Coral reefs status and fish species in coastal waters of Spelman Straits, Southeast Sulawesi, Indonesia

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Abstract. Spelman Strait, located in the Central Buton Regency of Southeast Sulawesi Province has a fisheries biodiversity of coral reef ecosystem that has not been elaborated. The aim of this study is, therefore, to determine the ecological conditions, coral coverage and identity of reef fish species under the coastal waters of Spelman Straits. Primary data were collected in the form of survey and field observation, where the results showed a decline in cover quality of the live corals, within the moderate category at all observation locations, including station 1 (42.86%), 2 (39.29%), 3 (43.57%), 4 (36.43%) and 5 (26.43%). Moreover, the target fish identified at station 1 were from the 7 families of Acanthuridae, Scaridae, Siganidae, Haemulidae, Lutjanidae, Lethrinidae, Serranidae, 6 families identified at station 2 were Acanthuridae, Scaridae, Siganidae, Haemulidae, Lutjanidae, Serranidae, while 5 at station 3 were Acanthuridae, Scaridae, Siganidae, Lutjanidae, Serranidae, 6 at station 4 (Acanthuridae, Scaridae, Siganidae, Haemulidae, Lutjanidae, Serranidae), and 5 families at station 5, including Acanthuridae, Scaridae, Sélidaidae, Siganidae, Haemulidae, Lutjanidae, and Serranidae. Furthermore, and the parameters of the coastal water are under the quality standards for sustainability of coral reef ecosystems in seawater.

Key Words: coral reef fish, ecological condition, existence of coral reef, sustainability, target fish.

Introduction. The community activities in relation to catching reef fish in Indonesia are threats to both its resource conservation, and the reef as a habitat. However, the ecosystems have been known to possess high biodiversity functions as a spawning, nursery, and feeding ground (White et al 2014), which ought to be protected for biota life.

Reef fish is an important resource that occurs in significant quantities within the coral ecosystem, which fills and supports relationships (Tuaputty et al 2018), and is also influenced by the health condition of the environment, indicated by the percentage of live coral cover (Zamani & Madduppa 2011).

The ecosystem promotes the potentials of Spelman Strait coastal waters, due to the high dependence of small scale fishermen, using standard fishing methods.

This is the first research conducted on the status of coral reef and its fish ecosystems in the coastal water, hence, it is highly relevant to ascertain their baseline and sustainable use. Previous studies on similar subject have been performed in various places, using various approaches, including a report of Zgliczynski & Sandin (2017), which was based on its trophic levels, Ford et al (2018) evaluated the effectiveness of proper management, Madduppa et al (2012) was centered on the structure of fish communities and the health of coral reefs on Pari Island, while Titaheluw & Ira (2017) established coral reefs status in the waters of Sidodadi and Tegal Island, Hastuty et al (2014) was concerned with coral cover and composition in Pulau Weh, while Patty et al (2015) was based on the communities present on the artificial reefs of Siladen Island. Furthermore, Runtuboi et al (2018) centered on the inventory of Numfor Island species,

and Salim et al (2017) characterized the physicochemical oceanographic parameters of Rerumputan Island.

Material and Method

Description of the research sites. This research was conducted from January to June 2019, in the coastal waters of the Spelman Strait, Central Buton Regency, Southeast Sulawesi Province (Figure 1).

