The stock status of *Lutjanus gibbus* (Forsskal, 1775) in Kupang waters, East Nusa Tenggara

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Abstract. *Lutjanus gibbus* is a commercially valuable demersal fish and a potential fish resource in the waters of Kupang. Morphometrics data were collected from 3,890 specimens landed at PPI Oeba from March 2019 through December 2020—analysis of data including population size structure, dynamics, mortality, and exploitation rate. Population dynamics, growth, and exploitation rates were analyzed using the FiSAT II and ELEFAN software programs. The most common fishing gear is a handline and a bottom longline used in one-day fishing. The results showed that the catch length was between 18 - 50 cm TL. The value of Lc (33,1 cmTL) was greater than that of Lm (28,66 cmTL). The growth parameter values showed asymptotic length (L) 52.50 cmTL, growth rate (K) 0.31 per year, and length at time zero (t0) -0.45. The natural mortality rate (M) of 1.18 exceeded the fishing mortality rate (F) of 0.87, the total mortality rate (Z) of 2.05, and the exploitation rate (E) of 0.42. The exploitation rate of *Lutjanus gibbus* in these waters indicates that the stock condition is below the optimal limit (underexploited) so that it can still be exploited with an additional effort equal to 16% of the current attempt while maintaining sustainability.

1 Introduction

The Paddletail snapper, or Humpback Red snapper (*Lutjanus gibbus*), is a fish species member of the Lutjanidae family that lives in tropical and sub-tropical waters with morphological characteristics of a maximum length of 500 mm but generally 350 mm [1-4]. This fish can reach a specific large size and lives in relatively deep waters. Red snappers of the Lutjanidae family generally have a length of 15 to 120 cm and a maximum weight of 40 kg. They can live more than 11 years with slow growth and also have a low natural mortality rate [5]. Their juveniles inhabit shallow water areas that are associated with coral reef and mangrove ecosystems. After entering the adult stage, they move to lagoons and deeper waters between 1 to 150 meters deep [1,6-8]. *Lutjanus gibbus* belongs to a group of demersal fishes that have high economic value and are caught by traditional and industrial fishermen for commercial and recreational purposes [9-12]. This red snapper species possesses an enormous retail worth, and its high market demand motivates fishermen to

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engage in aggressive fishing activities throughout the year, sometimes without proper regard for the sustainability of the species.

Kupang waters are located in Fisheries Management Area (WPP) 573 or in the Indian Ocean waters south of Java Island. The capture fisheries sector is one of the fisheries businesses that support the economic development of Kupang City. One of the potential capture fisheries sectors is demersal fish or reef fish commodities. *Lutjanus gibbus* is one of the demersal fish groups that are the main target of local and migrant fishermen (and on). Lutjanids have been favored for food source or sale, so they were targeted by fishermen [13,14], and their aggressive attitude makes them highly vulnerable to fishing gear [15]. The fishing gear used to catch red snapper (Lutjanus gibbus) are hand line and bottom longline. Generally, handline fishing gear is used by local fishermen, and bottom longline is used by migrant fishermen. Red snapper (Lutjanus gibbus) fishing efforts in Kupang waters are still categorized as small-scale fisheries using 5 - 10 GT fishing vessels. The fishing grounds of the bottom longline is located in a different place than the of hand line.

Data from the Ministry of Maritime Affairs and Fisheries (2021) [16] showed that the production volume of snapper caught in Kupang waters landed at PPI Oeba for the hand line was 30,515 kg, and the bottom longline was 125 kg.

Low natural growth, low recruitment, mortality rates, and the long time to reach sexual maturity put Lutjanids in an overfishing condition [17-20]. The length-based assessment data is one way to determine the stock status of the fish species. In order to responsibly manage fish resources, it is often necessary to collect and analyze data and information pertaining to various biological aspects, population dynamics, stock conditions, and fisheries-related factors. Some studies on the biological aspects of *Lutjanus gibbus* on length-weight relationship, sex ratio, fecundity, feeding habits, growth, age, and mortality in several waters were presented by [3,4,11,21-23].

