Iranian Journal of Fisheries Sciences
http:doi.org/ 10.22092/ijfs.2025.133122 2025, 24(2) 423-433

Research Article

Structure and organic matter content of the seafloor sediment affect the growth of sea cucumbers (*Holothuria scabra*) reared in sea pens

Giri N.A.[1*], Sembiring S.B.M.[1], Wibawa G.S.[2]; Nasukha A.[1], Sepory R.[1]

1 Research Center for Fishery, National Research and Innovation Agency, Gondol, Bali, Indonesia
2 Institute for Mariculture Research and Fisheries Extension, Gondol, Bali, Indonesia
[*]Correspondence: adiasmaranyoman@yahoo.com

Keywords

Sandfish,
Sea pens,
Growth,
Seafloor sediment,
Organic matters

Article info

Received: June 2023
Accepted: October 2024
Published: March 2025

Abstract

The sea cucumber, *Holothuria scabra* (sandfish), is an important aquaculture species due to its high economic value. This has led to over-exploitation causing population decline; consequently, aquaculture of sea cucumber is required to increase production. This study aims to obtain data and information on the growth performance of sandfish reared in a sea pen culture system and develop its cultivation in coastal areas of Sumberkima Village, Gerokgak District of Buleleng, Bali-Indonesia. Three 10 x 5 m^2 sea pens (KJT), namely KJT-A, KJT-B, and KJT-C, with a 3-m height net, were installed at the site using bamboo and plugged into the seabed to support the net. These three KJTs have different seafloor characteristics from the experimental group. The sediment composition in the KJT-B consisted of loamy sand with high organic matter compared to KJT-A and KJT-C, which were sandy. The sandfish juveniles were stocked into each KJT at a density of 300 individual/pen with an average initial weight of 17.7±6.6 g and an average total length of 6.6±1.2 cm for 180 days. The results showed the daily growth rate of sandfish in KJT-B was the highest (1.44 %/day) when compared with KJT-A (0.92 %/day), and KJT-C (0.96 %/day). These results indicated that the growth of sandfish (*H. scabra*) depends on the structure and composition of the seafloor sediment. The seafloor sediment structures of loamy sand with high organic matter and C-organic content promote the best growth of sandfish.

Introduction

Sandfish, *Holothuria scabra* Jaeger, 1833, has become the most important species of sea cucumber with high commercial value in the Asian market. It is mostly found on sandy or muddy beaches (Pangkey *et al*., 2012) and distributed along the Indo-Pacific waters (Mercier *et al*., 2000). Meanwhile, the extract matters of sea cucumber have a good nutritional value and contain certain active compounds that are used as a functional food and for health purposes (Chatterji *et al*., 2010; Bordbar *et al*., 2011; Karnila *et al*., 2011; Seo and Lee, 2011). This has led to a high demand for sandfish causing over-exploitation, which threatens the sustainability of its wild population (Purwati *et al*., 2010). Therefore, the development of sea cucumber aquaculture provides the opportunity to increase the volume of production. In Indonesia, the aquaculture practice has been supported by the development of hatchery technologies at the Institute for Mariculture Research and Fisheries Extension (IMRAFE) Gondol, Bali. This institute had successfully produced sandfish juveniles on a mass scale (Sembiring *et al*., 2015; Giri *et al*., 2017).

