Performance of yellowfin tuna spawning (*Thunnus albacares*) in floating net cage

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Abstract. Yellowfin tuna (*Thunnus albacares*) is an important export commodity in Indonesia. This tuna has an important economic value, so it becomes one of the foreign exchange that can provide solutions to the national economy. Yellowfin tuna hatchery technology that was carried out at the Research Institute for Mariculture and Fisheries Extension, with the management of broodstock maintenance in floating net cages has successfully spawned. However, the quality and quantity of eggs produced are still not optimal. This research was conducted in floating net cage with a diameter of 48.8 m with a depth of 8 meters, filled with 30 fishes of yellowfin tuna with body weights ranging from 60-80 kg per fish. Feed given is: fresh fish, squid and added vitamin C and vitamin E. The parameters observed were: spawning frequency, number of eggs produced, hatching rate, egg diameter, diameter of oil globule and the survival activity index value of newly hatched larvae (SAI). As supporting data, water quality observations were carried out which included: temperature, salinity, and water brightness on the floating net cage. This research was conducted for 10 months, from January to October 2019. Data analysis was carried out in descriptively. The results showed that yellowfin tuna reared in floating net cage can spawn well. Spawning occurs every month. The highest spawning frequency in October is 20 times spawning. While the highest total number of eggs successfully harvested was 11,030,000 eggs in August. Hatching rate between 70.5-92.2%. The survival activity index of newly hatched larvae (SAI) is 2.4-3.7

1. Introduction
The yellowfin tuna (*Thunnus albacares*) is a fish built for speed and endurance. Its streamlined body is metallic dark blue on the back, blending into yellow or silver on the belly. The belly is patterned with numerous broken lines, on each side of the body, a bright golden strip runs along from the eye to the tailpiece. This species has two dorsal fins, the second one of which can be extremely long and is located right over the long anal fin. The pectoral fins on each side of the body are also long, often reaching beyond the space between the two dorsal fins. The fins can be retracted, makes water flows even more smoothly over its body when swimming. The finlets present from the second dorsal fin and the anal fin to the tail. These finlets, along with the dorsal and anal fins, are bright yellow, giving this fish its common name. A narrow black band joins these finlets. The yellowfin tuna has a strongly fusiform shaped, and is most profound under its first dorsal fin and tapering considerably towards the caudal peduncle.

There are two dorsal fins present. In mature fishes, the dorsal fin and the anal fin are very long, and they become relatively longer in bigger individuals. The pectoral fin is also quite long compared to
other species, reaching of three sets of keels. There are seven to ten dorsals and ventral finlets present. A band of large scales forms a circle around the body behind the head, and scales are lacking behind the corselet. Yellowfin tuna have small eyes and conical teeth. A swim bladder is also present in this tuna species. This species can weight about 180 kg per each, and when matured enough it can reach to 450 kilograms. Yellowfin tuna prey includes other fish, pelagic crustaceans, and squid. Yellowfin tuna often travel in schools with similarly sized companions.

Indonesia region such as the Flores Sea and Makassar Strait have a high potential of this species. They also live in North Halmahera, North Maluku, Bali and others. The Yellowfin tunas are not only consumed by the locals but also one of the potential export commodities. The export destination countries including Japan, China, and United States of America. In Japan, the yellowfin tuna is used or served for sushi and sashimi.

Yellowfin tuna hatchery technology in Research Institute for Mariculture and Fisheries Extension Gondel Bali has begun success of spawning and seed production technology to reach more than 60 days [1, 2]. With the success of spawning, larval rearing and yellow fin tuna nursery is expected to be developed soon and can be applied in the community as a profitable business. Therefore tuna research activities are always new innovations in terms of accelerating spawning, larval rearing technology and breeding techniques as well as improvements to their reproductive techniques. Like milkfish, cobia fish [3], tiger pompano (Gnathanodon speciosus) [4] and humpback grouper fish [5, 6, 7], which are initiated with gonad maturation and spawning technology. With the passage of time the technology can be mastered well until the successful mass production of the seeds. Likewise for yellow fin tuna, we must recognize the biological nature, especially the reproductive aspects of the fish in nature [8].

