

The spawning season, growth, and mortality of humpback red snapper (*Lutjanus gibbus* (Forsskal, 1775)) in the Southern Banten waters, Indonesia

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Abstract. The humpback red snapper (*Lutjanus gibbus* (Forsskal, 1775)) is a species of Lutjanidae that has high economic value in Indonesia. The aim of this research was to study the reproductive biology and the population parameters of *L. gibbus* in the Southern Banten waters, Indonesia. Samples have been collected from fishing grounds and landing places in Binuangeun-Banten for 3 years (2013, 2015 and 2016). *L. gibbus* was caught by handline and bottom longline. The observation of gonadal maturity stage was examined by macroscopically method (gonadal morphology) and microscopically method (histology with paraffin method and haematoxylin-eosin staining). Battacharya method was used to examine the population dynamics that was based on the length frequency analysis. The results showed that the spawning season of *L. gibbus* occurred from January to February and from July to August. The length at first captured (L_c male = 240.27 mm; L_c female = 207.14 mm) of *L. gibbus* was lower than the length at first matured (L_m male = 310.96 mm; L_m female = 271.40 mm). The Von Bertalanffy growth equation of *L. gibbus* was $L(t) = 390.04[1 - e^{-0.22(t+0.38)}]$ for male and $L(t) = 323.77[1 - e^{-0.29(t+0.29)}]$ for female. Fishing mortality (F) of *L. gibbus* was higher than the natural mortality (M). It showed that the exploitation status was on overfishing level so the wise management is needed for the sustainable fisheries of *L. gibbus* in the Banten Waters.

Key Words: reproductive biology, population dynamics, *Lutjanus gibbus*, Banten-Indonesia.

Introduction. Humpback red snapper (*Lutjanus gibbus*) is one of the species from Lutjanids which has high economic value. Mature *L. gibbus* live on the rock bottom substrate and coral reefs (1-150 metres deep), while juveniles and pre-adults live in association with mangrove habitat (Allen 1985; Badrudin et al 2008; White et al 2013). *L. gibbus* is found in the Western Indo-Pacific, East Africa, Australia to Southern Japan (Carpenter & Niem 2001). *L. gibbus* is the target species that is captured by handline and longline in the southern Banten waters. The stock of *L. gibbus* has decreased according to historical catch data from 2008 to 2013 (DKP 2013).

Studies about the growth, the age, the reproduction, and the mortality of *L. gibbus* have been reported from several areas (Newman 1995; Vijay Anand & Pillai 2002; Martinez-Andrade 2003; Heupel et al 2010; Nanami et al 2010), but studies from Indonesia are still limited (Imbalan 2013; Holloway et al 2015).

The objectives of this study were to understand the reproduction and population dynamics of *L. gibbus* in Banten waters, Indonesia, by (1) assessing the spawning seasons, length at first captured and length at first matured; and (2) measuring the growth, mortality and exploitation rate of the species. The study about its reproduction and population dynamics was needed to determine the better management of red snapper in Banten waters.

Material and Method

Sample collection and study sites. *L. gibbus* was caught by bottom longline and handline. The hook size was number 7 to 9 and the vessel size was from 6 to 10 GT. The fishing ground of *L. gibbus* was in the southern Banten waters. The catches are landed at Binuangeun, Banten (Figure 1). The biological data collected were length, weight, gonad and age of fish. The length data were carried out for twenty days each month in 2013, 2015, and 2016, while the maturity stage collected in 2013 and 2016.