Since sandfish are generally known as a slow-growing species, there is a need for a relatively long period of farming. Some studies reported that sea ranching is an alternate method of raising this species (Hair *et al*., 2016; Han *et al*., 2016; Taylor *et al*., 2016). Through this method, sandfish easily obtain food sources from the surrounding habitats without being supplied. Sea cucumbers belong to the group of omnivores but are more likely to be herbivores (Hauksson, 1979). The species that inhabit coastal ecosystems often filter out seafloor sediment and prey on diatoms, bacteria, detritus, and organic matter (Uthicke and Karez, 1999; Hartati *et al*., 2017). For this reason, accumulated areas that have soft seafloor sediment, which consist of sandy loam substrate and are located in low physical exposure sheltered areas is the best habitat that is rich in food for sandfish (Garcia *et al*., 2015; Mayerle *et al*., 2020). In addition, seagrass beds are also an important habitat for sea cucumbers due to the availability of several types of microorganisms suitable for food. According to Taurusman *et al*. (2013), areas with poor conditions of seagrass need to be rehabilitated before restocking sea cucumber seed. In addition, Wulandari *et al*. (2016) also conducted a study on the suitability of the sandfish (*H. scabra*) farming areas based on parameters of depth, seafloor conditions, brightness, salinity, acidity, protection, dissolved oxygen content, and surface temperature in Kiowa Bay waters, Enggano. This shows that the characteristics of the aquatic environment greatly determine the success of sea cucumber farming by sea ranching and pens system. Han *et al*. (2016), also documented that the key to success in sea ranching is site selection and proper routine management. Tomatala *et al*. (2018), also examined the construction of sea pens that were suitable for the cultivation of sea cucumbers in the seashore of Maluku Tenggara Regency. Furthermore, Juinio-Menez *et al*. (2014), conducted a study on aquaculture to determine the effect of juvenile size, rearing period, and suitability of the location for growth and survival of the species that were maintained in sea pens and floating net cages. The results of their studies showed that the growth of the harvested sea cucumber varied considerably.

This study was conducted to obtain data and information on the growth performance of *H. scabra* which were reared in the sea pens culture system for the development of sea cucumber aquaculture clusters in coastal areas.

Materials and methods

Experimental locations and preparation of sea pens culture system

This study was conducted close to the mangrove area in Sumberkima Village, Gerokgak District, Buleleng Regency, Bali-Indonesia. In this site, there was a flow of water discharged from intensive shrimp ponds that could affect the characteristics of seafloor sediment. The three 10×5 m^2 sea pens (KJT), namely KJT-A, KJT-B, and KJT-C, with a 3-m height net, were installed at the site using bamboo and plugged into the seabed to support the net. Nylon nets with a mesh size of 5 mm were used, and its lower edge was held using a bamboo frame. The net was fitted to the seafloor, buried to a depth of 20 cm, and pressed tightly using a sand-sack weight to prevent sea cucumber from escaping (Fig. 1). Before the seeds were stocked, predatory animals inside the pen such as crabs and starfish were removed.

Figure 1: Sea pens (KJT) used for sea cucumber rearing.

Sandfish juveniles

Sandfish juveniles were produced in the IMRAFE's Sea Cucumber Hatchery, located in Gondol, Gerokgak District, Buleleng Regency, Bali-Indonesia, with an average weight of 17.7± 6.6 g and total length of 6.6 ± 1.2 cm and were stocked at a density of 300 ind./pen (6 ind./m^2). Growth observation was carried out in the sea pens for 180 days. After stocking for 60 days, the weight and total length of thirty samples from each pen culture were measured and were repeatedly conducted every 30 days until the end of the experiment. Also, at the end of the experiment, the number of sea cucumbers in each pen culture was calculated to obtain the survival data. Parameters of weight gain (WG), specific growth rate (SGR), daily growth rate (DGR), and survival rate (SR) of sandfish were calculated based on the following formula:

Weight gain (%) = 100 x (Wt – Wo)/Wo;

Specific growth rate (%/day) = 100 x (ln Wt − ln Wo)/t.

Daily growth rate (g/day) = (Wt – Wo)/t;

Survival rate (%) = 100 x (Nt/No).

Where, Nt and No are the number of sandfish at the end and the beginning of the experiment, Wt and Wo are the average weight of sandfish at the end and the beginning of the experiment, and t is the length of the experiment (days).

Observation of seafloor sediment structure

The relationship between the seafloor sediment characteristics and the growth performance of sea cucumber was determined by analyzing the sediment inside and around the sea pens culture where the sandfish were reared. Sediment samples were collected by a diver using a PVC pipe of 3-inch diameter and length approximately 25 cm as sediment corer. The sediment corer was pushed into sediment vertically, closed the cap to avoid sample disturbance inside the core and slowly brought vertically to the surface. The caps were removed, and water on the top layer was drained using a small plastic pipe (Corner, 2017; Runte *et al*., 2021). The redox potential was immediately measured on-site using Redox Electrode senTix Brand Type Multi 350i probe as well as pH values by pH meter Ohauss Brand Type ST 20. The redox and pH probes were introduced into the water-saturated sediment surface until stable values were obtained. Detection of hydrogen sulfide gas (H_2S) in sediment samples was done by odor testing. Approximately 1 cm sample of sediment surface was taken to measure total nitrogen, total phosphate, organic matter, and organic carbon analysis. These samples were dried on-site by smearing a thin layer on labeled plastic film and exposing them to sunlight for approximately 15-20 min to dry. The samples were then continuously dried in a laboratory oven (Memmert U-30, Germany) at 60°C for two days to complete the water evaporation. The total nitrogen of sediment was determined by the Kjeldahl method (APHA, 2005). The total phosphate was determined following the ascorbic acid method, while organic matter content by loss of ignition at 550°C using a muffle furnace by Gravimetric method SNI 01-2891-1992 (BSN, 1992), and organic carbon was analyzed using titration method (Walkley and Black, 1934). Sediment grain size distribution was determined using the hydrometer method as described by Bouyoucos (1962).