Nevertheless tuna commodities are facing a number of challenges, including: declining productivity, decreasing size, and fishing areas that tend to go out to sea [9]. While the Indonesian fisheries management area (WPPI) status of the exploitation level of albacore, yellowfin tuna, big eye and bluefin tuna has been very concerned with the status of overfishing [10]. Yellowfin tuna economically has a wide market share with high prices. Not surprisingly, in recent years there has been a decline in the amount of tuna catches [11]. Research on the reproduction of yellowfin tuna (Thunnus albacares) is gradually being carried out. Several studies have been carried out including: research on catching prospective tuna fish broodstock [12]; domestication of prospective tuna fish broodstock; indoparasit life cycle that infects tuna eggs [13]; Observation of the development of yellowfin tuna embryo [14, 15]; profile of yellow fin tuna spawning in a controlled tank by mitochondrial DNA (mt-DNA) analysis [1]; determination of genetic variation in catches at sea [16] and spawning performance of yellowfin tuna broodstock in concrete tank and floating net cages [17]. However, the quality and quantity of eggs and seeds production are still not optimal. The number of eggs and hatching rate is still fluctuating. This study aims to determine the continuity of spawning of yellowfin tuna that are kept in floating cages. The target to be achieved is the production of high quality eggs to support the success of seed production.

2. Methodology
The individuals used in this experiment were the yellowfin tuna broodstock which is continuation of the 2018. Using 1 floating net cage 48.8 m in diameter with a depth of 8 meters as a maintenance medium filled with 30 fishes yellowfin tuna broodstock. Body weights ranging between 60-80 kg per fish. Yellow fin tuna feed is given in the form of: fresh fish, squid and added Vitamin C and Vitamin E. The amount of feed given is between 3-5 percent of biomass. Feed is given once a day in the morning. This research was conducted for 10 months, from January to October 2019. Cleanliness in the net must be maintained so that the flow and oxygen in the floating net cage remain optimum. For that the net cleaning is done periodically.

The parameters observed were: Frequency of spawning, total number of eggs produced, hatching rate, egg diameter, diameter of oil glubole and the index activity value of newly hatched larvae (SAI).
As supporting data, observations of water quality include: temperature, salinity, and brightness of water in floating net cage. Data analysis is done descriptively.

3. Results and discussion

Yellowfin tuna (Thunnus albacores) is a type of marine fish whose life likes to cross the globe, cluster, fast swimmers and classified as fish that are difficult to catch. It turns out that through a series of research activities it can gradually be spawned in the tank or in a floating net cage by controlled.

Table 1. Observation results of spawning of yellowfin tuna during the study.