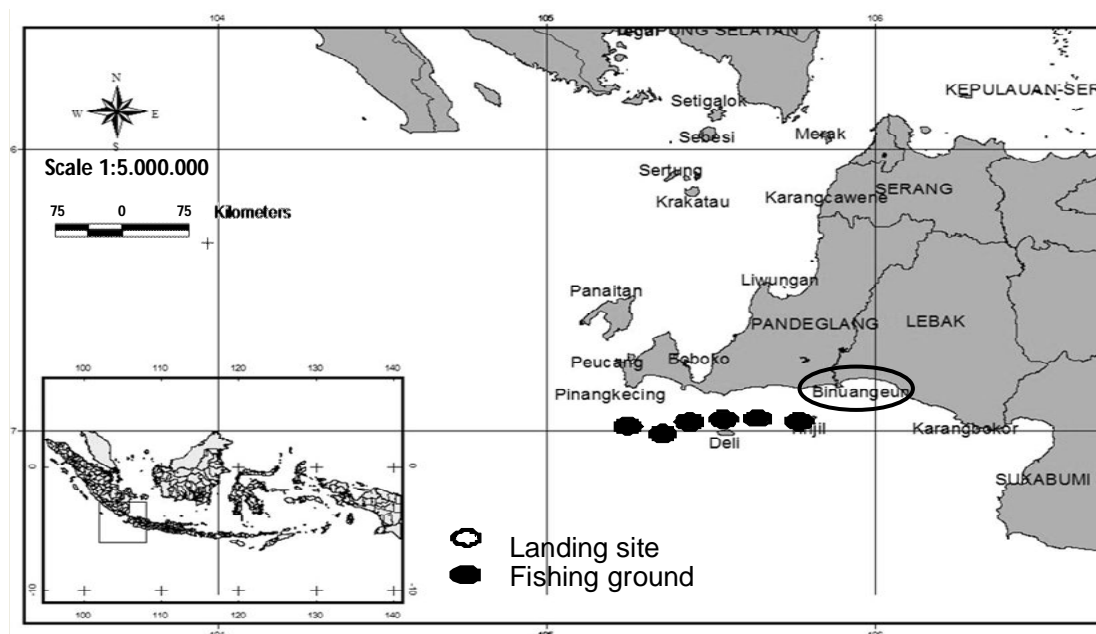


Figure 1. The fishing ground of humpback red snapper (*Lutjanus gibbus*) in the Southern Banten waters-Indonesia (Source: Prihatiningsih et al (2017)).

Field and laboratory protocol. Fish samples were collected from the landing area in Banten. The sampled fish were measured for fork length (FL) and total length (TL) using a measuring board at 1 mm accuracy, and weighted using a digital scale at 1.0 g accuracy. Fish samples were dissected by dissecting kit for gonad examination and sex determination. Gonad samples were then preserved in 10% formaldehyde solution. Gonadosomatic index (GSI) was examined visually and macroscopically to determine the morphological changes of the gonad. Selected gonads were prepared for histological examination using paraffin and hematoxylin–eosin staining methods (Davis 1982 in Russell & McDougall 2008; White & Palmer 2004). Gonad samples were weighted using scale at 0.01 g accuracy. Furthermore, the weight of male and female gonads were compared with total body weight for determining gonad maturity index (GMI). These gonads were then preserved for further observations, including fecundity, egg diameter, and histology. The otolith samples were collected by dissecting the heads of *L. gibbus*. The otolith was embedded and blocked by polyester resin. When the mold otoliths have been hardened, the otolith was sectioned by microtom knife at 5–6 μm of thickness. The sectioned otolith was observed and photographed by Discovery 8 stereo microscope and Primo star Zeiss (Bright field microscope). The cross section of humpback red snapper (*Lutjanus gibbus*) otolith is depicted in Figure 2.

