Macrobenthic community status at coastal cage aquaculture area in Xuan Dai bay, Phu Yen province, Vietnam

Phan Thi Kim Hong[*]**, Nguyen Ngoc Anh Thu, Dao Tan Hoc, Nguyen An Khang, Hua Thai Tuyen, Mai Xuan Dat, Ho Thị Hoa**

Institute of Oceanography, VAST, Vietnam
[*]E-mail: phn_kimhong@yahoo.com

ABSTRACT

Lobster cage culture started around 1990 in Xuan Dai bay and grew fast in recent years, contributing significantly to the socio-economic development of the region. But the impact on the ecological environment of cage culture operation also needs to consider. This paper points out the status of the macrobenthic community, studied at two stations inside the cage culture area ($X1$, $X2$) and one reference station (Xr) in the non-cage culture area. A total of 90 samples with 5 replicate samples per station were collected in six surveys during the dry and rainy seasons from June 2019 to May 2020. These samples were classified and recorded into 80 taxa belonging to 49 families and 5 classes. The class Polychaetes had the most diverse species composition with 53 taxa (66% of the total number of taxa). The crustacean group had 14 taxa (18%) belonging to 13 families; Molluscs had 9 taxa (11%) belonging to 6 families of class Bivalvia. The echinoderms had 4 taxa (5%). *Capitella capitata*, a species known as an indicator of organic pollution, was recorded in both stations of the culture area but was not present at the reference station. Furthermore, some dominant species presented in the culture stations such as *Cossura longocirrata* (contributed 43.52% in station X1) and *Ceratonereis* sp. (contributed 27.57% in station X2). These species are considered opportunistic species that can adapt to disturbed environmental conditions. Significantly, the species of echinoderms group were only recorded in the reference station. The species composition was only about 24% similar to those at the cage culture stations. The species richness index (D) values ranged from 1.50 (X2.6) to 6.82 (Xr.3). The diversity index (H') varied from 0.88 (X2.4) to 2.98 (Xr.3). The evenness index (J) had the lowest average value at station X2 ($J = 0.59 \pm 0.20$) and the highest value at the reference station Xr ($J = 0.78 \pm 0.03$). The indices D, H' and J of the macrobenthic community at the reference stations have higher average values compared to those estimated at cage culture stations. These results proved cage culture activities have gradually impacted the benthic fauna, reduced biodiversity, and encouraged the appearance of opportunistic species. Thus, further studies on the macrobenthic community dynamic with ecological criteria are necessary to establish a set of biological indicators to monitor the environmental quality of the coastal aquaculture area.

Keywords: Coastal cage aquaculture, macrobenthic community, Xuan Dai bay.

INTRODUCTION

Xuan Dai Bay locates in the north of Phu Yen province with an area of 9,000 ha. Lobster cage culture started in this semi-enclosed bay around 1990. Currently, the aquaculture areas develop widely about 1,000 ha with an annual commercial lobster yield is over 700 tons. The revenue from lobster culture is about 500–600 billion VND/year, contributing significantly to the socio-economic status [1].

However, many studies have shown that coastal aquaculture harms the ecological environment through aquaculture waste such as uneaten feed, animal manure, the use of chemicals and medicines, crossbreeding, and the transmission of parasites and diseases between cultured species and wild fish [2–6]. Sediment below the aquaculture cages often accumulates high organic content from food and fish feces (biological) and other cultured organisms. Still, the sedimentation rate is highly dependent on culture location, species reared, type of feed, culture operation management, water flow, and depth. Studies from different parts of the world show significant variation in sediment rates, but in general, most areas below the cage bottom have a sedimentation rate increase 2–20 times greater than that of other areas with no farming activities [7–10]. In the salmon farming industry, Hargrave (1994) [11] determined the organic carbon content below the trout cage to be 500 times higher, and other studies such as Brown et al., (1987) [12] found very high organic matter content, high sulfur content, and very little dissolved oxygen. The high organic content results from excess feed and fecal waste in intensive cage culture operations.