| Date | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1    | 0   | 4500| 0   | 0   | 77  | 0   | 0   | 3841| 0   | 0   |
| 2    | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| 3    | 0   | 55  | 0   | 0   | 1426| 0   | 0   | 894 | 0   | 0   |
| 4    | 0   | 0   | 0   | 0   | 32  | 0   | 111 | 0   | 0   | 0   |
| 5    | 0   | 0   | 0   | 0   | 0   | 0   | 102 | 34  | 0   | 310 |
| 6    | 0   | 23  | 0   | 0   | 0   | 661 | 0   | 0   | 0   | 0   |
| 7    | 0   | 0   | 0   | 0   | 242 | 0   | 0   | 2071| 0   | 1122|
| 8    | 0   | 0   | 0   | 0   | 8   | 28  | 21  | 1326| 0   | 0   |
| 9    | 0   | 0   | 0   | 0   | 5014| 0   | 0   | 463 | 8158| 45  |
| 10   | 0   | 0   | 0   | 10  | 92  | 0   | 6170| 688 | 0   | 0   |
| 11   | 0   | 0   | 34  | 672 | 1979| 0   | 2044| 0   | 807 | 961 |
| 12   | 0   | 0   | 1880| 20  | 163 | 2185| 755 | 3332| 200 | 0   |
| 13   | 0   | 0   | 626 | 0   | 367 | 26  | 94  | 895 | 1622| 280 |
| 14   | 0   | 0   | 0   | 0   | 1067| 71  | 0   | 483 | 31  | 0   |
| 15   | 0   | 64  | 652 | 2300| 0   | 4738| 0   | 480 | 0   | 0   |
| 16   | 0   | 0   | 285 | 0   | 112 | 0   | 2009| 0   | 0   | 188 |
| 17   | 0   | 0   | 70  | 540 | 0   | 65  | 710 | 0   | 0   | 63  |
| 18   | 0   | 43  | 974 | 941 | 0   | 2371| 298 | 0   | 0   | 18  |
| 19   | 0   | 62  | 285 | 312 | 0   | 185 | 3660| 1036| 0   | 0   |
| 20   | 0   | 1423| 563 | 0   | 0   | 1349| 195 | 820 | 0   | 0   |
| 21   | 112 | 32  | 32  | 0   | 1358| 122 | 0   | 533 | 0   | 118 |
| 22   | 0   | 21  | 285 | 0   | 135 | 46  | 558 | 0   | 0   | 334 |
| 23   | 1000| 0   | 430 | 644 | 222 | 0   | 3055| 687 | 244 | 227 |
| 24   | 150 | 0   | 0   | 1552| 27  | 60  | 1302| 680 | 0   | 100 |
| 25   | 200 | 17  | 0   | 138 | 182 | 95  | 2210| 430 | 125 | 139 |
| 26   | 0   | 12  | 58  | 0   | 0   | 0   | 100 | 1319| 0   | 297 |
| 27   | 0   | 0   | 32  | 0   | 0   | 1479| 2210| 504 | 0   | 417 |
| 28   | 130 | 0   | 0   | 0   | 0   | 0   | 1319| 430 | 0   | 1702|
| 29   | 0   | 0   | 0   | 914 | 0   | 0   | 340 | 2550| 0   | 31  |
| 30   | 2000| 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1664|
| 31   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 201 |

From Table 1 it can be seen that yellowfin tuna reared in floating net cage can spawn every month. The existence of yellow fin tuna eggs in the collector installed every day shows an indication that the tuna are spawning. In figure 1 the highest number of eggs found in the collector occurred on spawning on September 9, 8158 eggs. The second largest number of eggs in the collector occurred on August 10, amounted to 6170 eggs.
During the research activities of maintaining yellowfin tuna broodstock in floating net cages with productive broodstock sizes, optimal feeding management and an environment within tolerance it turns out that yellowfin tuna broodstock can spawn well every month. The results of studies and research conducted by [8] regarding the reproduction of yellowfin tuna in nature by looking at the histological results of tuna gonads obtained from catches of longline tuna ships that operate in the Indian Ocean and landed in the Benoa port state that fish spawning season Yellow fin tuna occur throughout the year. However, even though every month the tuna that are kept in floating net cage spawn, but no harvesting every time the spawning occurs. This is done by considering the presence of large sea waves, heavy rain, and egg quality is no good.

The results of experiment conducted by [13] stated that yellowfin tuna which were kept in a controlled concrete tank first spawning measuring 20 kg. Furthermore it is said that yellowfin tuna can grow and even spawn naturally both in round concrete tanks with a volume of 1,500 m³ and in floating cages [17]. The results of subsequent studies, [2] said that yellowfin tuna reared in floating net cage aged 2 years can spawn and produce a good spawning performance. The results of the analysis of the number of eggs in the collector and the yield at the same time of spawning showed that there was no positive correlation. In figure 2 the results also showed that the correlation coefficient between the number of eggs in the collector and the number of egg harvests obtained was not strong (R^2 = 0.0213).

Figure 1. Results of observing the number of eggs in the collector during the experiment
Figure 2. Relationship between the number of eggs in the collector and the number of eggs harvested

Yellowfin tuna that have been raised in KJA and are able to spawn every month, although not every spawning is harvested (Figure 3). In figure 3 shows that in January there were 6 spawns and only one harvest. Furthermore, in succession in February, March, April and May there were spawning of 10, 15, 11 and 16 times each harvesting of 1, 2, 1 and 3 harvested. In June, July, August, September and October there were 14, 20, 19, 11 and 20 spawning, and 1, 5, 9, 0 and 3 were harvested, respectively. Therefore the highest spawning frequency is in July and October. While the lowest in September did not occur spawning. Yellowfin tuna in the East Pacific Ocean apparently also spawn throughout the year and there are peak spawning in certain months [14].

