

Gonad Maturity Development of Shortfin Scad (*Decapterus macrosoma*, Bleeker 1851) Landed at the Fish Landing Base, Kedonganan Bali

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ABSTRACT

The shortfin scad (*Decapterus macrosoma* Bleeker, 1851) is the small pelagic fish which is caught in the Indonesian Water. The sustainability of shortfin scad should be maintained because it has high economic value in Indonesian marine fisheries sector. Sustainable efforts on managing shortfin scad's resources closely relate to the biological reproductive aspect. The objective of this study was to determine the gonad maturity development of shortfin scad landed at the fish landing base (PPI) Kedonganan, Bali. Sampling was carried out from November 2020 to January 2021 six times using a random sampling method. The ovary preparation uses paraffin method and Haematoxylin-Eosin staining. The parameters measured includes sex ratio, gonad maturity stage (GMS) according to morphological and histological analysis, oocyte diameter, gonadosomatic index (GSI), and length at first maturity. The result shows that the sex ratio of shortfin scad was balance. Morphological analysis shows that the immature (GMS I-II) and mature (GMS III-IV) females were found in every month of the sampling period which indicates that shortfin scad had protracted breeding season. Histological analysis shows that shortfin scad was at GMS I-VI. The oocyte development organization in the ovary was asynchronous and the oocyte diameter varied from 28,45-439,03 μm indicating that shortfin scad was partial spawner. The highest GSI value occurred in January. GSI ranged from 0,049-4,946% and the value increased along with enhancement of GMS. The female shortfin scad reached first maturity at a fork length of 16,91-17,63 cm.

1. Introduction

The shortfin scad is the source of small pelagic fish exists in the world. The shortfin scad dominates the catch of small pelagic fish in Indonesian water. The distribution of the shortfin scad is in Java sea, Bali strait, Banda sea, and Makassar strait [1], [2]. One of the scad's species which is caught during the years is the shortfin scad (*Decapterus macrosoma* Bleeker, 1851). The shortfin scad is mostly caught by purse seine, gillnet, seine net, and lift net. Purse seine is the most dominant utensil used to produce 80% of average production of the shortfin scad in Indonesia [3].

The people like to consume the shortfin scad because of its high nutrition and the price is affordable. The market high demand of the shortfin scad gives a contribution to increase fisherman's income. This case cause a big exploitation of the shortfin scad done by fisherman. Although fisheries resources is a renewable resources, if the catch is bigger than its regeneration so the aquatic biodiversity will not be balance [4].

In general, the use of shortfin scad in Indonesia year by year is constantly increased. This increase happened related to the increase of the fishing fleet amount and capacity. The increase of fishing gear, machine, and other utensils can increase the catch significantly. The utilization of the scad's resources which is increased cause the decrease of the scad's resources stock. Based on the statistic data, production of the scad in Indonesia in 2015 was 424.890.43 ton. In 2017 the amount of the production decreased 99.323.21 ton [5].

The continuous exploitation makes the production of shortfin scad is not optimal. The regeneration rate of shortfin scad toward the catch rate is imbalance so that it may cause degradation of the resources. This case put the sustainability in danger and damage the economic potency in it [6]. The sustainability of shortfin scad needs to be maintained because of its important role in fisheries sector. In this case, an optimal and continuous management efforts toward the shortfin scad needs to be done [7].

Management efforts of fisheries resources need biology reproduction data which include gonad maturity development. The research of gonad maturity development includes sex ratio, gonad maturity stage (GMS), gonadosomatic index (GSI), oocytes diameter, and the length of first maturity. The gonad maturity development is able to give significant data about breeding season, spawning types, and spawning success [10]. Observation through gonad histology analysis is used to find out the oocytes development specifically. The histology analysis gives accurate result about the fish reproduction status, but this method is still limited in Indonesia [8], [9].