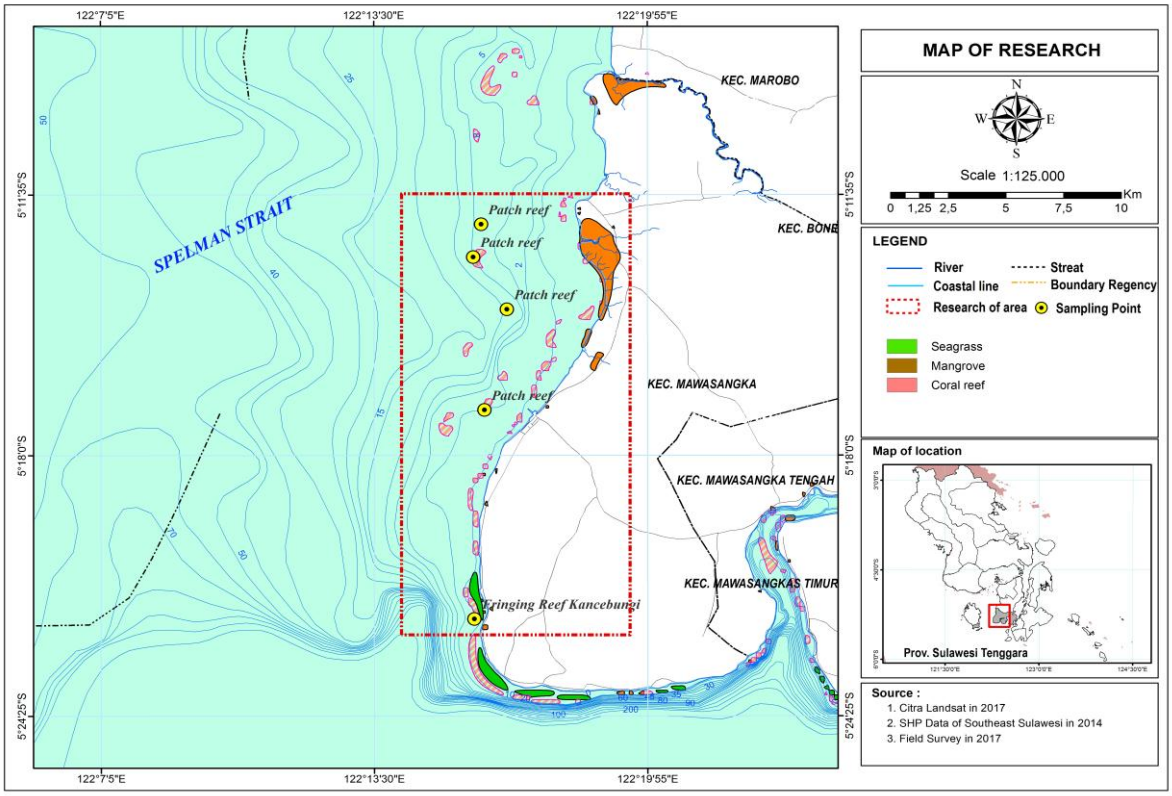

Figure 1. Research site.

Category and data source. The method used involved survey and field observations, which served as primary data, to assess the (1) characteristics of coral reef ecosystems, based on types, live coral cover area, using the underwater photo transect (UPT); (2) nature of reef fish was observed using the underwater visual census (UVC) method, and (3) the water parameters. In addition the UPT method uses similar line transects with UVC, by 70 meters (Giyanto et al 2017; Titaheluw & Ira 2017) (Figure 2).

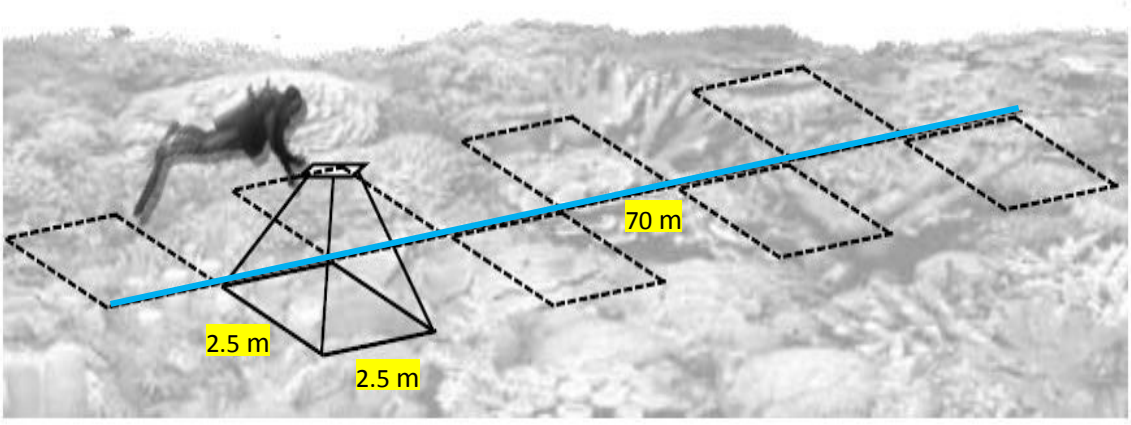

Figure 2. The Implementation of UPT and UVC techniques.