Results

The growth patterns of sandfish reared in the pen culture system for 180 days are presented in Figure 2. Sandfish reared in KJT-B showed the highest specific growth rate (SGR) of 1.44%/day from the initial average weight of 18.0±6.0 g to a final weight of 238.7±94.2 g, or with a daily growth rate (DGR) of 1.23 g/day for 180 days of the culture period (Table 1). Meanwhile, the specific growth rates of the sandfish reared in KJT-A and KJT-C were only 0.92%/day (DGR=0.41 g/day) and 0.96%/day (DGR=0.46 g/day), respectively.

The analysis of the seafloor sediment compositions inside the sea pens (KJT) is presented in Table 2. The sediment texture of the KJT-A and KJT-C was dominated by sand, while KJT-B was classified as loamy sand (Fig. 3). The organic matter content, organic carbon, total-N (N-NH3), and total phosphate (P-PO4) were higher in the sediment of KJT-B compared to KJT-A and KJT-C. Meanwhile, KJT-B with the highest organic matter content showed the lowest sediment pH value. Although the sediment redox values at the three pens culture locations showed negative values, KJT-B had the lowest. This is due to the higher organic matter content of sediment in the KJT-B.

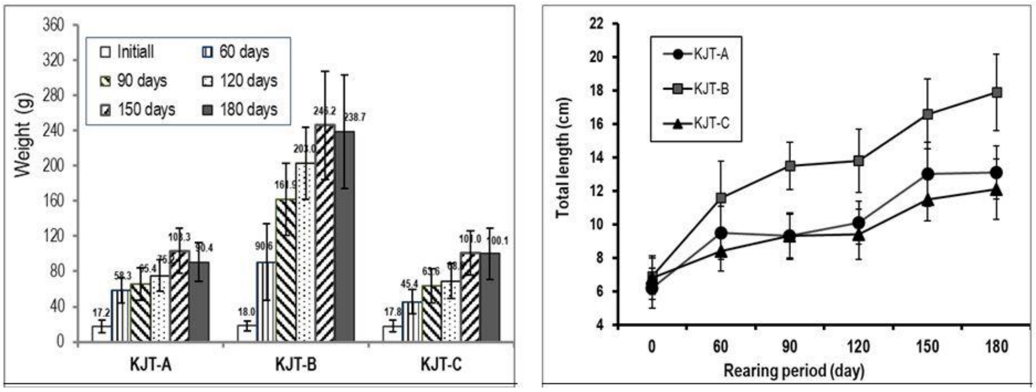

Figure 2: Growth patterns of weight (left) and total length (right) of sandfish (*Holothuria scabra*) that were maintained in the sea pen culture system (KJT) for 180 days.

Table 1: Growth performance of sandfish (*Holothuria scabra*) that were reared in sea pen culture systems for 180 days.

Parameters	Pen culture system (KJT)		
	KJT-A	KJT-B	KJT-C
Initial weight (g) (*n=50*)	17.2 ± 7.3	18.0 ± 6.0	17.8 ± 6.5
Final weight (g)	90.4 ± 21.9	238.7 ± 94.2	100.1 ± 29.3
Weight gain (%)	425.6	1226.1	462.4
Daily growth rate (g/day)	0.41	1.23	0.46
Specific growth rate (%/day)	0.92	1.44	0.96
Initial total length (cm)	6.2 ± 1.2	6.9 ± 1.1	6.8 ± 1.3
Final total length (cm)	13.1 ± 1.6	17.9 ± 2.9	12.1 ± 1.8
Survival (%)	65.3	23.7	60.3

Table 2: Composition of seafloor sediment inside the pen culture system (KJT) where sandfish (*Holothuria scabra*) was reared.

