

Success in gonad maturation and spawning of sea cucumbers (*Stichopus horrens* Selenka, 1867) raised in captivity

¹Jhon Harianto Hutapea, ¹Ketut Maha Setiawati, ²Zeny Widiastuti, ¹Sari Budi Moria Sembiring, ¹I Nyoman Adiasmara Giri

¹ Research Center for Fisheries, National Research and Innovation Agency, Cibinong, Bogor, 16912, Indonesia; ² Brackishwater Aquaculture Development Center, Situbondo, 68351, Indonesia. Corresponding author: J. H. Hutapea, hutapeaharianto@gmail.com

Abstract. *Stichopus horrens* Selenka, 1867, commonly known as Selenka's sea cucumber and locally named gamat in Indonesia, is heavily exploited from its natural environment and natural populations are in decline. Therefore, aquaculture rearing is needed to maintain the processing business and to reduce the exploitation of gamat natural population. Understanding the spawning profile of gamat in captivity was the main objective of this study. Observations were made on growth rate, spawning pattern, number of eggs produced, eggs diameter and hatching rate. Candidate broodstock is obtained from the Northern Bali Sea in 2019 and reared in a 4 m³ round fiberglass reinforced plastic tank. The water exchange rate was 400% per day and fed with *Ulva* sp. and *Sargassum* sp. at 3-5 % of body weight per day. Spawning is carried out from 2020 to 2022. Prior to spawning, broodstock selection is carried out to obtain 15-20 individuals from total broodstock in captivity, which are most likely to spawn. Average body weight initially was 115.50 ± 7.78 g and increased to 260.00 ± 90.00 g in the first year. During three consecutive years of experiment, they spawn throughout the year in the new moon phase. The number of eggs produced varied between 105,000 – 3,000,000 eggs, egg diameter was between 180 – 270 µm and hatching rate ranged from 38% to 99.5%. In conclusion, captive gamat sea cucumbers fed with fresh grounded seaweed and naturally grow benthos on the inner walls of tank, can be grown to become broodstock, support gonadal maturation, spawning and re-maturation.

Key Words: eggs quality, gamat, spawning profile.

Introduction. Sea cucumber is an important export commodity to the markets of Europe, Japan, Singapore, South Korea, and America. There are 60 species of sea cucumbers caught and utilized by more than 40 countries in the world (FAO 2010). The main supplier countries of sea cucumber in the international market include Indonesia, Hong Kong, The Philippines, New Caledonia, Maldives, India, and Sri Lanka (Albar et al 2013). The price of sea cucumber in the export market ranges from 1.4 to 112.50 USD (Conand 1989) and depends on species and its processed products. The development of Indonesian sea cucumber exports increased every year and in 2000 became the largest sea cucumber exporter, reaching 2,500 tons (Conand 1989; Ferdouse 2004). The increasing demand for the Asian market has broadly impacted the increasing exploitation of sea cucumbers in various producing countries (FAO 2010). In addition, since the late 1990s the exploitation of sea cucumbers has increased with the use of natural products and as aquarium animals. National regulations for sea cucumber protection in Indonesia do not yet exist even though sea cucumbers have been included in the 20-priority program of Coastal and Marine Resources Management Center (MMAF) (KKP 2015). Meanwhile, the Convention on International Trade of Endangered Species (CITES) in Plants and Wildlife has included several species of sea cucumbers in Appendix II, namely *Holothuria fuscogilva*, *Holothuria nobilis*, and *Holothuria whitmaei*, because of the increasing possibility of extinction (FAO 2010), and *Stichopus horrens* on the Yellow list due to data deficiency (SeaLifeBase 2024), where all uses of nature and trade will be

limited based on agreed quotas with due regard to resource sustainability. The purpose of this study is to determine aspects of reproductive biology (broodstock size, number of eggs produced, hatching rate of eggs) to understand the spawning profile of gamat (*Sticophus horrens* Selenka, 1867).