Data collection technique. The coral reef condition was assessed based on transect photo data, with the aid of CPCe software version 4.1 (Kohler & Gill 2006), and the percentage of coral cover was calculated using the formula below:

$$\% \text{ i category cover} = \frac{\text{Number of points with I category}}{\text{Number of random points samples}}$$

Results

The growth form of coral reefs and reef fish species. The observations and the measurements of coral reefs at the 5 observation stations showed different live coral and cover percentage, presented in Table 1 and Figure 3.

Table 1

Status of coral covers percentage in the coastal waters of Spelman Strait

St	*Location*	*Coordinate*	*Cover (%)*				
			Live coral	*Category*	*Dead coral*	*Others*	*Abiotic*
1	Fringing Reef	S 05° 22' 01,5" E 122° 15' 51,1"	42.86	Moderate	38.57	18.57	0.00
2	Patch Reef	S 05° 16' 52,8" E 122° 16' 05,6"	39.29	Moderate	36.43	6.43	17.86
3	Patch Reef	S 05° 13' 06,8" E 122° 15' 49,9"	43.57	Moderate	40.71	7.14	8.57
4	Patch Reef	S 05° 12' 18,6" E 122° 16' 01,3"	36.43	Moderate	42.14	3.57	17.86
5	Patch Reef	S 05 °14' 24,1" E 122° 16' 37,5"	26.43	Moderate	10.71	16.43	46.43

Source: primary data, 2019.

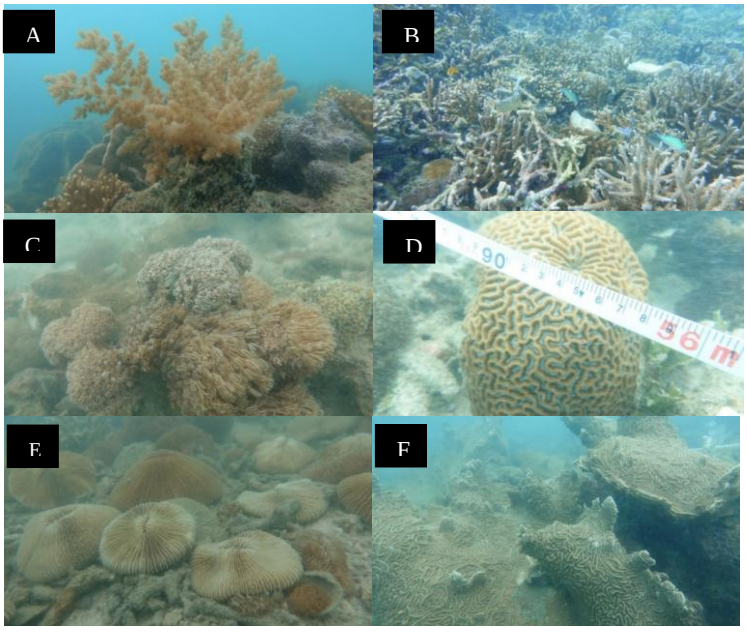

Figure 3. Conditions and several types of coral reefs in the coastal waters of the Spelman Straits (A - *Xenia* sp., B - *Acropora branchi*, C - *Goniastrea favulus*, D - *Dendronephthya* sp., E - *Lithophyllon concinna*, F - *Pachyseris rugosa*).

Table 2 and table 3 show target and indicator fish found in the coastal waters of the Spelman Strait. Acanthuridae as a target fish showed a higher number of genus compared to other families. Chaetodontidae was found as an indicator fish. Seven families as target fish and one family as an indicator fish were found in the coastal waters of the Spelman Strait.

Table 2

Families, genus, and species of reef fish (target fish) found in the coastal waters of the Spelman Strait

