Chapter 6

Impact of *Enteromorpha* Blooms on Aquaculture Research Off Qianliyan Island, Yellow Sea, China

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71434

Abstract

Between 2008 and 2016, there were mass summer blooms of *Enteromorpha* in the Yellow Sea, China. They covered an area of thousands of square kilometers annually, lasting an average of 90 days. Remote sensing data, model predictions, and marine environment ecological data measured by ships before, during, and after the *Enteromorpha* blooms were used in this study of the Qianliyan Island area. Underwater robots survey *trepang*, *wrinkles abalone,* and submarine ecological status. We found that the time taken by *Enteromorpha* to cover the Qianliyan Island area was relevant, as were changes in sea surface temperature (SST). The *Enteromorpha* made a rise in inorganic nitrogen, reactive phosphate, and heavy metals content in upper, middle, and bottom layers of sea water, dissolved oxygen (DO) and pH were reduced; and there were changes in the dominant animal and plant population. *Enteromorpha* sedimentation during outbreaks was measured by benthos sampling. Considerable growth in starfish number was obtained by underwater robot observation. All of this directly influenced the regional ecological environment. Numbers of *trepang* and *wrinkles abalone* were declined over the years. Global warming and SST anomalies are the two main reasons for frequent marine disasters that take place. National aquatic germ plasm resources of Qianliyan should be protected from the blooms.

Keywords: *Enteromorpha*, remote sensing data, SST, *trepang*, *wrinkles abalone*, Qianliyan Island

1. Introduction

Large summer blooms of *Enteromorpha* occurred in the Yellow Sea, China, from 2008 to 2016. These took place in the Yancheng shoals, Jiangsu Province, and covered an area of thousands of square kilometers, lasting for about 90 days each year. The blooms seriously affected the ecological environment of the Yellow Sea and attracted the attention of scholars [1].

Based on the differences in monitoring spectral caused by *Enteromorpha* covering the surface of the water, remote sensing data of MODIS data (TERRA/AQUA), image data of GF-1, HJ-1-A/1-B and Landsat-8 and so on, data source were used to study *Enteromorpha* drift, diffusion, and traceability [1–8]. Because the synthetic aperture radar (SAR) data are not affected by rain clouds, they are beginning to be used in *Enteromorpha* monitoring [9, 10]. Double polarization and cross-polarization retrieval factors were used to extract information about *Enteromorpha* on the sea surface. Although SAR has some limitations in the observation of large mass *Enteromorpha*, compact polarimetric synthetic aperture radar has solved this problem and will play an increasingly important role in such monitoring [11]. Researches show that the growth difference of *Enteromorpha* is not obvious when temperature is stable but nutrient conditions vary [11]. The growth difference in *Enteromorpha* is significant when nutrients are stable and temperature gradient is varying. The influence of temperature on *Enteromorpha* growth is considerable; the alga grows and quickly dies in water at 40°C; when the sea surface temperature (SST) is between 5 and 35°C, it can survive but it cannot maintain normal growth for a long time. In SST of 10–30°C, it grows normally. SSTs between 20and 25°C are most suitable for growth, and maximum growth takes place at the SSTs of 25°C. *Enteromorpha* can release spores at SSTs 15–35°C [11]. They are released in great quantities and grow normally when sea water salinity (SAL) is at a range of 12–40 psu; the most favorable range is when SAL is at 28–40 psu. At 32 psu, spore release is at its maximum [12]. The ability of *Enteromorpha* to adapt to high SAL is greater than its ability to adapt to low SAL. The most suitable conditions for *Enteromorpha* growth are when SAL is at 24–28 psu and the maximum are when SAL is at 24 psu [12]. Seawater pH values of 5 or 6 prevent *Enteromorpha* spore release; spore can be released at pH 7–10. A pH value of 9 allows maximum spore release [12]. *Enteromorpha* absorption of nitrogen and phosphorus is remarkable, the absorptive character for nitrogen and phosphorus have their own characteristics [13]. Wang [14, 15] simulated an indoor *Enteromorpha* tide using rotting leachate, and indicate that such tides may harm *wrinkles abalone* in the field. Results confirmed that *Enteromorpha* exudates, decaying and have an acute lethal effect for *wrinkles abalone*, *shrimps*, and *trepan*. The sulfide and ammonia in the leachate from *Enteromorpha* decay are the main causes of death of *wrinkles abalone*. Hypoxia stress for the green tide is an important cause of harm to farmed animals [12]. This chapter will study the impact of *Enteromorpha* on the ecological environment in the marine national aquatic germ plasm resources of Qianliyan Island, Yellow Sea, China. The greatest impact has been to *trepang* and abalone yield.

