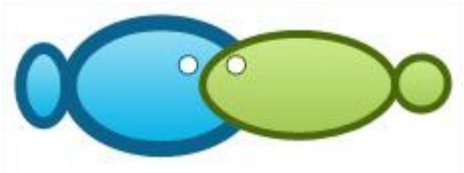

Reproductive pattern of yellowfin tuna *Thunnus albacares* in deep and shallow sea FAD in Makassar Strait

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Abstract. Yellowfin tuna (*Thunnus albacares*) is one of tuna species found in Indonesia waters and has already been exploited by fisherman. Capturing of yellowfin tuna was more intensive caused by better price and more supply requested in local, national and international markets. This research aimed to analyze reproductive pattern of yellowfin tuna in deep and shallow sea Fish Aggregating Device (FAD) area in Makassar Strait. Method used in this research was explorative method and this research was conducted from July 2013 to June 2014. Parameters observed were size (length and weight) gonad maturity, index of gonad maturity, size of mature gonad and spawning pattern. Gonad maturity was observed morphologically. The index of gonad maturity was performed based on comparison of gonad weight and body weight, size of mature gonad was computed with Udupa formula (1986) and spawning pattern was performed based on peaks of gonad maturity index. This research results showed that size structure of yellowfin tuna captured in deep sea FAD had longer and bigger weight than that captured in shallow sea FAD. In deep sea FAD gonad maturity of mature to spawning was observed while in shallow sea FAD gonad maturity of immature to maturing occurred. The first size of mature gonad in deep sea FAD in fork length was 114.80 cm and in shallow sea FAD was 105.41 cm or size of mature gonad in deep sea FAD was bigger than in shallow sea FAD. The index of gonad maturity in deep sea FAD was about 1.51-2.37 and in shallow sea FAD was about 1.22-1.79. The spawning peak started from October to March.

Key Words: Fishery, gonad maturity, market, spawning, Fish Aggregating Device.

Introduction. Yellowfin tuna (*Thunnus albacares*) is one of the most captured tuna species in Indonesia. This species is grouped as a big pelagic that is captured more by Indonesian fisherman in Makassar Strait. The yellowfin tuna in Makassar Strait is dominantly captured in Fish Aggregating Device (FAD) ground with hand line. The hand line is a traditional fishing gear with design and the simplest construction.

South and West Sulawesi are two provinces that highly contribute in tuna at national level to fulfil market demands either domestic or international. Increasing demand causes capturing to be intensively done by fisherman, so the species production decreases. The production decreasing almost happens in all fishing grounds in Indonesia. This problem is worried to affect reproductive pattern of yellowfin tuna.

Until now, the research about tuna fishery in Makassar Strait in FAD area have been conducted many times, such is the first measurement of gonad maturity (Kantun et al 2012b and 2013), population dynamics of *T. albacares* in WPPRI 713 (Kantun et al 2012a); abundance (Kantun & Ali 2012), age structure, growth pattern and mortality (Kantun & Amir 2013), relationship of long weight (Kantun & Yahya 2013), size structure and total of fishing results based on time and depth (Kantun et al 2014a), gonad maturity based on depth and fishing time (Kantun et al 2014b), *T. albacares* response toward bait kinds and depth (Kantun & Mallawa 2014), size structure comparison of *T. albacares* based on position of deep and shallow FAD (Kantun et al 2014c), reproductive potential (Kantun et al 2014d) and engineering technology of tuna fishing (Kantun & Angriawan 2015). Based on description above, the research about *T. albacares* has been already conducted in Makassar Straits but none of the researches have studied about

reproductive pattern of *T. albacares* in FAD area. This research aimed to observe reproductive pattern of *T. albacares* in FAD area through gonad maturity, index of gonad maturity, size of mature gonad and spawning size.

Material and Method

Time and location. The research was conducted for a year started from July 2013 to June 2014 in FAD area in Majene waters of Makassar Straits in Indonesia with fishing ground as shown in Figure 1. The research was conducted by directly participate in capturing activity.

