Acta Oceanol. Sin., 2019, Vol. 38, No. 10, P. 60–66
https://doi.org/10.1007/s13131-019-1488-1
http://www.hyxb.org.cn
E-mail: hyxbe@263.net

Decadal variations in the community status of economically important invertebrates in the Bohai Sea

Qiang Wu[1, 2], Lisha Guan[1, 2], Zhongyi Li[1, 2], Xiujuan Shan[1, 2], Xianshi Jin[1, 2*]

[1] Key Laboratory for Sustainable Development of Marine Fisheries, Ministry of Agriculture/Shandong Provincial Key Laboratory for Fishery Resources and Eco-environment, Yellow Sea Fisheries Research Institute, Academy of Fishery Sciences, Qingdao 266071, China

[2] Laboratory for Marine Fisheries Science and Food Production Processes, Pilot National Laboratory for Marine Science and Technology (Qingdao), Qingdao 266237, China

Received 19 July 2018; accepted 18 October 2018

Abstract
With the decline of fish stocks, the proportions of economically important invertebrates like crustaceans and cephalopods have increased in the Bohai Sea. The community structure and trophic level of economically important invertebrates were analyzed using the bottom trawl survey data collected by the Yellow Sea Fisheries Research Institute in the Bohai Sea in May and August of 1958–1959, 1982, 1992–1993, 2004, 2009 and 2015. A total of 37 species of economically important invertebrates, belonging to 5 orders, 24 families, were captured. The biomass densities of economically important invertebrates in the Bohai Sea displayed an overall downward trend from 1982 to 2015. *Oratosquilla oratoria* and *Loligo* spp. were the most dominant species in the past 30 years, the biomass proportion of *O. oratoria* increased gradually in both May and August from 1982 to 2015. Moreover, biodiversity indices of economically important invertebrates in the Bohai Sea appeared to decline from 1982 to 2004 and then increased in 2015. Similarly, the mean trophic level of economically important invertebrates declined from 1982 to 2004 and increased slightly in 2015. Overall, although the proportions of invertebrates have increased, the biomass densities in the Bohai Sea have displayed an overall downward trend from 1982 to 2015. The increases in the biodiversity and trophic level of economically important invertebrates after the 2000s, possibly benefit from stock enhancement projects implemented by governments at different levels and national fishery management measures such as the “double-control” of the total number and engine power of fishing vessels and summer moratorium of fishing.

Key words: decadal variations, community structure, trophic level, economically important invertebrates, Bohai Sea

Citation: Wu Qiang, Guan Lisha, Li Zhongyi, Shan Xiujuan, Jin Xianshi. 2019. Decadal variations in the community status of economically important invertebrates in the Bohai Sea. Acta Oceanologica Sinica, 38(10): 60–66, doi: 10.1007/s13131-019-1488-1

1 Introduction

The Bohai Sea is a semi-closed basin with an area of about 80 000 km^2 and an average water depth of 18 m (Tang et al., 2003). More than 40 rivers run into the Bohai Sea, including the Huanghe River (Yellow River), Haihe River, Luanhe River and Liaohe River, etc. These rivers discharge large amounts of nutrition (e.g., nitrate, nitrite, phosphate and silicate) into the Bohai Sea, promoting phytoplankton blooms and thereby providing plentiful food organisms for various fishery stocks. Therefore, the Bohai Sea serves as the spawning, nursery or feeding grounds of many fisheries-targeted species and used to be well-known as “the cradle of fisheries of the Yellow Sea and the Bohai Sea” (Deng et al., 1988; Jin, 2001).

Unfortunately, the production of fish has declined sharply in the Bohai Sea over the past half century, as a consequence of multiple stressors including overfishing, environmental pollution and climate change (Jin, 2003; Jin et al., 2013). The community structure of fishery stocks in the Bohai Sea has changed greatly (Jin, 2004), with dominant species shifted from large-sized groundfishes at high-trophic levels to small-sized pelagic fishes or invertebrates at low-trophic levels (Iversen et al., 2001; Tang et al., 2016; Wu et al., 2017). The mean trophic level (MTL) of fishery stocks dropped from 4.4 in 1959 to 3.4 in 2011 in the Laizhou Bay, Bohai Sea (Zhang et al., 2015). Crustaceans and cephalopods are important parts of marine ecosystems, which provide a large amount of high-quality proteins for humans. With the decline of fish stocks, the proportions of economically important invertebrates (EII) like crustaceans and cephalopods have increased in the Laizhou Bay within the Bohai Sea (Wu et al., 2016). In 2016, a total of 2.40 million tons of crustaceans and 0.70 million tons of cephalopods were captured in the offshore China, accounting for 18.04% and 5.32% of the total offshore catches, respectively (National Bureau of Statistics of China, 2015).