Section 2 provides an overview of the methods and results used to retrieve SST, chlorophyll concentration (CHL), sea state, and wind parameters from remote sensing; SAL and ecological environment data measured by ship. The remote sensing data and site monitoring data are discussed in Section 3, and Section 4 contains our conclusions.

2. Method and results

2.1. Study area and method

The national aquatic germ plasm resources of Qianliyan Island sea area are located in the south Yellow Sea, China, at latitude 36°15′57″ N, longitude 121°23′09″ E. The reserve covers an area of 1766.27 hectares (**Figure 1**). The specific location of each monitoring station and its contents are shown in **Table 1**. Experimental *Enteromorpha* data were collected from the monitoring sites before, during, and after the blooms of 2010–2016. The main protected species in the reserve are the *trepang, wrinkles abalone, other varieties of protection are the blue dot mackerel, anchovy, small yellow croaker, hairtail, Penaeus chinensis, Portunus trituberculatus, and Charybdis japonica*. The reserve area is 24.8 sea miles distant from land, with no residents and away from the land-source pollution. The *Enteromorpha* blooms pass this protection zone every year. Remote sensing data (MODIS, Windsat, HY2, and Radarsat2), model prediction, and the marine environment ecological data before, during, and after the *Enteromorpha* blooms as measured by ships (2010–2016) were used in this research. An underwater robot was used to survey *trepang*, *wrinkles abalone,* and submarine ecological status.