Material and Method. This research was conducted at the Institute for Mariculture Research and Fisheries Extension (IMRAFE)-Gondol, which is now, the research facility and human resources affiliate to the Research Center for Fishery-Research Organization for Earth Sciences and Maritime, National Research and Innovation Agency, Indonesia. The container used for rearing was a round fiberglass reinforced plastic (FRP) tank with a capacity of 4 m³. The water exchange system used was running water with a discharge of 8-9 L min⁻¹ (400% water exchange per day). With a flowing water system, water quality parameters such as temperature, salinity, pH, and dissolved oxygen were monitored every morning and showed optimal values: 29.0 ± 1.0°C, 33.0 ± 1.0 ppt, 8.25 ± 0.01 and 5.01 ± 0.01 mg/L respectively. The animals used were gamat sea cucumbers harvested from their natural environment in the Gerokgak sub-district, Buleleng Regency-Bali. Twenty-five candidate broodstock were reared with an average size of 19.50 ± 2.45 cm in total length and 115.50 ± 7.78 g in body weight. During rearing, candidate broodstock were fed with ground *Sargassum* sp. and *Ulva* sp. at a rate of 3 - 5% of their body weight per day (Setiawati et al 2021).

Spawning was carried out before or on a new moon phase. The broodstock to be spawned were fasted for 1-2 days to reduce the feces released at the time of spawning and to not contaminate the spawning medium. Because there is no specific morphological difference between males and females, spawning is carried out by mixing all broodstock who have been categorized as ready to spawn into one spawning container. Broodstock was put into a 200 L fiberglass tank filled with UV sterilized sea water and the tank was covered with a black plastic sheet to keep temperature around 29-30°C and let the broodstock spawn naturally. After spawning, fertilized eggs were harvested and rinsed with UV sterilized sea water to remove any remaining sperm. The eggs were incubated in a 200 L fiberglass tank for 24 hours. The number of eggs, fertilization rate and hatching rate were counted based on sampling. Three sub samples of 25 mL were taken on each occasion and calculated based on the formula below:

$$\text{Number of eggs} = \frac{n_1 + n_2 + n_3}{3v} \times V$$

Where:

n₁, n₂, n₃= number of eggs or larvae in sub sample 1, 2 or 3

v = volume of sub sample (mL)

V = total volume of water in incubation tank (mL)

The broodstock were temporarily removed to clean the tank and then returned to the spawning tank for several days to obtain spawning frequency. The data collected include length measurement and body weight, spawning frequency, number and hatching rate of eggs. The research data are presented in tables and figures and analysed descriptively.

Results and Discussion

Gonad maturation and spawning of broodstock. The cultivation and gonadal maturation of candidate broodstock have been carried out since January 2019 with an initial average total length of 19.50 ± 2.45 cm and a body weight of 115.50 ± 7.78 g. Within 12 months in captivity and feeding with *Sargassum* sp. and *Ulva* sp., in January 2020, average body weight has reached 260 ± 90 g, total length 23.2 ± 2.0 cm and in the first attempt, these specimens were successful in spawning (Table 1; Figure 1). The size was very far below the size reported by SeaLifeBase (2024) at 27 cm and Tehranifard et al (2006) at 31 cm total length. Biological data such as length at first

maturity, spawning and fecundity are limited for *Stichopus horrens*. Broodstock can spawn naturally by covering the tank with black plastic sheets that allow to increase temperature to 29-30°C. For species from temperate zones, the sea water temperature is more pronounced, both in gonadal maturation and spawning. When temperature increases, gonad maturation occurs, with spawning in summer, while during winter they experience a resting phase (Balogh et al 2019).

Table 1
Average of total length, body weight, number of broodstock and spawning attempt, and spawning success of *Stichopus horrens* during 2020 – 2022

Year	TL (cm)	BW (g)	Number of mature broodstock (ind.)	Spawning attempts	Spawning success (%)
2019	19.50 ± 2.45	115.50 ± 7.78	0	0	0
2020	23.20 ± 2.00	260.00 ± 90.00	19 - 24	10	100
2021	23.30 ± 1.40	420.00 ± 94.40	18 - 20	7	71
2022	20.70 ± 1.20	296.00 ± 50.00	24 - 25	4	50