Macrobenthic communities are considered "key species" in environmental quality monitoring programs. This species is capable of little transport, making it hard for them to avoid the adverse effects of the aquatic and sedimentary environment. Besides, they have a relatively long-life cycle, enabling them to indicate or synthesize disturbances in the aquatic and sedimentary environment over time. Moreover, this group consists of many species with good tolerance to significant environmental changes and can also proliferate to form dominant populations [13]. Furthermore, benthic animals are essential in nutrient cycling, sediments, and water column [14, 15].

This paper presents the status of the macrobenthic community at the coastal cage sites of Xuan Dai bay, Song Cau town, in Phu Yen province. These results form the basis for establishing an appropriate set of biological indicators to assess and warn environmental risks for coastal cage farming.

MATERIAL AND METHODS
Study sites

This study was carried out at three stations in Xuan Dai bay in South Central Vietnam, coded *X*1 (109.243123E; 13.472407N); *X*2 (109.268754E; 13.45524N), and *Xr* (109.239895E; 13.429361N), marked in Fig. 1. Two stations (*X*1, *X*2) locate inside the cage culture areas, and the reference station (*Xr*) is in non-cage culture areas.
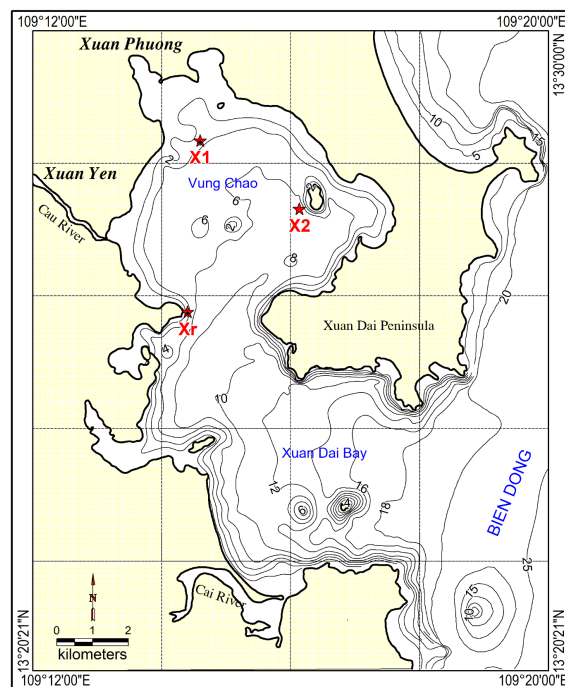

Figure 1. The map of study sites

Sample collection and analysis

Six surveys of macrobenthos samples collection were conducted at three stations

during the dry and rainy seasons (Table 1). Five replicate samples were collected at each station.

The benthic samples were collected using Van Veen grab with an area of 0.04 m^2.

Table 1. Information on the six surveys

Seasons	Month	Survey code	Station *X*1	Station *X*2	Station *Xr*
Dry Seasons	Jun. 2019	2	*X*1.2	*X*2.2	*Xr*.2
Dry Seasons	Aug. 2019	3	*X*1.3	*X*2.3	*Xr*.3
Rainy Seasons	Nov. 2019	4	*X*1.4	*X*2.4	*Xr*.4
Rainy Seasons	Jan. 2020	5	*X*1.5	*X*2.5	*Xr*.5
Dry Seasons	Mar. 2020	6	*X*1.6	*X*2.6	*Xr*.6
Dry Seasons	May 2020	7	*X*1.7	*X*2.7	*Xr*.7

The sediment samples were washed and sieved through a 500 µm mesh to collect all groups of the organisms. The specimens were then fixed with 70% alcohol and transferred to the laboratory. At the laboratory, macrobenthos was sorted into four main groups: polychaetes (Po.), molluscs (Mo.), crustaceans (Cr.), and echinoderms (Ec.); then identified as the lowest taxon as possible and counted. Classification of benthic animals by anatomical and morphological comparison method according to [16–31].

