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Assessment of carrying capacity and carbon sink capacity of *Argopecten irradians*: taking Qinhuangdao as an example

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Abstract: Based on the chlorophyll a concentration and primary productivity measured in the field, the results showed that the concentration of chlorophyll a in the mariculture area of Qinhuangdao city ranged from 1.07 to 2.45 mg ṁ$^{-3}$, and the average value of chlorophyll a was 1.68 ± 0.68 mg ṁ$^{-3}$. The concentration of chlorophyll a in the bottom was 0.93 ± 0.38 mg ṁ$^{-3,}$ and the primary productivity was 848.48 ± 343.7 mg C/m^2 ḍ. Combined with the basic environmental data and scallop culture data obtained in the survey area, the current situation of mariculture capacity in Qinhuangdao city was analyzed by biological index method, and the aquaculture capacity was assessed that did not exceed the aquaculture capacity, and the marine aquaculture in this sea area was expanded to about 13 times to reach the aquaculture capacity. Scallop culture in addition to a certain economic value, but also has a high carbon sink value, after accounting Qinhuangdao city annual carbon sequestration of 23561.92 t a^{-1}, the annual carbon sink value can be about 3.8877 million yuan / year, after analysis Qinhuangdao city scallop aquaculture has a high space for development, but still need to control the output, it is recommended to actively develop a multi-trophic level of breeding mode, improve aquaculture yield and environmental benefits, and strengthen research on fishery carbon sink methodology and fishery carbon trading to help achieve the goal of carbon neutrality.

Keywords: scallops; scallop culture; carrying capacity assessment; scallop carbon sink; carbon sink value evaluation

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1. Introduction

Filter-feeding shellfish mariculture is a green mariculture mode with the advantages of no baiting, high yield, large scale, simple structure and high ecological efficiency [1]. Shellfish mariculture can not only purify seawater quality [2], but also play a role in carbon sequestration, shellfish through feeding and calcification process to fix carbon in the ocean in organisms [3], compared with other ecosystem shellfish carbon sequestration capacity is stronger, its carbon sequestration capacity is 1.5 times that of algae culture, 10 times that of forests [4]. However, any long-term large-scale culture of a single species will have a serious impact on the ecosystem [5], and over-cultivation of shellfish can inhibit primary productivity and affect the balance and stability of the entire ecosystem [6].

Qinhuangdao city is located in the north of Bohai Bay, with a total land area of 7812 square kilometers, a coastline of 126.4 kilometers, a beach and shallow sea (0 ~20 meters water depth) area of 2145.1 square kilometers, and an average water depth of about 15.26 m. According to the "Planning of Aquaculture Waters in Qinhuangdao city, Hebei Province (2018-2030)", the total planned area of marine aquaculture in Qinhuangdao city is 621.75 km2. As of 2020, the mariculture output in Qinhuangdao city was 244700 tons, and the mariculture area was 34582.17 hectares.

2. Materials and methods

2.1. Evaluation methodology

2.1.1 Assessment of scallop culture capacity

Shellfish culture capacity is related to many factors, the most important of which is the feedback of shellfish to the biomass, growth and nutritional value of their feed, phytoplankton. Bivalve shellfish are also often the dominant group of filter feeders, and their feeding activities are considered to be one of the main reasons for the decrease in phytoplankton density, because theoretically, as long as the shellfish filter the food in the water body is comparable to the turnover time of phytoplankton, and less than the renewal cycle of the water body, it can lead to a significant decrease in phytoplankton biomass.

On the basis of the bioindicator method proposed by Dame and Prons [7], combined with the relevant research of domestic and foreign experts [8,9], it is found that for the marine aquaculture of bivalve shellfish, when the seawater renewal time cannot be full of the water filtration time of shellfish, the culture is divided into the following four stages: below the ecological capacity, the aquaculture biomass is the ecological capacity, the aquaculture biomass is the ecological capacity, and the aquaculture amount exceeds the ecological capacity. The assessment method of open scallop culture capacity is shown in the figure below.