Gonad maturity development of shortfin scad which was landed at the fish landing base Kedonganan, Bali was never reported yet. The purpose of this research was to find out the gonad maturity development of female shortfin scad landed at fish landing base Kedonganan, Bali. The gonad development can give information about the comparison between fish with mature gonad and immature gonad. This research also give information about sex ratio, spawning types, spawning period, and length at first maturity. This data can be used to manage the fisheries resources continuously based on biology parameter.

2. Literature Review

2.1 The shortfin Scad

Shortfin scad belongs to Carangidae's family. The specific characteristic which is found in the shortfin scad is there is finlet behind dorsal fin and anal fin and lateral scute in linea lateralis [1]. The shortfin scad is small pelagic schooling fish. The shortfin scad is predator of phytoplankton and zooplankton, especially Diatomae, Dinoflagellata, Mollusca, Crustacea, and Tintinnidae [10]. This kind of fish belongs to stenohaline with salinity 32-34 promil. The shortfin scad live at temperature 26,15-28,5°C and mostly caught in the water which is 20-30 mil apart from the coastal water. The shortfin scad is mostly found in the deep of 45-100 m [11]. The wide distribution of shortfin scad is found in tropic and sub tropic water. Most of it can be found in atlantic ocean to Brazil [12]. The shortfin scad is also live in Central Pasific Islands from South Korea to Gulf of California to Peru, and Galapagos Island [13].

2.2 The Ovary and Oocytes Developmet

Ovary is an female major reproduction organ which produce oocytes and reproduction hormone (estrogen and progesterone). Microanatomy of ovary indicates cell arrangement which involves follicle envelope which consists of granulosa cells, thecal cells, zona radiata, and oocytes itself [14]. There is no enough data to study about the development of shortfin scad's oocytes. Then the development of southern bluefin tuna was studied as comparison. The oocytes development of Tuna Albacares were divided into five stages such as unyolked stage, early yolked, advance yolked, migratory nucleus and hydrate stage [15], [16].

- a) Unyolked Oocyte is an oocyte which does not contain yolk. Unyolked stage is marked by perinuclear oocyte with purple cytoplasm and round nucleus.
- b) Early yolked is the early stage of yolk vesicles accumulation (previtellogenesis). The color of yolk vesicle is pale purple which concentrate on oocytes cytoplasm periphery and spread toward the nucleus. The purple yolk vesicle is still near the nucleus. Zona Radiata is clear and purple.
- c) Advanced yolked is next vitellogenesis stage. Yolk accumulation occurs continuously which cause oocytes size is getting bigger until reaches early maturity. Yolk globule is pink spreading from oocytes periphery to perinuclear zone. Oocyte shape is polygonal with nucleus is in the center. Following the ripening process, oocytes is round and nucleus is in the center of oocytes and zona radiata is widen.
- d) Migratory nucleus is early maturity stage. Nucleus migrates to oocyte periphery and large size of oil droplets appear. Migratory nucleus has short life, it can be less than 24 hours to become hydrate.
- e) Hydrate oocyte is final maturity stage. Yolk globule is completely united (completely pink). The oocyte size is getting bigger significantly and the shape is irregular. Oocyte has limited or no oil droplets. When oocyte is getting bigger, zona radiata is stretched becoming thin.

When the oocyte is ovulated, it is released from its follicle. The follicle is still in ovary and form distinctive fold structure which is called postovulatory follicle (POF). POF rapidly undergo degeneration and absorbed into the ovary. The mature oocyte which is not released during spawning will undergo degeneration and it is absorbed phagocytically which is called atresia. Atresia is divided into two stages which are alpha and beta [16],[17]. Atresia generally occurs to the fish which have done spawning in certain spawning period. Atresia presence in high percentage indicates that breeding season of that fish is over. The next development stage of atresia is called brown bodies. It is composed of granulosa cells with dark yellow pigment in the ovarian connective tissue . The existence of brown bodies indicates that the fish is in post spawning stage [18].