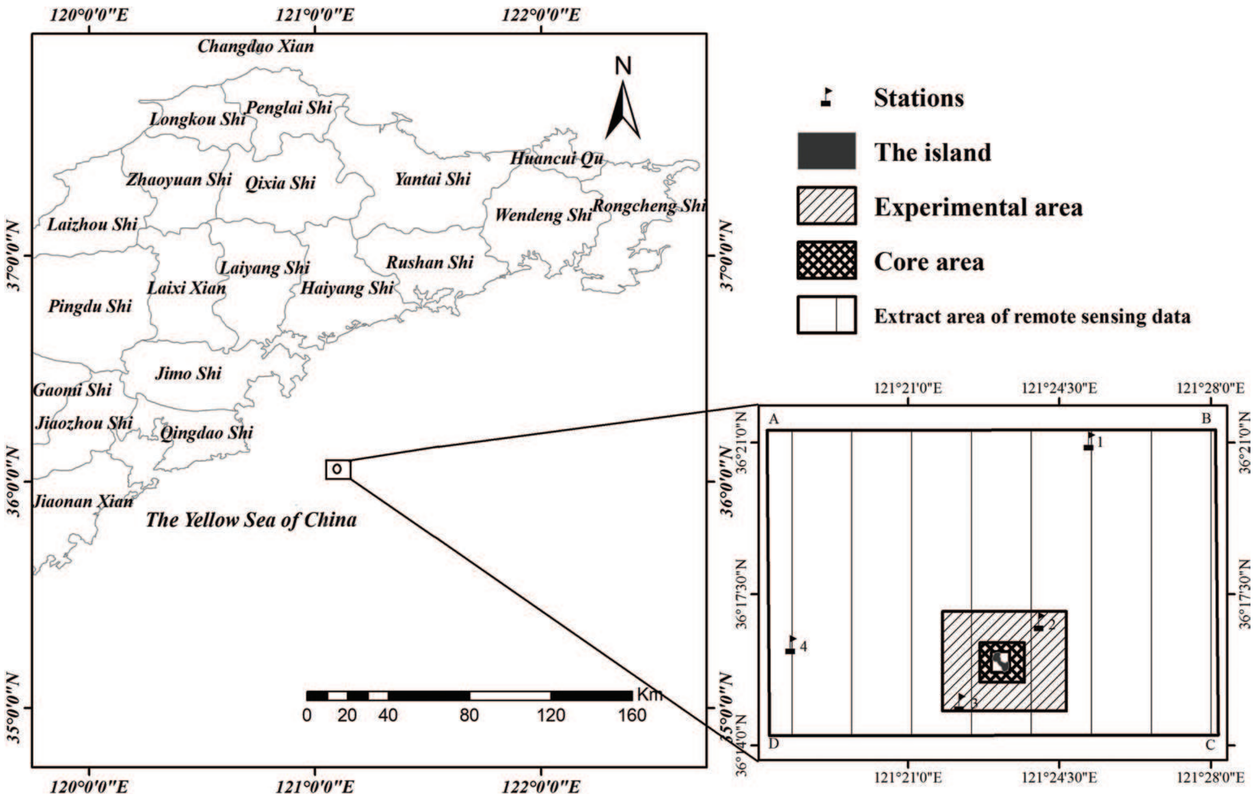

Figure 1. Qianliyan Island sea area sketch map, Black grid is core area; slant lines area is experiment area; blace is Qianliyan Island; rectangle ABCD is extract area of remote sensing data; black flag is monitoring station.

Position the serial number	Longitude (E)	Latitude (N)	Monitoring program
1	121°25′12″	36°21′00″	Water quality
2	121°24′00″	36°16′48″	Water quality, sediment, biology
3	121°22′12″	36°15′00″	Water quality
4	121°17′60″	36°16′12″	Water quality

Table 1. Position monitoring information.

2.2. Remote sensing and analysis of monitoring results

MODIS, Radarsat2 data, and the ocean numerical model of the North China Sea Marine Forecasting Centre of SOA, to predict the drift of the blooms, were used to analyze the period when *Enteromorpha* covered the sea off Qianliyan Island (see **Table 2**) from 2009 to 2016. The longest duration of an *Enteromorpha* blooms in the Yellow Sea was in 2012 (106 days); in contrast, the longest off Qianliyan Island was 54 days. Eight-day average MODIS data (resolution of 4 km) were used to retrieve the chlorophyll concentration (CHL) and the SST data; the altimeter data of HY2 were used to retrieve the significant wave height (SWH) and ASCAT data (resolution of 50 km) to retrieve wind field in research area (**Figure 1**). As *Enteromorpha* blooms off Qianliyan Island often occurred in June, July, and August, so average SST, CHL, wind field, and SWH change in these months were the main indexes used by remote sensing from 2009 to 2016.

Figure 2a shows that CHL rose significantly in July 2009–2016; this was because SST was between 20 and 25°C (**Figure 2c**) and so most suitable for the *Enteromorpha* growth [12]. As the SST in June, July, and August 2012 was between 20 and 25°C (**Figure 2c**), the duration of the *Enteromorpha* bloom covering the Yellow Sea and the Qianliyan Island area was the longest (**Table 2**). The SWH retrieved by HY2 data and at sea level in the research area were at levels 4–5 (**Figure 2b**). The SWH in July was the highest of these 3 months.

Year	Began to affect the Qianliyan	End of the impact on the Qianliyan	The time and place of first discovered by satellite	Duration time of Yellow Sea (Day)
2009	July 7	August 4	20th May Outside the sea of Yancheng	94
2010	June 30	August 12	2nd June Yancheng coast	76
2011	July 14	July 29	27th May Yancheng coast	82
2012	June 4	July 27	16th May Yancheng coast	106
2013	June 24	July 26	10th May Yancheng coast	96
2014	June 12	August 3	12th May Yancheng coast	95
2015	June 10	July 31	16th May Yancheng coast	93
2016	June 13	July 24	11th May Yancheng coast	90

Table 2. The *Enteromorpha* starting and ending time in Yellow Sea and Qianliyan Island area.