Parameters	Pen culture system (KJT)		
	KJT-A	KJT-B	KJT-C
Total organic matter (%)	5.68	13.54	6.06
Total C-organic (%)	1.57	3.58	0.78
Total-P (%)	0.029	0.065	0.015
Total-N (%)	0.011	0.059	0.010
Redox potential (mV)	-6.3	-39.6	-16.5
pH	8.21	7.98	8.16
H_2S	-	**	-
Texture	sand	loamy sand	sand

- : H_2S was not detected; **= H_2S was detected

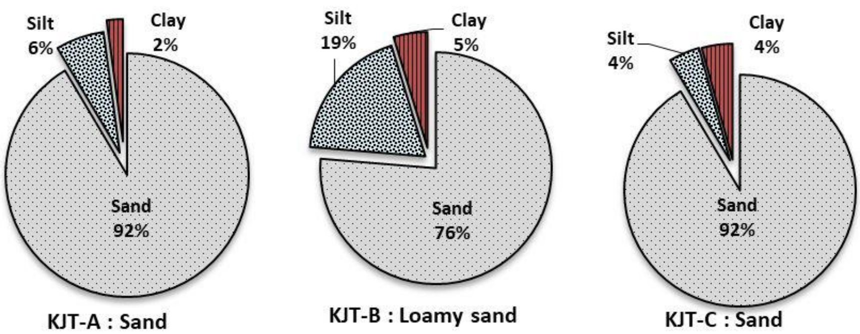

Figure 3: The texture of seafloor sediment inside the pen culture system where sandfish (*Holothuria scabra*) was reared.

Discussion

In this study, the growth rate of sea cucumber was in line with the results reported by Agudo (2006), which were the medium size grew on an average of 14 g/month or 0.46 g/day. This showed that the growth rate of the species maintained in natural habitats varied significantly. Hair *et al*. (2016), mentioned that the growth of sandfish reared for 4 months by pen culture system in a seagrass area can reach a weight of 74.8-113.6 g from an initial of 3-20 g or 0.59 - 0.69 g/day. Similarly, Juinio-Menez *et al*. (2012) also documented that sea cucumber maintained in several pen culture systems has a growth rate of 164 g from an initial weight of 8-10 g over 5 months. However, the growth of sea cucumbers varied significantly and also had negative growth. Stocking density also affects the growth of sea cucumbers that were maintained in the pen culture system (Pitt and Duy, 2004; Lavitra *et al*., 2010; Hannah *et al*., 2013; Namukose *et al*., 2016). Species with an initial weight of 114 g in a 1.5 x 1.5 m^2 pen culture system grew at a rate of 0.8 g/day and 0.14 g/day when reared at low and medium or high density, respectively (Namukose *et al*., 2016).

In a previous study, the cultivation of juveniles sea cucumber in concrete tanks with artificial feed for 5 months gave a low specific growth rate of 0.57 - 0.74%/day, while floating net cages installed in the earthen pond with the same feed for 4 months resulted in high specific growth rate of 1.46 - 1.64%/day. It is important to note that rearing in the floating nets in the ponds had a smaller initial weight (Giri *et al*., 2019). Sithisak *et al*. (2013), mentioned that the growth of sandfish was relatively slow, thus, it required two years from hatching to reach commercial size. Battaglene (1999), also presented that the average growth of juvenile sandfish is approximately 0.2-0.8 mm/day under normal culture conditions.