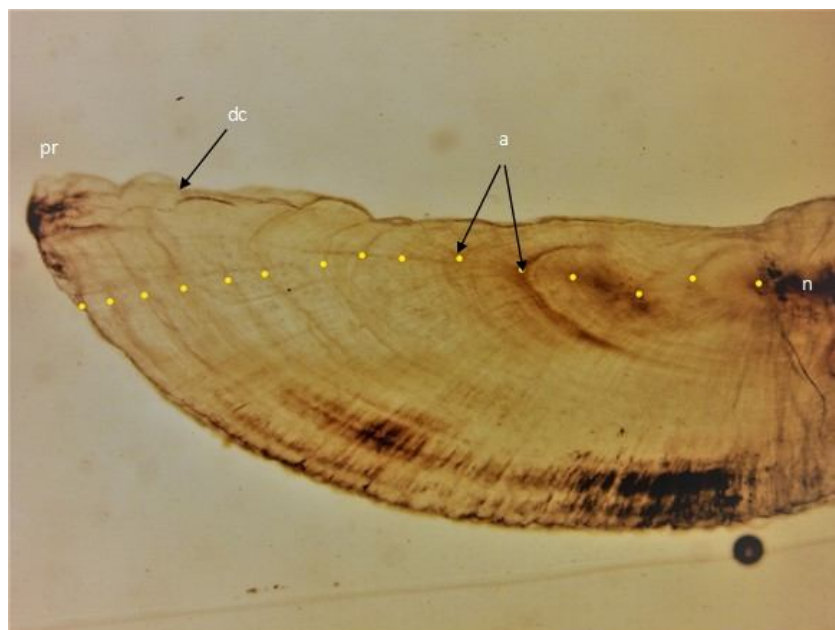


Figure 2. Cross section of humpback red snapper (*Lutjanus gibbus*) otolith. Several opaque zone rings are found in each annulus, age is determined by the existence of smoother transparent zone between the groups of opaque mark. Opaque mark is seen as yellow point. Description: n - nucleus; dc - dorsal crests; a - annulae; pr - postrostrum.

Data analysis. Gonad maturity stages (GMS) were observed visually both macroscopically and microscopically to see the morphological changes of the oocyte. Oocyte development was classified to four stages. These were stage I (peri-nucleolus stage), stage II (secondary yolk stage), stage III (tertiary yolk stage), stage IV (maturation oocytes and oil-droplet stage) (Russell & McDougall 2008; White & Palmer 2004; Nanami et al 2010). Gonadosomatic index (GSI) was calculated according to Strum (1978): $GSI = \text{weight of gonad (g)} / \text{weight of fish (g)} \times 100$.

Length at first maturity (L_m) was analyzed by Udupa (1986) equation:

$$m = X_k + \frac{X}{2} - \{X \sum p_i\}, \text{ anti log } \left[m \pm 1.96 \sqrt{X^2 \sum \left(\frac{p_i x q_i}{n_i - 1} \right)} \right]$$

where: m = log of fish length at first maturity;

X_k = log of median at first maturity of 100%;

X = log of median;

P_i = proportion of mature fish at class- i where $p_i = r_i/n_i$;

r_i = number of mature fish at class- i ;

n_i = number of mature fish at class- i ;

$q_i = 1 - p_i$.

The length at first captured (L_c) was estimated by the logistic curve between the fish length (X-axis) and the number of fish (Y-axis).

The growth parameters (L_∞ and K) were analyzed by Gulland-Holt Plot Model and t_0 was obtained by the equation of Pauly (1984): $\text{Log } -(t_0) = -0.3922 - 0.2752 \text{ Log } L_\infty - 1.038 \text{ Log } K$. The growth parameters were estimated by the Von Bertalanffy growth model (Sparre & Venema 1998): $L(t) = L_\infty (1 - e^{-K(t-t_0)})$, where $L(t)$ = the length at age t (fork length); L_∞ = the asymptotic length; t_0 = the theoretical age at zero length; K = the growth coefficient.

The estimation of total mortality (Z) can be used from the linearized catch curve based on length composition data (Sparre & Venema 1998):

$$\ln \frac{C(L1, L2)}{\Delta t(L1, L2)} = c - Z * t \left(\frac{L1 + L2}{2} \right)$$

this is a linear equation where $y = \ln \frac{C(L1, L2)}{\Delta t(L1, L2)}$, $x = t \left(\frac{L1 + L2}{2} \right)$ and the slope (b) is -Z.

Natural mortality (M) was estimated by the empirical equation method (Pauly 1983): $\ln M = -0.152 - 0.279 * \ln L_{\infty} + 0.6543 * \ln K + 0.463 * \ln T$, where M = natural mortality per year; L_{∞} = the asymptotic length; K = the growth coefficient; T = average annual temperature (°C). Fishing mortality (F) was determined by formula: $F = Z - M$. Exploitation rate (E) was measured by the formula: $E = F/Z$.

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Results and Discussion

Gonad maturity stages (GMS) and gonadosomatic index (GSI). The highest composition of mature male *L. gibbus* (GMS IV) was obtained in July, 2013 (50%). While, the highest composition of GMS IV in female was found in January, February and July 2013 (40%; 50%; 54.54% respectively) and during July-August 2016 (31.13% and 27.27% respectively) (Figure 3).