The results of research on the biological aspects of the same species in the waters of Labuan Banten and South Banten were presented by [23-26]. The availability of length-based assessment data has been developed for the determination of stock status values of fish resources applied to biological parameters as a basis for population dynamics, estimating growth and mortality rates [27-33]. Length-based data collection is a quick method to obtain the most common information that is relatively cheap and easy for researchers and policymakers to collect [34-36].

In this scientific paper, we used ELEFAN (Electronic Length Frequency Analysis) to determine von Bertalanffy's growth and growth estimation and mortality parameters with limited fisheries data in the waters [31,37]. To determine the exploitation rate and total mortality using length-converted catch curves [32,38]. This method is more commonly used to estimate fish stocks in Indonesian waters.

The objective of this study was to provide information regarding the stock status of the humpback red snapper (*Lutjanus gibbus*) in Kupang waters of East Nusa Tenggara based on the length-based assessment method. The results of this study are expected to serve as a scientific basis for recommendations on the utilization and management of sustainable red snapper (*Lutjanus gibbus*) stocks.

2 Materials and methods

2.1 Data collection

Data collection activities were carried out from March 2019 until December 2020 by a researcher and an enumerator at the Oeba Fish Landing Site, Kupang (Figure 1). The enumerator collected daily length data of fish from the handline, and the bottom longline

was caught in Kupang waters (Figure 2). The total number of fish specimens for length data was 3890 specimens. Fish lengths were measured from the tip of the mouth to the tip of the tail (cmTotal Length) using a measuring board. We gathered data and information about fishing grounds by discussing with fishermen and showing them where they were fishing on a map that was adjusted for latitude and longitude.

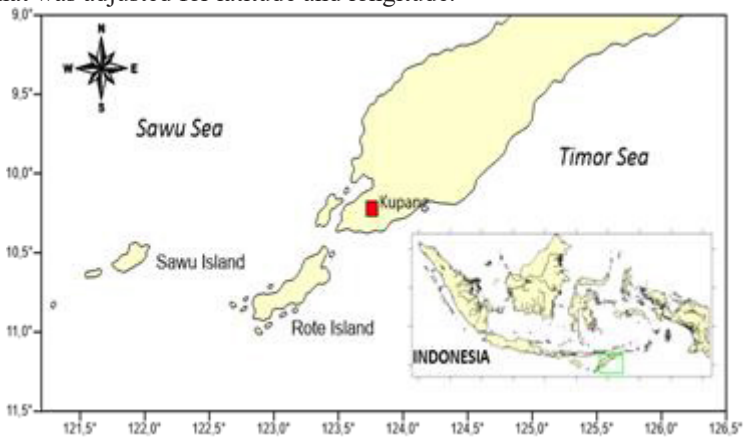

Fig. 1. Data collection location

Fig. 2. Red snapper (*Lutjanus gibbus*)

2.2 Data Analysis

2.2.1 Size structure

Length data were collected and tabulated to determine the size structure of fish caught with a class interval of 2 cm. Analysis data of length structure size using Excell program software. The size structure is a basis for obtaining the average length of the first catch (Lc).

2.2.2 Length at first capture (Lc)

To determine the mean length at first capture (Lc) using the trawl type selection curve in FiSAT based on the equation by [39].

$$ln\left(\frac{1}{P_l}-1\right)=S1-S2(L) \quad (1)$$

P_l define the probability of capture for length L and Lc50 was calculated using S1/S2.

2.2.3 Length at maturity (Lm)

To determine the mean of first gonad maturity (Lm) by using the asymptotic length as an input parameter based on the [40] equation:

$$Log_{10}L_m = 0.8979 \times log_{10}L_\infty - 0.0782 \quad (2)$$

L∞ is the asymptotic length, and Lm is the initial maturity length.

2.2.4 Growth

We use the von Bertalanffy model to calculate the fish growth parameter [38]:

$$L(t)=L_\infty\left(1-e^{-K(t-t_0)}\right) \quad (3)$$

The variable L(t) represents the length of *Lutjanus gibbus* at a given age t. L∞ is a theoretical of maximum length, often known as the asymptotic length. K represents the growth rate (year-1), and t0 denotes the theoretical age at which the length is zero. The value of t0 was estimated using an empirical equation proposed by [32]:

$$log\ log\ (-to) = (-0.3922) - 0.2752\ log\ log\ L\infty - 1.038\ log\ K \quad (4)$$

The L∞ and K parameters of *Lutjanus gibbus* were examined using the ELEFAN (Electronic Length Frequency Analysis) I and FISAT (FAO-ICLARM Stock Assessment Tools) II packages [32, 41] software tools.