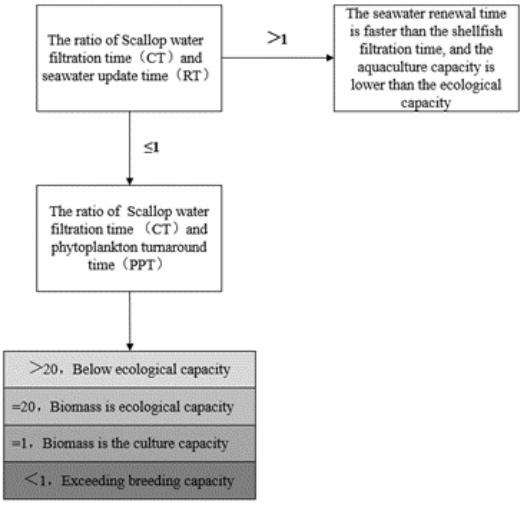


Figure 1. Flow chart of biological index evaluation.

The indicators are calculated as follows:

$$RT=V_s/\ Ti_{avg}\ S_s \quad (1)$$

$$CT=\ V_s/\ L_{scallop} \quad (2)$$

$$PPT=B/P \quad (3)$$

Formula: RT - the time required to update all water bodies in the sea area; Vs – the total volume of sea water in the sea area at high tide; Tiavg – average tidal difference; S - sea area; CT – the time it takes for shellfish to filter all the water in the area; Lscallop – the ability of shellfish populations to filter water; PPT - phytoplankton turnover time; B – existing stocks of phytoplankton; P – Primary productivity.

2.1.2 Scallop carbon sink accounting method

The At present, the carbon sink accounting for marine shellfish culture is generally obtained by estimation, and to achieve the carbon sink accounting of shellfish, it is necessary to know the values of the above parameters such as initial yield, conversion coefficient between wet and dry weight of different cultured species, shell dry weight and average carbon sequestration and soft tissue dry weight and average carbon sequestration [10]. In this paper, the carbon sink of farmed scallops was calculated by referring to the calculation method of shellfish carbon sink capacity in Ocean Carbon Accounting Methods (HY/T 0349-2022).

According to the relevant research on the evaluation of shellfish carbon sink capacity [11], shellfish carbon sink capacity includes shellfish sediment, shellfish carbon sink capacity and shellfish soft tissue carbon sink capacity, and shellfish carbon sink capacity accounting is calculated according to formula (4).

$$C_{scallop}= C_B+C_Z \quad (4)$$

In the formula:

$C_{scallop}$–scallop carbon sink capacity in tons per year (t a-1); C_B–Scallop shell carbon sink capacity in tonnes per year (t a^{-1}); C_Z–Scallop soft tissue carbon sink capacity in tons per year (t a^{-1}).

Among them, the carbon sink capacity of scallop shells is calculated according to formula (5):

$$C_B = \mathrm{T} \times K \times R_1 \times CF_1 \quad (5)$$

In the formula:

T–the biomass (wet weight) of scallops, in tons per year (t a-1); K–conversion coefficient between wet and dry weight of scallops, dimensionless; R1–proportion of shell dry mass in the dry weight state of scallops, dimensionless; CF_1–carbon content ratio under dry mass of scallop shells, dimensionless.

Among them, the carbon sink capacity of shellfish soft tissue is calculated according to Equation (6):

$$CZ = \mathrm{T} \times K \times R2 \times CF2 \quad (6)$$

In the formula:

R2–proportion of dry mass of soft tissue in the dry weight state of scallops, dimensionless; CF2–Carbon content ratio at dry mass of scallop soft tissue, dimensionless.

2.2. Investigation and acquisition of data required by the model

2.2.1 Chlorophyll a and primary productivity

The calculation of phytoplankton turnover time (PPT) requires a basic understanding of chlorophyll a and primary productivity in the study area. According to the basic requirements for station layout in the Code for Marine Survey (GB 17378.1-2007), combined with the main areas of open scallop culture, a total of 17 sampling points were set up in the coastal waters of Changli County and Beidaihe New Area (see Figure 2, the survey station number is 1, 2... 17), in the autumn of 2020, chlorophyll A and primary productivity in scallop culture areas in Qinhuangdao city were investigated. The determination method of chlorophyll a was spectrophotometric fluorescence (Marine Survey Specification. GB 17378.7-2007).