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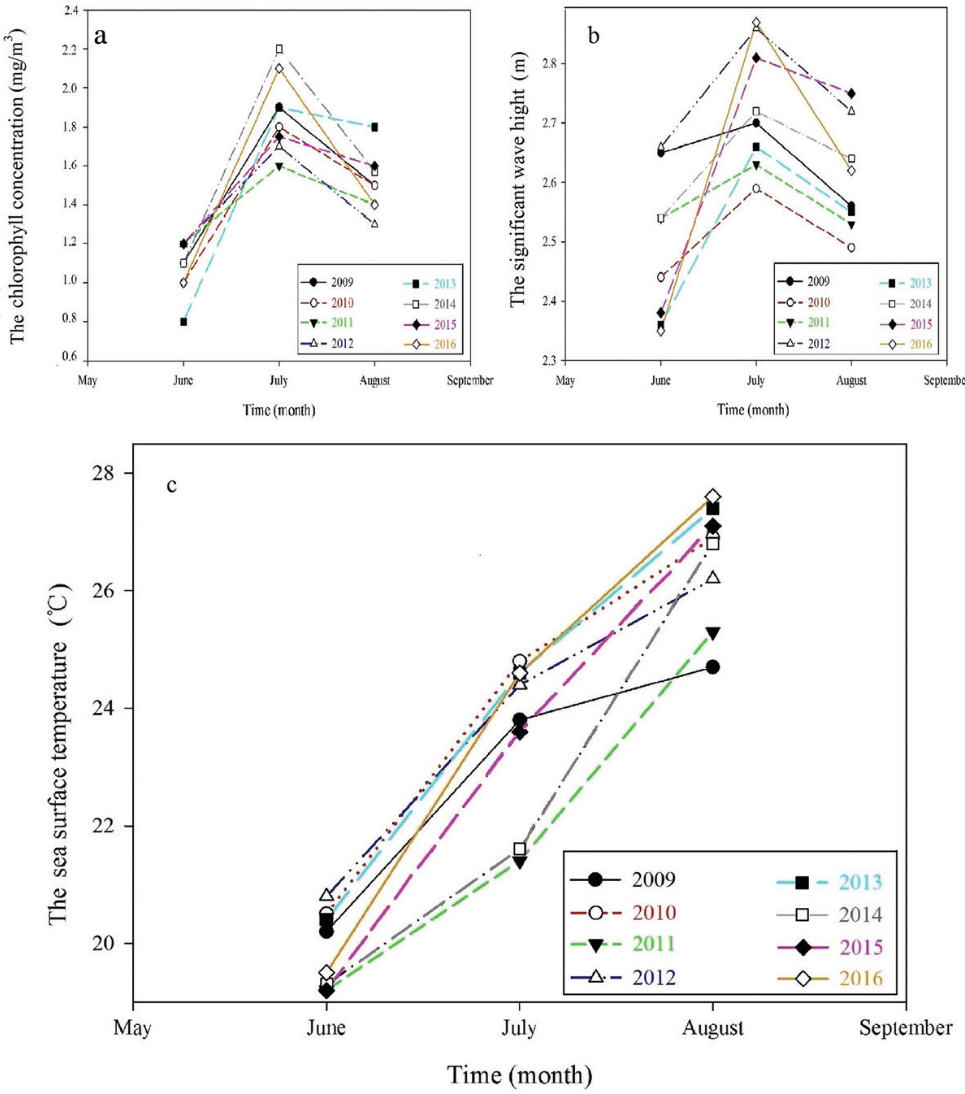

Figure 2. Average CHL (a), SWH (b), and SST (c) in June, July, and August, respectively from 2009 to 2016.

The MODIS *Enteromorpha* data (resolution of 1 km) were extracted on 06 May, 20 June, 06 July 2012 and on 02, 20 and 29 June 2013 (**Figure 3a** and **b**). The Radarsat 2 *Enteromorpha* data (resolution of 100 m, VV) was extracted on 12 June and 14 July 2016 (**Figure 3c**). The floating algae index (FAI) was used to the *Enteromorpha* data [16]. There are wind scale from 3 to 4 in the study area and the advantages by south winds in June and July (**Figure 4a** and **b**). In August, the southwesterly wind becomes northwesterly (**Figure 4c**). These wind fields assist the *Enteromorpha* blooms in coming ashore. The drift direction of the *Enteromorpha* blooms was basically consistent with the wind direction.

2.3. Real-time site observation data

Site observation data were measured at different water depths (0.5 m, upper; 10–18 m, middle; and 31.5–34 m, bottom) from ships (**Figure 1**). Observation data analyzed the impact of