3. Methodology

3.1 Sample collecting

The shortfin scad sample was gained from fish landing base Kedonganan, Bali in November 2020 until January 2021. The sampling was conducted twice in a month with random sampling method. The sample was taken 40-50 fish for each sampling. The sample was put in the cool box and then brought to laboratory to be analyzed. The measurement of the sample includes fork length (FL) and body weight. FL is the length of the fish which is measured from the tip of the mouth or lower jaw to the cartilaginous tip of the shortest or median caudal fin ray [19]. The sample was dissected to obtain their gonad to find the sex ratio. Then, only the female gonad (ovary) was analyzed. The ovary was observed morphologically and histologically. The ovary preparation using paraffin method and Haematoxylin-Eosin staining.

3.2 Sex ratio determination

Sex ratio was counted by comparing the amount of male and female fish. Sex ratio determination can be counted with this following formula [20]:

$$SR = \frac{A}{B} \times 100\% \dots\dots\dots(1)$$

Notes:

SR : Sex Ratio

A : The amount of certain fish types (male and female)

B : Total amount of fish

The balance of male and female shortfin scad sex ratio was analyzed by *Chi-Square* [21]:

$$X^2 = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i}; E_i = \frac{F+M}{2} \dots\dots\dots(2)$$

Notes:

O_i : observed frequency of male or female fish

E_i : expected frequency of male and female fish

F : female fish

M : male fish

3.3 Gonad maturity stage determination

Morphologic observation is based on ovary size, ovary color, the clarity of blood vessels, and the clarity of ova in ovary. GMS determination of female shortfin scad morphologically follows the gonad development according to Holden and Raitt [22].

Histologic observation was conducted by observing most advanced group of oocyte (MAGO) which includes unyolked, early yolked, advanced yolked, migratory nucleus and hydrated stage. The observation of POF's availability, percentage of alpha atresia from advanced yolked oocyte (absent, <50%, ≥50%, 100%, and the availability of beta atresia and maturity marker (brown bodies) [18].

3.4 Measurement of oocytes diameter

The measurement of oocytes diameter was done to fish with development gonad spawning. Oocytes was measured at anterior, median, and posterior ovary. Oocytes diameter was measured five times in each development stage (equation 4). Because oocytes shape is not a perfect round, so the oocytes diameter was measured vertically and horizontally (equation 3). Oocytes diameter measurement was done by using *Image Raster 3* application which was calibrated.

$$D_n = \frac{D_x + D_y}{2} \dots\dots\dots(3)$$

$$D = \frac{D_1 + D_2 + D_3 + D_4 + D_5}{5} \dots\dots\dots(4)$$

Notes:

D_n : Oocytes diameter (µm)

D_x : Oocytes diameter vertically (µm)

D_y : Oocytes diameter horizontally (µm).

3.5 measurement of gonadosomatic index

Gonadosomatic Index (GSI) measurement was done by comparing between gonad weight and body weight in percentage (%). GSI was counted by this following equation [23]:

$$GSI = \frac{GW}{BW} \times 100 \dots \dots \dots (5)$$

Notes:

GSI = Gonadosomatic Index (%)

GW = Gonad Weight (g)

BW = Body Weight (g)

3.6 measurement of length at first maturity

Length at first maturity (Lm) is the length corresponding to 50% maturity. The log size at first maturity is determined by Spearman-Kärber method [24]:

$$m = \left[X_k + \left(\frac{X}{2} \right) \right] - (X \sum P_i) \dots \dots \dots (6)$$

The mean of length at first maturity is gained from antilog (m). The length at first maturity with 95% confidence limit can be analyzed by this following equation:

$$CL = \text{antilog} \left(m \pm 1,96 \sqrt{X^2 \sum \frac{p_i \cdot q_i}{n_i - 1}} \right) \dots \dots \dots (7)$$

Keterangan:

CL : *Confidence limit* (upper and lower limit)

m : Log size at first maturity

X_k : Last log size in which 100% of fish are fully mature

X : Log size increment = X_{i+1} - X_i, i=1,2, 3...k-1

X_o : Last log size in which all fish are immature

P_i : Proportion of fully mature fish in the *i* size group (p_i = r_i/n_i)

r_i : Number of fully mature fish in the *i* size group

n_i : Number of fish of *i* interval class

q_i : 1-p_i

4. Results and Discussion

4.1 sex ratio

The total of shortfin scad in this research was 277 fish which consisted of 142 (51, 26%) female fish and 135 (48,74%) male fish. The distribution of amount and sex ratio of shortfin scad in each observation of the month can be seen in Table 4.1.