2.2.5 Mortality parameters and exploitation rate

The estimation of total mortality (Z) was done by employing the linearized length converted catch curve equation, which is based on the available length composition data [38]:

$$ln\ ln\ \frac{C(L1,\ L2)}{\Delta t(L1,\ L2)} = Zt\left(\frac{L1+L2}{2}\right) \quad (5)$$

C represents the class frequency of length, and Δt represents the time required for the *Lutjanus gibbus* to grow from L1 (age t) to L2 (age t+Δt)

The calculation for Natural mortality (M) was carried out using an equation developed by [42], which considers the relationship between L∞ and K with the average seawater temperature (T):

$$log\ log\ M = (-0.0066) - 0.279\ log\ log\ L\infty + 0.6543\ log\ log\ K + 0.4634\ log\ log\ T$$

The formula below was used to calculate Fishing mortality (F) and exploitation rate (E) [43]:

$$F = Z - M \text{ and } E = F/Z \quad (6)$$

3 Results and discussion

The distribution of humpback red snapper (Lutjanus gibbus) is in Indo-Pacific waters from the Line and Society Islands to East Africa, Australia to southern Japan [1,8]. The distribution in Indonesian waters includes the Java Sea, Karimunjawa Islands, Sunda Strait, South Java, South/West Kalimantan, East Kalimantan, Sulawesi Waters, Natuna Islands, Lingga Islands, and Riau Islands at a depth of 30-100 meters [1,44].

The dominant fishing gear used to catch this species by local and migrant fishermen are handlines and bottom longlines in the handline fishing gear, using a number 7 hook size. On one main fishing line, there are two branch fishing lines with two hooks; the distance between one branch fishing line and the other is 1 meter. The main fishing line uses number 400 monofilament nylon material with a length depending on the depth of the water, generally 20-30 meters. Branch fishing line using nylon monofilament nylon material number 400 with a length of 20-25 cm. At the end of the main fishing line, there is a sinker made of iron weighing about 250-400 grams.

In the bottom, longline fishing gear is divided into three types of lines, namely the main fishing line, branch lines, and float lines. The main fishing line and branch fishing line use nylon monofilament material number 500. The length of the main fishing line is 1000 - 1500 meters, and the number of hooks can reach 1000 pieces with the size of hook number 7. The length of the branch line is between 1 to 1.2 meters, and the distance between each branch line is generally 3 meters. On the main line, there are four buoys, each 300-400 meters apart, and each between the buoys, there are 100 hooks. The float used is a ball float with a diameter of up to 30 cm. The color of the main fishing line used is green or blue so that it resembles the color of the water, with the hope of not being seen by fish or tricking the fish's view.

The determination of the fishing grounds was done by interviewing the fishermen and showing them a map of Kupang waters. To map the fishing grounds, divide the waters into squares. Based on the fishing map, it shows that the main fishing grounds for handline fishing gears are far from the coast (offshore), with distances ranging from 40-50 miles south, which takes 7-8 hours, while for bottom longlines fishing gears are around the coast (near shore) covering the waters of Kupang, East Flores and Rote Island (Figure 3).

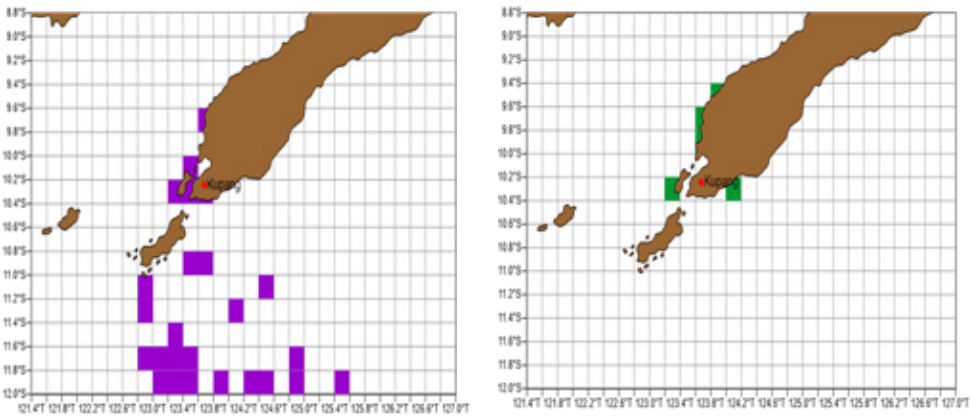

Fig. 3. Fishing location for handline (left) and bottom longline (right) fishing gear

