Life history parameters and spawning potential ratio of some reef fish species in Fisheries Management Area 715 of Indonesia

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Abstract. Some reef fish such as groupers, snappers, emperors, and fusiliers are economically and ecologically important fisheries resources, especially in Indonesia and the Asian region. They are continuously exploited, and in some areas depletion of the stock due to high fishing pressure is indicated. Therefore, it is particularly important to understand their status. The aim of this study was to evaluate the stock status of some reef fish species based on the life history and spawning potential ration in the Fisheries Management Area (FMA) 715 of Indonesia. There are 3 groupers (*Cephalopholis boenak, Epinephelus ongus* and *Variola albimarginata*), 3 snappers (*Etelis radiosus, Lutjanus gibbus,* and *Lutjanus vitta*), 1 emperor (*Lethrinus lentjam*), and 1 fusilier (*Pterocaesio tile*) recorded from 7 main landing sites in two province of FMA 715; North Maluku and Maluku Provinces. The analysis of growth parameters, mortality, length at first capture were estimated using Rstudio and TropFishR package while spawning potential ratio was calculated using LB-SPR method. We found that the growth coefficient (K) of groupers was in the range of 0.36-0.38; snappers, 0.18-0.37; emperor, 0.3; and fusilier, 0.6 year^{-1}. The asymptotic lengths of each group were 31.15-44.42, 34.03-104.20, 33.7, and 25.82 cm (total length), respectively. The natural mortality of all species ranged from 0.24 to 0.97. These life-history and natural mortalities resulted in spawning potential ratio of groupers from 17 to 38%, snappers 15-37%, emperor 22%, and fusilier 55%. The result showed that snappers, emperor, and groupers had higher fishing pressure than fusilier. The status of two snapper species (*E. radiosus* and *L. gibbus*), the emperor (*Lethrinus lentjan*), and two groupers (*C. boenak* and *E. ongus*) were overexploited and the others (*L. vitta* and *V. albimarginata*) were fully exploited. The fusiliers (*P. tile*) were underexploited due to threshold SPR of 0.3.
Key Words: fisheries management, FMA715, reef fish, spawning potential ratio.

Introduction. The Indonesian marine waters for fisheries management are divided into eleven Fisheries Management Areas (FMAs), one of which is FMA 715. Based on the Decree of the Ministry of Marine Affairs and Fisheries (MMAF) of the Republic of Indonesia No. 18, 2014, FMA 715 consists of Tomini Bay, Maluku Sea, Halmahera Sea, Seram Sea, and Berau Bay. Of all FMAs In Indonesia, FMA 715 has the highest potential of reef fish resources. In 2016, the potential of reef fish resources in this fisheries management area was recorded to reach 310,866 tons per year or around 45% of all potential reef fish in Indonesia. Additionally, the exploitation rate in aggregated fish was at an under-fishing level (MMAF Decree No. 50, 2017).

The reef fishes are significant commodities of commercial and artisanal fisheries and they are widely distributed throughout the world within coastal areas in tropical and subtropical waters (Ault et al 2018). The Indonesian archipelago is endowed with the world's richest coral reef fauna. The current reef fish fauna consists of 2,057 species belonging to 113 families. Based on Allen & Adrim (2003) the 10 largest groups of the total fauna consists of Gobiidae (272 species), Labridae (176 species), Pomacentridae

(152 species), Apogonidae (114 species), Blenniidae (107 species), Serranidae (102 species), Muraenidae (61 species), Syngnathidae (61 species), Chaetodontidae (59 species) and Lutjanidae (43 species), which is approximately 56% of the total fish fauna. Reef fishes are commonly known as a low migratory species, found in small schooling, moving within a narrow area (Aoyama 1973) and they exist in and associate with coral reef habitats.

Groupers (Serranidae), snappers (Lutjanidae), emperors (Lethrinidae) and fusiliers (Caesionidae) are mostly reef associated fish fauna groups that have a high economic value. They are major reef fish species in eastern Indonesia including in Fisheries Management Area (FMA) 715 which are continuously exploited using drop-lines, bottom long-line, fish traps, and other fishing gear (Purwanto et al 2020). There is a wide variety of fishing gear used in Indonesian waters (Fenner 2012). Drop line or hand line are mostly used in FMA 715. In Southeast Asia, live reef fish trading has caused a rise in catches of tropical coral reef fish (Sadovy et al 2003). The live reef fish for consumption has impacted a reduction of species variety of groupers and wrasse (Sadovy & Domeier 2005; Sadovy 2005).

Furthermore, data and information on historical catch, fishing effort and population abundance related with small-scale fisheries are limited and of poor quality (Fenner 2012; Ault et al 2008). These matters cause estimating the fish stock remaining a challenge while numerous models have been introduced for poor-data conditions which are effective for length-size data to estimate life history parameters such as growth, longevity, natural mortality, maturity as well as stock status (Pauly & Morgan 1987; Ault et al 2005; O'Farrel & Botsford 2005; Gedamke & Hoenig 2006; Ault et al 2008). The length-based approaches are frequently used for estimating fish stock status in tropical waters since otoliths are not easy to be identified for estimating the age of fish living in these waters (Hordyk et al 2015c). Nevertheless, the length data are usually inappropriate because of a lack of the life history parameter information for one definite region or globally (Nadon & Ault 2016). Understanding the life history of certain species is required to manage fish resources effectively (Fry et al 2006).