Table 1. Sex ratio of shortfin scad in each observation of the month

Observation time	Number of distribution		Sex ratio	X ² count
	Female	Male	Female : Male	
November	43	48	1 : 1,12	0,27*
December	49	47	1,04 : 1	0,04*
January	50	40	1,25 : 1	1,11*
Total	142	135	1,05 : 1	0,18*

Notes: * no significant difference between the distribution (sex ratio 1:1)

The results about sex distribution of shortfin scad in fish landing base Kedonganan, Bali shows that the number of female fish was bigger than male fish. The bigger number of female fish is one of population reproduction strategies to increase the chance of reproduction success. It is because the oocytes produced is limited rather than male spermatozoa. The result of shortfin scad's sex ratio balance test through Chi-Square ($\alpha = 0,05$; df=1) shows that the comparison between male and female fish did not indicate significant difference so that sex ratio is balance (Table 1). The balance sex ratio is an ideal condition in spawning because male and female fish are both active. Thus, it increases the chance of spawning success which affect the reproduction result. The fish spawning are really depended on male and female fish in the same location to make fertilisation happens easily [25].

Sex ratio is not always in ideal condition in which something may go wrong in nature. Other study report that sex ratio of shortfin scad in Barru water and Makassar strait was not balance in which the number of male fish was bigger that the female fish [3], [26]. The different number of male and female fish can be caused by several factors such as the substitution and male and female sexual variation in their growth and mortality rate. Sex ratio differentiation can be also caused by different behavior between male and female fish in which male fish tend to gather with other fish species, meanwhile female fish gather with other female groups so that the chance of getting caught is different. The different number of male and female fish is also related to fish migration behavior in looking for food based on preference [20], [27].

4.2 Gonad maturity stage (GMS) based on morphology analysis

Gonad maturity stage (GMS) distribution of female shortfin scad in each observation of the month can be seen on Figure 1.

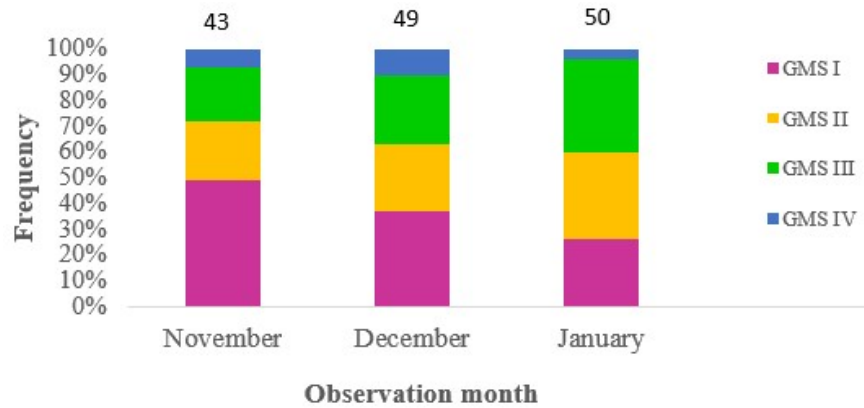


Figure 1. GMS distribution of the female shortfin scad in each observation month

Gonad maturity stage (GMS) distribution which was based on research period indicated that female shortfin scad with GMS I till IV was found in every observation (Fig. 1). The female shortfin scad had potential to do spawning during the research period which was proven by mature gonad that was found in each observation month. Fish which is found in GMS III and IV is a sign that the fish in that water is spawning. The spawning can be done when the environment is good and it supports larva’s life [28].