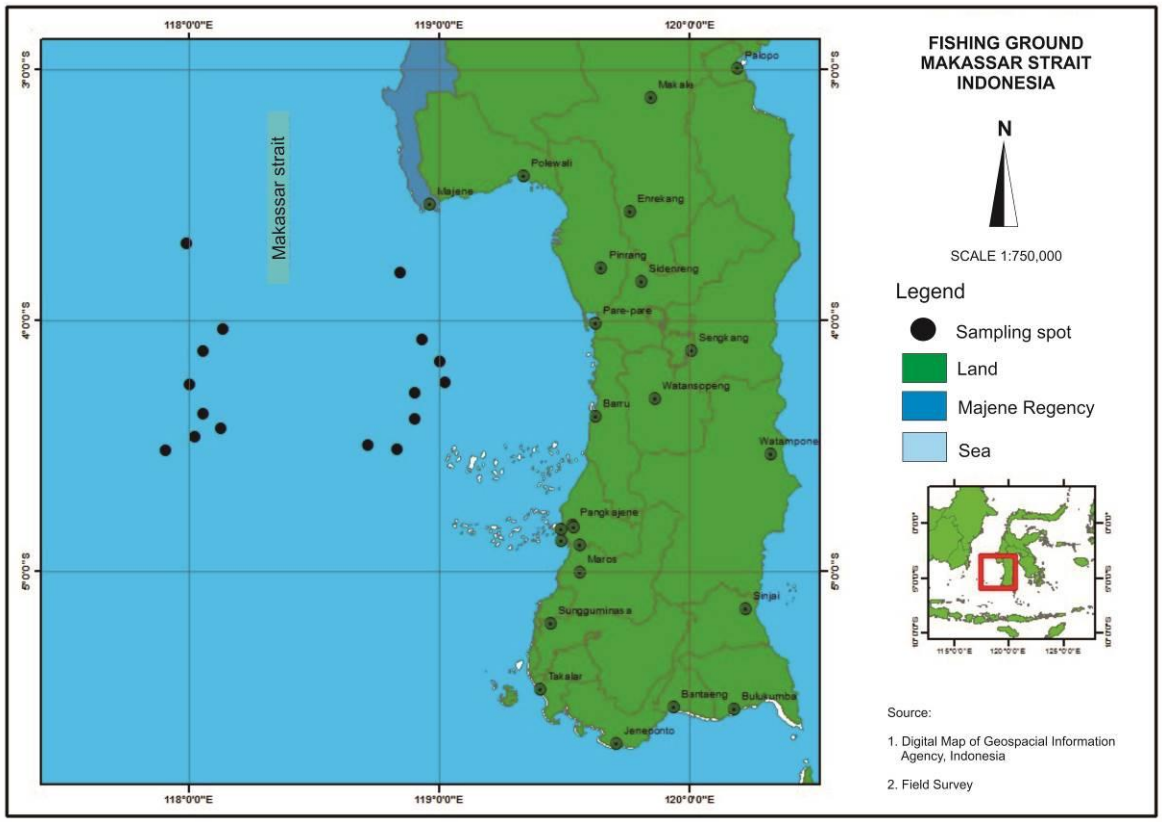

Figure 1. Fishing ground location of *Tunnus albacares* in Makassar Strait.

Research procedure

Size distribution. The measurement of fork length of *T. albacares* was done by elbow ruler with an accuracy of 0.5 cm. Total fish weight was weighed by hanging digital scales with an accuracy of 0.01 kg and gonad weight was weighed with digital scales with an accuracy of 0.01 g.

Gonad development. The development of morphological gonad maturity of *T. albacares* males and females was observed based on criteria in Table 1. The number of samples observed have related to gonad maturity in all captured fishes (total sampling). Total sampling consisted of 555 fishes from which 274 fishes were captured in deep sea FAD and 281 fishes were captured in shallow sea FAD. The development of gonad maturity was done by operating and observing them based on macroscopic characteristics.