Information on life-history parameter was important since it could be used to estimate stock status such as spawning potential ratio (SPR) (Ault et al 2018). SPR is a reproduction relative rate index in a utilized stock, while generally used as reference points for fisheries (Hordyk et al 2015a). The principle of SPR is a ratio of the unfished reproductive potency left by the fishing impact which has a 100% SPR (SPR100%) of virgin stock then fishing causes mortality that can reduce SPR100% from the unfished level to SPRx% (Prince et al 2015a).

The life history and stock status information of the reef fish in FMA 715 is very limited, therefore this paper describes the status according to their life history and spawning potential ratio that could be beneficial to inform management judgments under poor data situation.

Material and Method

Description of the study sites. The data collection was carried out through fish landing monitoring in 17 fish landing sites (Figure 1). The length data were recorded daily each month from August 2017 to November 2018 in North Maluku and Maluku Provinces. Number of samples for each species is shown in Table 1.

Table 1

Number of samples and range of total length each species in Maluku and North Maluku

Family	*Species*	*Location*	*Number of individuals*	*Total length range (cm)*
Lethrinidae	*Lethrinus lentjan*	Maluku	547	15.7-34.0
Caesionodae	*Pterocaesio tile*	Maluku	687	17.5-26.0
Serranidae	*Variola albimarginata*	North Maluku	839	14.1-44.9
Serranidae	*Cephalopholis boenak*	North Maluku	461	10.0-33.2
Serranidae	*Epinephelus ongus*	North Maluku	511	16.6-36.1
Lutjanidae	*Etelis radiosus*	North Maluku	447	19.4-101.6
Lutjanidae	*Lutjanus gibbus*	North Maluku	822	12.5-47.22
Lutjanidae	*Lutjanus vitta*	North Maluku	552	14.6-35.9

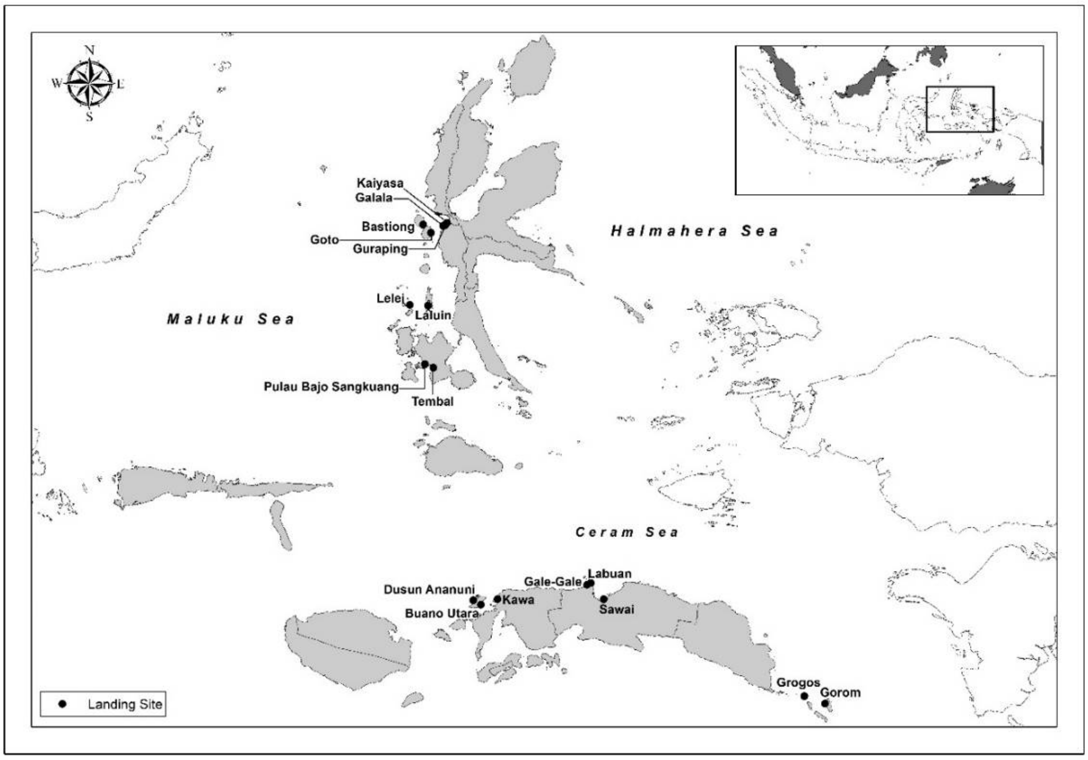

Figure 1. Sampling area in 17 fish landing sites of North Maluku and Maluku Provinces

Data analysis. Life-history parameters comprise the estimation of growth parameters (asymptotic length and growth coefficient), mortality rate (natural mortality and fishing mortality), selectivity length (SL or Lc), and maturity length (Lm). Growth parameters were estimated by von Bertalanffy growth model (Sparre & Venema 1999):

$$Lt = L\infty \left[1 - e^{(-K(t-t_0))}\right]$$

where: Lt is the fish length at age-t (cm), L∞ is fish asymptotic length (cm), K is growth coefficient (per year), and t_0 is theoretical age of fish at zero-length (year).