Data analysis

Data were processed using Excel software.

Analysis of the benthic community structure was carried out through the indices of diversity (*H'*), species richness (*D*), and evenness (*J*) using Primer 6.0 software.

Diversity index (*H'*) (Shannon and Weaver).

$$H' = \sum_{i=1}^{n} \frac{n_i}{N} \ln \frac{n_i}{N} \tag{1}$$

where: n_i: number of individuals of species *i*; *N:* total number of individuals.

Evenness index *J* (Pielou):

$$J = H'/\log S \tag{2}$$

where: H' is the Shannon diversity index; *S* is the total number of species.

Species richness index *D* (Margalef):

$$D = (S-1)/\ln N \tag{3}$$

where: S: total number of species; *N:* the total number of individuals.

Analysis the average cluster group was based on the data of species composition and density using the Bray-Curtis similarity method. The data were converted to log*x* before analysis.

The Two-way ANOVA was used to check the difference in density and biodiversity indices among seasons and survey stations.

RESULTS

Macrobenthic diversity

Analyzed 1966 macrobenthos individuals from 90 soft bottom quantitative samples recorded 80 taxa belonging to 49 families and 5 classes. The class Polychaetes was recorded as the most diverse species composition with 53 taxa (66% of the total number of taxa), with some families having more taxa than the others, such as Spionidae (7 taxa), Capitellidae (6 taxa), Cirratulidae (4 taxa). The crustacean group had 14 taxa (18%) belonging to 13 families; Molluscs had 9 taxa (11%) belonging to 6 families of class Bivalvia. The echinoderms had 4 taxa (5%), and all belonged to Amphiuridae, the Order Ophiurida family.

There was a remarkable difference in species diversity as well as the structure of macrobenthic species between the cage culture stations and the reference station (Table 2). The reference station (*Xr*) had 69 recorded taxa which were 2.38 times higher than the number of taxa at two stations in the cage culture area *X*1 and *X*2 (both had the same number of 29 taxa). This result confirmed the reveal of Habib et al., (2020) [32].

The analysis also showed that the *Capitella capitata* of the family Capitellidae, an indicator of organic pollution that

dominates the benthic community at fish farming [33–34], was recorded in both stations of the cage culture stations but was not present at the reference station.

In particular, the species *Ceratonereis* sp. belonging to the family Nereididae only appeared in station $X1$ with a very high frequency (80%) but did not appear in both station $X2$ (cage culture stations) and Xr (reference station). In contrast, some species that appeared in the reference station with high frequency but not or very rarely recorded in the cage culture station, such as *Linopherus* sp. (57%), *Orbinia vietnamensis* (53%), *Sternaspis papillosa* (50%), *Terebellides stroemii* (53%) and *Laonome triangularis* (33%). Especially, the species of echinoderms group were only recorded in the reference station (Xr).

Table 2. Number of taxa of macrozoobenthos groups
at surveyed stations at Xuan Dai bay (family level)

Area	Cage culture		Reference	Total
Station	$X1$	$X2$	Xr	
Polychaeta	*23*	*22*	*47*	*53*
Acoetidae			1	1
Amphinomidae		2	2	2
Capitellidae	2	2	5	6
Cirratulidae	2	2	3	4
Cossuridae	1	1	1	1
Chaetopteridae		1	1	1
Chrysopetalinae			1	1
Eunicidae			1	1
Glyceridae			1	1
Goniadidae			1	1
Hesionidae	2	2	2	2
Lumbrineridae			1	1
Magelonidae			1	1
Melinnidae			1	1
Nephtyidae	2	1	3	3
Nereididae	1		2	3
Oenonidae	1		1	2
Onuphidae			1	1
Opheliidae	2	2	2	2
Orbiniidae			1	1
Paralacydoniidae			1	1
Paraonidae	1		1	1
Pilargidae	1	1	1	1
Poecilochaetidae	1	1	1	1
Polynoidae	1			1
Sabellidae	1	1	2	2
Spionidae	5	6	6	7
Sternaspidae			2	2
Trichobranchidae			1	1
Crustacea	*2*	*4*	*11*	*14*
Alpheidae	1	1	1	2
Anthuridae			1	1
Bodotriidae			1	1
Chasmocarcinidae			1	1
Ectinosomatidae			1	1
Gammaridae	1	1	1	1