Table 1

The development of morphological gonad maturity of *Tunnus albacares* males and females (modified from Hunter & Macewicz (1985), Schaefer (1987, 1996, 1998) and Itano (2001))

Development stages of gonads	*Females*	*Males*
Immature	Thin and hollow gonad, with tube diameter of 3-4 μm and transparent.	Thin and hollow gonad, tube with diameter of 3-4 μm and transparent or white.
Developing	Oocyt seen in inner ovarium. Blood vessel seen clearly. Pale red or orange.	Testis tube grown and blood vessel seen in the tube. Gonad is pale white or reddish.
Maturing	Ovarium and oocyt grown, oocyt is oval not round and stick strongly. Blood vessel less seen than previous stage, pale orange color.	Testis tube is still growing and blood vessel less seen than previous. Sperm found much in cyst and lumen lobulus but not in outer. Gonad is reddish.
Mature	Ovarium is growing continuously. Oocyt is out of ovarium wall and oval round and also transparent. Pale orange or yellow color.	Gonad is full of sperm. Mature sperm is in lobules and outer. Gonad is white or reddish.
Spawning	Ovarium characteristic is soft, flat and flabby. The rest of oocyt found in ovarium. Dark orange or yellow.	Gonad condition is soft, flat and flabby. Gonad is dark and white.

Index of gonad maturity. Index of gonad maturity was only observed in maturing stage to spawning. The number of samples for observing index of gonad maturity of *T. albacares* in deep sea FAD was 72 fish, 36 female fishes and 36 male fishes, every month taken 3 fishes either male or female to represent stage maturing to spawning. While shallow sea FAD counted 24 fishes, 12 males and 12 females, in every month was taken for analyzes 2 fishes with consideration in shallow sea FAD captured based on their gonad maturity stage immature to maturing and number limitation.

Size of gonad maturity. To determine the first size of mature gonad, data used were stage maturing and mature either male or female fish with morphological observation. Results from all 555 fishes were used.

Results and Discussion

Size distribution. *T. albacares* captured in shallow sea FAD has smaller size structure than those captured in deep sea FAD. That indicates that in shallow sea FAD (<200 m) or neuritic is the growing area for tuna of larva stage (0-40 cm) and juvenile (40-90 cm) and some of them have begun to mature their gonads. Many *T. albacares* fish in juvenile stage are captured in shallow FAD sea area, and not only feeding factor, perhaps, is a cause to have influenced this part of life cycle (Figure 2B). Figure 2A shows friction of bigger distribution pattern. It is based on reproductive needs. When adult is ready to reproduce, tuna will migrate from neuritic area (shallow waters) to oceanic area (>200 m) to find comfort and safe area to reproduce, spawning as a way to keep its existence in this area of deep sea FAD.

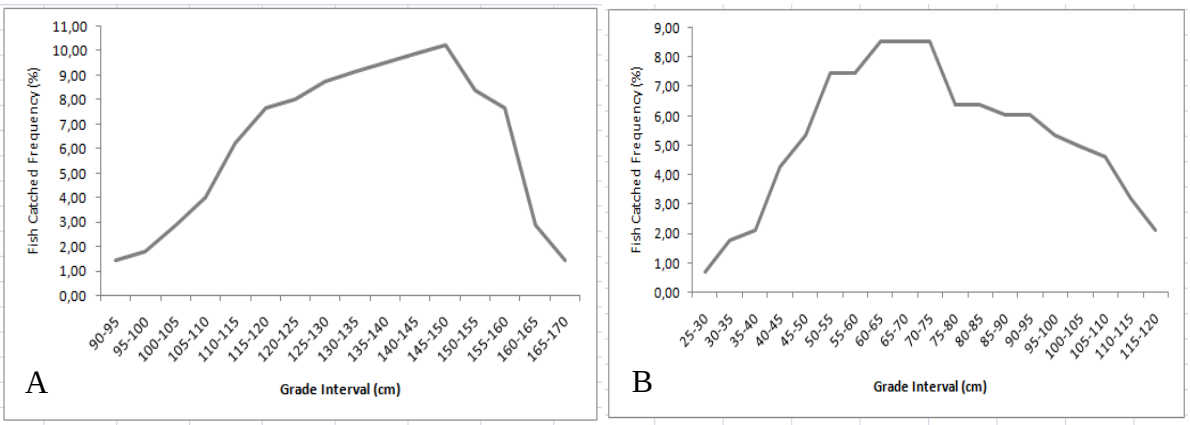

Figure 2. Fork length size distribution of *T. albacares* in deep sea FAD (A) and shallow sea FAD (B) in Makassar Strait, July 2013-June 2014.