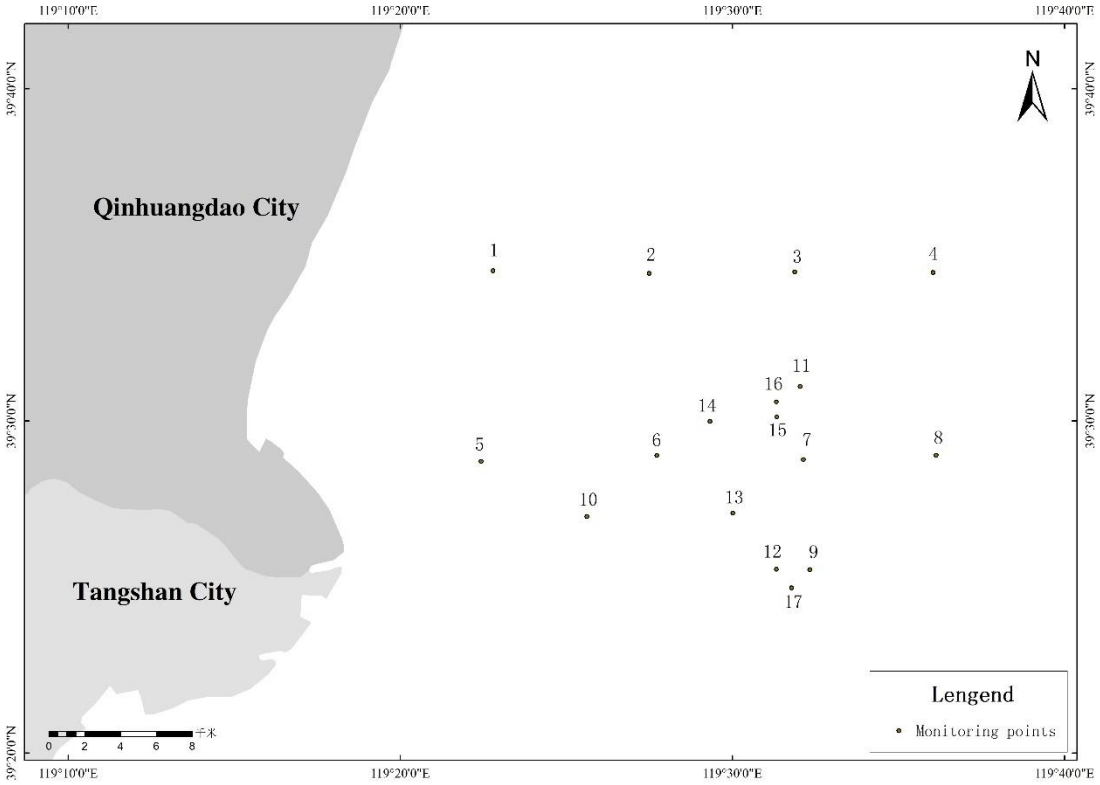


Figure 2. Survey station of scallop culture area in Qinhuangdao city.

The common detection methods for primary productivity of phytoplankton include black and white bottle method, biomass method, 14C method, chlorophyll a method, *etc.* [12], and the chlorophyll a method was used to calculate the primary productivity.

Primary productivity is calculated according to Equation (7):

$$P = PsED/2 \quad (7)$$

In the formula:

P–primary productivity in the daily field (mg C/m2 d); Ps–potential productivity of phytoplankton in surface water (mgC/m^{-3} h); E–the depth of the true light layer (m), 21 m in September; D–the length of daylight (h), 13h in September. Among them, the potential productivity (Ps) of phytoplankton in surface water is calculated based on the content of chlorophyll a in surface water:

$$Ps = CaQ \quad (8)$$

In the formula:

Ca–the content of surface chlorophyll a (mg/m^3); Q–the assimilation coefficient (mg C/mg Chl a h), and the assimilation coefficient (Q) takes the empirical value of 3.7 [13].

2.2.2 Physiological data of scallop feeding and values of marine carbon sink accounting parameters

Refer to the statistical yearbook of Qinhuangdao city, relevant research results and published standards to determine the values of feeding physiological data and marine carbon sequestration accounting of marine cultured bay scallops in Qinhuangdao city.

