract number 828i/UN29.20/PG/2020 received by the first author. We would like to thank the Ministry of Research and Technology, the Republic of Indonesia for funding this research. We also thank the crab fishermen in Kolono Bay for providing samples of bycatch of *P. pelagicus* fisheries, and to our students Atun Nurjanah, Amrin, Muhammad Aswandi, Agustina, Isra Mau'izah, and Karni Amelia, who have joined this research, and to Muhammad Abdul Rahman who made the site map.

Conflict of Interest. The authors declare that there is no conflict of interest.

References

Anggorowati D. A., 2014 [Community structure of crustacean fauna at the intertidal zone of West Lombok]. Jurnal Zoologi Indonesia 23(2):92-100. [In Indonesian].

Alverson D. L., Freeberg M. G., Murawski S. A., Pope J. G., 1994 A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper No. 339, Rome, 233 p.

Batista M. I., Teixeira C. M., Cabral H. N., 2009 Catches of target species and bycatches of an artisanal fishery: The case study of a trammel net fishery in the Portuguese coast. Fisheries Research 100(2):167-177.

Broadhurst M. K., Butcher P. A., Cullis B. R., 2014 Effects of mesh size and escape gaps on discarding in an Australian giant mud crab (*Scylla serrata*) trap fishery. PLoS ONE 9(9):e106414, 8 p.

Brower J., Zar J., von Ende C. N., 1990 Field and laboratory methods for general ecology. 3rd edition. Wm. C. Brown Publishers, Dubuque, Iowa, USA, 220 p.
Budiarto A., Adrianto L., Kamal M. M., 2015 [The status of ecosystem approach to fishery management for blue swimming crab (*Potunus pelagicus*) at Java Sea waters (FMA 712)]. Jurnal Kebijakan Perikanan Indonesia 7(1):9-24. [In Indonesian].
Campbell M. J., Sumpton W. D., 2009 Ghost fishing in the pot fishery for blue swimmer crabs *Portunus pelagicus* in Queensland, Australia. Fisheries Research 95(2-3):246-253.
Erzini K., Costa M. E., Bentes L., Borges T. C., 2002 A comparative study of the species composition of discards from five fisheries from the Algarve (southern Portugal). Fisheries Management and Ecology 9(1):31-40.
Fazrul H., Hajisamae S., Ikhwanuddin M., Pradit S., 2015 Assessing impact of crab gill net fishery to bycatch population in the lower Gulf of Thailand. Turkish Journal of Fisheries and Aquatic Sciences 15(1-2):761-771.
Hamid A., Wardiatno Y., 2018 Diversity of decapod crustaceans in Lasongko Bay, Southeast Sulawesi, Indonesia. Biodiversity Journal 9(3):303-311.
Hamid A., Wardiatno Y., Lumbanbatu D. T. F., Riany E., 2017 [Sustainable management of blue swimming crab (*Portunus pelagicus*) based of bioecology aspectsin Lasongko Bay, Southeast Sulawesi]. Jurnal Kebijakan Perikanan Indonesia 9(1):41-50. [In Indonesian].
Hamid A., Kamri S., 2019 [Bycatches of blue swimming crab fishing in Lasongko and Kendari Bay Southeast Sulawesi]. Marine Fisheries 10(2): 215-224. [In Indonesian].
Hamid A., Kamri S., Irawati N., Wardiatno Y., 2020 Community structure of crustacean bycatch of blue swimming crab (*Portunus pelagicus*) fisheries in Kendari Bay, Southeast Sulawesi, Indonesia. AACL Bioflux 13(2):694-704.
Hanafi A. N. H., Hamid A., Arami H., 2020 [Fish biodiversity of seagrass bed in Tanjung Tiram Waters, South Konawe, Southeast Sulawesi]. Habitus Aquatica 1(2):1-10. [In Indonesian].
Kalayci F., Yeşilçiçek T., 2014 Effects of depth, season and mesh size on the catch and discards of whiting (*Merlangius merlangus euxinus*) gillnet fishery in the Southern Black Sea, Turkey. Turkish Journal of Fisheries and Aquatic Sciences 14:449-456.
Kembaren D. D., Ernawati T., Suprapto, 2012 [Biology and population parameters of blue swimming crab (*Portunus pelagicus*) in the Bone Bay and adjacent waters]. Jurnal Penelitian Perikanan Indonesia 18(4):273-281. [In Indonesian].
Khvorov S., 2012 Crabs of Sultanate of Oman. Marine Science Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, Muscat, Oman, 60 p.
Kuiter R. H., Tonozuka T., 2001 Pictorial guide to: Indonesian reef fishes. Part 1, 2, 3. Zoonetics, Seaford, Victoria, Australia, 893 p.
Kumar A., Balasubramanian S., Jakhar J., 2013 Standardization of crab bottom set gillnet for reduction of bycatch at Thoothukudi coast, Tamilnadu, India. Archives of Applied Science Research 5(6):74-81.
Kunsook C., Dumrongrojwatthana P., 2017 Species diversity and abundance of marine crabs (Portunidae: Decapoda) from collapsible crab trap fishery at Kung Krabaen Bay, Chanthaburi Province, Thailand. Tropical Life Sciences Research 28(1):45-67.
Leland J. C., Butcher P. A., Broadhurst M. K., Paterson B. D., Mayer D. G., 2013 Relative trap efficiency for recreationally caught eastern Australian blue swimmer crab (*Portunus pelagicus*) and associated injury and mortality of discard. Fisheries Research 147:304-311.
Madduppa H., Zairion, Nuraini S., Nugroho K., Nugraha B. A., 2016 Setting up trace-ability tools for the Indonesian blue swimming crab fishery: A case study in Southeast Sulawesi. In: Fisheries and Aquaculture in the Modern World, Chapter 7, 16 p.
Mardhan N. M., La Sara, Asriyana, 2019 [Analysis of blue swimming crab Catch (*Portunus pelagicus*) catch as main target and by-catch composition of gillnet fishing gear in Purirano coastal waters, Southeast Sulawesi]. Jurnal Biologi Tropis 19(2):205-213. [In Indonesian].