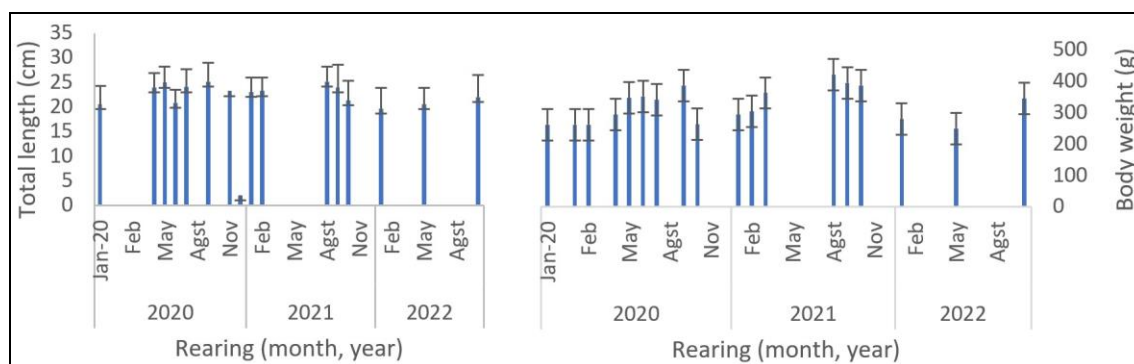


Figure 1. Total length and body weight of *Stichopus horrens* broodstock during 2020 – 2022.

The number of broodstock used for spawning varies between 18-25 individuals, depending on visual appreciation of ripeness of broodstock. Selected broodstock is then put into one spawning tank. Figure 2 shows the total number of eggs per spawning.

In 2020, the weight of broodstock used for spawning fluctuated. In January 2020, the average was 260 ± 90 g, during the year there were several fluctuations of body weight (Figure 1). Spawning was carried out in January, February, April, May, June, July, September, and October, 10 times, and broodstock always spawned. In January and February broodstock spawn twice each. The number of eggs produced varies between 180,000-3,000,000 eggs, the lowest being in January and the highest in September.

In 2021, the weight of the broodstock was significantly increased and in August 2021 reached 420 ± 94.4 g. Spawning was carried out 7 times (January, February, March, May, July, September, October) but in May and July there was no broodstock spawn. The highest number of eggs produced was 2,400,000 eggs in February and the lowest was 330,000 in September.

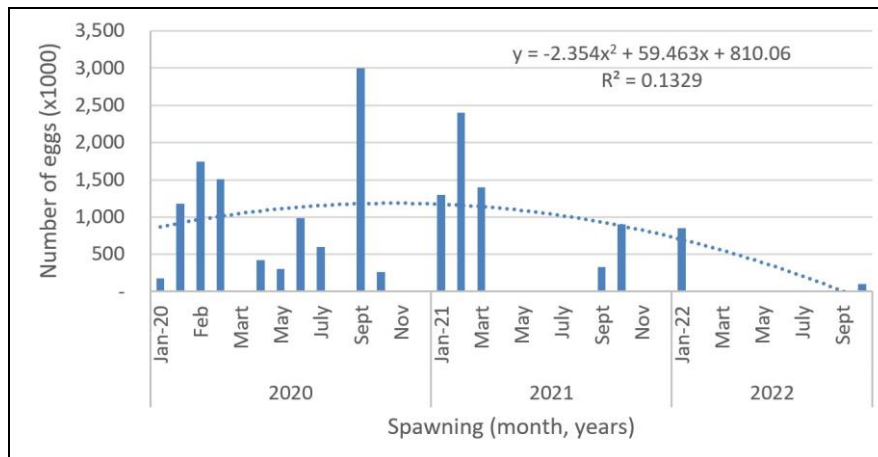


Figure 2. Spawning frequency and number of eggs produced during the *Stichopus horrens* spawning experiment in 2020 – 2022.

At the end of 2021, the body weight of broodstock again fluctuated and reached the lowest at 296 ± 50 g in January 2022. Fortunately, the weight again increased to 340 ± 50 g in October 2022 (Figure 1). In 2022, spawning was carried out 4 times but the broodstock spawned only 2 times: in January, when even though body weight of broodstock was at the lowest, the broodstock was still able to produce 850,000 eggs and in October, when with very good body weight, broodstock only produced 105,000 eggs. Referring to Tehranifard et al (2006), sea cucumber *Stichopus hermanni* undergoes first gonads maturation at 31 cm total length with 200 μ m mean oocyt diameter. Meanwhile, Conand (1993) reported for *Stichopus variegatus*, first sexual maturity at 27 cm with ripe oocyt of 180 μ m, *Stichopus vastus* at the total length of 269-286 mm (Sulardiono 2011) and for *Stichopus horrens* 114 μ m oocyt diameter (Hu et al 2013). It seems the eggs diameter depends on broodstock size, season, and feed quality. In this experiment, the eggs size was above other references from the speciality literature and were ranging between 200-210 μ m. This could be due to different measurement time after spawning. The size of the egg slightly increases during the incubation period, because as the embryo develops closer to the hatching time, the eggshell becomes more permeable and allows water absorption, which increases pressure inside the egg, causing the egg's diameter to slightly enlarge. This is useful for facilitating the hatching process. Setiawati et al 2021, found that eggs diameter of *Stichopus* sp. have a wide variation from 100 to 280 μ m, even though they were fed with nearly the same feed.