Area	Cage culture		Reference	Total
Station	*X*1	*X*2	*Xr*	
Harpactidae		1		1
Leptocheliidae			1	1
Mysidae			1	1
Palaemonidae			1	1
Parapseudidae		1		1
Pasiphaeidae			1	1
Portunidae			1	1
Echinodermata			*4*	*4*
Amphiuridae			4	4
Mollusca	*4*	*3*	*7*	*9*
Corbulidae	1	1		1
Lucinidae			1	1
Pteriidae			1	1
Solenidae			1	1
Tellinidae	2	2	2	3
Veneridae	1		2	2
Total	29	29	69	80
	38		69	80

Macrobenthic density

The average density of the macrobenthic community in the cage culture stations was 420 ± 258.6 at *X*1, and 523 ± 412.3 at *X*2 individuals/m^2 (ind./m^2); the reference station (*Xr*) was higher in density (695 ± 310.7 ind./m^2) comparing to both cage culture stations. Polychaetes population always dominated at all stations, with an average density of 388 ± 218.2 ind./m^2 (92.5 % of total density) at *X*1, 514 ± 410.3 ind./m^2 (98.3%) at *X*2, and 623 ± 288.1 ind./m^2 (89.7%) at *Xr* (Table 3). Crustaceans, molluscs, and echinoderms had a very low density, varying from 0–6.1%. Nevertheless, the difference in the average density of the macrobenthic community was not statistically significant between stations ($p = 0.65$) and survey seasons ($p = 0.39$) in Xuan Dai bay.

Macrobenthic community structure

Analysis of the benthic community structure in the study area by the Bray-Curtis similarity method shows 3 main groups representing 3 survey stations *X*1, *X*2, and *Xr* (Figure 2).

Group 1 includes a collection of 27 benthic taxa obtained at station *X*1 (except for *X*1.7) with 41% similarity. The benthic species composition in the rainy season surveys (*X*1.4 and *X*1.5) had a very high similarity (68%), while that in the dry season ranges from 41–55%. The dominant species of this group were *Ceratonereis* sp., *Ophelia grandis*, *Prionospio cirrifera*, and *Pseudopolydora* sp. with the rate of 37%, 15.5%, 10.3%, respectively.

Group 2 includes macrobenthos at station *X*2 (except for *X*2.3 of the August 2019 survey) and *X*1.7 with a similarity level of 45%. The two surveys in the rainy season had a similarity of 50% and in the dry season from 36–50%. The most dominant density of this group belongs to *Cossura longocirrata* (64% of total group density); the remaining 26 species account for only 0.2–7.3%.

Group 3 includes a collection of 62 benthic taxa of the reference station (except *Xr*.2 in the June 2019 survey) with a similarity level of 45%. There was a little change in species composition between the rainy and dry seasons (ranging from 45–50%). *Cirriformia* sp. accounted for the highest density (25.9%), and the remaining species accounted for 0.1–12.2%.

Thus, there was a difference in the structure of benthic fauna between the cage culture area and the non-cage culture area. Group 3 had only a similarity of about 24% to groups 1 and 2. Moreover, the two stations in the cage

culture area also had different species compositions (only 27% of similarity). Both stations had dominant species, but the composition and density were different.