3. Results

3.1. Basic situation of marine aquaculture of scallops in the bay of Qinhuangdao city

The area of open mariculture planned in the "Planning of Aquaculture Waters in Qinhuangdao city, Hebei Province (2018-2030)" is about 621.75 km^2, and the actual open marine aquaculture area of Qinhuangdao city is about 313.33 km^2, the development utilization rate is 50.42%. The average water depth of the coastal waters of marine aquaculture in Qinhuangdao is about 15.26 m, the tidal difference is between 0.96-1.5 meters, the average tidal difference is 0.67 meters, the average water depth is 15.26 meters, and the water volume of the coastal aquaculture area of Qinhuangdao is about 9.48×10^9 m^3.

3.2. Chlorophyll a and primary productivity

The average values of surface chlorophyll a and primary productivity in the survey area are shown in Table 1, the concentration of surface chlorophyll a is between 1.07 and 2.64 mg m^{-3}, and the average value of surface chlorophyll a is 1.68 ± 0.68 mg m^{-3}. The concentration of chlorophyll a in the bottom layer ranged from 0.56 to 1.32 mg m^{-3}, and the concentration of chlorophyll a in the bottom layer was 0.93 ± 0.38 mg m^{-3}. The vertical distribution of chlorophyll a was relatively uniform, and the surface concentration was higher than that of the bottom layer. The variation of primary productivity ranged from 540.4 to 1333.32 mg C/m^2d, and the average value was 848.48 ± 343.7 mg C/m^2 d, and the average primary productivity was good.

Table 1. Chlorophyll a concentration and primary productivity in marine aquaculture areas of Qinhuangdao.

Chlorophyll a content（mg m^{-3}）		Primary productivity(mg C/m^2 d)
Surface layer	Underlying	
1.68 ±0.68	0.93 ±0.38	848.48 ±343.7

3.3. Assessment of scallop culture capacity in Qinhuangdao city

According to the 2021 Qinhuangdao Statistical Yearbook, the output of scallops in Qinhuangdao city in 2020 was 231800 tons. According to Wang Fang's [14] experimental results on bay scallops in Qinhuangdao city, the water filtration rate per unit body weight of bay scallops is about 0.24-0.9 L/(g h), the average water filtration rate per unit body weight is about 0.57 L/(g h), and the average meat yield is about 14.35% [15]. Combined with the basic situation of the above study area, it can be calculated that the water filtration rate of

marine aquaculture scallop population in Qinhuangdao city is about 4.44 × 10^8 m^3/h. Physiological data of scallop culture and feeding in the bay are shown in Table 2.

Table 2. Physiological data of scallop culture and feeding in the bay.

Parameters	Value
Scallop yield	23.18 Tons of tons
Average water filtration rate per unit body weight of scallops	0.57 L/（g ħ）
Water filtration rate in scallop populations	1.51
Average meat yield	14.35%

Based on the values of the above parameters and the above evaluation methods, the estimation results of each index are shown in Table 3. After calculation and comparative analysis, it can be seen that the ratio of time (CT) and phytoplankton turnover time (PPT) for scallops to filter through all water bodies in this area is about 14.15, between 1 and 20, combined with the biological index method, the cultivation capacity of scallops in Qinhuangdao Bay is between ecological capacity and production capacity, and does not exceed the aquaculture capacity.

Table 3. Assessment of scallop culture capacity and carbon sequestration accounting results in Qinhuangdao city.

Parameters	Annual average
The time it takes for shellfish to filter all the water in the area（CT，d）	21.36
The time required to update all water bodies in the area（RT，day）	22.78
Phytoplankton turnaround time（PPT，d）	1.51
The ratio of the time (CT, d) required for shellfish to filter all the water in the area to the turnover time of phytoplankton (PPT, d)	14.15

3.4. Accounting of marine carbon sink of scallops in the bay of Qinhuangdao city

The values of the relevant parameters required for carbon sink accounting of maricultured scallops in Qinhuangdao city are shown in Table 4. According to the calculation method of shellfish carbon sink capacity combined with the values of various parameters, the carbon sink capacity of bay scallops cultured in Qinhuangdao city was calculated, and the carbon sink capacity of shells was about 14458.66 t a^{-1}, and the carbon sink capacity of soft tissue was about 9103.26 t a^{-1}, so the carbon sink capacity of bay scallop culture in Qinhuangdao city was about 23561.92 t a^{-1}.

Table 4. The values of each parameter are taken.