Natural mortality was calculated by Then et al (2015), Alverson & Carney (1975), Pauly (1980), and Hoenig (1983) and the modus of the value we used to estimate the natural mortality rate. Total mortality was estimated using a length catch curve model (Sparre & Venema 1993). Size at first maturity (L_m or L_{50}) indicates the length where 50% of the individuals caught by fishing are adults or mating. The L_m is analyzed by calculating coefficients a and b respectively, in the following equation of logistic curve by maximizing the likelihood of binomial distribution using "solver" tool in Excel (Tokai & Mitsuhashi 1998):

$$M(TL) = \frac{1}{\left(1 + exp(-aTL + b)\right)}$$

Spawning potential ratio (SPR) is the number of eggs produced by an average recruit in a fished stock divided by the number of eggs that could be produced by an average recruit in a stock without fishing (Blackhart et al 2006). The parameters required in SPR analysis are natural mortality (M), growth coefficient (K), asymptotic length (L∞), and length at first maturity (Lm). The analysis is undertaken using LB-SPR (length-based spawning potential ratio) method, which requires length distribution frequency as its input. The formula of SPR is as follows (Hordyk et al 2015b):

$$\mathrm{SPR} = \frac{\sum (1-L_x)^{(M/k[(F/M)+1])} L_x^b}{\sum (1-L_x)^{M/k} L_x^b} \quad \text{for } x_m \le x \le 1$$

where: L_x is total length; M is natural mortality; k is the growth coefficient; F is the fishing mortality; and b is exponent usually close to 3.

Results

Growth parameters and mortality rates. Table 2 summarizes growth parameters and mortality rates estimated from a total of 5,433 individuals of eight species dominant of reef fish recorded in 17 fish landing sites in North Maluku and Maluku waters. Information of life history parameters (growth and mortality parameters) is important to define the exploatation of the stock (optimally exploited or not). The von Bertalanffy growth model describes length-at-age in terms of asymptotic length (L∞) and growth coefficient (k) in year-1. The presence of total (Z), natural (M), fishing (F) mortalities, as well as the exploitation ratio (E) and relative fishing mortality (F/M) are shown in Table 2. In general, the eight (8) species of reef fish in North Maluku and Maluku waters have a slow growth rate and medium growth for dark-banded fusilier (*Pterocaesio tile*).

Size at maturity. Size at maturity is estimated by maximizing the likelihood of binomial distribution shown in Table 3 and Figure 2. The Logistic equation used to estimate Lm has simple mathematical functions and can follow a cumulative normal curve where Lm corresponds to the normal average. Based on size at maturity, we have estimated how much fish caught before maturity size (mature) defined as immature fish.

Table 3

Size at maturity and immature presentation of some reef fish species in Fisheries Management Area 715 of Indonesia

Species	*Location*	*Lm (L50)*	*L95*	*% immature*
Lethrinus lentjan	Maluku	20.26	23.50	21%
Pterocaesio tile	Maluku	19.01	22.75	15%
Variola albimarginata	North Maluku	25.82	30.00	15%
Cephalopholis boenak	North Maluku	18.36	21.50	32%
Epinephelus ongus	North Maluku	21.07	23.10	10%
Etelis radiosus	North Maluku	56.86	66.00	69%
Lutjanus gibbus	North Maluku	25.35	28.30	41%
Lutjanus vitta	North Maluku	20.84	25.50	19%

Spawning potential ratio. We estimated spawning potential ratio (SPR) using a length-based spawning potential ratio (LB-SPR) method, which requires length distribution frequency as its input (Hordyk et al 2015a). We used the SPR threshold in 30% which is under the threshold, a stock is no longer sustainable at the current exploitation level (USA Federal standards; Ault et al 2008). We estimated SPR for eight reef species in North Maluku and Maluku waters (Figure 3) that consisted of two grouper species, an emperor and two snapper species below the 30% standard for sustainability (*C. boenak, E. ongus, E. radiosus, L. lenjtan, and L. gibbus*) and three species (*P.tile, L. vitta* and *V.albirmaginata*) had SPR above 30%.

Table 2

Growth parameters and mortality rates of some reef fish species in Fisheries Management Area 715 of Indonesia

Species	*Common name*	*Location*	*L∞ (cm)*	*k*	*t0 (year)*	*Age_{max} (years)*	*M*	*Z*	*F*	*E*	*F/M*
Lethrinus lentjan	Pink ear emperor	Maluku	33.7	0.3	-0.54	11	0.44	1.11	0.67	0.60	1.52
Pterocaesio tile	Dark-banded fusilier	Maluku	25.82	0.6	-0.28	6	0.97	1.65	0.68	0.41	0.71
Variola albimarginata	White-edged lyretail	North Maluku	44.42	0.38	-0.39	8	0.54	1.09	0.55	0.51	1.02
Cephalopholis boenak	Chocolate hind	North Maluku	31.15	0.36	-0.45	9	0.40	1.15	0.75	0.65	1.88
Epinephelus ongus	White-streaked grouper	North Maluku	36.17	0.37	-0.43	9	0.40	0.93	0.53	0.57	1.33
Etelis radiosus	Pale snapper	North Maluku	104.18	0.18	-0.66	17	0.24	0.64	0.40	0.62	1.67
Lutjanus gibbus	Humpback red snapper	North Maluku	43.23	0.33	-0.45	10	0.40	0.90	0.50	0.56	1.25
Lutjanus vitta	Brownstripe red snapper	North Maluku	34.03	0.37	-0.43	9	0.40	0.83	0.43	0.52	1.08