The results of this research show that the female shortfin scad wick was landed on fish landing base Kedonganan, Bali could do spawning every month in which the highest mature gonad percentage was found in January. Other research, reports that the shortfin scad in Banda Neira water can do spawning in every month of the observation with peak breeding season is suspected occurs in February or March [29]. Also, the shortfin scad in Barru water do spawning every month in which the highest mature gonad percentage is found in July and September [3]. The shorfin scad with mature gonad in several water’s area was found every month of observation so that suspected it can do spawning during the year.

4.3 Gonad maturity stage (GMS) based on histology analysis

Histologic observation indicates that female shortfin scad was found in several gonad development stages which are immature and mature. Observation result of immature fish involves immature and developing. Observation result of mature fish involves spawning capable, spawning, regressing potentially reproductive, and regress 1 (Fig. 2). Fish regress 2 and regenerating in this research were not found. This following is the observation result of gonad development histologically:

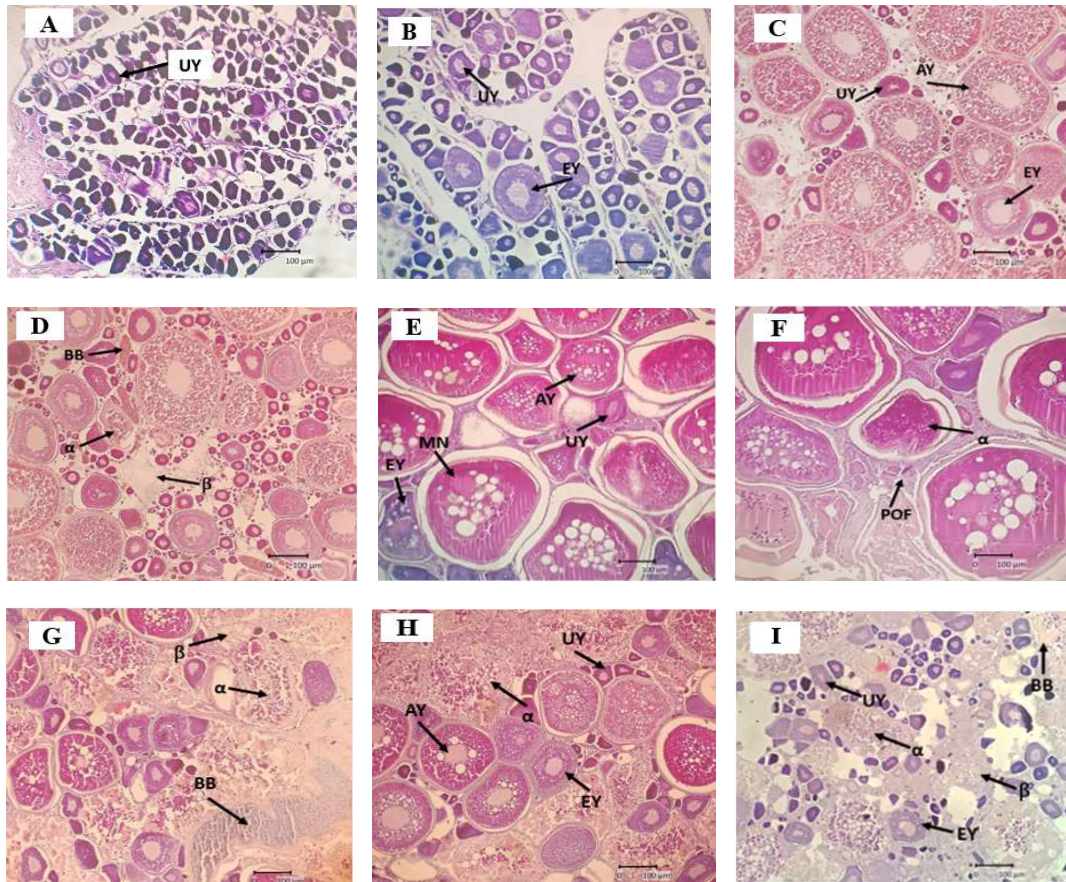


Figure 2. Histology of the shortfin scad ovary. (A) immature, (B) developing, (C-D) spawning capable, (E-F) spawning, (G-H) Regressing potentially reproductive, (I) regress 1. Unyolked (UY), early yolked (EY), advanced yolked (AY), migratory nucleus (MN), postovulatory follicle (POF), alpha (α) beta (β) atresia and brown bodies (BB). Staining: H-E. Magnification: 100X.