It is demonstrated that gamat broodstock fed with grounded *Ulva* sp., *Sargassum* sp., and naturally grow benthos on the walls of the rearing tank, can support gonad maturation, spawning and re-maturation repeatedly in the period of 2020-2022, but was not efficient for sustainable spawning. Spawning sustainability of *Stichopus* sp. relates to the type of feed and organic matter available (Tanita et al 2021), like in coral waters and fine sandy habitats. In addition, *Stichopus hermanni*, was found to consume diatoms, blue-green algae, and microbenthic animals such as nematodes, foraminifers, and gastropods (Fariba et al 2017). Furthermore, success in artificial spawning of *Stichopus* sp. broodstock reported by Agudelo and Rodriguez (2015) by feeding them with *Spirulina* powder and subsequently a mixture of marine sediment and *Spirulina* powder.

The observations within 3 years of broodstock rearing and spawning process, there was noted a tendency to decrease in spawning success, and a decrease in the number of eggs produced as the time in captivity increases (Table 1; Figure 3).

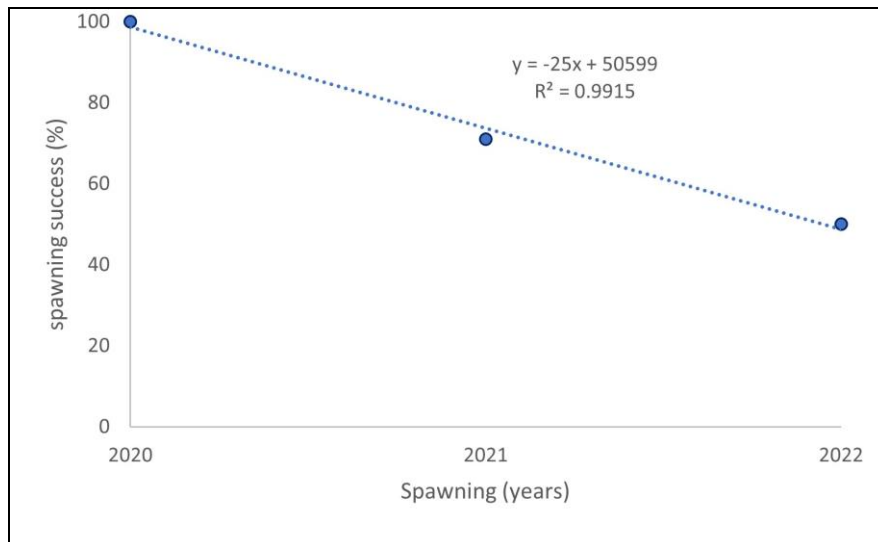


Figure 3. Percentage of spawning success of *Stichopus horrens* during 2020 - 2022.

The figure above shows that percentage of spawning success of gamat sea cucumber which are cultured in FRP tank and fed with *Ulva* sp. and *Sargassum* sp. This was the first successful spawning of *Stichopus horrens* ex-situ in Indonesia and it was shown it can spawn several times within 3 years in captivity. The decrease in spawning frequency seen in Figure 2, is perhaps due to the limitations of the combination of feed given. As the previous result by Setiawati et al (2021), *Stichopus* sp. performed better growth and higher gonad weight when fed with a combination of benthos and seaweed. This study proved that in a controlled environment and good feed, the broodstock can provide successful gonadal maturation and re-spawning.