Foundation item: The National Key Research and Development Program of China under contract No. 2018YFD0900902; the National Key Basic Research Development Program (973 Program) of China under contract No. 2015CB453303; the Special Funds for Taishan Scholar Project of Shandong Province; the AoShan Talents Cultivation Program supported by Qingdao National Laboratory for Marine Science and Technology under contract No. 2017ASTCP-ES07.
*Corresponding author, E-mail: Jin@ysfri.ac.cn

Changes in the biomass, structure and biodiversity of fish community in the Bohai Sea have been evaluated using the bottom trawl survey data provided by the Yellow Sea Fisheries Research Institute (YSFRI) from 1959 to 1998 (Jin, 2003). The decadal variations in the ecosystem productivity and control mechanisms of the Bohai Sea during the 1959 to 1999 have also been evaluated (Tang et al., 2003). However, long-term variability in the invertebrate community has been ignored in the Bohai Sea. This study aims at filling this gap through quantifying spatio-temporal trends in the biomass, structure, biodiversity and trophic level of the EII community in the Bohai Sea. Results of this study would provide scientific supports for the sustainable utilization of EII, including shrimps, crabs, squillas and cephalopods.

2 Materials and methods

2.1 *Sampling time and areas*

Data used were obtained from the spring and summer bottom trawl surveys by the Yellow Sea Fisheries Research Institute (YSFRI), Chinese Academy of Fishery Science (CAFS) in the Bohai Sea during the years of 1982, 1992–1993, 2004, 2009 and 2015. The spring and summer surveys were implemented in May and August, respectively. We divided the Bohai Sea into four subareas (i.e., the Laizhou Bay, the Bohai Bay, the Liaodong Bay and the central Bohai Sea) in order to evaluate spatio-temporal variations in the community of EII (Fig. 1). The number of stations for all the selected surveys was listed in Table 1 by season and subarea. Although the number and spatial distribution of sampling stations slightly differed by year, all the surveys covered the same broad area of the Bohai Sea. Moreover, the surveys were only conducted during the daytime to avoid the effect of diel vertical movements of different species on catchability.

2.2 *Fishing vessels and gears*

The same paired trawlers have been used in the surveys since 1982, with the same type of fishing gears. The gears had a cod-end mesh size of 2 cm, a headline height of 5–6 m and a distance of 22.6 m between wings. Please see related studies (Deng et al., 1988; Tang et al., 2003; Jin, 2004) for detailed descriptions of the sampling protocol during 1982 to 2015. All catch rates by species from the surveys were standardized for 1 h for each station.

2.3 *Data analysis*

In this study, we used the Shannon-Wiener diversity index (H') (Shannon and Weaver, 1963), Pielou's evenness index (J') (Pielou, 1966), and Margalef's richness index (D) (Margalef, 1958) as biodiversity indicators for the EII community in the Bohai Sea.

Fluctuations in the trophic level of the marine catches can reflect dynamic variations in community structure of the living marine resources (Pauly et al., 2001). Mean trophic level (MTL) from catches is one of the most widely adopted marine indicators, intended to detect shifts from high-trophic-level predators to low-trophic-level invertebrates and plankton-feeders (Pauly et al., 1998; Pauly and Palomares, 2005; Pauly and Watson, 2005). This indicator underpins reported trends in human impacts, declining when predators collapse ("fishing down marine food webs" (Pauly et al., 1998) and when low-trophic-level fisheries expand ("fishing through marine foodwebs") (Essington et al., 2006). The MTL of EII was calculated using the following formula:

$$MTL = \sum_{i=1}^{k} TL_i Y_i / Y_t,$$

where TL_i is the trophic level of the species i, Y_i is the biomass of the species i, and Y_t is the total biomass of all species. The trophic level of biomass-dominant species of EII (Table 2) were obtained from historical articles (Zhang and Tang, 2004; Yang, 2001).

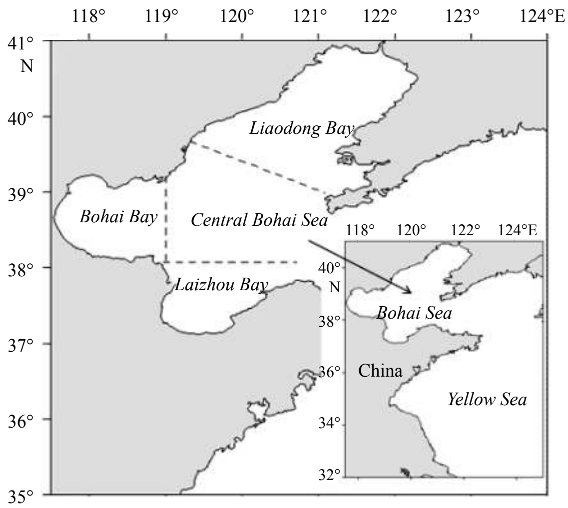

Fig. 1. The survey regions in the Bohai Sea.