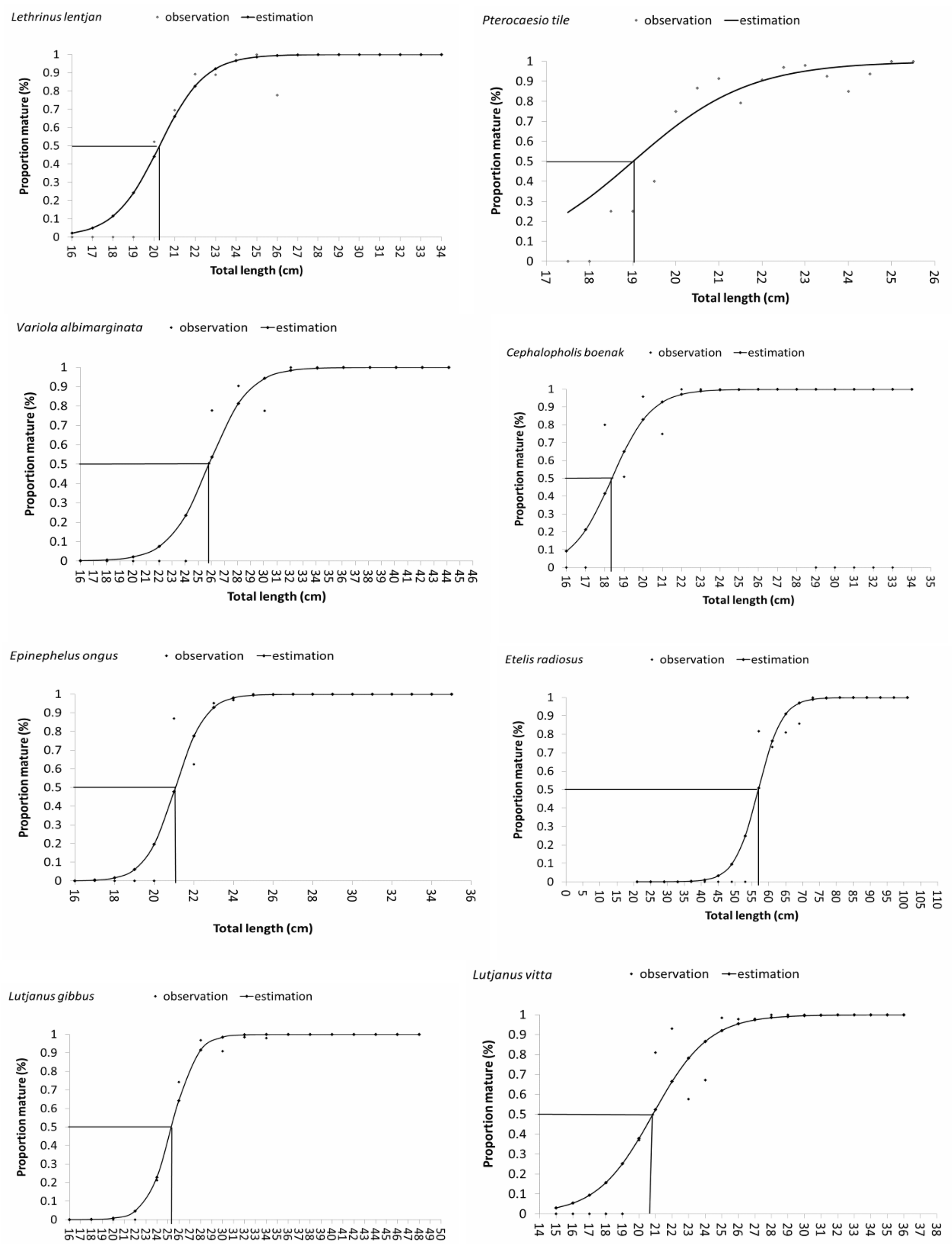

Figure 2. Observed (dot) and estimated (lines) proportions of mature female of (left to right) *Lethrinus lenjan*, *Pterocaesio tile*, *Variola albimarginata*, *Cephalopholis boenak*, *Epinephelus ongus*, *Etelis radiosus*, *Lutjanus gibbus*, and *Lutjanus vitta*.