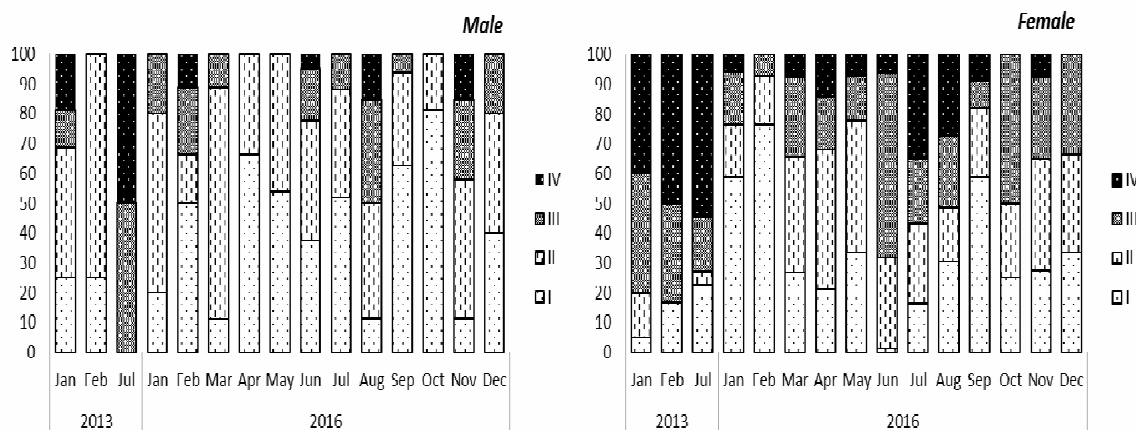


Figure 3. The proportion of GMS for *L. gibbus* in the southern Banten waters.

Developed oocytes such as stage I (*PNS* peri-nucleolus stage, small ovaries, $\emptyset = 0.060$ mm); stage II (*SYS* secondary yolk stage, ovaries increasing in size, $\emptyset = 0.114$ mm); stage III (*TYS* tertiary yolk stage, dominated by yolk vesicle and yolk globule stage oocytes, $\emptyset = 0.270$ mm); stage IV (*MO* maturation oocytes and *ODS* oil-droplet stage, $\emptyset = 0.908$ mm) were shown in Figure 4.

The highest GSI value of male was found in February 2016 ($0.77 \pm 0.88\%$) (Figure 5). The highest GSI value of female was found in January, February, and July 2013 ($1.50 \pm 0.92\%$; $1.73 \pm 0.71\%$; $2.89 \pm 1.95\%$ respectively) and in July-August 2016 ($1.26 \pm 1.15\%$ and $1.49 \pm 1.36\%$ respectively). The GSI value of female *L. gibbus* was higher than the the GSI value of male. This indicates the weight of female *L. gibbus* was relatively higher than the weight of male. Effendie (2002) noted that the increase in the weight of female gonads was ranging from 10 to 25% of the body weight, while the increase in the weight of male gonads was ranging from 5 to 10% of the body weight.