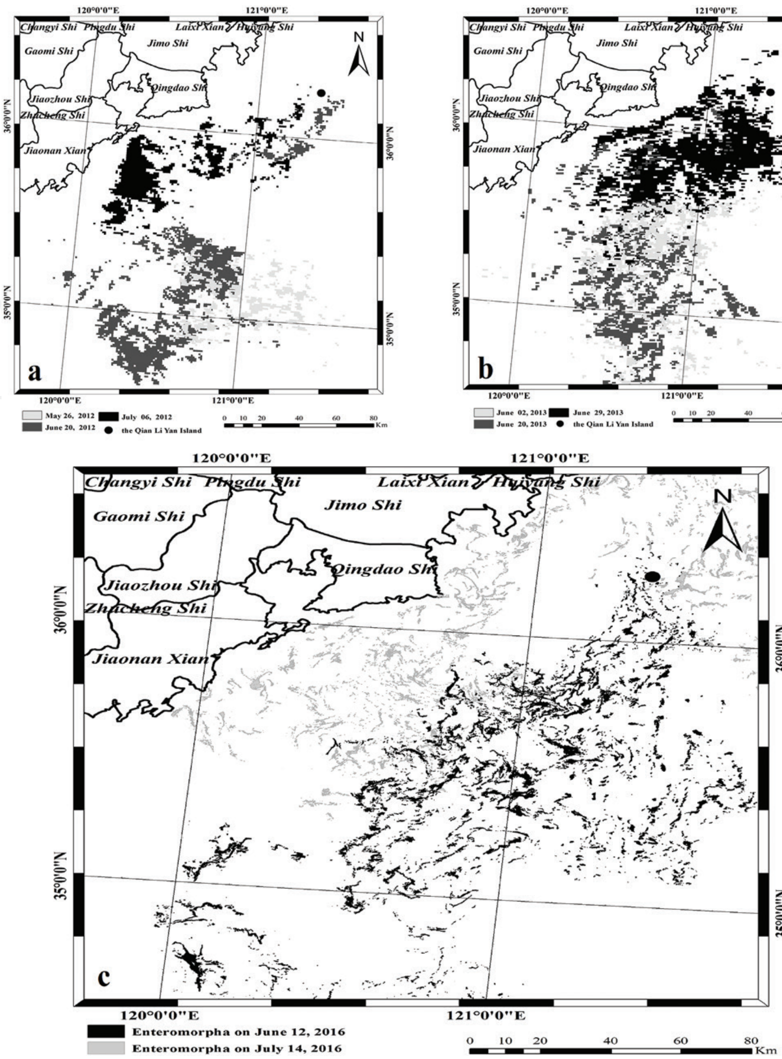

Figure 3. *Enteromorpha* image extraction by MODIS data on 26 May, 20 June, and 06 July 2012(a); 02, 20, and 29 June 2013(b); and on 12 June and 14 July 2016(c) by Radarsat 2 data from an area near Qianliyan Island.

Enteromorpha on the Qianliyan Island area (average data from stations 1, 2, 3, and 4) from 2010 to 2016. Samples were taken in February, March, and May, before *Enteromorpha* blooms; in July, during the *Enteromorpha* blooms; and in August, October, and November after the *Enteromorpha* blooms. **Figure 5a** shows that the SAL was between 30 psu and 32 psu in February, March, May, July, August, October, and November from 2012 to 2016. This allowed *Enteromorpha* to grow normally. During the *Enteromorpha* blooms, the SAL was between 30.8 and 31.7 psu in July of 2013. Spores dispersal is most favored when SAL is 30.5–32 psu [11]. The dissolved oxygen (DO) content of sea water is influenced by biological, chemical, physical, and other factors. When the density of phytoplankton is very great, the high concentrations of chlorophyll-a and active photosynthesis increase the oxygen content of the water. In contrast, when large numbers of phytoplankton die, oxidation is greater than photosynthesis and the DO content of the water falls sharply [17]. DO was clearly lower in upper, middle, and bottom water layers after blooms than before them, from 2014 to 2016 (**Figure 5b**). We suggest that this was because of *Enteromorpha* decomposition and settlement. After the large algal blooms, seaweed decomposition release large amounts of ammonium salts into the water, leading to a hypoxic environment and the