3 Results

3.1 *Long-term changes in the relative biomass*

Figure 2 illustrates long-term changes in the density (i.e., relative biomass) of EII in the Bohai Sea. The relative biomass of EII fluctuated in the range of 2.54 to 8.69 kg/h in May and 14.20 to 31.49 kg/h in August during the 1982 to 2015. Overall, the densities of EII in the Bohai Sea showed a downward trend after 1982. The biomass densities in August were significantly higher than

Table 1. Number of sampling stations by year, month and subarea in the Bohai Sea

Year	Month	Liaodong Bay	Bohai Bay	Laizhou Bay	Central Bohai Sea	Total
1982	May	12	6	14	15	47
	Aug.	15	6	18	19	58
1993	May	17	5	9	13	44
1992	Aug.	21	4	6	14	45
2004	May	16	7	9	13	45
2009	Aug.	16	9	9	12	46
2015	May	11	8	14	14	47
	Aug.	10	3	12	17	42

Table 2. The trophic level of biomass-dominant species of economically important invertebrates

Species	Trophic level	Reference
Oratosquilla oratoria	3.47	Zhang and Tang (2004)
Loligo spp.	3.72	Zhang and Tang (2004)
Portunus trituberculatus	3.58	Zhang and Tang (2004)
Octopus spp.	3.80	Zhang and Tang (2004)
Charybdis japonica	3.60	Zhang and Tang (2004)
Crangon affinis	3.30	Yang (2001), Zhang and Tang (2004)
Fenneropenaeus chinensis	3.32	Zhang and Tang (2004)
Trachypenaeus curvirostris	3.31	Zhang and Tang (2004)
Alpheus spp.	3.40	Yang (2001)
Sepiella maindroni	4.20	Yang (2001)
Exopalaemon carinicauda	3.70	Yang (2001)

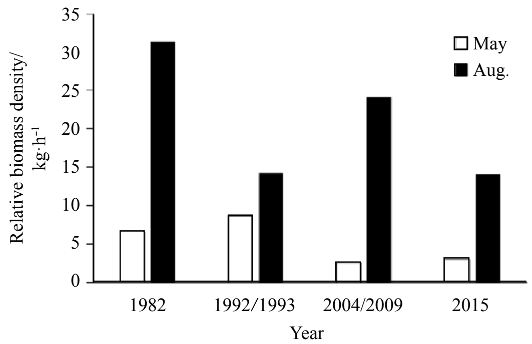

Fig. 2. Long-term changes in the biomass density of economically important invertebrates in the Bohai Sea.

the biomass densities in May (P<0.05). In May, the biomass density of EII increased from 6.64 kg/h in 1982 to 8.69 kg/h in 1992, then decreased to 2.54 kg/h in 2004 and increased again to 3.05 kg/h in 2015. In August, the biomass density of EII declined from 31.49 kg/h in 1982 to 14.20 kg/h in 1993, then increased to 24.08 kg/h in 2009 and decreased again to 14.11 kg/h in 2015.

3.2 *Long-term changes in dominant species*

Figure 3 displays long-term changes in the biomass-dominant species of EII in the Bohai Sea. *Oratosquilla oratoria* and *Loligo* spp. (including *Loligo japonica* and *Loligo beka*) were the most abundant species in May and August during 1982–2015. Moreover, the biomass proportion of *O. oratoria* increased gradually in May and August after 1982.

Oratosquill oratoria was the most dominant species in May of 1982, 2004 and 2015, which separately accounted for 41%, 59% and 64% of the overall biomass each year. *Loligo* spp. was the most dominant species in the spring of 1993, contributing to 62% of the total biomass of EII in the Bohai Sea. The most dominant species changed to be *O. oratoria* in August of 1992, 2009 and 2015, respectively. *Loligo* spp. was the most dominant species in the Bohai Sea in August of 1982, accounting for 59% of the overall biomass of EII.

3.3 *Variations in species composition and biomass density*

In May, the overall density of EII in the Bohai Sea was the highest in 1993, secondly highest in 1982 and the lowest in 2004. In August, the overall density of EII in the Bohai Sea was the highest in 1982 and the lowest in 2015. Overall, the biomass-dominant species of EII have changed in the Bohai Sea since 1982. In May, the biomass-dominant species were mantis shrimp and cephalopods in 1982 and 1993. Subsequently, mantis shrimp became the most dominant species in 2004 and 2015, with the proportion of cephalopods largely reduced. Similarly, the ecological niches of crabs and shrimps in the Bohai Sea have been gradually occupied by mantis shrimp in August during the last 40 years.

Figure 4 showed long-term changes in the biomass composition of EII in four subareas of the Bohai Sea. The biomass of invertebrates first increased and then decreased in the Laizhou Bay (August), Bohai Bay (May) and Liaodong Bay (May) during 1982–2015. In addition, the biomasses of invertebrates were bimodal in the Laizhou Bay (May), Bohai Bay (August), Liaodong Bay (August) and the central Bohai Sea (May and August) from 1982 to 2015. The biomass-dominant species of EII differed by subarea. In the Laizhou Bay, the biomass-dominant species were cephalopods (May) and crabs (August) from 1982 to the 1990s, and mantis shrimp became the biomass-dominant species after 2000. In the Bohai Bay, the proportion of mantis shrimp has increased gradually in the last 30 years. In the Liaodong Bay, the biomass-dominant species were cephalopods in 1982, and mantis shrimp became the biomass-dominant species in the last 30 years. In the central Bohai Sea, the proportion of the mantis shrimp in the overall biomass of EII has increased continuously in the last 30 years.