Sandfish cultured in the pen system in this study were not fed, hence, they depended on food available in their habitats or the seafloor sediment. Therefore, the structure and composition of seafloor sediment largely determine their growth rate. The results showed that the structure and composition of loamy sand sediment in KJT-B supported the good growth of the sandfish. The sediment in KJT-B had higher organic matter content which provides a food source for sea cucumber to support its growth (Table 2; Fig. 3). This is in line with Namukose *et al*., (2016), where the total organic matter content (TOM) and total organic carbon (TOC) in the bottom sediment decreased during the period of sea cucumber culture, particularly when stocked at high densities. Similarly, it is concluded that the sea cucumber inhabiting the coastal benthos ecosystem filters out sediment and feeds on diatoms, bacteria, detritus, and organic matter that passes through the digestive tract (Uthicke and Karez, 1999). According to Hamel *et al.* (2001), the seabed sediments of muddy sand were considered ideal because they have sufficient organic matter as food, are easy to consume and sea cucumbers can easily be submerged. Gutajar *et al*. (2022) reported that sea cucumbers *Holothuria poli* could grow better in locations near a commercial fish cage because sediment near commercial fish cages provides a good food source enriched by waste released from fish cages. Altamirano *et al*. (2017) mentioned that juvenile sandfish tend to choose a muddy sand substrate to inhabit, search for food, and also prefer coarser sediment to fine-sized particles. A study by Ceccareli *et al*. (2018), it showed that sand particles of 100 - 300 µm with high organic matter, especially organic-C and an abundance of benthic microbiota were good substrates for sea cucumber. In addition to particle size, Tsiresy *et al*. (2011) discovered that sediment friability was an important aspect of supporting their growth because they can easily obtain available food in the sediment.

Although sediment conditions in the KJT-B produced the best growth rate, lower redox values, and the presence of H_2S can be an obstacle to the life of sea cucumber. A negative value for redox potential indicated an increase in organic matter accumulation that was higher than the degree of decomposition in the aquatic substrate. This usually occurs in sediments with a higher silt and clay texture composition (Viaroli *et al*., 2004). Based on field observations, there was a flow of water discharged from intensive shrimp ponds towards the location of KJT-B. This was assumed to be the cause of an increase in the value of organic matter. In the 4th month of rearing, there were a significant number of dead sea cucumbers in KJT-B which made the number of the survivors the lowest compared to KJT-A and KJT-C (Table 1). In addition, the presence of predators also determines the success of sea cucumber cultivation in the sea as found by Eriksson *et al*. (2012). Some crustaceans, especially crabs, starfish, several species of fish, and gastropods also could be predators, causing a low survival rate for sea cucumber aquaculture (Dance *et al*., 2003; Zamora and Jeffs, 2013).

Seafloor sediment sand with little clay and silt content is physically harder than those with loamy sand. These conditions can inhibit the burying activities of sea cucumbers and deter their growth as observed in KJT-A and KJT-C. This is because sandfish usually immerse their bodies in the sand during the day and actively search for food before dusk and at night (Hamel *et al*., 2001; Tomatala *et al*., 2018; Sulardiono and Hendrarto, 2014) since they prefer habitats of fine to a medium grain of sand (Plotieau *et al*., 2013). Furthermore, Hair *et al*. (2016) reported that seafloor with a coarse sand substrate, high chlorophyll-a content, and covered with seagrass overgrown epiphytes support the growth and survival of sandfish.

This study found that the growth of sandfish (*Holothuria scabra*) depends greatly on the structure and composition of the seafloor sediment. In addition, this species of sea cucumber grew better in the sediment of loamy sand with high organic matter content.

Acknowledgments

The authors are grateful to the team of sea cucumber technicians at IMRAFE for their dedication to the supply of sea cucumber juveniles in the hatchery and in conducting this experiment. Furthermore, the authors are also grateful to the members of the Segara Indah Fishing Group, Sumberkima Village, Gerokgak-Buleleng for their assistance in pen culture system installation and field monitoring during the experiment.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding this research article.

References

Agudo, N., 2006. Sandfish hatchery techniques. Australian Centre for International Agricultural Research (ACIAR), the Secretariat of the Pacific Community (SPC) and the World Fish Centre. 44 P.

Altamirano, J.P., Recente, C.P. and Rodriguez Jr, J.C., 2017. Substrate preference for burying and feeding of sandfish *Holothuria scabra* juveniles. *Fisheries Research,* 186, 514−523. DOI:10.1016/j.fishres.2016.08.011

APHA (American Public Health Association)., 2005. Standard methods for the examination of water and wastewater, 21st Edition. In Franson, M.A. (Ed.). Washington, D.C., USA.