Gonad maturity. Gonad observation results in *T. albacares* males and females in deep sea FAD and shallow sea FAD are shown in Table 2.

Table 2

Gonad development macroscopically observation of *Tunnus albacares* males and females

Development stages of gonads	*Females*	*Males*
Immature	Ovary is getting longer, pairing and sliming or thin, gray-red.	Hollow testis, pairing, and clear transparent and getting longer and sliming.
Developing	Ovary is getting bigger, pairing, reddish, blood vessel started to be clear, orb egg can't be seen with bare eyes.	Pairing testis gray-white and condition still close or solid, long and bigger.
Maturing	Bigger ovary, pairing and swollen, reddish-orange; egg grain started to be seen by bare eyes; ovary fills 2/3 at bottom part.	Testis is getting bigger, pairing, gray-white, little white liquid, however not really liquid yet (still thick).
Mature	Ovary is getting bigger, pairing, egg grain is getting bigger and clear, can be out from lumen with little pressing on stomach and ovary fully fills bottom part.	Pairing testis, milky-white and milt in outer center, spermatozoa liquid has formed, if tough the condition dilute and melt.
Spawning	Pairing ovary, quite dark color, soft condition (because already spawned). Mature egg still found in ovary.	Pairing testis, white, already produces sperm, testis is getting bigger, but there is an empty pocket because used, but some left.

Results of macroscopic observation of gonad maturity are shown in Figure 3. The figure shows that *T. albacares* from shallow sea FAD is mainly captured within gonad development as immature (Figure 3B) with immature stages in about 223 fishes (79.36%) and mature condition in about 58 fishes (20.64%).

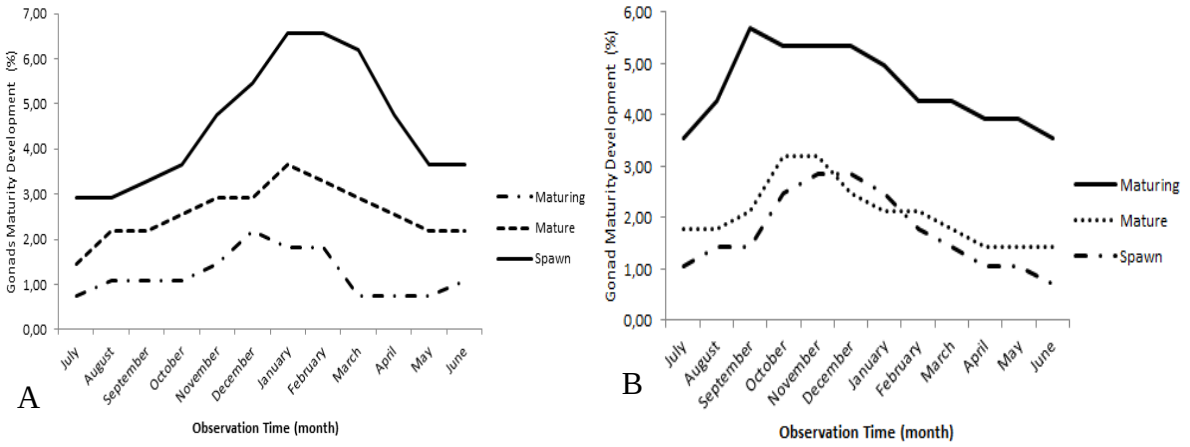

Figure 3. Gonad maturity development of *Tunnus albacares* in deep sea FAD (A) and shallow sea FAD (B) from July 2013 to June 2014.