3.4 *Long-term changes in biodiversity*

A total of 37 species of EII within 5 orders and 24 families, were captured in the Bohai Sea from 1982 to 2015. We listed the occurrence frequencies of all species in Table A1. Totally, 16, 17, 30 and 31 species were caught in 1982, 1992/1993, 2004/2009, and 2015, respectively. We also evaluated long-term trends in the biodiversity of EII in the Bohai Sea (Fig. 5). In May, the temporal trends of three diversity indices (D, J', H') of EII were similar in the Bohai Sea, which declined from 1982 to 2004 and then increased in 2015. In August, three diversity indices (D, J', H') were relatively stable from 1982 to 2009 and then increased greatly in 2015.

We compared the long-term changes of EII biodiversity in four subareas of the Bohai Sea (Fig. 5). In May, the changing trend of three diversity indices (D, J', H') was similar in the Liaodong Bay, central Bohai Sea and Laizhou Bay. The changing trend of three diversity indices (D, J', H') was the opposite in the Bohai Bay. In August, temporal changes of three diversity indices (D, J', H') differed by subarea.

3.5 *Long-term changes in trophic level*

Overall, the EII community in the Bohai Sea indicated a

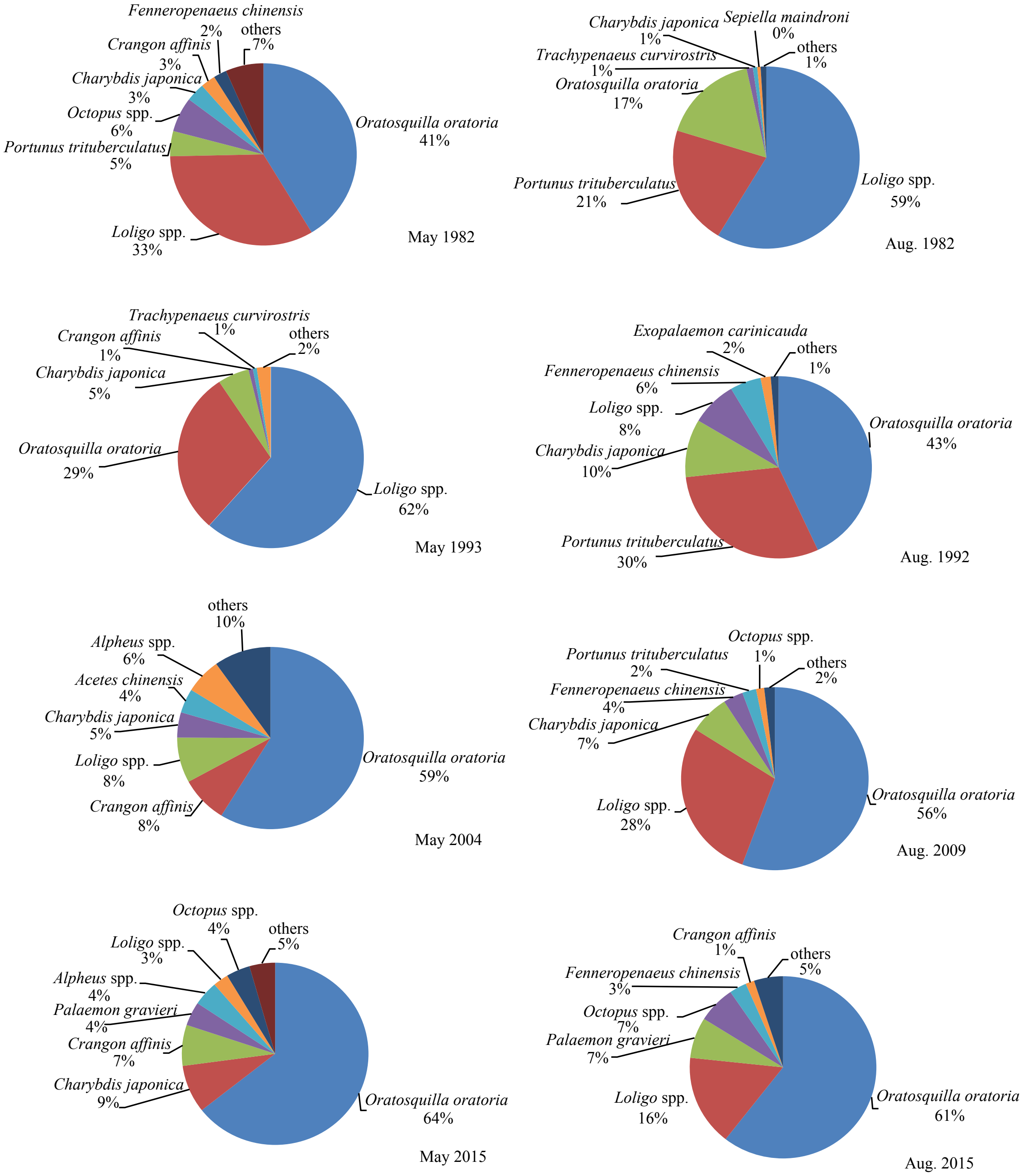

Fig. 3. Long-term biomass-dominant species variation of economically important invertebrates in the Bohai Sea.

downward trend, which was the highest in 1982, when the dominant species were *Loligo* spp. and *O. oratoria* at high trophic levels. The MTL of EII in the Bohai Sea appeared to decrease from 1982 to the 2000s, and then slightly increased in 2015 (Fig. 6).