Battaglene, S., Seymour, J. and Ramofafia, C., 1999. Survival and growth of cultured sea cucumbers *Holothuria scabra*. *Aquaculture*, 178(**3-4**), 293–322. DOI:10.1016/S0044-8486(99)00130-1

Bordbar, S., Anwar, F. and Saari, N., 2011. High value compounds and bioactives from sea cucumbers for functional foods-A Review. *Journal Marine Drugs*, 9(**10**), 1761-1805. DOI:10.3390%2Fmd9101761

Bouyoucos, C.J., 1962. Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal*, 54(**5**), 464-465. DOI:10.2134/agronj1962.00021962005400050028x

BSN (National Standardization Agency of Indonesia)., 1992. Food and beverages test method, SNI (Indonesian National Standars). No: 01-2891-1992. Badan Standardisasi Nasional. Indonesia. 36 P.

Ceccarelli, D.M., Logan, M. and Purcell, S.W., 2018. Analysis of optimal habitat for captive release of the sea cucumber *Holothuria scabra*. *Marine Ecology Progress Series*, 588, 85–100. DOI:10.3354/meps12444

Chatterji, A., Kassim, Z., Hassan, A., Therwath, A. and Shaharom, F., 2010. Marine living resources in the practice of traditional medicine. *Journal of Coastal Environment*, 1(**1**), 41-52.

Corner, R.A., 2017. Guidelines on Environmental Monitoring for Cage Aquaculture within the Kingdom of Saudi Arabia. Food and Agriculture Organization of the United Nations (FAO), Italy. 144 P.

Dance, S.K., Lane, I. and Bell, J.D., 2003. Variation in short-term survival of cultured sandfish (*Holothuria scabra*) released in mangrove-seagrass and coral reef flat habitats in Solomon Islands. *Aquaculture*, 220(**1-4**), 495–505. DOI:10.1016/S0044-8486(02)00623-3

Eriksson, H., Robinson, G., Slater, M. and Troell, M., 2012. Sea cucumber aquaculture in the western Indian Ocean: challenges for sustainable livelihood and stock improvement. *AMBIO: A Journal of the Human Environment*, 41(**2**), 109–121. DOI:10.1007/s13280-011-0195-8

Garcia, E.M., Jerez, P.S., Lazaro, C.S., Carlsson, M.S., Lizaso, J.L.S. and Holmer, M., 2015. Effect of sediment grain size and bioturbation on decomposition of organic matter from aquaculture. *Biogeochemistry,* 125(**1**), 1-16. DOI:10.1007/s10533-015-0119-y

Giri, N.A., Sembiring, S.B.M., Marzuqi, M. and Andamari, R., 2017. Formulation and application of artificial seaweed-based diets for nursery of sea cucumber (*Holothuria scabra*) juveniles. *Jurnal Riset Akuakultur*, 12(**3**), 263-273. (In Indonesian)

Giri, N.A., Sembiring, S.B.M., Wibawa, S.G. and Haryanti, H., 2019. Growth performance of sea cucumber, *Holothuria scabra* fed with different artificial feeds and reared in concrete tanks and pond-based floating net cages. *Media Akuakultur*, 14(**1**), 19-29. (In Indonesian)

Gutajar, K., Falconer, L., Massa-Gallucci, A., Cox, R.E., Schenke, L., Bardocz, T., Sharman, A., Deguara, S. and Telfer, T.C., 2022. Culturing the sea cucumber *Holothuria poli* in open-water integrated multi-trophic aquaculture at a coastal Mediterranean fish farm. *Aquaculture*, 550, 737881. DOI:10.1016/j.aquaculture.2021.737881

Hair, G.C., Mill, D.J., McIntyre, R. and Southgate, P.C., 2016. Optimising methods for community-based sea cucumber ranching: Experimental releases of cultured juvenile *Holothuria scabra* into seagrass meadows in Papua New Guinea. *Aquaculture Reports*, 3, 198–208. DOI:10.1016/j.aqrep.2016.03.004

Hamel, J.F., Conand, C., Pawson, D.L. and Mercier, A., 2001. The sea cucumber *Holothuria scabra* (Holothuroidea: echinodermata): its biology and exploitation as beche-de-mer. *Advances in Marine Biology*, 41, 129–223. DOI:10.1016/S0065-2881(01)41003-0

Han, Q., Keesing, J.K. and Liu, D., 2016. A review of sea cucumber aquaculture, ranching, and stock enhancement in China. *Reviews in Fisheries Science & Aquaculture*, 24(**4**), 326-341. DOI:10.1080/23308249.2016.1193472