Figure 3 provides data about the synchronization of the maturation phase from shallow sea to deep sea FAD based on feeding needs, life cycle and reproduction. In gonad maturity phase of fish from deep sea FAD, spawning peaks occurs between months of October to April, and peaks are present from November to March. This provide information that mature and spawning *T. albacares* are dominatly caught in the deep sea FAD. It strengthens and supports the research results by Kantun et al (2014c) who stated that *T. albacares* is spawning in Makassar Strait. This research gives more important information as comparative reason and comprehension that Makassar Strait is a migration routes of *T. albacares* and one of options to spawn.

Maturity development pattern of *T. albacares* gonad in shallow sea FAD, which is dominated by immature stages, suggests a decline of development friction for each gonad maturity stage with less percentage day by day. It shows that the similar size of *T. albacares* fish does not automatically occurring at the same time. It is expected to relate to energy consumption and types of food which can be captured by fish so it will towards contribute to its gonad maturity process.

A similar study of *T. albacares* gonad maturity development in shallow sea FAD and deep sea FAD from January to December 2011 by Kantun et al (2012b) made on a number of 474 sample fish showed a spreading of immature gonad maturity development of 53.81%, mature gonad of 39.24% and spawning 6.95%. It showed that the development of mature gonad is higher than that spawning. In present study, spawning condition is higher.

Index of gonad maturity. In this research it was obtained an index of gonad maturity around 1.22-2.37 with index detail of gonad maturity in deep sea FAD around 1.51-2.37 and shallow FAD around 1.22-1.97 (Figure 4). Index of gonad maturity is higher in September to December period in shallow sea FAD while in deep sea FAD in November to March period. Decreasing of index of gonad maturity started from January to April in shallow sea FAD and is probably related to tuna movement to deeper waters to deep sea FAD to reproduce.

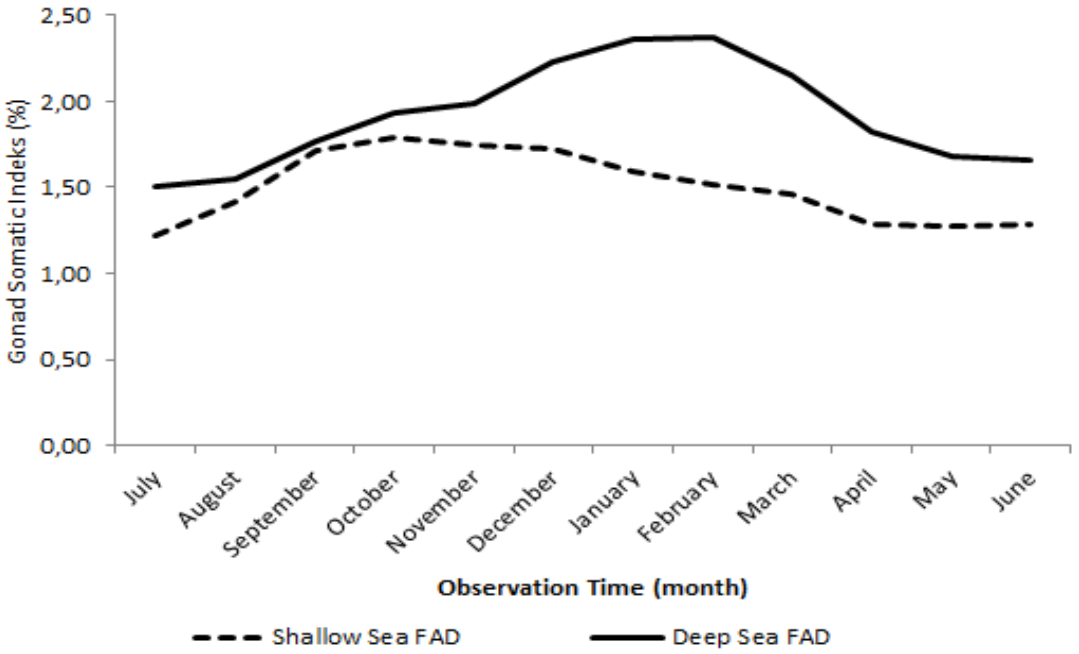

Figure 4. Gonad maturity index of *Tunnus albacares* in deep and shallow sea FAD in Makassar Strait.