Figure 3. Observation of spawning and harvesting of yellow fin tuna eggs in floating net cage
Furthermore, the results of observations of the total number of yellowfin tuna eggs from harvests carried out during the study are shown in figure 4. The highest total number of eggs in August was 11,030,000 eggs. Whereas the second and third ones were in January and October 4,000,000 and 3,399,333 eggs, respectively.

![Figure 4](image)

**Figure 4.** Observation of the total number of yellowfin tuna eggs successfully harvested during the experiment.

| Month   | Egg Diameter (µm) | Diameter of oil globule (µm) |
|---------|-------------------|------------------------------|
|         | Avrge  | Max.  | Min.  | Std.dev. | Avrge  | Max.  | Min.  | Std.dev. |
| January | 842.5  | 862.4 | 806.1 | 15.5     | 195.8  | 219.6 | 168.4 | 12.6     |
| February| 938.7  | 969.9 | 897.9 | 19.8     | 204.5  | 224.7 | 163.2 | 18.9     |
| March   | 880.4  | 908.2 | 831.7 | 17.9     | 831.8  | 209.4 | 168.5 | 13.6     |
| April   | 802.2  | 827.1 | 765.4 | 8.2      | 180.0  | 188.9 | 163.4 | 6.9      |
| May     | 839.6  | 867.4 | 821.7 | 13.8     | 195.2  | 214.5 | 178.6 | 8.1      |
| June    | 862.9  | 892.9 | 816.3 | 22.1     | 199.7  | 224.4 | 181.3 | 10.6     |
| July    | 871.1  | 913.3 | 837.5 | 21.9     | 191.6  | 209.4 | 178.6 | 8.9      |
| August  | 891.2  | 928.6 | 863.2 | 15.4     | 208.2  | 220.4 | 188.8 | 8.5      |
| Septimb | 917.3  | 946.3 | 875.8 | 20.8     | 214.5  | 232.7 | 191.8 | 9.8      |
| October | 899.1  | 924.3 | 854.1 | 19.1     | 201.9  | 227.1 | 178.7 | 12.2     |

The total number of eggs successfully harvested every time a spawning occurs is very fluctuation. This also occurs in other marine fish, such as sunu grouper [18], humpback grouper fish [19, 20]; tiger pompano [4] and cobia fish [3]. One reason for the poor quality of eggs depends on the type / nutrition of the feed given, the frequency and dosage of the right feed, fish density and fish size [6]. This was confirmed by the results of research by [18] that one of the important nutrient requirements for marine fish, such as groupers and other marine fish is protein.
Therefore the availability of feed that has the right nutritional value will have an impact on the quality and quantity of eggs produced. Nutrient content that meets the requirements and adequate chemical composition of feed is an important factor to produce the perfect oocyte development. The quality and quantity of yellowfin tuna eggs that are kept in the floating net cage which includes the diameter of the egg and also the diameter of the oil bubble is influenced by the content of protein, phosphorus, pigments and essential fatty acids. Therefore, the adequacy of vitamin C and vitamin E can accelerate the process of vitellogenesis. In Table 2 the results of observations of the diameter of the yellow fin tuna eggs during the experiment took place a maximum: 969.9 μm and a minimum: 765.4 μm. While the diameter of the oil bubble, a maximum of 232.7 μm and a minimum: 163.2 μm.