Family	*Genus*	*Observation station*				
		1	*2*	*3*	*4*	*5*
Acanthuridae	*Acanthurus*	*nigricans* *nigrofuscus* *thompsoni* *auranticavus* *pyroferus*	*nigricans* *blochii* *thompsoni* *auranticavus* *pyroferus*	- *Blochii* *thompsoni* *nigrofuscus* *pyroferus*	*nigricans* *blochii* *thompsoni* *nigrofuscus* *pyroferus*	*nigrofuscus* - *thompsoni* *nigrofuscus* *pyroferus*
	Ctenochaetus	*binotatus* *striatus*	*binotatus* *striatus*	*binotatus* *striatus*	*binotatus* *striatus*	*binotatus* *striatus*
	Zebrasoma	*scopas* -	- -	*scopas* *veliferum*	*scopas* -	*scopas* -
	Chlorurus	*bleekeri* *sordidus*	- -	*bleekeri* *sordidus*	*bleekeri* *sordidus*	- -
	Naso	-	-	*lituratus*	*unicornis*	-
Scaridae	*Scarus*	*tricolor* *dimidiatus* *rivulatus* - -	*tricolor* *dimidiatus* *rivulatus* - -	*tricolor* *dimidiatus* *rivulatus* *ghobban* *scaber*	*tricolor* *dimidiatus* *rivulatus* *ghobban* *scaber*	*tricolor* - *rivulatus* - *scaber*
Siganidae	*Siganus*	*puellus* *vulpinus* -	- *vulpinus* -	*puellus* - -	*puellus* *vulpinus* *puelloides*	- *vulpinus* -
Haemulidae	*Plectorhinchus*	*chaetodonoides*	*chaetodonoides* -	- -	*chaetodonoides* *gibbosus*	- -
Lutjanidae	*Lutjanus*	*rivulatus* *kasmira* *fulvus* *semicinctus*	- *fulviflamma* *carponotatus* *semicinctus*	*rivulatus* *kasmira* *carponotatus* -	*rivulatus* *kasmira* *carponotatus* *semicinctus*	*rivulatus* *kasmira* *carponotatus* -
Lethrinidae	*Gnathodentex*	*aureolineatus*	-	-	-	-
	Lethrinus	*olivaceus*	-	-	-	-
Serranidae	*Cephalopholis*	*boenak* *urodeta*	- -	*boenak* -	*boenak* -	*boenak* -
	Epinephelus	-	*merra*	*merra*	*merra*	*merra*
	Macolor	-		*niger*	*niger*	-
7	14	24	Total 16	23	28	16

Table 3

Families, genus, and species of reef fish (indicator fish) found in the coastal waters of the Spelman Strait

Family	*Genus*	*Observation station*				
		1	*2*	*3*	*4*	*5*
Chaetodontidae	*Chaetodon*	*xanthocephalus lunulatus vagabundus bennetti*	*- lunulatus bennetti*	*vagabundus lunulatus semeion bennetti*	*xanthocephalus lunulatus vagabundus bennetti*	*- lunulatus vagabundus bennetti*
	Heniochus	*chrysostomus* - -	- -	*chrysostomus singularis* -	*chrysostomus singularis varius*	- - -
			Total			
1	2	5	2	6	*7*	3

Table 4 shows that station 4 had the highest number of individual reef fish. The second highest number of individual reef fish was found at station 3. Acanthuridae and Scaridae were abundant in all stations, while Lethrinidae was found only at station 1.

Table 4

Family and individuals of reef fish found in the coastal waters of Spelman Strait

Family	*Station 1*	*Station 2*	*Station 3*	*Station 4*	*Station 5*
Chaetodontidae	6	6	32	21	6
Acanthuridae	25	19	41	61	35
Siganidae	8	6	2	8	2
Scaridae	25	19	20	48	26
Lutjanidae	23	12	18	24	19
Serranidae	12	2	-	6	5
Haemulidae	2	1	-	4	-
Lethrinidae	2	-	-	-	-
Total	103	65	113	172	93

Source: primary data, 2019.

The parameters of reef fish waters. The results of the water parameters analysis conducted at all observation stations are presented in Table 5 (west monsoon season) and Table 6 (east monsoon season).

Table 5

Measurement results of water parameters in the coast of Spelman Strait in January 2019 (west monsoon season)

Parameter/unit	*Quality standards*	*Mean of measurement results/analysis*				
		St. 1	*St. 2*	*St. 3*	*St. 4*	*St. 5*
Temperature (^oC)	Coral 28-30	30	30	29	30	29
Salinity (ppt)	Coral 33-34	32	32	32	32	32
Brightness (m)	Coral >5	5.8	3.2	3.4	2.2	4.0
pH	7-8.5	8	8	8	8	8
Strong currents (m sec^{-1})	-	0.05	0.1	0.1	0.08	0.09
DO (mg L^{-1})	>5	7.0	7.4	7.8	7.4	7.0
BOD_5 (mg L^{-1})	20	3.7	5.3	6.2	4.5	3.7
Nitrate (mg L^{-1} L)	0.008	0.087	0.090	0.094	0.098	0.093
Phosphate (mg L^{-1})	0.015	0.030	0.051	0.042	0.017	0.033
Ammonia (mg L^{-1})	0.3	0.031	0.027	0.024	0.037	0.031

Source: primary data and standard criteria of Ministry of Environment (2004).