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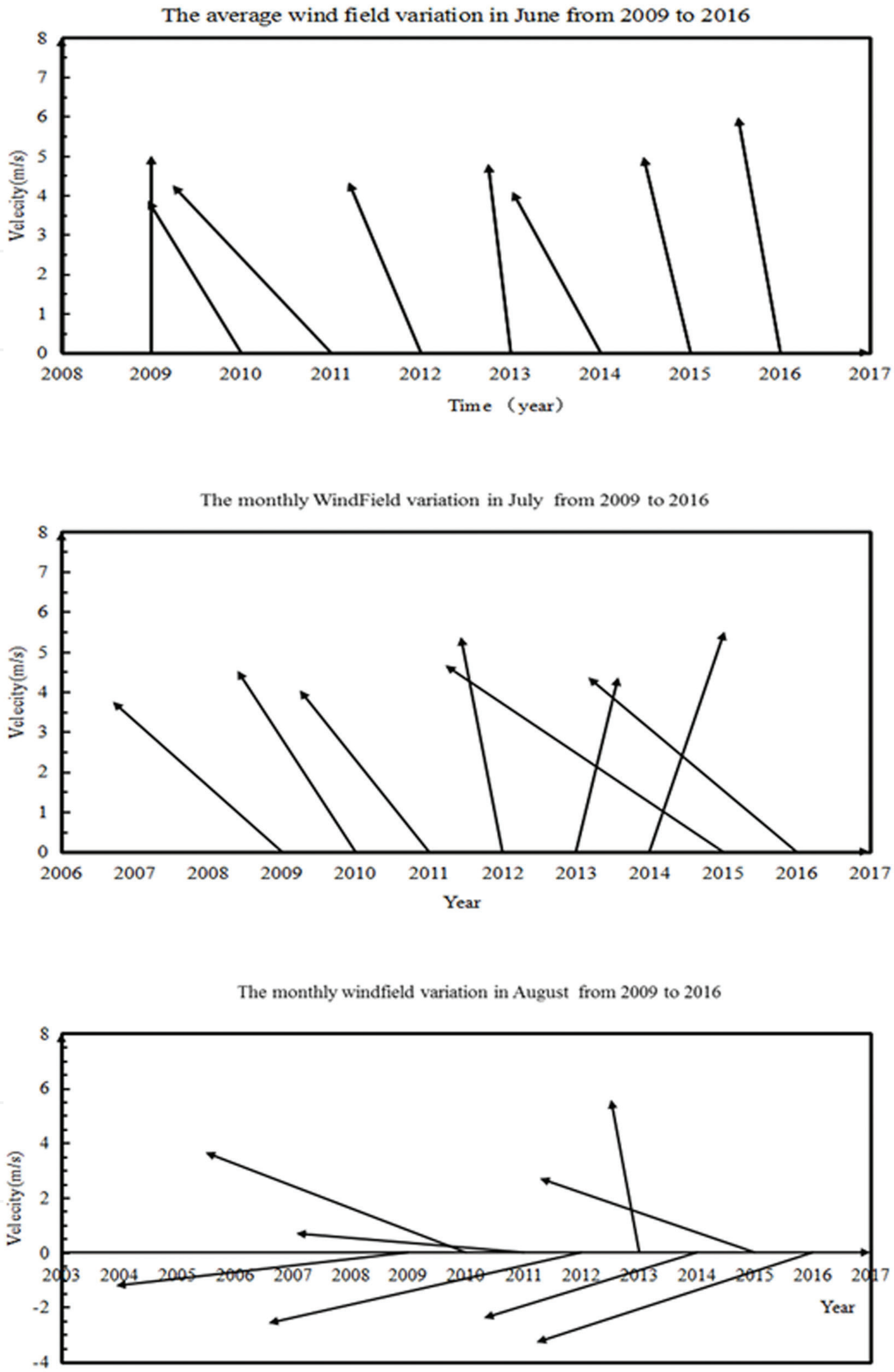

Figure 4. Average wind field variation in Qianliyan area in June (a), July (b), and August (c) 2009–2016.

formation of hydrogen sulfide [18]. The inorganic nitrogen concentration (INC) of research area from upper, middle, and bottom layers in August was more than in May, in 2010 and 2015, only upper INC in August 2016 was more than in May 2016 (**Figure 5c**). In October 2016, the DIN