Parameters	*p*-scallops biomass (wet weight)/(ten thousand tons)	K-scallops dry wet weight conversion coefficient	R_1-dry scallop shell under the dry weight of state quality accounted for	CF_1-dry scallop shell quality CF carbon ratio	R_2-quality dried scallops dry weight state software organizations accounted for	CF_2-scallops soft tissue on the quality of dry carbon ratio	*p*-scallops biomass (wet weight)/(ten thousand tons)
Numeric value	23.18	63.89%	85.65%	11.4%	14.35%	42.84%	23.18

4. Discussion

4.1. Assessment of scallop culture capacity in the bay of Qinhuangdao city

Large-scale scallop raft scallop culture will have negative effects on the marine ecological environment in coastal waters, such as reduced phytoplankton concentration, decreased primary productivity, and weakened hydrodynamic conditions [16]. Understanding the current situation of scallop mariculture capacity is very important for dynamically regulating the amount of mariculture and promoting the scientific and sustainable development of mariculture. The above results show that the primary productivity level of scallop culture area in Qinhuangdao city is good, and phytoplankton as the main food for scallops, the concentration can meet the growth needs of scallops [17]. The calculated time (RT) for updating all water bodies in the area was an average of 22.78 d, and the time required for shellfish to filter all the water in the area (CT) The average was 21.36 d, and the water filtration time of maricultured scallops was faster than that of seawater renewal, indicating that the seawater scallop culture activities in Qinhuangdao city had certain feeding pressure on the aquaculture area. Shellfish can control the biomass of phytoplankton through feeding [18,19], so the environmental pressure of scallop culture activities on the sea area can be reflected by comparing the supply time of phytoplankton and the speed of scallop feeding The ratio of CT to PPT is about between 1 and 20, indicating that the aquaculture capacity of scallops is between ecological capacity and production capacity, does not exceed the aquaculture capacity, has certain development potential, and the existing aquaculture volume will not cause significant negative impact on the ecological environment of the sea area. Taking into account the actual production time, actual breeding area and other practical conditions, the current aquaculture volume will be increased by 13 times, so that the CT value and PPT The values are equal, so that the scallop culture reaches the production capacity. The food supply in this sea area can meet the growth demand of shellfish, and food supply is not the main limiting factor for the expansion of scallop culture in Qinhuangdao city. From the current aquaculture status and aquaculture capacity evaluation results, scallop culture in the bay of Qinhuangdao has great development space and development potential, but it is still necessary to control the culture of scallops, because when the culture volume reaches the culture capacity, shellfish will seriously affect the number and community of phytoplankton, and the

quantity and quality of suspended particulate matter will also be reduced [20]. When the amount of culture is too large, the yield and quality of scallops will decrease, which will affect the sustainable development of scallop culture [21]. The planned open marine aquaculture area of Qinhuangdao city is about 621.75 km^2, and the development utilization rate is about 50.42%, considering the gap between each aquaculture patch and the need to retain the passage channel and other factors. The area available for further development is limited. Bottom-seeding culture technology of scallops can be actively explored, although the growth cycle is long, it can improve the quality of scallops and prevent the occurrence of diseases [22]. In addition, it can also guide farmers to develop multi-trophic level integrated breeding technology, improve breeding efficiency, at present, scholars in Qinhuangdao scallop culture area to carry out multi-trophic level aquaculture technology research exploration and carry out breeding demonstration work, the study shows that by adding dragon beard vegetables between the scallop breeding cages, not only can increase the yield of scallops, but also increase additional income by harvesting dragon beard vegetables [23,24]. Therefore, we can continue to encourage the development of multi-trophic level aquaculture technology, build marine ranching, reduce environmental pressure, and increase aquaculture production.