Table 6

Measurement results of water parameters in the coast of Spelman Strait in May (east monsoon season)

Parameter/unit	*Quality standards*	*Mean of measurement results/analysis*				
		St. 1	*St. 2*	*St. 3*	*St. 4*	*St. 5*
Temperature (^oC)	Coral 28-30	29	29	29	30	29
Salinity (ppt)	Coral 33-34	32	32	32	32	32
Brightness (m)	Coral >5	13	8	10	10	6
pH	7-8.5	8	8	8	8	8
Strong currents (m sec^{-1})	-	0.07	0.1	0.1	0.2	0.2
DO (mg L^{-1})	>5	7.0	7.4	7.8	7.4	7.0
BOD_5 (mg L^{-1})	20	3.7	5.3	6.2	4.5	3.7
Nitrate (mg L^{-1})	0.008	0.087	0.090	0.094	0.098	0.093
Phosphate (mg L^{-1})	0.015	0.030	0.051	0.042	0.017	0.033
Ammonia (mg L^{-1})	0.3	0.031	0.027	0.024	0.037	0.031

Source: primary data and standard criteria of Ministry of Environment (2004).

Temperature range in west and east monsoon season was 29-30^{o}C. Salinity was 32 psu both in west season and east monsoon season. pH value at all stations was pH 8 both in west and east monsoon season. DO range was 7-7.8 in west and east monsoon season. Nitrate content range was 0.087-0.98 mg L^{-1} and phosphate content range was 0.017-0.051 in west and east monsoon season. Furthermore, ammonia content range was 0.027-0.37 mg L^{-1}. Based on the quality standard of the Ministry of Environment and Forestry of the Republic of Indonesia (2004) (in parameters such as temperature, salinity, brightness, pH, current strength, DO, BOD_5, Nitrate, Phosphate, Ammonia), BOD_5 condition in west and east monsoon season was above the standard. However, other water parameters in the coast of Spelman Strait in both west and east monsoon season fulfilled standard conditions of the environment.

Discussion

The growth form of coral reefs and reef fish species. The coral reefs with the fringing types were found at station 1 with depths of 3-15 meters, while the patch type, also known as burnt reefs were identified at stations 2-5. In addition, station 1 and 2 were dominated by growth in the form of acroporant branching (ACB) from the live coral component, although it was found at a depth of 3-8 meters in the second station.

At the 3rd and 4th locations, it was identified at the 5-10 meters depth, both of which were dominated by DCA (dead coral with algae) components. Meanwhile, station 5 observations were performed at 3-6 meters, dominated by sand (S) from abiotic components, and the percentage of live coral's obtained ranged from 26.43 to 43.57%, at an average of 37.71% (Figure 2). This percentage was assessed to be in the medium category, due to the high amount of dead coral found in each station, while the level in Pari Island waters shows the degree of damage that has occurred continuously, for a long time, with numerous fragments of coral reefs (rubbles) (Hartati & Edrus 2010). This excessive proportion was reported to be caused by human activities that are not responsible for the original existence. In addition, the most common factors include the outcome of using bombs (destructive fishing), applying corals as building materials, as well as sand mining activities on the coast, all of which are capable of causing a decline in the growth quality of coral reef. This further results in a reduction of its role and function as a habitat for spawning, nursery, and as a feeding ground, which leads to a drop in the ecosystem production, due to an observed decreased in live coral cover. Moreover, it is also said to affect its abundance and diversity (Bell & Gazlin 1984; Anderson 2002; Titaheluw & Ira 2017; Jones et al 2004), which makes the ecosystem in the Spelman Strait coastal waters to experience environmental degradation.