4 Discussion

4.1 *Long-term changes in the biomass density*

The biomass density of fish in the Bohai Sea declined from 85.2 kg/h in 1982 to 3.7 kg/h in 1998 (Jin, 2004). The biomass densities of EII in the Bohai Sea fluctuated in the range of 2.54 to 8.69 kg/h in spring and 14.20 to 31.49 kg/h in summer during 1982–2015. Overall, the biomass densities of EII in the Bohai Sea displayed a downward trend from 1982 to 2015. The biomass density of EII was the highest in August 1982, due to the outbreak of *Loligo* spp. and *P. trituberculatus*, which accounted for 80% of the total yields. Since then, with the decline of the biomass density of *Loligo* spp. and *P. trituberculatus*, the biomass densities of EII declined continuously from 1992 to 2015.

4.2 *Long-term changes in the biomass-dominant species*

Biomass-dominant species of EII in the Bohai Sea have changed gradually. The biomass-dominant species were *Loligo* spp., *O.oratoria* and *P. trituberculatus* during 1982–1993, which contributing to more than 79% of the total biomass density, totally. Recently, *O. oratoria* has gradually dominated the biomass density of EII, which accounts for more than 56% of the total biomass density.

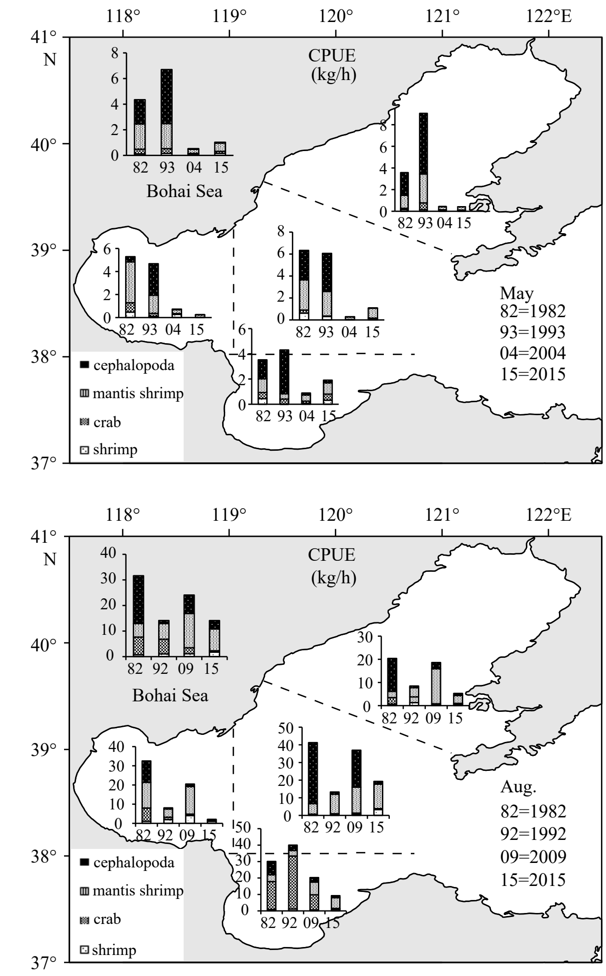

Fig. 4. Regional variations in the biomass density and species composition of economically important invertebrates in the Bohai Sea.