The length of *Lutjanus gibbus* caught by two fishing gears, handline, and bottom longline, were landed at PPI Oeba from March 2019 to December 2020, ranging from 18 through 50 cm TL. The most dominant size length was caught 30 through 34 cm TL. The results of the analysis with the length distribution chart show that the length of the fish is more towards the right, which means that more large fish were caught than small fish (Figure 4).

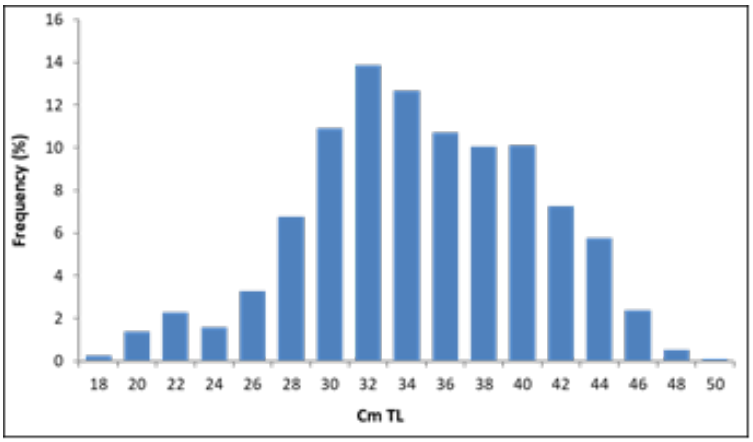

Fig. 4. Size structure of *Lutjanus gibbus*

Some of the length structure research results presented can be seen in Table 1.

Table 1. Results of *Lutjanus gibbus* length structure research in several waters

Location	Length Range	Reference
Gulf of Aden	265 - 475 mm	Druzhimin & Filotova (1980) in Karyaningsih et al., (1993)
Australia, Great Barrier Reef, Asia dan Indo Pasifik	500 mm	Allen, (1999)
Jepang	177 - 391 mmFL	Nanami et al., (2010)
Australian waters	227 - 418 mmFL	Heupel et al., (2010)
Location	Length Ranger	Reference
Kamiali Wilidlife Management Area, Papua New Guinea	130 - 300 mm	Longenecker et al., (2012) [58]
Pandeglang waters Banten	225 - 387 mmTL	Imbalan (2013)
Bunaken waters, Sulawesi Utara	151 - 312 mm FL	Holloway et al.,(2015)
Suthern Banten waters	103 - 360 mmFL	Prihatiningsih et al., (2017, 2020)
Guam coral waters	54 - 515 mm	Nadom, (2019) [59]
Alor waters	183 - 538 mm	Pakro et al ., (2020) [57]
Kupang waters	18 - 50 cmTL	This study

Differences in the length of fish caught can be caused by several factors, including the use of fishing gear, environmental conditions of the waters, available nutrients in fish habitat, temperature, light intensity, and fishing ground [45]. This difference is also influenced by the nature of the species; young fish to pre-adults are more often found in

shallow waters associated with coral reefs, and adult fish live more in deep waters and lagoons at a depth of 150 m [1,6,7,8]. The use of hook size and fishing grounds also determine the length of fish caught. The use of hook size no. 7 - 9 will dominate the length of the big fish that is caught.

The fishing grounds with hand line fishing gear are in deep waters or lagoons so that catches are dominated by large fish, while bottom longlines are in shallow waters or coral waters, so the size of fish caught is generally small.