There were also threats on the existence of several important economical fish families, including the *Lethrinidae,* which was not found at station 2 and 5. However,

several genus and species, encompassing the *Cephalopholis*, *Epinephelus*, *Macolor*, of *Serranidae* family and *Plectorhinchus* of the *Haemulidae* family, while *Siganidae* family entailed the *Siganus* genus, are also in danger (Table 2).

Furthermore, the indicator fish (*Chaetodontidae* family) were observed to be present in the five observation stations, indicating the probability of restoring the existence of coral reef ecosystems. Meanwhile, the experts placed *Chaetodon lanula* as an "indicator species" while evaluating the ecosystem condition, and also its inhabitants (Suryanti et al 2011). This close relationship has previously been investigated (Titaheluw & Ira 2017), where the presence and abundance of *Chaetodontidae* fish in water can be considered as indicator of environmental stress. Another aspect of uniqueness is observed based on the presence and abundance of species and individuals that are capable of providing a picture of the scenario.

The *Chaetodon kleinii* species prefer branched coral reefs as predatory or protected areas, and Nurjirana & Burhanuddin (2017) found this association within the Karang Bangkok, Kapoposang, Pulau Lanjukang, Badi and Lumu-lumu Island.

The parameters of coral fishery waters. The water temperature is a limiting factor for ecosystems at all observation stations, both in the west (strong winds) and east seasons (calm waters), which ranges between 29-30°C. Based on the criteria of quality standards, the recorded values in Spelman Strait corresponded with the requirements. According to Guan et al (2015), the optimum range is from 25 to 28°C, while Muqsit et al (2016) stated the values reported in Pulau Dua, Enggano District was from 28.6 to 29.30°C. However, they are also known to be tolerant at 20°C, up to 36-40°C (Nybakken 1992).

Meanwhile, the salinity level at each station was 32‰, while the recommendation for coral life ranges from 30 to 33‰ (DKTNL 2006), and the condition of lands facing the Spelman Strait was not influenced by the river, or the presence of industrial and other activities. Supriharyono (2007) reported the suitable salinity for growth and formation fluctuate from 27 to 40‰, while other researches identified the characteristics of waters in Persian Gulf to be of high salinity, of 27-42 ‰ (Nybakken 1992), and 27-29‰ in Pulau Dua, Enggano Subdistrict (Muqsit et al 2016).

The brightness of the water body greatly affects the ecosystem life, as seen in the photosynthesis process of zooxanthellae, which was measured at station 1 (5.8 m), station 2 (3.2 m), station 3 (3.4 m), station 4 (2.2 m), and station 5 (4.0 m) during the western season, a period of strong winds. In addition, based on standards, only station 1 met the criteria due to the turbid condition caused by the number of floating particles, although the values recorded in the east season, i.e., shady waters, was almost 100% visibility at station 1 (13 m), station 2 (8 m), station 3 (10 m), station 4 (10 m), and station 5 (6 m), indicating a very supportive platform for coral growth. This makes the photosynthesis rate very effective, further enhancing the production of calcium carbonate, and the subsequent formation of coral reef (Nybakken 1992). According to Maharbhakti (2009), this is influenced by the clarity of water way, which confers a high brightness level, as seen in the photosynthetic process of *Zooxanthellae*.

The acidity (pH) level at each station was 8, which is optimal for coral growth, following the KMLH quality standard No. 51 of 2004, of 7-8.5. Muqsit et al (2016) recorded an average range of 8 in Pulau Dua waters Enggano Subdistrict.

The highest current speed in the wet season occurred at station 1 (0.05 m s^{-1}), which is directly facing the Flores Sea and is right in front of the strait, and the lowest was at the fourth station (0.08 m s^{-1}), as seen in Table 5, while others were situated at some distance and blocked by the winds from Mount Sabampolulu. In addition, the highest measurement obtained in the east monsoon season (shaded waters) was at station 1 (0.09 m s^{-1}), while the lowest was at station 4 and station 5 (0.15 m s^{-1}), due to the relatively calm water condition between April and August. According to Suharsono (2008), the optimal current speed for coral reefs is 0.05-0.08 m s^{-1}, while Wuwumbene et al (2017) stated that the velocity that supports growth of *Acanthaster planci* in the waters of Bero Island, Tiworo Strait, Southeast Sulawesi ranges from 0.07 to 0.50 m s^{-1}. Moreover, there was no significant difference between each research station, based on the ability to support the life of coral reefs.