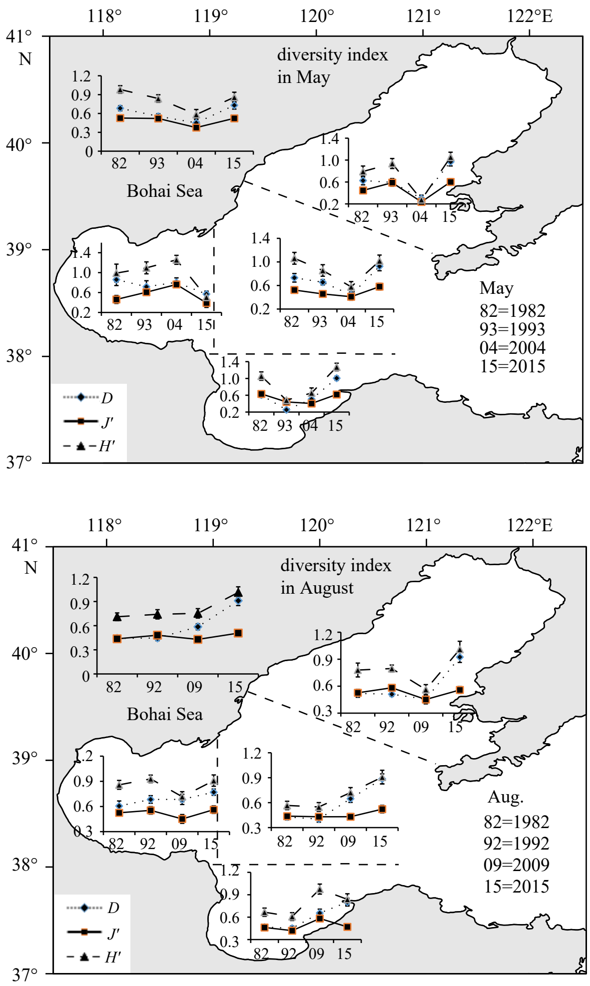

Fig. 5. Long-term changes in the biodiversity of economically important invertebrates in the Bohai Sea.

Multiple reasons could explain why *O. oratoria* has become the unique dominant species in the Bohai Sea (Wu et al., 2016, 2018). First, the Bohai Sea has widespread silty clay substrates, which provide suitable habitats for *O. oratoria* with burrowing habit. Second, *O. oratoria* can tolerate a wide range of temperatures (6–31°C) and have shown a high resistance to diseases (Wang et al., 1998). Third, *O. oratoria* is a r-strategy species with a high reproductivity and short life cycle (Keita et al., 2004, 2005). Finally, long-term overfishing has severely depleted the *F. chinensis* and *P. trituberculatus* stocks which compete with *O. oratoria* for food and space, and thereby increased the food sources and living space of *O. oratoria*.

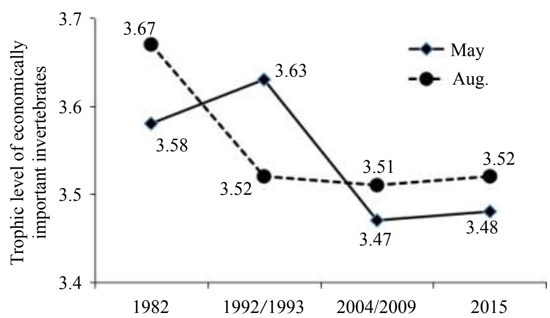

Fig. 6. Long-term changes in the trophic levels of economically important invertebrates in the Bohai Sea.

4.3 *Long-term changes in the trophic levels*

The changes in the MTL of the total offshore fishing species in China were analyzed using the data from FAO, with invertebrates contributing 14.2%–26.9% to the MTL of captured species in China (Du et al., 2014). According to the statistical data from the Chinese Fisheries Statistics Yearbook during 1956–2014, the MTL of marine catches in the Yellow Sea and Bohai Sea tends to decrease especially after 1980 (Wu et al., 2017). The results of this study are consistent with the conclusions above. This phenomenon can be explained by the ecological attributes and feeding characteristics of dominant species, which have shifted from large-sized groundfishes at high-trophic levels to small-sized pelagic fishes or invertebrates at low-trophic levels.

4.4 *Management measures and recommendations*

Under the influence of over-exploitation, both the biomass density and biodiversity of EII in the Bohai Sea have declined from 1982 to 1993 (Figs 2 and 5). Chinese government has implemented a lot of regulations and strategies to promote the recovery of fishery resources since 1995, such as “double-control” of the total number and power of fishing vessels, closed season/

areas, and limits of catchable size, etc. (Tang et al., 2016). This has contributed to increases in the biodiversity and MTL of EII in the Bohai Sea from 2004 to 2015 (Figs 2 and 5). Therefore, we propose to implement stricter management measures, such as total catch limit and fisheries moratorium, to conserve and restore the invertebrate resources in the Bohai Sea.

5 Conclusions

A total of 37 species of EII, belonging to 5 orders, 24 families, were captured in the Bohai Sea from 1982 to 2015. The biomass densities of EII in the Bohai Sea demonstrated an overall downward trend from 1982 to 2015. *Oratosquilla oratoria* and *Loligo* spp. were the most dominant species in the past 30 years. The biomass proportion of *O.oratoria* increased gradually in both May and August from 1982 to 2015. The changing trends of three diversity indices (D, J', H') for EII in the Bohai Sea were similar, which declined in the springs or kept relatively stable in the summers of 1982 to 2004, then increased in 2015. The MTL of EII in the Bohai Sea appeared to decrease from 1982 to the 2000s, and then slightly increased in 2015. Overall, both the biodiversity and trophic level of EII in the Bohai Sea have increased gradually from 2004 to 2015, possibly benefiting from the stock enhancement project and management measures, such as “double-control” of the total number and power of fishing vessels, closed season/areas, and limits of catchable size, etc.