The results of this study are in line with the results of a study conducted by [2] that the diameter of the yellow fin tuna eggs reach 900 μm and the diameter of the oil globule 200 μm. Egg quality is a reflection of the chemical composition of the yolk which is influenced by the nutritional state of the

### Table 3. Observations result of hatching rate and activity index of newly hatched larvae (SAI) during the experiment

| Month   | Hatching rate (%) | Survival activity index (SAI) |
|---------|-------------------|-------------------------------|
| January | 85.8 - 91.5       | 2.8 - 3.4                     |
| February| 83.0 - 85.2       | 2.9 - 3.0                     |
| March   | 86.2 - 87.4       | 3.0 - 3.2                     |
| April   | 84.6 - 85.0       | 3.2 - 3.4                     |
| May     | 88.8 - 90.2       | 3.0 - 3.6                     |
| June    | 90.0 - 92.2       | 2.8 - 3.2                     |
| July    | 70.5 - 72.3       | 2.8 - 3.7                     |
| August  | 72.0 - 76.2       | 2.9 - 3.4                     |
| September| 70.5 - 74.4     | 2.7 - 3.2                     |
| October | 75.2 - 80.5       | 2.4 - 3.4                     |

### Table 4. Water quality parameters of yellowfin tuna in floating net cage

| Month   | Temperature (°C) | Salinity (ppt) | Brightness of water (m) |
|---------|------------------|----------------|-------------------------|
| January | 28.3 - 29.8      | 32.0 - 33.6    | 12.0 - 14.5             |
| February| 28.5 - 30.5      | 31.5 - 33.5    | 13.5 - 15.0             |
| March   | 28.2 - 30.5      | 32.0 - 34.0    | 12.8 - 15.0             |
| April   | 28.0 - 30.5      | 32.8 - 33.8    | 13.5 - 14.5             |
| May     | 28.4 - 29.8      | 32.0 - 34.0    | 14.5 - 15.0             |
| June    | 27.5 - 30.4      | 33.0 - 34.0    | 14.3 - 15.0             |
| July    | 28.4 - 30.2      | 33.5 - 34.0    | 14.0 - 14.5             |
| August  | 28.2 - 29.5      | 33.5 - 34.0    | 14.5 - 15.0             |
| September| 28.2 - 30.3     | 33.5 34.0      | 14.3 - 15.0             |
| October | 28.5 - 31.5      | 33.5 - 34.0    | 14.5 - 15.0             |
feed and the condition of the parent. Egg size can be genetic as indicated by the small variation in egg size or as a result of the influence of food and the environment. Likewise, egg size has a role in the survival and growth of post larvae produced. The size of the yellow fin tuna egg diameter which has a range between 765.4 - 969.9 μm is almost the same as the diameter of the humpback grouper eggs [5].

In general, the hatching rate of yellowfin tuna eggs during the experiment was quite good. The highest reached 92.2%, which was produced in June. The results of research on egg hatching rate of marine fish, such as cobia fish [3], golden trevally fish [4] and humpback grouper [6] that have hatching rate below 40% will affect the larvae produced. While the survival activity index (SAI) is the ability to live in newly hatched larvae by relying on energy reserves, namely egg yolks and oil droplets. In Table 3 the index of larval life activity is closely related to the quality of eggs produced from spawning of yellowfin tuna that are reared in floating net cage. From table 3 it can be seen that the results of SAI during the experiment ranged from 2.4 - 3.7. The results of this SAI can illustrate that the higher SAI value is an indicator of high egg quality. Therefore, if the SAI value is high enough it is to be able to increase the larvae growing.

In tropical waters the difference or variation in sea water temperature throughout the year is not too large. In Table 4 the results of observing sea water temperatures in the floating net cage range between 27.5 °C - 31.5 °C. This temperature range is normal for marine fish culture. While the salinity range between 31.5-34.0 ppt. The water brightness between 12.8 - 15.0, this is greatly influenced by water conditions such as turbidity, thickness, color and surface water waves. The higher the turbidity level of water the shallower the light that can penetrate the water (light penetration). Similarly, the size of the ocean waves will affect the translucency in water. Thus the results of observations of water quality parameters which include: temperature, salinity and brightness of the waters are in the optimal range in supporting the process of gonad maturation and spawning of yellowfin tuna in floating net cage.

4. Conclusion
The results showed that yellowfin tuna reared in floating net cage can spawn well. Spawning occurs every month. The highest spawning frequency in July and October is 20 times. While the highest total number of eggs successfully harvested was 11,030,000 eggs in August. Hatching rate between 70.5-92.2%. The survival activity index (SAI) is 2.4-3.7.

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