The shortfin scad which do spawning actively is characterized by the availability of oocytes in advanced yolked stage, migratory nucleus or hydrate stage. The shortfin scad which is not actively spawning only has unyolked or early yolked in its ovary. Observation of ovary histologic structure of mature shortfin scad which is spawning actively in spawning class shows that oocytes development in the ovary has different phase which consists of several oocytes stage such as unyolked, early yolked, advanced yolked, and migratory nucleus. Various oocytes development in the ovary in the same period is called as asynchronous ovary [17], [30].

The comparison of GMS observation morphologically and histologically indicates that there was inappropriate gonad development stage. For example fish which belongs to GMS II based on morphology, after doing the histologic observation it shows different development stage which are developing and regress. Reviewing the gonad development, partial spawner is iteroparous fish. It is a fish which do spawning frequently during its life [30][31]. When the fish is on post spawning period, the ovarian cycle repeats until ovum reaches minimum number and the fish stop to do reproduction. The existence of brown bodies as maturity marker indicates that the fish has done spawning previously [18]]. The developing fish is the one that is immature or never do spawning, meanwhile the regress fish is mature that has done spawning previously. Because the developing and regress fish are in different gonad development stage, so they should be categorized into different GMS.

Gonad maturity stage (GMS) classification morphologically according to Holden dan Raitt [22] is not differentiating between developing and regress fish. Those fish are classified into GMS II because their characteristics are almost the same. Oocytes observation through histologic analysis was not done yet so there is no reference that differentiate between the ovary of developing and regress fish. Besides, GMS determination was made generally for partial spawner fish so it is not for other fish types specifically. The specific GMS for the shortfin scad or genus *Decapterus* is never reported yet. Thus, based on the result of this research GMS classification for shortfin scad can be made (*Decapterus macrosoma* Bleeker, 1851) as follow :

Table 2. Gonad maturity classification of the female shortfin scad (*Decapterus macrosoma* Bleeker, 1851)

GMS	Maturity	Reproduction activity	Histologic ovary	Morphologic ovary	Fork length (cm)	GSI (%)
I (immature)	Immature	Inactive	Oocytes in unyolked stage, and there were no atresia oocytes, POF, and brown bodies found.	The color of clean ovary is reddish, the ova is invisible to naked eye, Ovary surface is smooth and thin, ovary is about 1/3 length of body cavity.	Range; 13,8-17,8 mean: 15,5	0,125
II (developing)	Immature	Inactive	Oocytes in unyolked and early yolked stage, and there were no atresia oocytes, POF, and brown bodies found.	The ovary color is reddish, ovary wall is thin, the ova is invisible to naked eye, ovary is about 1/2 length of body cavity.	Range: 14,5-17,8 Mean: 16,5	0,374
III (spawning capable)	Mature	Active	Oocytes in unyolked, early yolked and advanced yolked stage, there was no POF, atresia oocytes (< 50% alpha atresia, beta atresia and brown bodies may be present.	The ovary color is reddish yellow with blood vessels on ovary wall, the ovary is thicken, the ova is visible to naked eye and opaque, ovary is about 2/3 length of body cavity.	Range: 15,6-18,8 Mean:17,3	1,680
IV (spawning)	Mature	Active	Oocytes in unyolked, early yolked, advanced yolked, and migratory nucleus stage, and POF, atresia oocytes (< 50% alpha atresia), beta atresia and brown bodies may be present.	The ovary color is orange with conspicuous blood vessels on its ovary wall, the ovary is thicken, ripe ova is transparent (translucent) and easy to separate. ovary is about 2/3 or more length of body cavity.	Range: 17,1-19,7 Mean: 18,7	3,566
V (regressing potentially reproductive)	Mature	Inactive	Oocytes in unyolk, early yolk and advanced yolk stage, there was no POF, atresia oocytes (> 50% alpha atresia), beta atresia and brown bodies may be present.	The ovary color is dark red, thick wall, the ovary is shrunken containing the rest of ova from ovulation, ova is opaque, ovary is about 2/3 length of body cavity.	Range: 17,6-20,1 Mean: 18,8	1,366
VI (regress)	Mature	Inactive	Oocytes in unyolk and early yolk stage, POF were not found, atresia oocytes (100% alpha atresia), beta atresia and brown bodies were present.	The ovary color is grey red, thick wall, the ova is invisible to naked eye, ovary is about 1/2 length of body cavity.	Range: 18,1-20,6 Mean: 19,0	0,308