References

Deng Jingyao, Meng Tianxiang, Ren Shengmin, et al. 1988. Species composition, abundance and distribution of fishes in the Bohai Sea. Marine Fisheries Research (in Chinese), 9(1): 11–89

Du Jianguo, Ye Guanqiong, Chen Bin, et al. 2014. Changes in the marine trophic index of Chinese marine area. Biodiversity Science (in Chinese), 22(4): 532–538, doi: 10.3724/SP.J.1003.2014.13200

Essington T E, Beaudreau A H, Wiedenmann J. 2006. Fishing through marine food webs. Proceedings of the National Academy of Sciences of the United States of America, 103(9): 3171–3175, doi: 10.1073/pnas.0510964103

Iversen S A, Johannessen A, Jin Xianshi, et al. 2001. Development of stock size, fishery and biological aspects of anchovy based on R/V “Bei Dou” 1984–1999 surveys. Marine Fisheries Research, 22(4): 33–39

Jin Xianshi. 2001. The dynamics of major fishery resources in the Bohai Sea. Journal of Fishery Sciences of China (in Chinese), 7(4): 22–26

Jin Xianshi. 2003. Fishery biodiversity and community structure in the Yellow and Bohai Seas. American Fisheries Society Symposium, 38: 643–650

Jin Xianshi. 2004. Long-term changes in fish community structure in the Bohai Sea, China. Estuarine, Coastal & Shelf Science, 59(1): 163–171

Jin Xianshi, Shan Xiujuan, Li Xiansen, et al. 2013. Long-term changes in the fishery ecosystem structure of Laizhou Bay, China. Science China Earth Sciences, 56(3): 366–374, doi: 10.1007/s11430-012-4528-7

Keita K, Shimizu T, Yamakawa T, et al. 2004. Reproductive biology of the female Japanese mantis shrimp *Oratosquilla oratoria* (Stomatopoda) in relation to changes in the seasonal pattern of larval occurrence in Tokyo Bay, Japan. Fisheries Science, 70(5): 734–745, doi: 10.1111/j.1444-2906.2004.00866.x

Keita K, Yamakawa T, Shimizu T, et al. 2005. Age estimation of the wild population of Japanese mantis shrimp *Oratosquilla oratoria* (Crustacea: Stomatopoda) in Tokyo Bay, Japan, using lipofuscin as an age marker. Fisheries Science, 71(1): 141–150, doi: 10.1111/j.1444-2906.2005.00941.x

Margalef D R. 1958. Information theory in ecology. General Systems, 3: 36–71

National Bureau of Statistics of China. 2015. China Fishery Statistical Yearbook (in Chinese). Beijing: Science Press

Pauly D, Christensen V, Dalsgaard J, et al. 1998. Fishing down marine food webs. Science, 279(5352): 860–863, doi: 10.1126/science.279.5352.860

Pauly D, Palomares M L. 2005. Fishing down marine food web: it is far more pervasive than we thought. Bulletin of Marine Science, 76(2): 197–212

Pauly D, Palomares M L, Froese R, et al. 2001. Fishing down Canadian aquatic food webs. Canadian Journal of Fisheries & Aquatic Sciences, 58(1): 51–62

Pauly D, Watson R. 2005. Background and interpretation of the ‘Marine Trophic Index’ as a measure of biodiversity. Philosophical transactions of the Royal Society B: Biological Sciences, 360(1454): 415–423, doi: 10.1098/rstb.2004.1597

Pielou E C. 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology, 13: 131–144, doi: 10.1016/0022-5193(66)90013-0

Shannon C E, Weaver W. 1963. The Mathematical Theory of Communication. Urbana, IL: University Illinois Press

Tang Qisheng, Jin Xianshi, Wang Jun, et al. 2003. Decadal-scale variations of ecosystem productivity and control mechanisms in the Bohai Sea. Fisheries Oceanography, 12(4–5): 223–233, doi: 10.1046/j.1365-2419.2003.00251.x

Tang Qisheng, Ying Yiping, Wu Qiang. 2016. The biomass yields and management challenges for the Yellow Sea large marine ecosystem. Environmental Development, 17: 175–181, doi: 10.1016/j.envdev.2015.06.012

Wang Bo, Zhang Xilie, Sun Pixi. 1998. On biological characters and artificial seedling-rearing techniques of Mantis Shrimp (*Oratosquilla oratoria*). Journal of Oceanography of Huanghai and Bohai Seas (in Chinese), 16(2): 64–73

Wu Qiang, Li Zhongyi, Wang Jun, et al. 2018. Inter-annual variation in the community structure of crustaceans in the Bohai Sea during summer. Progress in Fishery Sciences (in Chinese), 39(2): 16–23