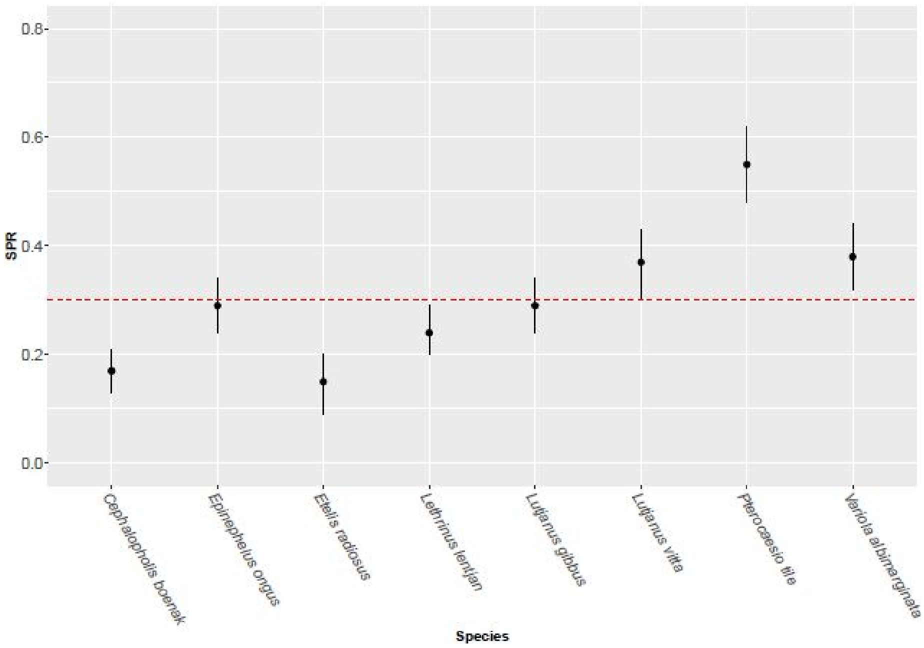

Figure 3. Spawning potential ratio some reef fish species in Fisheries Management Area 715 of Indonesia, red line as a threshold of 0.3 level of SPR (Ault et al 2008).

Discussion. Estimating the growth of the fish in tropical waters can often be difficult, alternatively using a length-based approach is a good option. Although length data are simple to collect, life-history parameters information of reef fish in FMA 715, based on length-data, are still not available. The eight species of reef fish in this study show the variety rate of growth. There are significant differences between dark-banded fusilier (*Pterocaesio tile*) and others, indicating that this species has the fastest growth of all. It could be categorized as a relatively medium or moderate growth with growth rate (K) 0.6 year^{-1}. From previous research in Natuna Sea, it was reported that red-belly yellowtail fusilier (*Caesio cuning*), which is the same group, had also the same growth rate (K) as 0.6 year^{-1} (Prihatiningsih et al 2018). This fish was characterized by moderate natural mortality (M) (Sparre & Venema 1993); in this study, M of fusilier is 0.97. On the other hand, the species pale snapper (*Etelis radiosus*) could be classified as a slow-growth species where K is only 0.18 year^{-1}, this result is also similar to the group from Cendrawasih Gulf; where it was notified that the same species had K as 0.17 year^{-1} (Nurulludin et al 2016). Pale snapper is grouped as a deep-water or deep-slope snapper with depth between 90 and 360 m (Anderson & Allen 2001). The previous studies conducted by Manooch (1987), Haight et al (1993), Pilling et al (2000), and Ernawati & Budiarti (2020) showed deep-water species of tropical fish have a slow growth, long-live and low natural mortality. In this current study, it shows that M of *Etelis radiosus* is the lowest of all species but *Pterocaesio tile* is the highest.

Furthermore, for other species, groupers (i.e *Variolla albirmaginata, Cephalopholis boenak, Epinephelus ongus*), emperor (*Lethrinus lentjan*) and other lutjanids (*Lutjanus gibbus* and *L. vitta*), presented similar K around 0.3 year^{-1}, M about 0.4 and maximum ages (A_{max}) varied from 8 to 11 years. Previous research of groupers in the Great Barrier Reef (Australia) found that K of three species of *V. albimarginata, C. boenak* and *E. ongus* were 0.48, 0.06, and 0.18 year^{-1}, respectively (Mapleston et al 2009). Age maximum (A_{max}) of *V. albimarginata* and *E. ongus* were 8 years and 18 years, respectively (Mapleston et al 2009). The M of *V. albimarginata* was notified as 0.85 in Papua New Guinea (Fry et al 2006). For emperor fish, usually is as long-lived species with generally A_{max} over 20 years (Carpenter & Niem 2001), it was often slow growth. Other studies for emperor were reported K about 0.7 year^{-1} and A_{max} 11 years in the southern Arabian Gulf (Grandcourt et al 2011); K 0.75 year^{-1} and A_{max} age 19 years in the Great Barrier Reef, Australia (Currey et al 2013), and in the coast of Thoothukudi India was reported for K 0.37 year^{-1}, A_{max} 11 years and M 0.55 (Vasantharajan et al