Table 3. Density (ind./m^2) of macrobenthic community in Xuan Dai bay

Station	Po.	Cr.	Ec.	Mo.	Total
X1.2	230	0	0	0	230
X1.3	160	0	0	0	160
X1.4	485	20	0	25	530
X1.5	720	110	0	5	835
X1.6	510	5	0	15	530
X1.7	225	0	0	10	235
Mean X1	388	23	0	9	420
SD	218.2	43.6	0.0	9.7	258.6
X2.2	200	0	0	5	205
X2.3	155	5	0	10	170
X2.4	700	0	0	0	700
X2.5	525	10	0	10	545
X2.6	270	0	0	0	270
X2.7	1,235	15	0	0	1,250
Mean X2	514	5	0	4	523
SD X2	410.3	6.3	0,0	4,9	412.3
Xr.2	360	10	0	15	385
Xr.3	500	35	55	40	630
Xr.4	305	15	5	5	330
Xr.5	840	95	0	15	950
Xr.6	690	60	5	0	755
Xr.7	1,045	40	10	25	1,120
Mean Xr	623	43	13	17	695
SD Xr	288.1	31.4	21.2	14.4	310.7

Transform: Log(X+1)
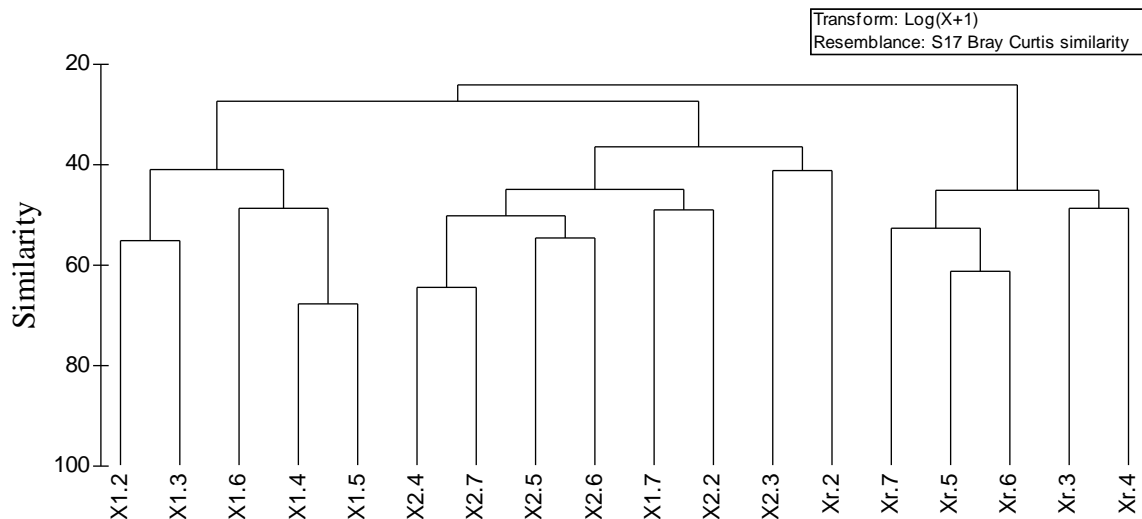Resemblance: S17 Bray Curtis similarity

Figure 2. Bray-Curtis similarity analysis of macrobenthic community at study stations

The results of species richness, diversity, and evenness indices of the macrobenthic community in the Xuan Dai bay are shown in Table 4.

Table 4. Species richness, diversity, and evenness indices
of the macrobenthic community in the Xuan Dai bay

Month	Survey code	Station $X1$			Station $X2$			Station Xr		
		D	J	H'	D	J	H'	D	J	H'
Jun. 2019	2	1.57	0.62	1.20	1.88	0.67	1.39	5.29	0.77	2.43
Aug. 2019	3	2.60	0.87	2.01	2.55	0.94	2.17	6.82	0.84	2.98
Nov. 2019	4	3.43	0.81	2.30	1.62	0.40	0.88	4.06	0.78	2.25
Jan. 2020	5	2.34	0.64	1.65	3.41	0.56	1.58	5.15	0.77	2.55
Mar. 2020	6	2.36	0.59	1.48	1.50	0.49	0.94	4.78	0.78	2.51
May 2020	7	3.12	0.93	2.39	2.17	0.48	1.22	5.91	0.75	2.64
Mean		2.57	0.75	1.84	2.19	0.59	1.36	5.34	0.78	2.56
SD		0.65	0.15	0.47	0.71	0.20	0.48	0.95	0.03	0.24