Based on gonad development classification of shortfin scad which can be seen in Table 2, the ovary of mature and immature shortfin scad as well as active and inactive spawning shortfin scad can be differentiated. The fish with gonad development (developing and regress) can be differentiated by ovary mophologic characteristics. GMS observation based on the ovary mophologic characteristics such as color difference, thick or thin wall, clarity of blood vessels on ovary wall is qualitative. Because the qualitative data can not be measured certainly and it can be assumed subjectively so quantitative measurement is

needed. Thus, the fork length and GSI mean in each GMS need to be stated. Through the fork length measurement it can be pointed out that the mean size of developing fish is (16, 5 cm FL) and regress (19,0 cm FL) in which it shows quite significant difference.

4.4 Oocytes diameter

The result of oocytes diameter measurement of shortfin scad can be seen in Table 3.

Table 3. Oocytes diameter of the shortfin scad in every stage of oocytes development

Oocytes development stage	Range (μm)	Mean (μm)
Unyolked	28,45 – 75,82	53,300 \pm 12,568
Early yolked	88,74 – 170,61	123,325 \pm 21,358
Advanced yolked	216,35 – 302,91	260,899 \pm 24,751
Migratory nucleus	336,20 – 439,03	381,317 \pm 26,954

Based on Table 3, the result of oocytes diameter measurement of shortfin scad with gonad development in spawning stage shows that there are several variations of oocytes size in the ovary. Oocytes maturity is not happened simultaneously. Beside mature oocytes in different stage (advanced yolked and migratory nucleus), the immature oocytes (unyolked and early yolked) were also found. Various development oocytes stage with various diameter size variations in the ovary of active spawning fish, indicating that shortfin scad is partial spawner. The oocytes in migratory nucleus stage are hydrated and go out to the water and the oocytes in advanced yolked stage are developing until reach the final maturation. Then the oocytes will be ovulated and released to the water for fertilization. It happens continuously until ovum reach its minimum number [32].

Partial spawner is the fish strategy to increase the chance of reproduction success due to spawning can occur several times and in long period. If environmental factor does not support like there is predator or physics and chemical changes of the water that can prevent the fertilization, so it can occur in the next spawning . Oocytes diameter are the parameter to find out the oocytes quality. The bigger oocytes diameter the bigger yolk size which has function as food reseve in larva phase [33], [34].

4.5 Gonadosomatik Index (GSI)

The GSI mean of female shortfin scad in each observation month can be seen in Table 4.

Table 4. GSI value of female shortfin scad in each observation month

Observation month	Number of sample	GSI	
		Range (%)	Mean (%)
November	43	0,057 - 3,986	0,503 \pm 0,806
December	49	0,049 – 4,946	0,988 \pm 1,203
January	50	0,078 – 4,705	0,995 \pm 1,027

Gonasomatic Index (GSI) is comparison percentage of between fish gonad weight and body weight which indicates gonad development in quantitative. Based on observation period, the highest GSI mean was gain in January and the lowest one was found in November (Table 4). The data shows that in January the reproduction is increased compare to November and December. GSI value can indicate population reproduction development.