Hannah, L., Pearce, C.M. and Cross, S.F., 2013. Growth and survival of California sea cucumbers (*Parastichopus californicus*) cultivated with sablefish (*Anoplopoma fimbria*) at an integrated multi-trophic aquaculture site. *Aquaculture*, 406-407, 34−42. DOI:10.1016/j.aquaculture.2013.04.022

Hartati, R., Trianto, A. and Widianingsih, 2017. Habitat characteristic of two selected locations for sea cucumber ranching purposes. *IOP Conf. Series: Earth and Environmental Science*, 55(**1**), 012041. DOI:10.1088/1755-1315/55/1/012041

Hauksson, E., 1979. Feeding biology of *Stichopus tremulus*, a deposit-feeding holothurian. *Sarsia*, 64, 155–160

Juinio-Menez, M.A., Evangelio, J.C. and Miralao, S.J.A., 2012. Trial grow-out culture of sea cucumber *Holothuria scabra* in sea cages and pens. *Aquaculture Research*, 45(**8**), 1332–1340. DOI:10.1111/are.12078

Karnila, R., Astawan, M., Sukarno, S. and Wresdiyati, T., 2011. Characteristics of protein concentrate of sea cucumber (*Holothuria scabra*) extracted with acetone. *Jurnal Perikanan dan Kelautan*, 16(**2**), 90-102. (In Indonesian). DOI:10.31258/jpk.16.2.%25p

Lavitra, T., Fohy, N., Gestin, P., Rasolofonirina, R. and Eeckhaut, I., 2010. Effect of water temperature on the survival and growth of endobenthic *Holothuria scabra* (Echinodermata: Holothuroidea) juveniles reared in outdoor ponds. *SPC Beche-de-mer Information Bulletin*, 30, 25−28.

Mayerle, R., Nierderndorfer, K.R., Jaramillo, J.M.F. and Runte, K.H.,

2020. Hydrodinamic method for estimating production carrying capacity of coastal finfish cage aquaculture in Southeast Asia. *Aquaculture Enginering*. 88, 102038. DOI:10.1016/j.aquaeng.2019.102038

Mercier, A., Battalene. S.C. and Hamel, J.F., 2000. Settlement preferences and early migration of the tropical sea cucumber *Holothuria scabra*. *Journal of Experimental Marine Biology and Ecology*, 249, 89-110. DOI:10.1016/S0022-0981(00)00187-8

Namukose, M., Msuya, F.E., Ferse, S.C.A., Matthew, J., Slater, M.J. and Kunzmann, A., 2016. Growth performance of the sea cucumber *Holothuria scabra* and the seaweed *Eucheuma denticulatum*: integrated mariculture and effects on sediment organic characteristics. *Aquaculture Environment Interactions*, 8, 179–189. DOI:10.3354/aei00172

Pangkey, H., Lantu, S., Manuand, L. and Mokolensang, J.F., 2012. Prospect of sea cucumber culture in Indonesia as potential food sources.*Journal of Coastal Development*, 15(**2**), 114–124.

Pitt, R. and Duy, N.D.Q., 2004. Breeding and rearing of the sea cucumber *Holothuria scabra* in Vietnam. In: Lovatelli, A., Conand, C., Purcell, S., Uthicke, S., Hamel J. F. and Mercier, A. (eds.) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper 463. FAO, Rome. pp 333−346.

Plotieau, T., Baele, J.M., Vaucher, R., Hasler, A., Kounad, D. and Eeckhaut, I., 2013. Analysis of the impact of *Holothuria scabra* intensive farming on sediment. *Cahiers de Biologie Marine*, 54, 703–711. DOI:10.21411/CBM.AC6450EC1

Purwati, P., Hartati, R. and Widianingsih, 2010. Eighteen sea cucumber species fished in Karimunjawa Islands, Java Sea. *Marine Research in Indonesia*, 35(**2**), 23-30. DOI:10.14203/mri.v35i2.474

Runthe, K.H., Mayerle, R., and Sugama, K., 2021. Monitoring strategy for analyzing the impacts of coastal finfish aquaculture on seafloor sediments in Indonesia. *International Journal of Oceanography and Aquaculture*, 5(**3**), 1-11. DOI:10.23880/ijoac-16000207