The species richness index (D) values varied from 1.50 ($X2.6$) to 6.82 ($Xr.3$). Generally, the D values were higher, an average of 5.34 (± 0.95), at the reference station Xr than at the two stations in the culture area $X1$ and $X2$, with the averages of 2.57 (± 0.65) and 2.19 (± 0.71), respectively. This result was consistent with the study of Habib et al., (2020) [32] that the highest D value was obtained in the non-cage culture area. The two-way ANOVA showed species richness index was significantly different between stations ($p = 0.00$), but it was not significant between seasons ($p = 0.90$) and station*season interaction ($p = 0.19$).

The diversity index (H') ranged between 0.88 ($X2.4$) and 2.98 ($Xr.3$). The average value of H' was highest at the reference station Xr (2.56 $\pm$ 0.24) and lowest at station $X2$ (1.36 $\pm$ 0.48), with a significant difference between stations ($p = 0.003$). The difference between survey seasons and station*season interaction was not statistically significant ($p = 0.73$ and $p = 0.67$, respectively). According to Habib et al., (2020) [32] in the study on the macrobenthic community around fish cage culture in Bangladesh pointed out the range of H' value from 1.34 (in cage culture site) to 2.10 (in non-cage culture site), the present study has the same conclusion.

Table 5. The contribution of species at survey stations

Station	Species	Contribution (%)	Cumulation (%)
$X1$	*Ceratonereis* sp.	27.57	27.57
	Sigambra sp.	18.36	45.93
	Prionospio cirrifera	12.17	58.10
	Oxydromus angustifrons	9.28	67.38
	Poecilochaetus paratropicus	9.16	76.54
$X2$	*Cossura longocirrata*	43.52	43.52
	Sigambra sp.	15.38	58.89
	Prionospio komaeti	8.57	67.47
	Polydora sp.	6.89	74.36
	Prionospio cirrifera	6.63	80.99
Xr	*Cirriformia* sp.	17.33	17.33
	Sigambra sp.	14.98	32.31
	Cossura longocirrata	8.40	40.71
	Linopherus sp.	8.15	48.86
	Orbinia vietnamensis	6.71	55.56

For the evenness index (J), the lowest average value was recorded at station $X2$ ($J = 0.59 \pm 0.20$) since the presence of two

dominant species *Cossura longocirrata* (contributed 43.52%) and *Sigambra* sp. (contributed 15.38%) led to an imbalance in the

macrobenthic community (Table 5). The dominant species were also different between two cage culture stations, *Ceratonereis* sp. and *Sigambra* sp. (contributed 27.57 and 18.36%), dominated at station *X*1. The highest value of the evenness index was estimated at the reference station *Xr* ($J = 0.78 \pm 0.03$), revealing the most balanced macrobenthic community. This result also shows the same opinion as [32]. Nevertheless, the difference was not statistically significant between stations ($p = 0.07$), season ($p = 0.38$) and station*season interaction ($p = 0.65$).

CONCLUSION

The present study demonstrates the differences in macrobenthic community between the survey stations: stations in the cage culture area (*X*1, *X*2) and the reference station (*Xr*) in the non-cage culture area of Xuan Dai bay. The number of macrobenthic taxa and their density in the reference station (*Xr*) is higher than in stations *X*1 and *X*2. The Shannon-Wiener diversity index (*H'*), the Pielou's Evenness Index (*J*), and Margalef's species richness index (*D*) are examined for all stations. The macrobenthic community in the reference station has the highest *H'*, *D*, and *J* values compared to stations *X*1 and *X*2. *Capitella capitata*, the benthic organism used as an indicator for organic pollution, was only recorded in the cage culture area at both stations. Furthermore, some dominant species appeared in the culture stations, such as *Cossura longocirrata* (contributed 43.52% in station *X*1) and *Ceratonereis* sp. (contributed 27.57% in station *X*2). These species are opportunistic species that can adapt to disturbed environmental conditions.