Wu Qiang, Wang Jun, Zhang Bo, et al. 2016. Monthly variation in crustacean assemblage (Decapod and Stomatopod) and its relationships with environmental variables in Laizhou Bay, China. Journal of Ocean University of China, 15(2): 370–378, doi: 10.1007/s11802-016-2714-5

Wu Jiaying, Xue Ying, Liu Xiaoxiao, et al. 2017. Long-term trends in the mean trophic level of marine fisheries in the Yellow Sea and Bohai Sea. Periodical of Ocean University of China (in Chinese), 47(11): 53–60

Yang Jiming. 2001. A study on food and trophic levels of Bohai Sea invertebrates. Modern Fisheries Information (in Chinese), 16(9): 8–16

Zhang Bo, Tang Qisheng. 2004. Study on trophic level of important resources species at high trophic levels in the Bohai Sea, Yellow Sea and East China Sea. Advances in Marine Science (in Chinese), 22(4): 393–404

Zhang Bo, Wu Qiang, Jin Xianshi. 2015. Interannual variation in the food web of commercially harvested species in Laizhou Bay from 1959 to 2011. Journal of Fishery Sciences of China (in Chinese), 22(2): 278–287

Appendix:

Table A1. Species list of economically important invertebrates captured with frequency of occurrence (F, %) in different decades

Order	Family	Scientific name	Frequency of occurrence in trawls (F, %)							
			1982		1992/1993		2004/2009		2015	
			May	Aug.	May	Aug.	May	Aug.	May	Aug.
Decapoda	Penaeidae	*Fenneropenaeus chinensis*	31.91	17.24	6.82	44.44		26.09		30.95
		Marsupenaeus japonicus						4.35		2.38
		Trachypenaeus curvirostris	31.91	67.24	54.55	28.89	6.67	8.70		11.90
	Palaemonidae	*Palaemon gravieri*	25.53	31.03	34.10	37.78	33.33	43.48	76.6	66.67
		Exopalaemon carinicauda	4.26		4.55	15.56		2.17	2.13	
	Crangonidae	*Crangon affinis*	76.60	6.90	45.45	2.22	46.67	8.7	89.36	47.62
	Alpheidae	*Alpheus japonicus*	57.45	22.41	34.10	80	31.11	28.26	70.21	52.38
		Alpheus distinguendus	34.04		47.73	20	13.33	39.13	48.94	40.48
	Pasiphaeidae	*Leptochela gracilis*					2.22	4.35		21.43
	Hippolytidae	*Latreutes anoplonyx*					4.44	15.22		14.29
		Latreutes planirostris						2.17	2.13	57.14
	Upogebiidae	*Upogebia major*					2.22		4.26	
	Sergestidae	*Acetes chinensis*					8.89	4.35	34.04	35.71
	Portunidae	*Portunus trituberculatus*	48.94	65.52	2.27	17.78	8.89	54.35	2.13	47.62
		Charybdis japonica	42.55	44.83	52.27	62.22	11.11	54.35	19.15	52.38
		Charybdis bimaculata					4.44	4.35	2.13	11.90
	Dorippidae	*Heikeopsis japonicus*					2.22	13.04		23.81
	Matutudae	*Matuta planipes*					4.44			
	Varunidae	*Hemigrapsus penicillatus*					8.89	8.70		
		Eriocheir sinensis							2.13	
	Macrophthalmidae	*Tritodynamia rathbunae*					4.44		2.13	7.14
	Oregoniidae	*Oregonia gracilis*					2.22			
	Leucosiidae	*Arcania undecimspinosa*							2.13	
		Pyrhila pisum							2.13	
	Goneplacidae	*Carcinoplax vestita*						52.17	40.43	45.24
	Euryplacidae	*Eucrate crenata*							2.13	16.67
	Diogenidae	*Diogenes edwardsii*						6.52		7.14
	Canceridae	*Cancer gibbosulus*								4.76
Stomatopoda	Squillidae	*Oratosquilla oratoria*	97.87	98.28	95.45	95.56	57.78	89.13	91.49	88.10
Sepiida	Sepiidea	*Sepiella maindroni*	4.26	34.48	4.55					
		Sepia esculenta						6.52		
		Sepiola birostrata	48.94	6.90	20.45		35.56	4.35	36.17	38.10
Octopoda	Octopodidae	*Octopus ocellatus*	31.91	10.34	18.18	2.22	2.22	26.09	14.89	21.43
		Octopus variabilis	29.79	20.69	22.73	22.22		58.70	12.77	33.33
Teuthoidea	Loliginidae	*Loligo* spp.	93.62	96.55	95.45	91.11	42.22	93.48	55.32	90.48
	Ommastrephidae	*Todarodes pacificus*				4.44	9.11			

Note: *Loligo* spp. includes *Loligo japonica* and *Loligo beka*.