Spawning season. Based on three years of spawning observations of gamat sea cucumber, in an optimal environmental arrangements and sufficient feed both in quantity and quality, broodstock can induce gonad maturation and spawning without seasonal restrictions, especially in 2020. These observations were also made by Hu et al (2013) and Juinio-Meñez et al (2024) that *Stichopus horrens* can spawn throughout the year. In Central Java, Indonesia, in nature, *Stichopus vastus* matured in May and September, then spawning occurs in June and October (Sulardiono 2011) and for *Stichopus hermanni* in the Persian Gulf, Iran, naturally spawning occurs only in July-August period (Fariba et al 2017). Spawning of *Stichopus horrens* follows periodic phases of the moon (Hu et al 2013), which is also true for *Isostichopus badionotus* (Guzman et al 2003; Foglietta et al 2004; Zacarias-Soto et al 2013) and for the species *Stichopus* sp., *Holothuria scabra*, and *Isostichopus fuscus* (Babcock et al 1992; Battaglione & Hamel 2000).

In this experiment, spawning induction method is a modification of the spawning system of *Holothuria scabra* (Sembiring et al 2015), by raising the temperature of the media gradually just by covering the tank using a black plastic sheet. Common artificial spawning induction for sea cucumber is by drying, thermal or microalgae stimulation (Hu et al 2013) and low temperature induction for *Stichopus monotuberculatus* (Cheng et al 2021). Spawning of *Stichopus* sp. can occur in new moon phase, before or after (Balogh et al 2019), between the first and second night after the new moon phase from May to August, both in captivity and in the wild (Agudelo & Rodriguez 2015). In this study, the influence of the new moon phase greatly affects the gamat sea cucumber reproduction. Thus, its influence is possibly related to endogenous rhythms of each species. The greater reproductive rate occurred in September 2020, where three consecutive days of natural spawning took place (Figure 2; Figure 4).

Generally, the main challenge from long-term broodstock rearing in captivity is the inability for repeated re-maturation. This experiment showed it is possible to rear gamat sea cucumber to become broodstock, spawn and achieve re-maturation in captivity (Hu et al 2013). So, it is not necessary to continuously capture broodstock from

nature. Nevertheless, improvements need to be made in feed composition to keep a good quality of spawning and eggs.

Hatching rate of eggs. Hatching rate of eggs from spawning conducted during 2020-2022 varied between 38% and 99.5%. High hatching rate of eggs mostly happens in 2020, with low hatching rates happening twice, once in January 2020 and once in February 2021, while most of the other hatching rates were above 80% (Figure 4). Low hatching rate could be related to environmental conditions, apart from the routinely water quality parameters measured, and highest hatching rate also happens in February 2020.

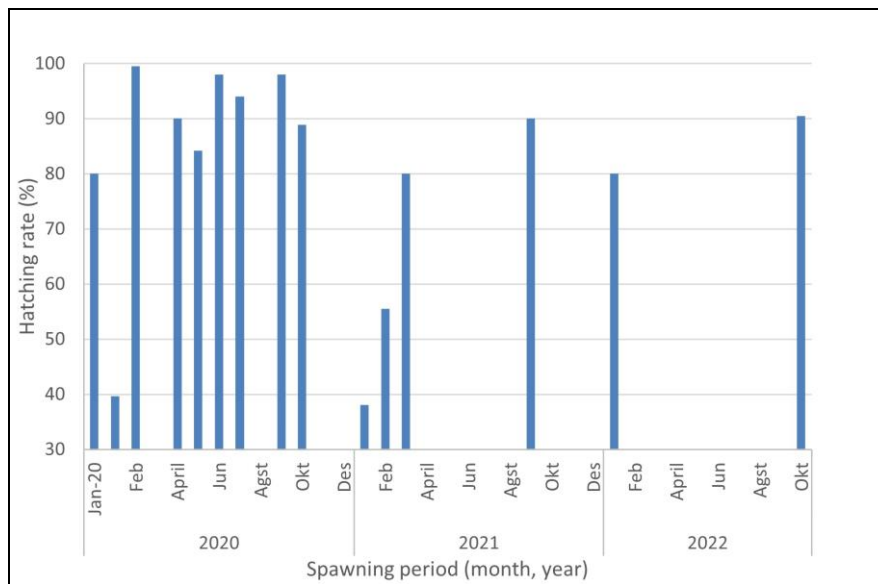


Figure 4. Hatching rate of *Stichopus horrens* eggs, from spawning during 2020 - 2022.

The largest number of fertilized eggs was found in September 2020 (3.0×10^6). The reproductive behaviour of this species is nearly the same as in *Isostichopus badionotus*, showing reproductive peaks from July to November, as described by various authors (Guzman et al 2003; Foglietta et al 2004; Zacarias-Soto et al 2013).