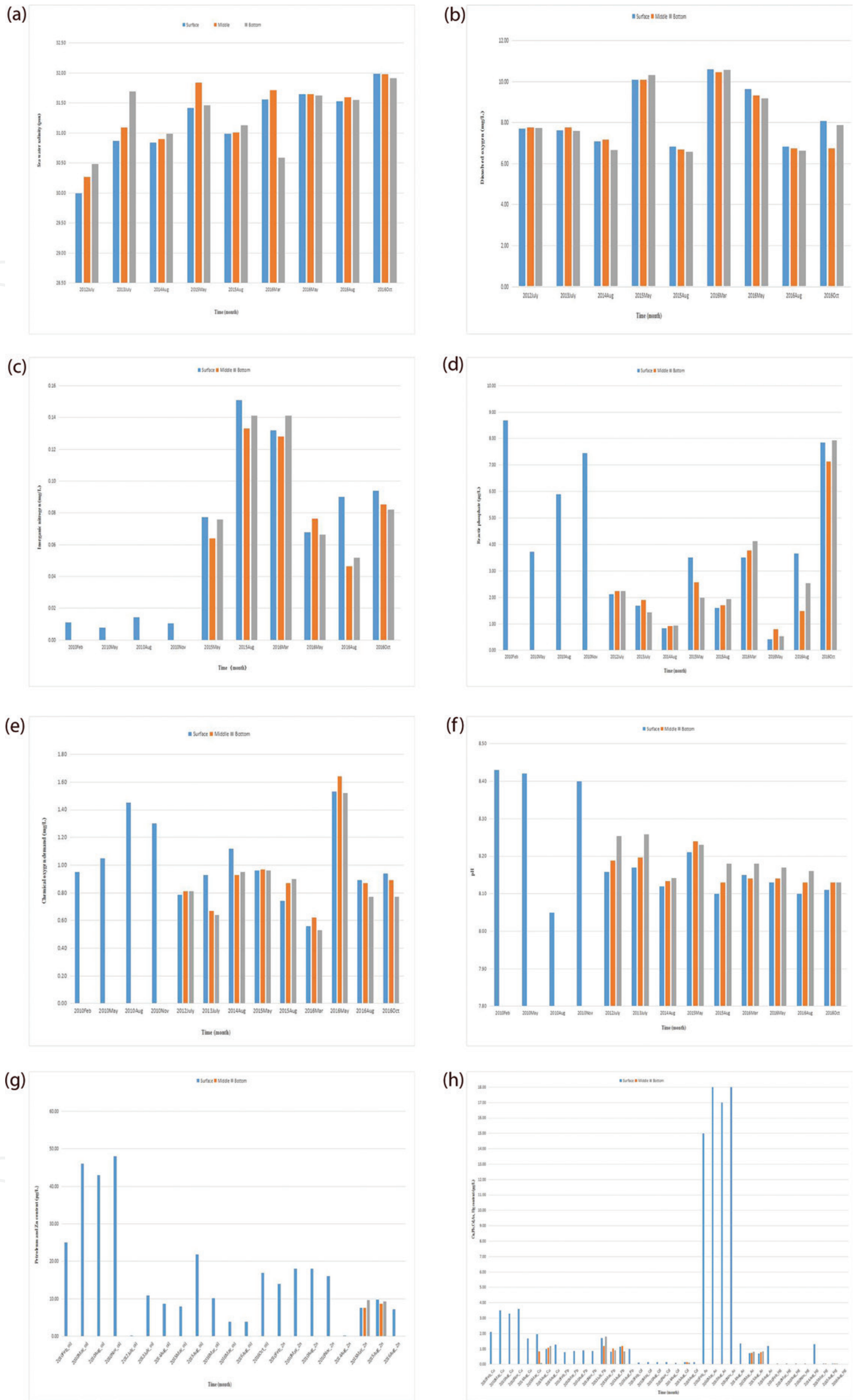

Figure 5. Variations in SAL, DO, INC, RP,COD, PH, oil; and Zn, Cu, Pb, Cd, Hg at surface, middle, and bottom layers of research area. Observation data from ship, 2010–2016.

of upper, middle, and bottom levels of the research area was more than in May and August of 2016. H_3PO_4 is often referred to as reactive phosphate (RP), for around 10% of PO_4^{3-} ion, and the rest are almost all HPO_4^{2-} ion RP in sea water, the main source is input from mineral weathering