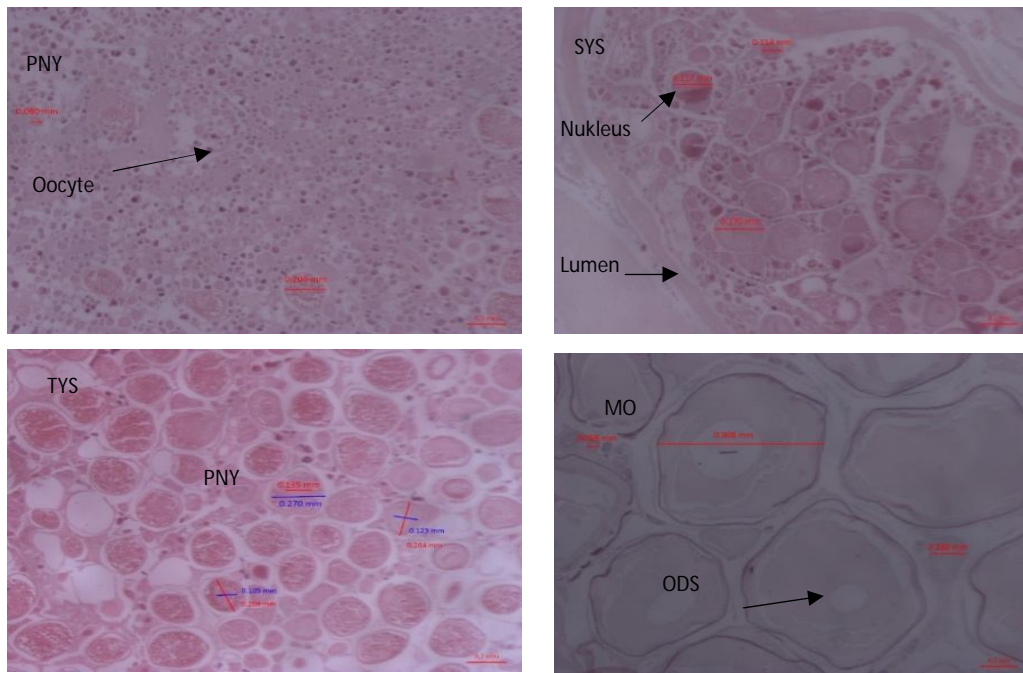


Figure 4. The histological section of female *L. gibbus* at GMS I-IV (bar scale of 1 mm; 10 μ m; at 10x magnification). Hematoxylin – Eosin staining. PNY = peri-nucleud stage; SYS = secondary yolk stage; TYS = tertiary yolk stage; MO = maturation oocytes; ODS = oil-droplet stage.

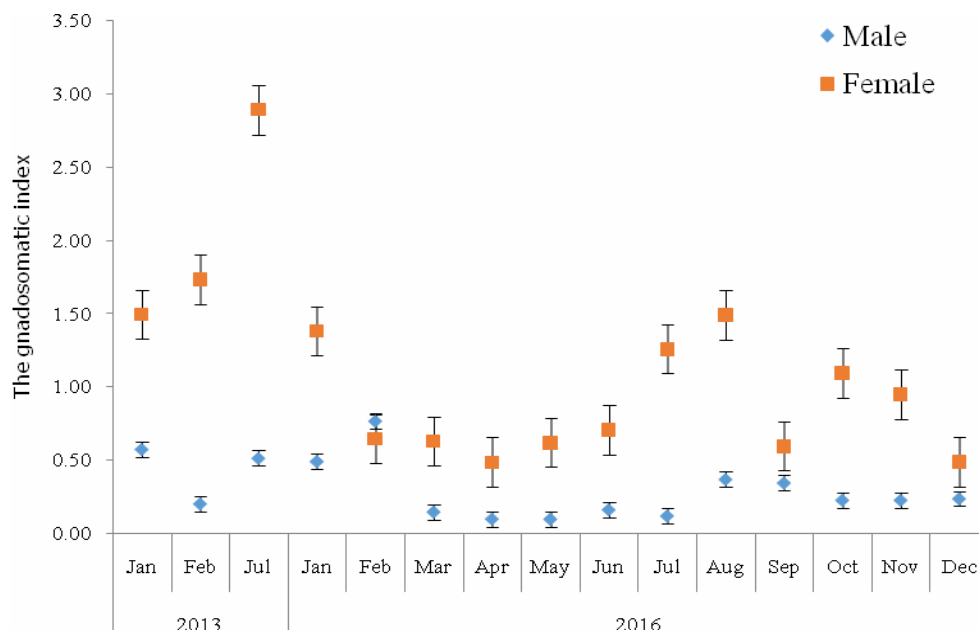


Figure 5. The gonadosomatic index value of *L. gibbus* in the southern Banten.

According to the GMS and GSI, the spawning season of male and female *L. gibbus* occurred in January to February and from July to August annually. The spawning seasons occurred in the West Monsoon (December-February) and the East Monsoon (June-August). Grimes (1987) reported that the snappers were often spawning from November to January, meanwhile Rahardjo et al (2011) concluded that the fishes in the tropical waters were spawning throughout the year and some of them spawned earlier during the rainy seasons. The spawning seasons of *L. gibbus* in different locations, such as in Okinawa waters, Japan occurred in May and October (Nanami et al 2010) and in Indian waters occurred from January to April (Vijay Anand & Pillai 2002). The differences in the spawning season for *L. gibbus* could be caused by the different growth (L_{∞} , K),

population genetic structure, temperature, monthly cycle, rainfall and coastal productivity that could increase the food availability (Kritzer 2004; Heyman et al 2005; Fernandes et al 2012).