Conclusions. Gamat broodstock with an average size of 22.5 cm and body weight 260 g can provide successful gonadal maturation and re-spawning when a controlled environment and good feed are available. Optimal feed is *Ulva* sp., *Sargassum* sp., and naturally grow benthos on the inner walls of the rearing container. Spawning occurred during 2020 - 2022 observations 15 times with average eggs number per spawning of $1.18 \pm 0.82 \times 10^6$ and hatching rate varying between 38% and 99.5%. There was a tendency to decrease in spawning success and the number of eggs produced as the time in captivity increased.

Acknowledgements. Authors are thankful to the Agency for Marine and Fisheries Research and Human Resources, Ministry of Marine Affairs and Fisheries of The Republic of Indonesia for funding this research. Authors also thanked to sea cucumber hatchery technicians who had worked hard in the implementation of this experiment at the Institute for Mariculture Research and Fisheries Extension, Bali, Indonesia.

Conflict of interest. The authors declare that there is no conflict of interest.

References

- Agudelo V., Rodríguez A., 2015 Advances on spontaneous captive breeding and culture conditions of Caribbean-sea cucumber *Stichopus* sp. SPC Beche-de-mer Information Bulletin 35:50-57.
- Albar A. I., Nurani T. W., Haluan J., 2013 [Sea cucumber fishery business and its development at Thousand Islands, DKI Jakarta Province]. PSP Bulletin 21(3):294-305. [in Indonesian]
- Babcock R., Mundy C., Keesing J., Oliver J., 1992 Predictable and unpredictable spawning events: in situ behavioural data from free-spawning coral reef invertebrates. Invertebrate Reproduction and Development 22(1-3):213-227.
- Balogh R., Wolfe K., Byrne M., 2019 Gonad development and spawning of the vulnerable commercial sea cucumber, *Stichopus herrmanni*, in the southern Great Barrier Reef. Journal of the Marine Biological Association of the United Kingdom 99(2):487-495.
- Battaglione S. C., Hamel J. F., 2000 Settlement preferences and early migration of the tropical sea cucumber *Holothuria scabra*. Journal of Experimental Marine Biology and Ecology 249(1):89-110.
- Cheng C., Wu F., Ren C., Xiao Jiang X., Zhang X., Li X., Luo P., Hu C., Chen T., 2021 Aquaculture of the tropical sea cucumber, *Stichopus monotuberculatus*: induced spawning, detailed records of gonadal and embryonic development, and improvements in larval breeding by digestive enzyme supply in diet. Aquaculture 540(3):736690. <https://doi.org/10.1016/j.aquaculture.2021.736690>
- Conand C., 1989 The fishery resources of Pacific Island countries. Part 2. Holothurians. FAO Fisheries Technical Papers. FAO, Rome. 143 pp.
- Conand C., 1993 Reproductive biology of the Holothurians from the major communities of the New Caledonian lagoon. Marine Biology 116:439-450.
- Fariba R. F., Ehsan K., Mohammad S. R., 2017 Study of feeding regime of sea cucumber *Stichopus herrmanni* using nutritional indices on coral reefs of Southeast of the Qeshm Island, Persian Gulf. Oceanography 8(29):35-41.
- Ferdouse F., 2004 World markets and trade flows of sea cucumber/beche-de-mer. In: Advances in Sea Cucumber Aquaculture and Management. (Editors: Lovatelli A, Conand, C., Purcell, S., Uthicke, S., Hamel, J. F., & Mercier, A.). FAO Fisheries Technical Paper, Rome. 101-118 pp.
- Foglietta L. M., Camejo M. I., Gallardo L., Herrera F. C., 2004 A maturity index for holothurians exhibiting asynchronous development of gonad tubules. Journal of Experimental Marine Biology and Ecology. 303:19-30.
- Guzman H. M., Guevara C. A., Hernández I. C., 2003 Reproductive cycle of two commercial species of sea cucumber (Echinodermata: Holothuroidea) from Caribbean Panama. Marine Biology 142:271-279.
- Hu C., Li H., Xia J., Zhang L., Luo P., Fan S., Peng P., Yang H., Wen J., 2013 Spawning, larval development and juvenile growth of the sea cucumber *Stichopus horrens*. Aquaculture 404-405:47-54.
- Juinio-Meñez M. A., Palomar-Abesamis N., Edullantes C. M., Cabanayan-Soy R., Rioja R. A., 2024 Chapter 50 - Ecology and culture of the warty sea cucumber (*Stichopus* cf. *horrens*) in the Philippines. The World of Sea Cucumbers Challenges, Advances, and Innovations. 783-799 pp.
- Sembiring S. B. M., Hutapea J. H., Sugama K., Susanto B., Giri N. A., Haryanti, 2015 Breeding technology of sandfish (*Holothuria scabra*). In: Technology Recommendation Marine and Fisheries. Agency for Research and Development Marine and Fisheries, Ministry of Marine and Fisheries Affairs, Jakarta. 187-200 pp.
- Setiawati K. M., Widiastuti Z., Sembiring S. B. M., Giri N. A., 2021 Growth and reproduction performance of sea cucumber (*Stichopus* sp.) fed with different feed regime. E3S Web of Conferences 322:02009. <https://doi.org/10.1051/e3sconf/202132202009>
- Sulardiono B., 2011 [Gonadal maturity of commercial species of *Stichopus vastus* sea cucumber (Holothuriidea : Stichopodidae) in Karimunjawa waters, Jepara Districts, Central Java]. Jurnal Saintek Perikanan 7(1):24-31. [in Indonesian]