2017). The last group of lutjanid, from foregoing studies, *L. gibbus* showed of their K and A_{max} from different waters were 0.21-0.25 $year^{-1}$ and 21-24 years, respectively in Okinawa, Japan (Nanami et al 2010); and 0.78 $year^{-1}$ and 9 years in North Sulawesi, Indonesia (Holloway et al 2015). While *L. vitta* from previous studies was relatively similar to the current study which showed for the life history parameters in each research were 0.66 $year^{-1}$ for K and 1.33 for M in southwest coast India (Ramachandran et al 2013); from West Sulu Sea, Philippines recorded as 0.34-0.53 $year^{-1}$ for K, 10.7-11.7 years for A_{max} and 0.50-0.53 for M (Palla et al 2016); and from the south-east coast of India, it found that K = 0.34 $year^{-1}$, A_{max} = 9 years and M = 0.44 (Pradeep 2016). Finally, though some species of reef fish were known as long-lived and slow growth, but there are limited information on life history of these 8 species in this region. The differences of life-history parameters from the current research compared to all previous studies in varying waters possibly happen due to the uncertainties of using prediction models of length-based estimation (Pope et al 2010). Overall, former research findings agreed that commercial fishing has reduced the populations and has impacted the life-history parameters.

Information of size at maturity of fish is basically required to provide advice to effective management for ensuring the recruitments process and sustainability of the species. For the reef fish, the study on maturity is quite hard in term of having large samples through time under a limited budget, in addition another challenge is hermaprodtism or sex change which commonly occurs in reef fish species. Based on our results of length at maturity (Lm) to eight species, only *E. radiosus* was late mature which shown by the biggest size of length as 56.86 cm. This species is quite difficult to be sustained due to high fishing pressure and low resilience to over-fished (Fry et al 2006). With 0% immature fish in the catch as an ideal target of the sustainable fishery (Froese 2004), a target of 10% or less is considered a reasonable indicator for sustainable harvesting (Fujita et al 2012), while the target of 20% immature fish in the catch is an indicator for a fishery at risk. The fishery is considered highly at risk of over-exploited when more than 50% of the fish in the catch are immature (Froese et al 2016). Based on the analysis, *E. radiosus* has a high risk at current fishing level (immature > 50%).

The stock status of fish resources could be determined with some indicators, two of them are exploitation rate (E) and SPR. The stock status is esential for fishery manager to define control rule in the harvesting process. SPR can be effectively used as reference for harvest control rules and determine the target reference point (Hordyk et al 2015c). Based on the length and catch curve method resulted from the exploitation rate E for five species (*E. radiosus, C. boenak, L. lentjan, E. ongus,* and *L. gibbus*) are overexploited, while two others (*V. albimarginata* and *L. vitta*) are fully exploited and fusilier (*P. tile*) is still underexploited. These results are relatively similar to the use of the SPR method with the threshold of 0.3 or 30% (Ault et al 2008). From the eight species only three species are not overfished and the others are overfished, and specifically for two species (*C. boenak* and *E. radiosus*) having very low SPR (below 20%) they need to be carefully managed by developing a rebuilding stock strategy. Subsequent studies on SPR for the reef fish also reported some of groupers species, snappers species, and emperors species had SPR under 20% even below 10% (Ault et al 2008; Prince et al 2015b). The low SPR indicates the reduced ability of spawning stocks to sustain their abundance in the environment since their biological capacity for producing adult stocks in the structures of population decreases. As noted, long-lived (low M) and relatively slow-growing (low K) species are more sensitive to exploitation and take the longest time to recover. It should become the main consideration of the management option to rebuild overfished stocks.

Conclusions. Based on the length and catch curve method that informs about the exploitation rate E and SPR, it indicated that snappers, emperors, and groupers had a higher fishing pressure than fusiliers. The status of two snapper species (*E. radiosus* and *L. gibbus*), the emperor species (*Lethrinus lentjan*), and two grouper species (*C. boenak* and *E. ongus*) were overexploited and the others (*L. vitta*, *V. albimarginata, P. tile*) were underexploited since their SPR was above the threshold of 0.3. This study will benefit fisheries management under poor data situation by providing inputs and recommendation such as reference points as well as knowledge related with fisheries sciences development.

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References

Allen G. R., Adrim M., 2003 Coral reef of Indonesia. Zoological Studies 42(1):1-72.

Alverson D. L., Carney M. J., 1975 A graphic review of the growth and decay of population cohorts. ICES Journal of Marine Science 36(2):133-143.

Anderson Jr. W. D., Allen G. R., 2001 Lutjanidae: Snappers (jobfishes). In: FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol. 5. Bony fishes part 3 (Menidae to Pomacentridae), Carpenter K. E., Niem V. (eds), FAO, Rome, pp. 2840-2918.

Aoyama T., 1973 The demersal fish stocks and fisheries of the South China Sea. FAO/UNDP, Rome, IPCF/SCS/Dev/ 73/3, 80 pp.

Ault J. S., Smith S. G., Bohnsack J. A., 2005 Evaluation of average length as an indicator of exploitation status for the Florida coral-reef fish community. ICES Journal of Marine Science 62(3):417-423.

Ault J., Smith S. G., Luo J., Monaco M. E., Appeldoorn R. S., 2008 Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico. Environmental Conservation 35(3):221-231.

Ault J. S., Smith S. G., Bohnsack J. A., Luo J., Stevens M. H., DiNardo G. T., Johnson M. W., Bryan D. R., 2018 Length-based risk analysis for assessing sustainability of data-limited tropical reef fisheries. ICES Journal of Marine Science 76(1):165-180.