Marwati, Hamid A., Arami H., 2018 [Species diversity of crustaceans in seagrass beds in Tanjung Tiram North Moramo waters South Konawe Regency]. Jurnal Manajemen Sumber Daya Perairan 3(2):83-91. [In Indonesian].
Moosa M. K., Aswandy I., 1994 [Crustaceans of seagrass beds in the waters of South Lombok]. In: [Biological community structure of seagrass on the southern coast of Lombok and environmental conditions]. Kiswara W., Moosa M. K., Hutomo M. (eds), Research Center for Oceanography, Indonesian Institute of Sciences, Jakarta, pp. 42-51. [In Indonesian].
Ng P. K. L., 1998 Crabs. In: The living marine resources of the Western Central Pacific. Carpenter K. E., Niem V. H. (eds), FAO Species Identification Guide for Fishery Purposes, FAO, Rome, pp. 1046-1155.
Ng P. K. L., Guinot D., Davie P. J. F., 2008 Systema brachyurorum: part I. An annotated checklist of extant brachyuran crabs of the world. The Raffles Bulletin of Zoology 17:1-286.
Pillai S. L., Kizhakudan S. J., Radhakrishnan E. V., Thirumilu P., 2014 Crustacean bycatch from trawl fishery along north Tamil Nadu coast. Indian Journal of Fisheries 61(2):7-13.
Prakosa E. F., Fitri A. D. P., Kurohman F., 2017 [Analysis of escape gap on dome trap to catch blue swimming crab (*Portunus pelagicus*) at TPI Demaan Jepara district]. Journal of Fisheries Resources Utilization Management and Technology 6(4):103-109. [In Indonesian].
Pratama G., Nurjanah, Suwandi R., Jacoeb A. M., 2014 [Chemical compound, phytochemical and toxicity of green roughbacked puffer from Cirebon District]. PHPI 17(2):127-133. [In Indonesian].
Pratiwi R., 2010 [Crustaceans association in seagrass ecosystems Lampung Bay waters]. Ilmu Kelautan Indonesian Journal of Marine Sciences 15(2):66-76. [In Indonesian].
Pratiwi R., 2012 [The species and distribution patterns of crustaceans on seagrass beds in Tikus Island, Thousand Islands]. Oseanologi dan Limnologi di Indonesia 38(1):43-55. [In Indonesian].
Pratiwi R., Wijaya N. I., 2013 [The community diversity of crustacean in Matasiri Islands, South Kalimantan]. Berita Biologi 12:127-140. [In Indonesian].
Pratiwi R., Elfidasari D., 2020 The crustaceans fauna from Natuna Islands (Indonesia) using three different sampling methods. Biodiversitas 21(3):1215-1226.
Samanta R., Chakraborty S. K., Sheroy L., Nagesh T. S., Behera S., Bhoumik T. S., 2018 Bycatch characterization and relationship between trawl catch and lunar cycle in single day shrimp trawls from Mumbai Coast of India. Regional Studies in Marine Science 17:47-58.
Shester G. G., Micheli F., 2011 Conservation challenges for small-scale fisheries: Bycatch and habitat impacts of traps and gillnets. Biological Conservation 144(5):1673-1681.
Suman A., Irianto H. E., Satria F., Amri K., 2016 [Potency and exploitation level of fish resources 2015 in Fisheries Management Area of Indonesian Republic (FMAs) and its management option]. Jurnal Kebijakan Perikanan Indonesia 8(2):97-110. [In Indonesian].
Wee D. P. C., Ng P. K. L., 1995 Swimming crabs of the genera *Charybdis* De Haan, 1833, and *Thalamita* Latreille, 1829 (Crustacea: Decapoda: Brachyura: Portunidae) from peninsular Malaysia and Singapore. The Raffles Bulletin of Zoology, Supplement Series No. 1, pp. 1-128.
White W. T., Last P. R., Dharmadi, Faizah R., Chodrijah U., Prisantoso B. I., Pogonoski J. J., Puckridge M., Blaber S. J. M., 2013 Market fishes of Indonesia, ACIAR monograph No. 155. Australian Centre for International Agricultural Research, Canberra, 438 p.
Wijaya N. I., Pratiwi R., 2011 [Spatial Distribution of crustaceans in Matasiri Islands, South Kalimantan]. Ilmu Kelautan 16(3):125-134. [In Indonesian].
Widyastuti E., 2003 [Toxic crab, Xanthidae family]. Oseana 28(2):11-19. [In Indonesian].