Further studies on the macrobenthic community dynamic with ecological criteria could support establishing a set of biological indicators to monitor the environmental quality of the coastal aquaculture area.

REFERENCE

[1] Department of Economic, Song Cau Town, 2000. Plan of aquaculture in Xuan Dai bay to 2025, vision to 2030. (in Vietnamese)

[2] Karakassis, I., Tsapakis, M., Hatziyanni, E., Papadopoulou, K. N., and Plaiti, W., 2000. Impact of cage farming of fish on the seabed in three Mediterranean coastal areas. *ICES Journal of Marine Science*, *57*(5), 1462–1471. https://doi.org/ 10.1006/jmsc.2000.0925

[3] Black, K. D. (Ed.), 2001. Environmental impacts of aquaculture (Vol. 5). *Taylor & Francis US*. 214 p.

[4] Buschmann, A. H., Riquelme, V. A., Hernández-González, M. C., Varela, D., Jiménez, J. E., Henríquez, L. A., Vergara, P. A., Guíñez, R., and Filún, L., 2006. A review of the impacts of salmonid farming on marine coastal ecosystems in the southeast Pacific. *ICES Journal of Marine Science*, *63*(7), 1338–1345. https://doi.org/10.1016/j.icesjms.2006.04. 021

[5] Apostolaki, E. T., Tsagaraki, T., Tsapakis, M., and Karakassis, I., 2007. Fish farming impact on sediments and macrofauna associated with seagrass meadows in the Mediterranean. *Estuarine, Coastal and Shelf Science*, *75*(3), 408–416. https://doi.org/10.1016/j.ecss.2007.05.024

[6] Giles, H., 2008. Using Bayesian networks to examine consistent trends in fish farm benthic impact studies. *Aquaculture*, *274*(2–4), 181–195. https://doi.org/ 10.1016/j.aquaculture.2007.11.020

[7] Hall, P., and Holby, O., 1986. Environmental impact of a marine fish cage culture. *ICES CM*, 1–14.

[8] Weston, D. P., and Gowen, R. J., 1988. Assessment and prediction of the effects of salmon net-pen culture on the benthic

environment. *Seattle, Washington, Dept. of Fisheries. Technical report* 414.

[9] Kupka-Hansen, P., 1991. Organic waste from marine fish farms: effects on the seabed, Marine aquaculture and environment. *Nord*, *22*, 105–119.

[10] Holmer, M., Pérez, M., and Duarte, C. M., 2003. Benthic primary producers—a neglected environmental problem in Mediterranean maricultures?. *Marine Pollution Bulletin*, *46*(11), 1372–1376. https://doi.org/10.1016/S0025-326X(03) 00396-5

[11] Hargrave, B. T., 1994. A benthic enrichment index. In *Modelling Benthic Impacts of Organic Enrichment from Marine Aquaculture* (Vol. 1949, pp. 79–91). *Canadian Technical Report of Fisheries and Aquatic Sciences, Canada.*

[12] Brown, J. R., Gowen, R. J., and McLusky, D. S., 1987. The effect of salmon farming on the benthos of a Scottish sea loch. *Journal of Experimental Marine Biology and Ecology*, *109*(1), 39–51. https://doi.org/ 10.1016/0022-0981(87)90184-5

[13] Gray, J. S., and Pearson, T. H., 1982. Objective Selection of Sensitive Species Indicative of Pollution-Induced Change in Benthic Communities. I. Comparative Methodology. *Marine ecology progress series. Oldendorf*, *9*(2), 111–119.

[14] Hily, C., 1984. Variabilité de la macrofaune benthique dans les milieux hyper-trophiques de la rade de Brest. *Doctoral dissertation.*

[15] Dauer, D. M., 1993. Biological criteria, environmental health and estuarine macrobenthic community structure. *Marine Pollution Bulletin*, *26*(5), 249–257. https://doi.org/10.1016/0025-326X(93)90063-P

[16] Abbott, R. T., 1991. Seashells of southeast Asia. *Graham Brash*.