Gonasomatic Index (GSI) value of female shortfin scad landed on fish landing base Kedonganan, Bali is about 0,049 – 4,946%. This value is almost the same as other research that report GSI of shortfin scad in Haruku Island water is about 0,2525–4,0491% [35]. The fish with GSI less than 20% are the fish which spawning several times in a year and generally fish species in tropical water is spawning during the year. It is supported by scad with mature gonad which were found frequently in each observation month. Besides, the ovary type of the shortfin scad which is asynchronous indicates that the shortfin scad is partial spawner that can do spawning during the year [36].

4.6 Length at first maturity

The result of the research shows that length at first maturity of the female shortfin scad landed on fish landing base Kedonganan, Bali is 16,91-17,63 cm FL. This is almost the same as the other research that female shortfin scad in Makassar water reaches its first maturity at 16,45-17,24 cm FL. length at first maturity is important parameter to study in which length that fish reaches its first maturity. Length at first maturity can be reference to standard size of the fish which is worth it to be caught [37].

Length at first maturity at the same fish species can be different. This may cause by the temperature distinction and the availability of food. The size distinction when it reaches first maturity may also cause by environmental changes. The water quality and the big number of exploitation make the reproduction process of the fish in that water faster and reach its first maturity at smaller size. Fast regeneration is reproduction strategy to recover population balance and avoid extinction [38].

5. Conclusion

The sex ratio of the male and female shortfin scad landed on fish landing base Kedonganan, Bali is 1,05 : 1 or in balance condition. Based on morphologic analysis, GMS is found from GMS I to IV in each observation month which is a sign that the shortfin scad can do spawning in each observation month. Histologic analysis shows that the shortfin scad is in GMS I to GMS IV. Oocytes diameter size variation is about 28,45 – 439,03 μm with oocytes development pattern in ovary is asynchronous which indicates that spawning type is partial spawner. GSI value is about 0,049 – 4,946%. GSI is increased from November to January indicates that reproduction activity is increased during the observation month. The female shortfin scad reaches its first maturity at 16,91-17,63 cm FL.

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Conflicts of Interest:

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Appendix 1. Gonad maturity stage based on morphologic analysis according to Holden and Raitt (1974)

Maturity stage	Condition	Remark
1	Immature	The ovary is about 1/3 length of body cavity. It is pinkish and translucent. Ova is invisible to naked eye.
2	Developing and recovering spent	The ovary is about 1/2 length of body cavity. It is pinkish and translucent. Ova is invisible to naked eye.
3	Ripening	The ovary is about 2/3 length of body cavity. It is pinkish yellow color. The ova is visible to naked eye and opaque (not transparent)
4	Fully Mature	The ovary is about 2/3 to full length of body cavity. It is orange pink with many blood vessels visible on its surface. Ripe ova is large and transparent.
5	Spent	The ovary is shrunken about 1/2 length of body cavity. The wall is disintegrated. The ovary may contain disintegrating opaque and ripe ova.

Appendix 2. Gonad maturity stage based on histology analysis according to Farley et al. (2013)

Class	Maturity status	Activity	Development class	MAGO	POF	A and β atresia of yolked oocytes	Brown bodies
I	Immature	Inactive	Immature	Unyolked	None	Absent	None
II	Immature	Inactive	Developing	Early yolked	None	Absent	None
III	Mature	Active	Spawning capable	Advanced yolked	None	<50% α atresia, β atresia may be present	May be present
IV	Mature	Active	Spawning	Migratory nucleus/hydrated	Present	<50% α atresia, β atresia may be present	May be present
V	Mature	Inactive	Regressing-potentially reproductive	Advanced yolked	None	\geq 50% α atresia, β atresia present	May be present
VIa	Mature	Inactive	Regressed 1	Unyolked or early yolked	None	100% α atresia, β atresia may be present	May be present
VIb	Mature	Inactive	Regressed 2	Unyolked or early yolked	None	No α atresia, β atresia present	May be present
VII	Mature	Inactive	Regenerating	Unyolked or early yolked	none	Absent	Present

*MAGO : most advanced group of oocytes, POF : postovulatory follicle.