The length at first captured and the length at first matured. The lengths at first captured (L_c) of *L. gibbus* were 240.27 mm FL for male and 207.14 mm FL for female. The L_c in Banten waters was lower than the L_c that was reported by Imbalan (2013) in Labuan waters, Banten (294.6 mm). The length at first matured (L_m) was 310.96 mm FL for male and 271.40 mm FL for female (Table 1). These results show that the development of maturity stages for female *L. gibbus* was faster than the male. This L_m of *L. gibbus* in the present study has bigger size than the L_m of *L. gibbus* in Indian waters (111-170), in Monterey waters (250 mm) and in Indonesian waters (250 mm) (Vijay Anand & Pillai 2002; Martinez-Andrade 2003; Pet & Mous 2016). Carpenter & Niem (2001) reported that *L. gibbus* matured at the length of 300 mm. The L_m differences of *L. gibbus* in some areas were likely related to the depths and habitat types which affect the food availability and aquatic environment. Generally, snapper reached gonad maturity at size of 40-50% of its maximum length (Grimes 1987; Newman 1995).

Table 1

The length at first captured (L_c) and the length at first matured (L_m) of *L. gibbus* in the southern Banten waters

Sex	L_c (mm)	L_m (mm)
Male	240.27	310.96
Female	207.14	271.40

The L_c of *L. gibbus* in Banten waters was lower than L_m which means the population of *L. gibbus* is often caught before they have spawned (growth overfishing).

Growth. The asymptotic length of *L. gibbus* was 390 mm for male and 323 mm for female. The coefficient of growth (K) was 0.22 year⁻¹ for male and 0.29 year⁻¹ for female (Table 2).

Table 2

The growth parameter of *L. gibbus* in the southern Banten waters

Parameters	Male	Female
L_∞	390.04	323.77
K	0.22	0.29
t_0	-0.38	-0.29
r^2	0.73	0.78

The von Bertalanffy growth equation of *L. gibbus* was $L(t) = 390.04[1 - e^{-0.22(t + 0.38)}]$ for male and $L(t) = 323.77[1 - e^{-0.29(t + 0.29)}]$ for female. This results was close to the study by Nanami et al (2010) in Okinawa that recorded the growth equation of $L(t) = 390.5[1 - e^{-0.210(t + 1.88)}]$ for male and $L(t) = 303.4[1 - e^{-0.256(t + 3.05)}]$ for female. Therefore, the growth coefficient of *L. gibbus* is less than 0.4 year⁻¹ which indicated *L. gibbus* has slow growth rate. Sparre & Venema (1998) noted that the slow growing fish had long life span thus needed a long time to reach its maximum length. Newman (1995) noted that the snappers had long life span, slow growth rate and low natural mortality rate.

The growth coefficient (K) of female *L. gibbus* was higher than the growth coefficient of male. This result indicates that the growth of female *L. gibbus* is faster than the male. This is different from the growth coefficient of several species of snappers where males grow faster than females (Newman et al 1996; Nanami et al 2010).

The asymptotic length of male and female *L. gibbus* in the southern Banten waters was close to the value that was found in Okinawa waters but lower than the results that were found in Palau; Papua New Guinea and higher than the value in Great Barrier Reef, Australia and Bunaken-Sulawesi, Indonesia (Table 3). The different values of the

asymptotic length in some areas are likely caused by internal factors such as heredity, sex, age, parasite, and disease, and external factors such as temperature and food availability (Effendie 2002). Nikolsky (1963) noted that the growth was not only affected by the environmental conditions, but also influenced by some biological factors during the life cycle of the mother of which these factors contribute the yolk reserve, fat content and the growth rate of the young fish.