- Tanita I., Nambu R., Iwasaki T., Sanda T., 2021 Observation of the nursery and microhabitat of juveniles of sea cucumber *Stichopus* cf. *vastus* in the Kabira Bay Marine Protected Area, Ishigaki Island, Okinawa, Japan. *Galaxea Journal of Coral Reef Studies* 23(1):37-38.
- Tehranifard A., Uryan S., Vosoghi G., Fatemy S.M., Nikoyan A., 2006 Reproductive cycle of *Stichopus herrmanni* from Kish Island, Iran. *SPC Beche-de-mer Information Bulletin* 24:22-27.
- Zacarias-Soto M., Olvera-Novoa M. A., Pensamiento-Villarauz S., Sánchez-Tapia I., 2013 Spawning and larval development of the four-sided sea cucumber, *Isostichopus badiotus* (Selenka 1867), under controlled conditions. *Journal of the World Aquaculture Society* 44(5):694-705.
- *** Food and Agriculture Organization (FAO), 2010 The fishery resources of Pacific Island countries. Part 2. Holothurians, *FAO Fisheries Technical Papers*. FAO, Rome, 1990. 143 pp.
- *** Ministry of Marine Affairs and Fisheries of The Republic of Indonesia (KKP), 2015 [National Action Plan 2016 - 2020 Sea cucumber management (NAP Sea cucumber)]. Directorate of Marine Conservation and Biodiversity, Directorate General of Marine Space Management, Ministry of Marine Affairs and Fisheries of The Republic of Indonesia. 11 pp. [in Indonesian]
- *** SeaLifeBase, 2024 *Stichopus horrens* Selenka, 1867 Selenka's sea cucumber. Accessed on 28 March 2024. Available at: <https://www.sealifebase.se/summary/Stichopus-horrens.html>

Received: 30 April 2025. Accepted: 10 June 2025. Published online: 19 December 2025.

Authors:

Jhon Harianto Hutapea, Research Center for Fisheries, National Research and Innovation Agency, Cibinong, Bogor, 16912, Indonesia, e-mail: hutapeaharianto@gmail.com

Ketut Maha Setiawati, Research Center for Fisheries, National Research and Innovation Agency, Cibinong, Bogor, 16912, Indonesia, e-mail: nike011@brin.go.id

Zeny Widiastuti, Brackishwater Aquaculture Development Center, Situbondo, 68351, Indonesia, e-mail: zeny23ast@gmail.com

Sari Budi Moria Sembiring, Research Center for Fisheries, National Research and Innovation Agency, Cibinong, Bogor, 16912, Indonesia, e-mail: sari027@brin.go.id

I Nyoman Adiasmara Giri, Research Center for Fisheries, National Research and Innovation Agency, Cibinong, Bogor, 16912, Indonesia, e-mail: inyo012@brin.go.id

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Hutapea J. H., Setiawati K. M., Widiastuti Z., Sembiring S. B. M., Giri I. N. A., 2025 Success in gonad maturation and spawning of sea cucumbers (*Stichopus horrens* Selenka, 1867) raised in captivity. *AAFL Bioflux* 18(6):2800-2807.