Blackhart K., Stanton D. G., Shimada A. M., 2006 NOAA Fisheries Glossary. NOAA Technical Memorandum NMFS-F/SPO-69. National and Atmospheric Administration. Silver Spring, 61 pp.

Carpenter K. E., 2001 Lethrinidae. Emperors (emperor snappers). In: FAO species identification guide for fishery purposes. Vol. 5. Bony fishes part 3 (Menidae to Pomacentridae), Carpenter K. E., Niem V. (eds), FAO, Rome, pp. 3004-3050.

Currey L. M., Williams A. J., Mapstones B. D., Davies C. R., Carlos G., Welch D. J., Simpfendorfer C. A., Ballagh A. C., Penny A. L., Grandcourt E. M., Mapleston A., Wiebkin A. S., Bean K., 2013 Comparative biology of tropical *Lethrinus* species (Lethrinidae): challenges for multi-species management. Journal of Fish Biology 82(3):764-788.

Decree of Ministry of Marine Affairs and Fisheries (MMAF) of the Republic Indonesia No. 18, 2014 Fisheries Management Area of Republic Indonesia. [in Indonesian]

Decree of Ministry of Marine Affairs and Fisheries (MMAF) of the Republic Indonesia No. 50, 2017 Estimation of potential, total allowable catch, and utilization level of fisheries resources in Fisheries Management Area of Republic Indonesia. [in Indonesian]

Ernawati T., Budiarti T. W., 2020 Life history and length base spawning potential ratio (LBSPR) of malabar snapper *Lutjanus malabaricus* (Bloch & Schneider, 1801) in western of South Sulawesi, Indonesia. IOP Conference Series: Earth and Environmental Science 404(1):012023.

Fenner D., 2012 Challenges for managing fisheries on diverse coral reefs. Diversity 4(4):105-160.
Froese R., 2004 Keep it simple: three indicators to deal with overfishing. Fish and Fisheries 5:86-91.
Froese R., Winker H., Gascuel D., Sumalia U. R., Pauly D., 2016 Minimizing the impact of fishing. Fish and Fisheries 17(3):785-802.
Fry G. C., Brewer D. T., Venables W. N., 2006 Vulnerability of deepwater demersal fishes to commercial fishing: evidence from a study around a tropical volcanic seamount in Papua New Guinea. Fisheries Research 81(2-3):126-141.
Fujita R., Karr K., Apel A., Mateo I., 2012 Guide to the use of Froese sustainability indicators to assess and manage data-limited fish stocks. Oceans Program, Environmental Defense Fund, Research and Development Team, 5 pp.
Gedamke T., Hoenig J. M., 2006 Estimating mortality from mean length data in nonequilibrium situations, with application to the assessment of goosefish. Transactions of the American Fisheries Society 135(2):476-487.
Grandcourt E., Al Abdessalaam T. Z., Francis F., Al Shamsi A., 2011 Demographic parameters and status assessments of *Lutjanus ehrenbergii, Lethrinus lentjan, Plectorhinchus sordidus* and *Rhabdosargus sarba* in the southern Arabian Gulf. Journal of Applied Ichthyology 27(5):1203-1211.
Haight W. R., Kobayashi D. R., Kawamoto K. E., 1993 Biology and management of deepwater snappers of the Hawaiian Archipelago. Marine Fisheries Review 55(2):20–27.
Hoenig J. M., 1983 Empirical use of longevity data to estimate mortality rates. Fishery Bulletin - National Oceanic and Atmospheric Administration 82:898-903.
Holloway C. J., Bucher D. J., Kearney L., 2015 A preliminary study of the age and growth of paddletail snapper *Lutjanus gibbus* (Forsskål 1775) in Bunaken Marine Park, North Sulawesi, Indonesia. Asian Fisheries Science 28:186-197.
Hordyk A., Ono K., Valencia S., Loneragan N., Prince J., 2015a A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. ICES Journal of Marine Science 72(1):217-231. numarul revistei este din ian 2015
Hordyk A., Ono K., Sainsbury K., Loneragan N., Prince J. D., 2015b Some explorations of the life history ratios to describe length composition, spawning-per-recruit, and the spawning potential ratio. ICES Journal of Marine Science 72(1):204-216. numarul revistei este din ian 2015
Hordyk A., Loneragan N., Prince J. D., 2015c An evaluation of an iterative harvest strategy for data-poor fisheries using the length-based spawning potential ratio assessment methodology. Fisheries Research 171:20-32.
Manooch C. S., 1987 Age and growth of snappers and groupers. In: Tropical snappers and groupers: biology and fisheries management. Polovina J. J., Ralston S. (eds), Westview Press, Boulder, CO, pp. 329-373.
Mapleston A., Currey L. M., Williams A. J., Pears R., Simpfendorfer C. A., Penny A. L., Tobin A., Welch D., 2009 Comparative biology of key inter-reefal serranid species on the Great Barrier Reef. Project Milestone Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns, 55 pp.
Nadon M. O., Ault J. S., 2016 A stepwise stochastic simulation approach to estimate life history parameters for data-poor fisheries. Canadian Journal of Fisheries and Aquatic Sciences 73(12):1874-1884.
Nanami A., Kurihara T., Kurita Y., Aonuma Y., Suzuki N., Yamada H., 2010 Age, growth and reproduction of the humpback red snapper *Lutjanus gibbus* off Ishigaki Island, Okinawa. Ichthyological Research 57:240-244.
Nurulludin, Suprapto, Prihatiningsih, 2016 [Population parameters of deep-water snapper (*Etelis radiosus*, Anderson 1981) in the gulf of Cenderawasih, Papua]. BAWAL 8(2):125-130. [in Indonesian]
O'Farrel M. R., Botsford L. W., 2005 Estimation of change in lifetime egg production from length frequency data. Canadian Journal of Fisheries and Aquatic Sciences 62(7): 1626-1639.