[17] Abbott, R. T., and Dance, S. P., 1986. Compendium of Seashells. A Color Guide to More than 4,200 of the World's MarineShells. *Third printing (revised). Madison Pub1 Assoc*, *41*(1).

[18] Böggemann, M., and Eibye-Jacobsen, D., 2002. The glyceridae and goniadidae (Annelida: Polychaeta) of the bioshelf project, Andaman Sea, Thailand. *Phuket Marine Biological Center Special Publication*, *24*, 149–196.

[19] Cernohorsky, W. O., 1972. Marine shells of the Pacific. Volume II. Pacific Publications. *Sydney*. 411 p.

[20] Aiyun, D., and Siliang, Y., 1991. Crabs of the China seas. *China Ocean Press*. ISBN 3-540-15719-0 or 0-387-15719-0

[21] Dance, S. P., 1977. Das grobe Bush der Meeresmuscheln: Schnecken u. *Muscheln d. Weltmeere. Verlag Eugen Ulmer Stuttgart*. 304 p.

[22] Day, J. H., 1967. A monograph on the Polychaeta of Southern Africa. *British Museum of Natural History, Publication*, (656), 1–878.

[23] Fauvel, P., 1953. The fauna of India. *Annelida Polychaeta. Allahabad, i–xii*.

[24] Fitzhugh, K., 2002. Fan worm polychaetes (Sabellidae: Sabellinae) collected during the Thai-Danish BIOSHELF project. *Phuket Marine Biological Center Special Publication*, *24*, 353–424.

[25] Gallardo, V. A., 1968. Polychaeta from the Bay of Nha Trang, South Viet Nam. *Naga report*, *4*(3), 35–279.

[26] Holthuis, L., 1993. The Recent Genera of the Caridean and Stenopodidean Shrimps (Crustacea. Decapoda) with an Appendix on the Order Amphionidacea. *Nationaal Natuurhistorisch Museum, Leiden*, 328 p.

[27] Imajima, M., 1972. Review of the annelid worms of the family Nereidae of Japan, with descriptions of five new species or subspecies. *Bulletin of National Science Museum*, *15*, 37–153.

[28] Morris, P. A., and Clench, W. J., 1975. A field guide to shells: of the Atlantic and Gulf Coast and the West Indies (No. QL 416. M67 1975).

[29] Radashevsky, V. I., and Hsieh, H. L., 2000. Polydora (Polychaeta: Spionidae) species from Taiwan. *Zoological Studies-Taipei-*, *39*(3), 203–217.

[30] Sakai, T., 1976. Crabs of Japan and the adjacent seas. *Kodansha Ltd, Tokyo, Japan*.

[31] Serene, R., 1984. Crustaces Decapodes Brachyoures de l'Ocean Indien occidental et de la Mer Rouge. Xanthoidea: Xanthidae et Trapeziidae. Addendeum Carpillidae et Menippidae-A. Crosnier. *Faune Tropicale (ORSTOM)*, *24*, 1–400.

[32] Tania, N. J., Hossain, M. B., Habib, A., and Musa, N., 2020. Effects of fish cage culture on macrobenthic communities in a subtropical river. *Biodiversitas*, *21*(8), 3583–3589. https://doi.org/10.13057/biodiv/d210822

[33] Tsutsumi, H., 1987. Population dynamics of *Capitella capitata* (Polychaeta; Capitellidae) in an organically polluted cove. *Mar. Ecol. Prog. Ser*, *36*, 139–149.

[34] Tsutsumi, H., Fukunaga, S., Fujita, N., and Sumida, M., 1990. Relationship between growth of Capitella sp. and organic enrichment of the sediment. *Marine ecology progress series. Oldendorf*, *63*(2), 157–162.