After most of gonad maturity peaks have spawned so the next month the decreasing of gonad maturity index occurs. Decreasing process occurs gradually referred to egg excretion and sperm. Peaks of gonad maturity of *T. albacares* in every research location usually depend on food availability when migrating, biological need to fulfill reproductive process and physical-chemical conditions of environmental conditions like temperature, salinity and current speed. Some comparative values of gonad maturity index in *T. albacares* from various research locations are presented in Table 3.

Table 3

Gonad maturity index (GMI) in *Tunnus albacares* from various research locations (comparative data)

Locations	*GMI estimations*	*Peaks of GMI*	*References*
Central and West Pacific	1.46-4.13	Primary from January to March and secondary from July to August	Sun et al (2005)
East India	1.50-2.50	-	Nootmorn et al (2005)
West and Central India	0.74-2.55	Primary from December to March and secondary in June	IOTC (2009)
West Pacific (Makassar Strait)	1.37-2.29	Primary from October to March and secondary from June to August	Kantun et al (2012b)
West Pacific (Makassar Strait)	1.22-2.37	Primary from October to March and secondary from June to August	Present study

Table 4

The first size of mature gonad in various research locations (comparative data)

Locations	*The first size of mature gonad (cm)*	*Method/fishing gears*	*References*
West Pacific (Makassar Strait)	105.41 (♀ and ♂) 114.80 (♀ and ♂)	Shallow FAD, Deep FAD, Hand line gear	Present study
West Pacific (Makassar Strait)	118.61 (♀) 119.27 (♂)	FAD/hand line	Kantun et al (2012b)
West Pacific	113.77 (♀) 120.20 (♂)	-	Guoping et al (2005)
Australia, Filipine and Indonesia	120.0 (♀ and ♂) 104.6 (♀ and ♂)	Long line, FAD/hand line	Itano (2001)
West Pacific	104 (♀and ♂)	Long line	Itano (2000)

Table 5

Spawning season in various research locations (comparative data)

Locations	*Spawning peaks*	*References*
West Pacific (Makassar Strait)	Primary from October to March and secondary from June to August	Present study
West Pacific	April to July	Yamanaka (1990)
West Pacific	October to March	Cole (1980)
West and central India Ocean	December to March	IOTC (2009)
West and central India Ocean	December to March	Zudaire et al (2010)

The first size of mature gonad. Due to criteria of mature gonad vs. immature gonad, mature and spawning stages are described in Figure 5. Figure 5 shows that *T. albacares* captured in deep sea FAD is dominated by spawning condition in about 26.85% and shallow sea FAD is dominated by immature condition in about 40.18%. If it is compared with Kantun research (2012b), we obtained immature condition score equal to 53.81% (Figure 5 A,B), while condition of mature gonad decreases 16.72% from 39.24% to 22.52%. Spawning pattern grows 19.90% from 6.95% to 26.85%. That indicates that fishing method implementation and understanding biology of *T. albacares* will be easier in fishing.