Wilson B. R., Gillett K., 1979 A field guide to Australian shells (Prosobranch gastropods): illustrating and describing 700 species of marine gastropods found in Australian waters. Terrey Hills N. S. W., Reed, 287 p.
*** FAO (Food and Agriculture Organization), 2019 Monitoring discards in Mediterranean and Black Sea fisheries: Methodology for data collection. FAO Fisheries and Aquaculture Technical Paper No. 639, Rome, 77 p.
*** IMACS (Indonesia Marine and Climate Support), 2015 [Fishery data collection protocol blue swimming crab (*Portunus pelagicus*), Indoensia], USAID Indonesia, Jakarta, 29 p. [In Indonesian].
*** MMAF (Ministry of Marine Affairs and Fisheries), 2016 Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia No. 70/Kepmen-KP/2016 concerning management plan for blue swimming crab fisheries in fisheries management area of Indonesian Republic]. Jakarta, 47 p. [In Indonesian].
*** Sai Global, 2014 Marine stewardship council pre-assessment report for the Asosiasi Pengelolaan Rajungan Indonesia (APRI) Tiworo Strait, Southeast Sulawesi blue swimming crab trap and gillnet fisheries. Indonesia Marine and Climate Support (IMACS), Jakarta, 57 p.

Received: 25 November 2020. Accepted: 17 February 2021. Published online: 07 June 2021.
Authors:
Abdul Hamid, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Halu Oleo University, FPIK Bld. 2nd Floor, Kampus Hijau Bumi Tridharma Andounohu, 93232 Kendari, Indonesia, e-mail: abdhamid_lamun@yahoo.com
Syamsul Kamri, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Halu Oleo University FPIK Bld. 2nd Floor, Kampus Hijau Bumi Tridharma Andounohu, 93232 Kendari, Indonesia, e-mail: syamsulkamri@gmail.com

How to cite this article:
Hamid A., Kamri S., 2021 Bycatch biodiversity of blue swimming crab (*Portunus pelagicus*) fisheries in Kolono Bay, Southeast Sulawesi, Indonesia. AACL Bioflux 14(3):1548-1560.