Table 3

The estimation of growth parameters of *L. gibbus* in some areas

Sex	L_{∞} (mm)	K year^{-1}	t_0 year	Location	Source/Ref
Male	390.50 FL	0.210	1.88	Okinawa	Nanami et al (2010)
Female	303.40 FL	0.256	3.05		
Total	429.00	0.40	-0.37	Palau	Kitalong & Dalzell (1994) in Martinez-Andrade (2003)
Total	476.00	0.31	-0.47	Papua New Guinea	Munro & Williams (1985)
Total	352.00	0.51		Great Barrier reef, Australia	Heupel et al (2010)
Total	274.00	0.78		Bunaken-Sulawesi, Indonesia	Holloway et al (2015)
Male	390.04 FL	0.22	-0.38	South Banten, Indonesia	This research
Female	368.75 FL	0.29	-0.29		
Combined	432.40 FL	0.25	-0.32		

Age. The estimation of the age for female *L. gibbus* ranging from 6 to 18 years by the mode of 12 years old (Figure 6). The estimation of the age for male *L. gibbus* was ranging from 8 to 20 years old by the mode of 10 and 12 years old (Figure 7). The maximum length of female *L. gibbus* was 317 mm and was reached at the age of 18 years old. The maximum length of male *L. gibbus* was 322 mm that was reached at the age of 20 years old. Thus, male *L. gibbus* has a longer time to reach its maximum length than female. These results are different from the studies by Nanami et al (2010) that recorded the maximum age of *L. gibbus* in Okinawa waters was 21 years old for male fish and 24 years old for female, while the maximum age of red snapper *L. carponotatus* and *L. fulviflamus* was 20 years old in several areas in Okinawa and Great Barrier Reef (Newman et al 2000; Shimose & Tachihara 2005). Holloway et al (2015) found that the maximum age of humpback red snapper (*L. gibbus*) in Bunaken waters, North Sulawesi (Indonesia) was 9 years old.

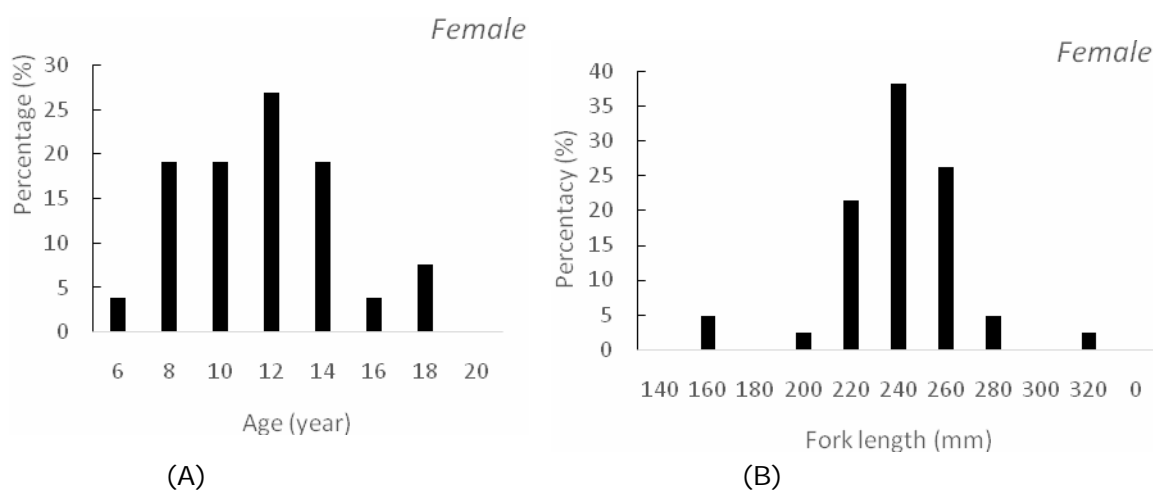


Figure 6. (A) Age distribution; and (B) length distribution used of female *L. gibbus* in the Southern Banten waters, Indonesia (n = 26).