The results of DO measurements at the observation stations varied considerably between 5.1 and 5.6 mg L^{-1}, indicating the waters to be in very good condition, consequently meeting the standards seen in the Decree of the Ministry of Environment (2004) for marine biota life, with values >5 mg L^{-1}. In conclusion, the concentrations in the coastal waters of Spelman Strait are observed to be suitable, as each station met the recommendation. Furthermore, the abundance of *Chatodontidae* and *Pomacentridae* reef fishes in the coral reefs of Bedukang waters, Bangka Regency was also positively correlated with the environmental parameter of dissolved oxygen, which ranged from 6 to 7.7 mg L^{-1} (Fatimah et al 2017).

In addition, the magnitude of BOD5 at all stations, both in the west (strong winds) and east monsoon seasons (calm waters) ranged from 3.7 to 6.2 mg L^{-1}, which was below the maximum recommendation (<20 mg L^{-1}) according to the Decree of the Ministry of Environment (2004). This parameter is generally used to determine the level of water pollution, which is considered low on instances where the value is 0-10 mg L^{-1}, and moderate at 10-20 mg L^{-1} (Salmin 2005).

In natural waters, nitrate (NO_3-N) is the main form of nitrogen, which is an important nutrient for the synthesis of animal and plant proteins, and high concentrations are capable of stimulating the growth and development of aquatic organisms, supported by the availability of nutrients. The analysis showed that the range of values obtained at all stations (west and east monsoon seasons) fluctuated from 0.008 to 0.098 mg L^{-1}. Moreover, based on the criteria for standard by the Decree of the Ministry of Environment (2004), its content within the waters of Spelman Strait is in good condition and within tolerance limits, while nitrate-nitrogen concentration almost never exceeded 0.1 mg L^{-1}.

Phosphate (PO_4-P) is an essential element for metabolism and protein formation, and also one of the most important nutrients in the sea, presented as dissolved inorganic and organic particulate forms (Penido & Alon 2012; Yang et al 2017). Sigman & Hain (2012) reported phosphorus as a significant limiting factor in productive and unproductive waters, based on its role in determining the amount of phytoplankton. In addition, the analysis results showed its concentration at all stations (east and west monsoon seasons) ranged from 0.015 to 0.051 mg L^{-1}, indicating its occurrence within the tolerance limits of seawater recommendation for marine biota (0.015 mg L^{-1}), as stated in the Decree of the Ministry of Environment (2004). Moreover, the requirement according to Anhwange et al (2012) was 0.1 mg L^{-1} as the maximum for rivers, while those exceeding 0.1 mg L^{-1} are eutrophic, capable of generating phytoplankton for blooming Verspagen et al (2014). Gorontalo Bay was reported to have exceeded the threshold standard, with a score of -8 (Kadim et al 2017).

Furthermore, a common chemical contained in waste is ammonia (NH_3) (Bonnin et al 2008), known to be toxic to biota at levels beyond the limits. The results of analysis at all stations (west and east monsoon seasons) showed that the total concentration in the coastal waters of Spelman Strait ranged from 0.024 to 0.037 mg L^{-1}, which is about the 0.3 mg L^{-1} recommended by the Decree of the Ministry of Environment (2004). This therefore indicates the area as natural and that it has not been contaminated by land influences, including agricultural activities and household waste.

Conclusions. Spelman Strait is one of the coastal waters with a coral reef ecosystem that has experienced degradation, based on the decline in live coral cover, observed to be within a moderate category. In addition, the reef fish identified also suffered overfishing, and the *Chatodontidae* family, which served as the indicator, was recognized in all research stations, denoting the probability of proper recovery. However, the characteristics of water parameters in this coastal area were below the seawater standards for sustainability of the coral reef ecosystem.

Acknowledgements. The first author is thankful to the Ministry of Research and Technology of Higher Education, Indonesia for providing fellowship for pursuing Ph.D.

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Received: 09 September 2019. Accepted: 14 October 2019. Published online: 30 October 2019.
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How to cite this article:
Muis, Kurnia R., Sulistiono, Taryono, 2019 Coral reefs status and fish species in coastal waters of Spelman Straits, Southeast Sulawesi, Indonesia. AACL Bioflux 12(5):2020-2029.