Analysis results show that the Lc value was 33,1 cmTL and the Lm value was 28,66 cmTL, and this indicates that the value of Lc is greater than the value of Lm (Lc > Lm) (Figure 5). If the Lc value is greater than the Lm value, the process of recruiting or regenerating fish in nature is going well because it is suspected that the fish were caught after spawning first.

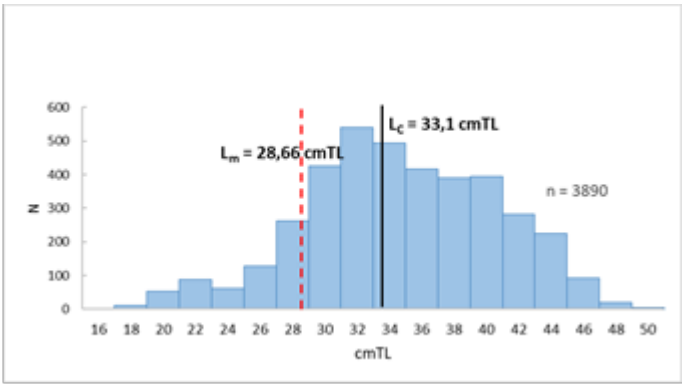

Fig. 5. Value of Lc and Lm *Lutjanus gibbus* in Kupang Waters

The Lc and Lm values of *Lutjanus gibbus* caught in Kupang waters also show higher values than the Lc and Lm values caught in Labuan Banten [24] and Banten Selatan [26] (Table 2).

Table 2. Lc and Lm values of *Lutjanus gibbus* in several waters

Location	Lc (mm)	Lm (mm)	Reference
Labuan Banten waters	294,6	-	Imbalan, 2013
Guam coral waters	-	249	Nadom, (2019)
Southern Banten waters	240,27 FL(Male)	310,96 FL	Prihatiningsih et al, 2020
	207,14 FL (Female)	271,4 FL	
Kupang waters	33,1 cmTL	28,66 cmTL	This study

According to [46], snapper will mature at a length of 300 mm. Generally, snapper species reach gonadal maturity at 40-50% of their maximum length [21,47]. The length of the first mature fish can vary depending on each location because it is influenced by the availability of feed, age, size, sex, habitat, and aquatic environment.

The importance of research related to growth in representatives of the Lutjanidae family in tropical fisheries is indispensable. The growth rate will affect the time it takes for a fish to reach its adult size and asymptotic size. The results from growth parameters calculation are displayed using the von Bertalanffy growth equation [48] via Electronic Length Electronic Frequency Analysis (ELEFAN). Based on the results of size structure-based

analysis, the growth rate (K) of *Lutjanus gibbus* was 0.31 per year with an asymptotic length (L∞) of 52.5 cmTL (Table 3).

Table 3. Growth parameter values in several waters

Location	L_∞ (mm)	K year-1	t0 year	Reference
Okinawa*	429 FL	0,4	-0,37	Nanami et al., (2010)
Great Barrier reef, Australia	352	0,51	-	Heupel et al., (2010)
Kota Baru, South Kalimantan	578.6 TL	0,238	-	Prihatiningsih et.al., (2012)
Bunaken-North Sulawesi	274	0,78	-	Holloway et al. (2015)
Guam coral waters	303 FL	0,25	-3,25	Nadom, (2019) [59]
Southern Banten waters	432,4 FL	0,25	-0,32	Prihatiningsih et al., (2020)
Alor waters	594,25	0,69	0.1027	Pakro et al ., (2020) [57]
Kupang waters	52,5 cmTL	0,31	-0,45	This Study

Fish or other aquatic organisms exhibit rapid growth throughout their early life stages, often occurring within the first three years. Subsequently, their growth rate gradually slows down in an exponential manner during the years that follow [49]. The growth rate (K) of *Lutjanus gibbus* (0,31), which is less than 0.5, indicates that this species has a relatively slow growth to reach asymptotic length. According to [50], if the growth rate value is bigger than 0.5, the growth rate is fast; on the other hand, if it is smaller than 0.5, the growth rate is slow. According to [51], the two growth parameters, namely the asymptotic length (L∞) and the growth coefficient (K), are inversely proportional, meaning that fish with a high L∞ has a lower K, indicating a slow growth rate, so the fish is long-lived and takes a long time to reach L∞ otherwise the lower L∞ has a larger K so the growth rate is fast and short-lived and takes a fast time to reach L∞.