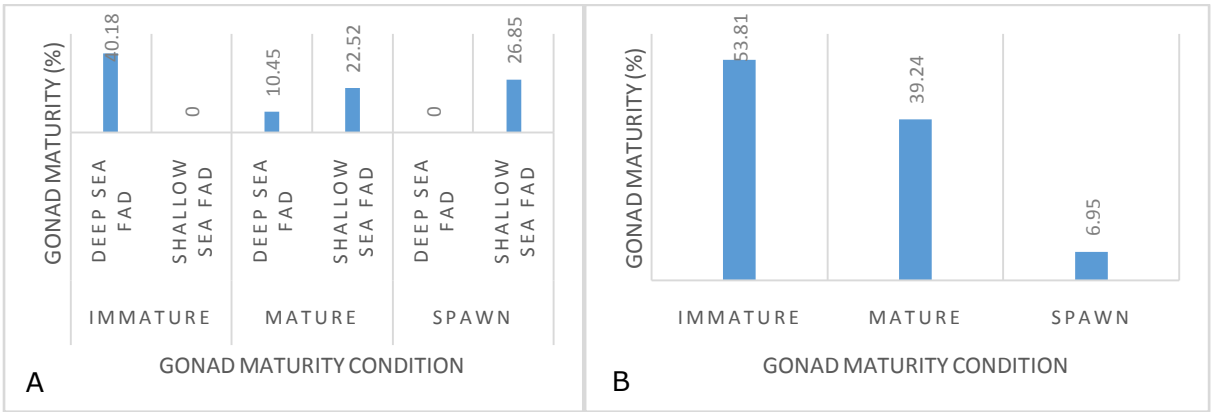

Figure 5. Gonad maturity condition of *Tunnus albacares* from July 2013 to June 2014 (A) and from January to December 2011 (B) in deep sea FAD in Makassar Strait.

The smallest *T. albacares* of mature gonad captured has the fork length of 102.52 cm with 21.60 kg in shallow FAD and 105.29 cm with 23.20 kg in deep sea FAD. Kantun (2012b) obtained gonad mature in smallest fish a fork length of 104.70 cm with body weight of 27.90 kg. The first size of mature gonad in this research for shallow FAD was 105.41 cm and in deep FAD was 114.80 cm. It shows a drastically decrease of the first size of gonad maturity if it is compared with previous research, which obtained the mature gonad for the first time in female fish when the size of 118.61 cm was achieved and in male fish of 119.27 cm in the same waters with different research coordinates. In the second transitional season (July to October) the first size of mature gonad for male and female fish was about 119.20 cm, while Kantun et al (2014b) observed in the first transitional season (March to June) that the first size of mature gonad for two kinds of sex was when the fish were about 118.88 cm length. The results show a decreasing at the first size of mature gonad. Fishing during rainy season tends to decrease because the fishermen try to limit the fishing activity on bad weather, so the fishermen captures are mostly from shallow sea FAD. Some comparative studies reveals the first size of different matured gonad (Table 4). Those differences are probably related to research location, sample taking period, fishing method and types of fishing gears used to limit the fish size captured.

Spawning. Observation results toward the gonad maturity development of *T. albacares* in FAD area show that in deep FAD the spawning was about 22.52% (Figure 3A and 5A) while in shallow sea FAD was not found spawning tuna but dominated by immature gonad size (40.18%). In deep sea FAD has been observed a pattern of adult tuna with mature gonad until spawning that prefers to live in deep sea FAD. Shallow sea FAD it is generally dominated by larval stage and juvenile, followed by adult stage; it is also related to life cycle of *T. albacares* when tuna is still young and it will spend more of its life in neuritic area.

After the peak maturity of gonads, most *T. albacares* spawn but progressed gradually (partial spawning). This spawning model enables the existence of *T. albacares* in nature, during the management referred to reproductive aspects like capturing in spawning size, at least once. The more tuna spawns, the more chances to keep its existence. Therefore, it is very important in managing by paying attention to biology aspect of its reproduction in order that its existence can be assured (Kantun et al 2014d).

T. albacares is an oviparous, asynchronous spawning, and the fish spawning all year (West 1990; Schaefer & Fuller 2007); spawning takes place gradually and little by little (Romena 2000; Schaefer 2001; Niwa et al 2003 and Nootmorn et al 2005).

Conclusions

1. Reproductive pattern of *T. albacares* in deep sea FAD is found that started from gonad maturity of maturing, mature and spawn, while in shallow sea FAD is limited in gonad maturity of immature and maturing gonads.
2. The peak of primary gonadal maturity occurs in October-March.
3. The first size of mature gonad in deep sea FAD is associated with fork lenght size of 114.80 cm while in shallow sea FAD is 105.41 cm.

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