Sembiring, S.B.M., Hutapea, J.H., Sugama, K., Susanto, B., Giri, N.A. and Haryanti, H., 2015. Sea cucumber, *Holothuria scabra* hatchery techniques. In: Soekadi, F., Sugama, K., Nurhakim, S., Heruwati, E. S., Purba, M., Kusnendar, E., Djunaidah, I. S., Sudibjo, E. R. and Sakti, I. (eds.) Marine and Fisheries Technology Recommendation. (pp. 187-200) Agency for Marine and Fisheries Research and Development, Ministry of Marine Affairs and Fisheries. Jakarta, pp. 187-200. (In Indonesian)

Seo, J.Y. and Lee, S.M., 2011. Optimum dietary protein and lipid levels for growth of juvenile sea cucumber *Apostichopus japonicus*. *Aquaculture Nutrition*, 17(**2**), e56-e61. DOI:10.1111/j.1365-2095.2009.00728.x

Sithisak, P., Pongtippatee, P. and Withyachumnarnkul, B., 2013. Improving inland culture performance of juvenile sea cucumbers, *Holothuria scabra*, by co-culture with red tilapia. *Songklanakarin Journal Science Technology*, 35(**5**), 501-505.

Sulardiono, B. and Hendrarto, B., 2014. Analysis of the density of sea cucumbers Holothurians based on the type of coral cover in Karimun Jawa Waters, Jawa Tengah. *Jurnal Saintek Perikanan*, 10, 7–12. DOI:10.14710/ijfst.10.1.7-12

Taurusman, A.A., Isdahartati, I., Isheliadesti, I. and Ristiani, R. 2013. Restocking and habitat restoration of sea cucumbers: status of seagrass ecosystem at the restocking sites in Pramuka and Kelapa Dua Island, Seribu Island, Jakarta, Indonesia. *Jurnal Ilmu Pertanian Indonesia*, 18(**1**), 1-5. (In Indonesian)

Taylor, A.L., Nowland, S.J., Hearnden, M.N., Hair, C.A. and Fleming, A.E., 2016. Sea ranching release techniques for cultured sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea) juveniles within the high-energy marine environments of northern Australia. *Aquaculture*, 465, 109–116. DOI:10.1016/j.aquaculture.2016.08.031

Tomatala, P., Letsoin, P.P. and Kadmaer, E.M.Y., 2018. The effectiveness of pen-culture construction for cultivation of sea cucumber. *Jurnal Akuakultur Indonesia*, 17(**1**), 26–33. DOI:10.19027/jai.17.1.26-33 (In Indonesian)

Tsiresy, G., Pascal, B. and Plotieau, T., 2011. An assessment of *Holothuria scabra* growth in marine micro-farms in southwestern Madagascar.*SPC Beche-de-mer Information Bulletin*, 31, 17−22.

Uthicke, S. and Karez, R., 1999. Sediment patch selectivity in tropical sea cucumbers (Holothurioidea: Aspidochirotida) analyzed with multiple choice experiments. *Journal of Experimental Marine Biology and Ecology*, 236, 69-87. DOI:10.1016/S0022-0981(98)00190-7

Viaroli, P., Bartoli, M., Giordani, G., Magni, P. and Welsh, D.T., 2004. Biogeochemical indicators as tools for assessing sediment quality/vulnerability in transitional aquatic ecosystems. *Aquatic Conservation Marine Freshwater Ecosystem*, 14(**S1**), S19-S29. DOI:10.1002/aqc.647

Walkley, A. and Black, I.A., 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37, 29-37.

Wulandari, U., Sulistyo, B. and Hartono, D., 2016. Application of GIS for the analysis of suitablility of sea cucumber (*Holothuria scabra*) farming area in the waters of Kiowa Bay, Kahyapu village, Enggano subdistrict. *Jurnal Enggano*, 1(**1**), 57-73. DOI:10.31186/jenggano.1.1.57-73 (In Indonesian)

Zamora, L.N. and Jeffs, A.G., 2013. A Review of the research on the Australasian sea cucumber, *Australostichopus mollis* (Echinodermata: holothuroidea) (Hutton1872), with emphasis on aquaculture. *Journal of Shellfish Research*, 32(**3**), 613–627. DOI:10.2983/035.032.0301