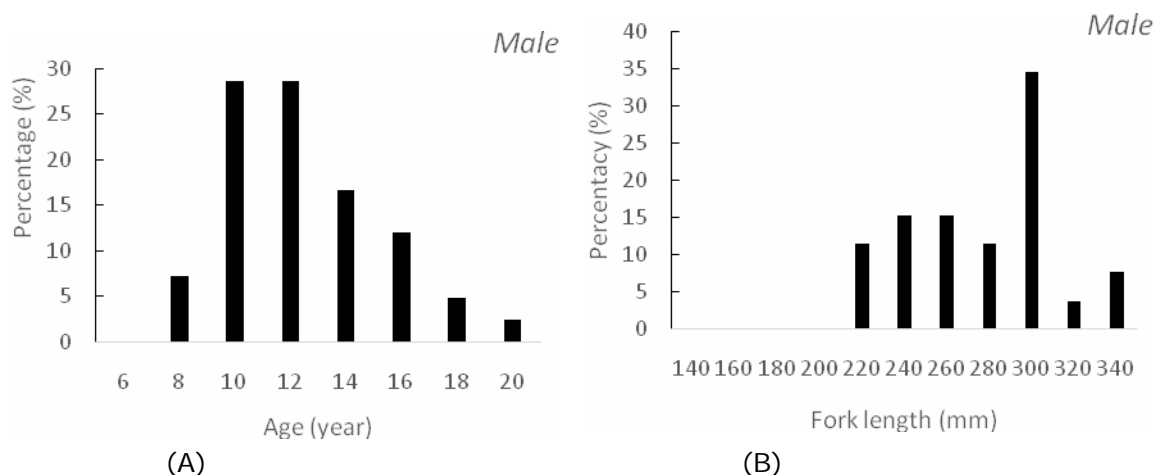


Figure 7. (A) Age distribution; and (B) length distribution of male *L. gibbus* in the southern Banten waters, Indonesia (n = 42).

Total mortality rate (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) of male *L. gibbus* in the Southern Banten waters in the temperature of 27.72°C (Amri et al 2013) were 0.69 year⁻¹, 0.28 year⁻¹, 0.41 year⁻¹ and 0.59 year⁻¹ respectively. Total mortality rate (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) of female *L. gibbus* in the Southern Banten waters were 1.11 year⁻¹, 0.34 year⁻¹, 0.77 year⁻¹ and 0.69 year⁻¹ respectively.

The total mortality rate (Z) of female *L. gibbus* is higher than the total mortality rate of male this indicates the stock of female is more vulnerable than the male. The natural mortality rate (M) of female *L. gibbus* was higher than the natural mortality rate of male due to its the higher growth coefficient (K) thus the female *L. gibbus* can reach faster asymptotic length (L_{∞}) than the male. The natural mortality is influenced by predation, including cannibalism, disease, spawning stress, hunger and old age (Sparre & Venema 1998; Widodo & Suadi 2006). The fishing mortality rate of *L. gibbus* appears to be higher than the natural mortality rate ($F > M$) meaning that there is a high fishing pressure on *L. gibbus*.

Gulland (1983) noted that the optimum exploitation rate was on 0.5 year⁻¹ ($E = 0.5$ year⁻¹). In this study the exploitation rate of male and female *L. gibbus* ($E = 0.59$ -0.69) was higher than the optimum value ($E = 0.5$) so *L. gibbus* in the southern Banten waters was already in the stage of overfishing.

The management of fishery resources in Indonesia aim to maintain or improve the fishery resources. Moreover, it also has a role as stock conservation to avoid excessive catch (Effendie 2002). Some recommendations from the results of this study include (1) the arrangement of fishing season such as open/closed season. The spawning season of *L. gibbus* are estimated happening in January-February and July-August so it is suggested to reduce fishing efforts during these periods; (2) the regulations on the fishing hook sizes more than number 10 to ensure more selective fish catch; (3) the regulation on the minimum legal size. The fish at first captured (L_c) must be larger than L_m size i.e. > 304.08 mm FL; (4) the regulation of fishing effort quota (number of vessels, trips and fishing gear). Besides these, monitoring, control and surveillance activities also need to be improved.

Conclusions. The spawning seasons of *L. gibbus* were estimated happening throughout the year and reached its peak in January-February and from July-August. The length at first captured of male and female *L. gibbus* was lower than the length at first matured ($L_c < L_m$). The von Bertalanffy growth equation of male and female *L. gibbus* were $L(t) = 390.04[1 - e^{-0.22(t + 0.38)}]$ and $L(t) = 323.77[1 - e^{-0.29(t + 0.29)}]$. The fishing mortality rate was higher than the natural mortality rate ($F > M$) thus *L. gibbus* in the southern Banten is on the stage of overfishing.

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