Palla H. P., Gonzales B. J., Sotto F. B., Ilano A. S., Tachihara K., 2016 Age, growth and mortality of brown stripe snapper *Lutjanus vitta* (Quoy and Gaimard 1824) from West Sulu Sea, Philippines. Asian Fisheries Science 29:28-42.
Pauly D., 1980 On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES Journal of Marine Science 39(2):175-192.
Pauly D., Morgan G. P. R., 1987 Length-based methods in fisheries research. ICLARM, Kuwait Institute for Scientific Research Conference Proceedings 13, Manila, 468 pp.
Pilling G. M., Millner R. S., Easey M. W., Mees C. C., Rathacharen S., Azemia R., 2000 Validation of annual growth increments in the otoliths of the lethrinid *Lethrinus mahsena* and the lutjanid *Aprion virescens* from sites in the tropical Indian Ocean, with notes on the nature of growth increments in *Pristipomoides filamentosus*. Fisheries Bulletin 98(3):600-611.
Pope K. L., Lochmann S. E., Young M. K., 2010 Methods for assessing fish populations. In: Inland fisheries management in North America, 3th edition. Hubert W. A., Quist M. C. (eds), American Fisheries Society, pp. 325-351.
Pradeep H. D., 2016 Age, growth and mortality of *Lutjanus vitta* (Quoy & Gaimard, 1824) off madras coast along south-east coast of India. International Journal of Fisheries and Aquatic Studies 4(5):183-188.
Prihatiningsih, Edrus I. N., Sumiono B., 2018 [Reproductive biology, growth and mortality of yellowtail fusilier (*Caesio cuning* Bolch, 1791) in the Natuna waters]. BAWAL 10(1):1-15. [in Indonesian]
Prince J., Hordyk A., Valencia S. R., Loneragan N., Sainsbury K., 2015a Revisiting the concept of Beverton-Holt life-history invariants with the aim of informing data-poor fisheries assessment. ICES Journal of Marine Science 72(1):194-203.
Prince J., Victor S., Kloulchad V., Hordyk A., 2015b Length based SPR assessment of eleven Indo-Pacific coral reef fish populations in Palau. Fisheries Research 171:42-58.
Purwanto, Mardiani S. R., Ernawati T., Kembaren D. D., Tirtadanu, Nurdin E., Zamroni A., Budiarti T. W., Fauzi M., Prihatiningsih, Muchlis N., Taufik M., Panggabean A. S., Yulianto I., Agustina S., 2020 [Fisheries resources and snapper-grouper fisheries status in Halmahera Island Waters, and the management strategies alternative]. Prepared by Research Institute for Marine Fisheries, MMAF and USAID Sustainable Ecosystems Advanced Project, 49 pp. [in Indonesian]
Ramachandran S., Ali D. M., Varghese B. C., 2013 Age, growth and maturity of brown stripe snapper *Lutjanus vitta* (Quoy & Gaimard, 1824) from southwest coast of India. Journal of Marine Biological Association of India 55(2):61-68.
Sadovy Y. J., 2005 Troubled times for trysting trion: three aggregating groupers in the live reef food-fish trade. SPC Live Reef Fish Inform Bull 14:3-6.
Sadovy Y. J., Domeier M., 2005 Are aggregation-fisheries sustainable? Reef fish fisheries as a case study. Coral Reefs 24:254-262.
Sadovy Y. J., Donaldson T. J., Graham T. R., McGilvray F., Muldoon G. J., Philips M. J., Rimmer M. A., Smith A., Yeeting B., 2003 While stocks last: the live reef food fish trade. Asian Development Bank, 147 pp.
Sparre P., Venema S. C., 1993 Introduction to tropical fish stock assessment. Part 1: Manual. FAO Fisheries Technical Paper No. 306.1 Rev. 2, 407 pp.
Then A. Y., Hoenig J. M., Hall N. G., Hewitt D. A., 2015 Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science 72(1):82-92.
Tokai T., Mitsuhashi T., 1998 Select model for estimating selectivity curve from comparative fishing experiment. Bulletin of the Japanese Society of Fisheries Oceanography 62:235-247.
Vasantharajan M., Jawahar P., Santhoshkumar S., Ramyalakshmi P., 2017 Age, growth and mortality characteristics of *Lethrinus lentjan* (Lacepede 1802) exploited off Thoothukudi coast, Tamil Nadu, India. Indian Journal of Geo Marine Sciences 46(11):2367-2371.

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