Differences in L∞ and K values of red snapper may arise due to variations in physical and chemical conditions, the aquatic environment of the fish habitat, and the size distribution of the observed fish. The L∞ and K values can vary within in the same species of fish due to differences in the size structure of the fish observed, the maturity level of the fish, food availability, physico-chemical parameters of water, environmental factors, and habitat conditions [49].

Natural mortality can be caused by several factors, including extreme changes in ambient temperature, habitat degradation, predation by predators, cannibalism, spawning, and old age [38,52]. *Lutjanus gibbus* mortality calculations showed that fishing mortality (F) is lower than natural mortality (M) (F < M); this indicates that this fish species is experiencing small exploitation. When fish achieve a size suitable for capture, their mortality within the population can be related to both natural and fishing mortality. In this scenario, it is observed that natural mortality exceeds fishing mortality. When individuals belonging to that age group are continuously exploited or when fish from that age group may be caught and have reduced predation, the fishing mortality rate surpasses the natural mortality rate [49].

The value of the exploitation rate (E) is still below or equal to the threshold of E = 0.5 (Table 5). Thus, the utilization rate of *Lutjanus gibbus* (0.42) is less than the optimum utilization value (0.5), indicating an underexploited condition. This indicates that its utilization efforts can still be developed or increased. The fishery management in relation to the exploitation rate is how to manage the exploitation rate under or not to exceed the

threshold (E of 0.5 per year); this is done by regulating the fishing mortality rate [53]. The exploitation rate has a great influence on the recruitment process of a population, where a higher level can reduce the optimacy of the recruitment process [54].

According to [55], the optimum utilization rate (E) occurs when E = 0.5 per year. If the exploitation rate value is below the optimal limit with a threshold of E = 0.5, it means that the stock status of the fish species is still underexploited. Based on the results of research conducted by [26] in the southern waters of Banten, it was shown that the natural mortality rate of *Lutjanus gibbus* was below the fishing mortality rate and the exploitation rate exceeded the utilization rate threshold (0.5) at 27.72°C (Table 4).

Table 4. Mortality rate and exploitation rate of *Lutjanus gibbus* in several waters

Location	Sex	Z	M	F	E	Reference
		(year -1)	(year -1)	(year -1)	(year -1)	
Southern Banten waters	male	0.69	0,28	0,41	0,59	Prihatinigsih et al, 2020
	female	1,11	0,34	0,77	0,69	
Guam coral waters		0,21	0,12	0,09	-	Nadom, (2019) [59]
Alor waters	-	1,47	0,63	0,84	0,57	Pakro et al ., (2020) [57]
Kupang waters	-	2,05	1,18	0,87	0,42	This study

Results showing an E value <0.5 means that utilization efforts can still be developed or improved. Additional production utilization rate can still be increased by 16% from current conditions. However, increasing production utilization must be carried out through a precautionary approach to ensure sustainable use of resources. Increasing efforts with a precautionary approach so that fish resources can continue while still paying attention to resource sustainability and the application of conservative and careful management is urgently needed. In the context of sustainable fisheries management, the availability of fisheries resources and responsible utilization are very important. Knowledge of fisheries management is needed in an effort to manage the utilization of fisheries resources in order to provide optimal and sustainable results. According to [56], there are four main components in the sustainability of fisheries utilization: ecological sustainability, socio-economic sustainability, community sustainability, and institutional sustainability.

4 Conclusions

The length of *Lutjanus gibbus* caught by handline and bottom longline ranges from 18 - 50 cmTL, with the dominant length being caught at 30 - 34 cmTL. The process of recruiting or regenerating this species in nature goes well because the value of Lc is greater than Lm (Lc > Lm), which means that this fish species is suspected to have been caught after spawning first. This fish species has a relatively slow growth rate, the fishing mortality rate is lower than the natural mortality rate (F < M), and the exploitation rate status is still at the underexploited condition. Production increase can still be done by 16% from current conditions but with a precautionary approach. Increasing efforts with a precautionary approach so that fish resources can continue while taking into account the conservation of resources and the application of conservative and careful management.

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