4.2. Evaluation of the carbon sink value of scallops in the bay of Qinhuangdao city

Academician Tang Qisheng proposed the concept of "carbon sink fishery", that is, the process and mechanism of promoting the absorption of carbon dioxide in water by aquatic organisms through fishery production activities, and fixing "carbon" by harvesting aquatic products [25]. Scallops are not fed any bait during the culture process, and nutrient growth is obtained by filtering microalgae and organic debris in seawater, while algae growth absorbs seawater nitrogen and phosphorus, so shellfish culture can indirectly absorb nitrogen and phosphorus in seawater; At the same time, shellfish absorb CO2 from seawater during the growth process and form shells with calcium carbonate as the main component through biomineralization. With the harvest of shellfish products, nitrogen, phosphorus and carbon in shellfish soft and shells can be directly removed from seawater, and the carbon in shells is not easy to degrade and fix carbon for a long time [26], and has a good ecological and carbon sink effect, which is a typical "carbon sink fishery", by calculating the carbon sink capacity of the existing scallop culture activities in Qinhuangdao city is about 23561.92 t a-1. According to Wen Rui's [27] accounting for the carbon sink price of farmed scallops, the carbon sink price of bay scallops is about 165 yuan t-1. It is calculated that the annual carbon sink value of scallop farming in Qinhuangdao city is about 3.8877 million yuan per year. Shellfish culture has the characteristics of high nutritional value products and low carbon footprint, according to the research of relevant scholars, the culture of oysters, scallops, clams, cockles and mussels in China in 2019 can be fixed about 117.98 Tons of carbon dioxide. The benefits of emission reduction and foreign exchange increase are obvious [28]. Although experts in China have studied and explored the methodology of fishery carbon sink in recent years [29]. However, at present, the methodology for measuring and monitoring

fishery carbon sinks, which is the basis for carbon trading, has not yet been completed, and the capacity of comprehensive fishery carbon sink capacity is relatively weak. The establishment of fishery carbon sink methodology should be improved as soon as possible, the dispute over fishery carbon sink should be resolved, and the requirements of "measurable, reportable and verifiable" fishery carbon sink should be realized. In order to achieve the ambitious goals of CO2 emissions committed by China, "strive to peak before 2030" and "strive to achieve carbon neutrality before 2060".

5. Conclusion

The assessment conclusion of the biological index method can reflect that the amount of bay scallop culture in Qinhuangdao city does not exceed the aquaculture capacity, and the open mariculture in Qinhuangdao city has a certain space for development, and if combined with the three-dimensional multitrophic level of culture to carry out mariculture activities has great development potential. Moreover, marine aquaculture of bay scallops can bring high carbon sink value, so in addition to continuing to tap the potential of mariculture on the basis of not exceeding the aquaculture capacity, we should also increase research on carbon sink methodology and fishery carbon sink trading to realize the time of carbon sink value spillover value brought by mariculture fishery.

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Conflicts of interests

The authors declare no conflicts of interests.

References

[1] Zhang J, Liu J, Zhang Y, Li G. Ways of practicing "negative marine discharge" in mariculture. *Bulletin of Chinese Academy of Sciences* 2021, 36(3):252-258 (In Chinese).
[2] Huang L, Xu S, Wang X, *et al*. Comparative study on the purification effect of three tidal shellfish species on tailwater purification of P. vannabin shrimp. *Journal of Ningbo University (Science and Engineering Edition)* 2020, 33(6):7-12. (In Chinese).
[3] Zhang J, Liu J, Zhang Y, Li G. Ways of practicing "negative marine discharge" in mariculture. *Bulletin of Chinese Academy of Sciences* 2021, 36(3):252-258. (In Chinese).
[4] Cao L, Wang Y. Estimation of carbon sink potential of mariculture and analysis of its decoupling from economic development: A case study of three major coastal areas. *Ocean Economy* 2020, 10(5):48-56. (In Chinese).

[5] Yang Y. Evaluation of the impact of large-scale aquaculture in Sanggou Bay on the substrate environment. Dalian Ocean University, 2018. (In Chinese).
[6] Zhao Y. New model of healthy marine aquaculture:Interview with researcher Fang Jianguang of Yellow Sea Fisheries Research Institute. *Scientific Fish Farming* 2009, (1):4-5. (In Chinese).
[7] Dame R, Prins T. Bivalve carrying capacity in coastal ecosystems. *Aquat Ecol*. 1997, 31:409-421.
[8] Zhang J, Fang J, Wang S. Aquaculture capacity of Ezo scallops in the waters of Zhangzi Island, Dalian. *Journal of Fisheries of China* 2008, (2):236-241. (In Chinese).
[9] Gibbs M. Sustainability performance indicators for suspended bivalve aquaculture activities. *Ecol. Indic.* 2007, 7(1):94-107.
[10] Yue D, Wang L. Preliminary study on carbon sink accounting system for marine shellfish farming in China. *Hunan Agricultural Sciences* 2012, (15):120-122+130. (In Chinese).
[11] Sun K, Cui X, Su Z, Wang Y. Spatial-temporal evolution and influencing factors analysis of economic value of carbon sink in mariculture in China. *Geogr. Res*. 2020, 39(11):2508-2520. (In Chinese).
[12] Huang X, Chen W, Cai Q. *Observation, observation and analysis of lake ecology*. Beijing: China Standard Press. 1999, 77-79.
[13] Wu J, Peng M, Li L, Tan F, He Q, *et al*. Assessment of primary productivity of phytoplankton in Xiaowan reservoir area of Lancang River and its temporal and spatial changes. *Freshwater Fisheries* 2021, 51(04):3-11. DOI:10.13721/j.cnki.dsyy.20210603.001. (In Chinese).
[14] Wang F, Dong S, Zhang S, Wang R. Experimental study on food selectivity and filtration rate of bay scallops and Pacific oysters. *Oceanography and Limnology* 2000, (2):139-144. (In Chinese).
[15] Fang X, Zhang F, Wang L, Li G. Evaluation of the culture effect of the new species "Haiyifeng 12" of bay scallops (Argopecten irradians). *Hebei Fisheries* 2019, (6):1-3+13.) (In Chinese).
[16] Zhang X. Interaction between filter-feeding shellfish and environment and its culture capacity. Ocean University of China, 2003. (In Chinese).
[17] Chen Y. Study on the ecological characteristics of phytoplankton and the physiological mechanism of the relationship between key species in the scallop culture area of Bohai Bay. Xiamen University, 2017. (In Chinese).
[18] Officer C, Smayda T, Mann R. Benthic Filter Feeding: A Natural Eutrophication Control. *Mar. Ecol Prog Ser*. 1982, 9(2):203-210.
[19] Smaal A, Prins T. The Uptake of Organic Matter and the Release of Inorganic Nutrients by Bivalve Suspension Feeder Beds. NATO ASI SERIES G ECOLOGICAL SCIENCES, 1993.
[20] Wang S. Study on the interaction between filter-fed shellfish culture and environmental factors in Jiaozhou Bay. Shandong: Qingdao Agricultural University, 2008. DOI:10.7666/d.Y2332432. (In Chinese).
[21] Zheng X, Zhang F, Wu X, Zhang B, Wang L. Nutrient salt in bay scallop culture area of Changli County. *Hebei Fishery* 2011, (1):35-38. (In Chinese).
[22] Chen W, Xie X, Teng W, Yu Z, Liu X, *et al.* Research progress on Magellanic scallop culture biology and augmentation technology. *Journal of Dalian Ocean University* 2023, 38(1):158-167. DOI:10.16535/j.cnki.dlhyxb.2022-048. (In Chinese).
[23] Sun G, Zhao Z, Mu K, Wu X, Guo J, *et al*. Study on multitrophic multitrophic culture technology of longbeard and bay scallop. *Hebei Fishery* 2015(12):27-30. (In Chinese).
[24] Sun G, Zhao Z, Mu K, Wu X, Wang L, *et al*. Dragon beard culture technology in scallop culture area of Changli Bay. *Hebei Fishery* 2015, (6):34-35. (In Chinese).

[25] Tang Q. Carbon sink fishery and good and rapid development of modern fishery. *Jiangxi Fisheries Science and Technology* 2011, (2):5-7. (In Chinese).
[26] Shu S, Xiang C, Dong H, Luan H, Li Z, *et al.* Shellfish aquaculture production and carbon sink assessment in Weihai City from 2007 to 2016. *Fisheries Science and Technology Information* 2018, 45(1):48-51. (In Chinese).
[27] Wen R, Zhang J, Gao C, *et al*. Research on carbon sink price accounting of farmed shellfish. *Ocean Development and Management* 2022, 39(3):16-23. (In Chinese).
[28] Sun L, Yang C, Feng J, Zhang S, Zeng X. Evaluation of low-carbon effect of marine shellfish aquaculture in China. *Marine Bulletin* 2022, 41(5):593-600. (In Chinese).
[29] Zhang J, Liu Y, Wu W, Wang X, Zhong Y. Methodological exploration of marine fishery carbon sink project. *Advances in Fisheries Science* 2022, 43(5):151-159. DOI:10.19663/j.issn2095-9869.20220325004. (In Chinese).