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process and rivers. The RP of August, October, and November was more than in May in 2010 and 2016; but the RP of August in 2015 was less than in May 2015 (**Figure 5d**). Chemical oxygen demand (COD) as a characterization of the effective index of organic matter content in water, indirectly reflects the degree of organic pollution in a water body. The COD of August was less than in May in 2015 and 2016; but the COD of August was more than that of May in 2010. We found that the COD of August 2010, 2014, 2015, and 2016 was less than that of July 2012 and 2013 (**Figure 5e**). Death of *Enteromorpha* lethal effect of micro algae has a strong nutrient that is almost not consumed, but DO and pH got reduced [19]. The pH from upper, middle, and bottom layers in August were less than in May in 2010, 2015, and 2016 ($8.10 < pH < 8.30$) and the pH of July from upper and bottom layers was between 8.15 and 8.27 in 2012 and 2013. All the pH levels shown in **Figure 5f** are above 8 and less than 8.5. *Enteromorpha* spores can be released at this pH level (**Figure 5f**). **Figure 5g** shows that the oil content of upper layers in August was higher than those of May in 2015 and 2016, but the oil content in August was less than in May in 2010. The oil content in July 2012 was very low, but in July 2013, it was above 10 μg/L. The Zn content in August was more than in May in 2010 (upper layer) and 2015 (upper, middle, and bottom layers). Concentrations of Cu, Zn, Pb, and As were more than 0.2 mg/L, and *Enteromorpha* experienced an inhibitory effect on growth [20]. Concentrations of Cd and Hg were less than 0.2 mg/L. *Enteromorpha* drift introduced oil, Zn, Cu, Pb, Cd, Hg, and As into the reserve (**Figure 5g** and **f**) and polluted the environment. The underwater robot (**Figure 6a**) was used to survey the marine ecological environment in March and May of 2017 from Island 3 and 4 off Qianliyan Island (**Figure 1**), About 10 *trepangs* (**Figure 6b** and **c**) were distributed at a distance of 1000 m and there were many *starfish* in this area, but no *wrinkles abalone* could be found. Monitoring and field investigation data indicated that the total yield of *trepang* was decreasing yearly in the Qianliyan

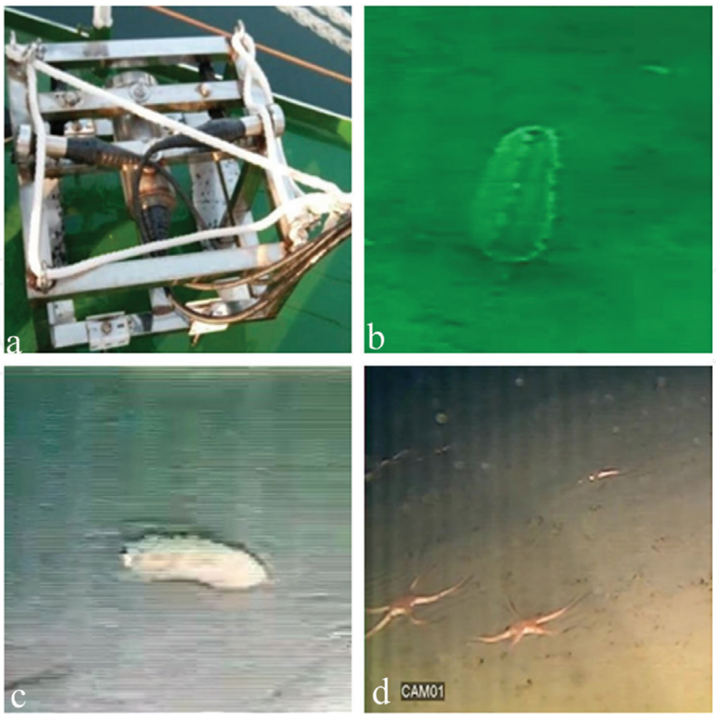

Figure 6. (a) The underwater robot; observations of (b, c) *trepang*, and (d) *starfish* in March and May 2017.

Time (year)	The sea cucumber yield	Explain
2000	5000 kg	Two seasons
2011	2500~3000 kg	A year
2010	6.33 g/m^2	Local biomass
2012	4.53 g/m^2	Local biomass
2013	4.22 g/m^2	Local biomass
2014	4.41 g/m^2	Local biomass

Table 3. Annual survey table of the sea cucumber of Qianliyan Island area.

Time								
Item	**Aug 2010**		**July 2012**		**July 2013**		**Aug 2014**	
Phytoplankton	D_2	–	D_2	0.63	D_2	0.62	D_2	0.73
	H'	1.98	H'	2.32	H'	2.45	H'	2.05
	d	2.39	d	0.47	d	0.53	d	0.51
	J	0.54	J	0.83	J	0.75	J	0.67
Zooplankter	D_2		D_2	0.90	D_2	0.75	D_2	0.66
	H'	1.28	H'	1.23	H'	1.90	H'	2.19
	d	1.39	d	0.84	d	1.15	d	1.34
	J	0.62	J	0.51	J	0.55	J	0.72
Bentonic organism	H'	0.68	H'	1.89	H'	10	H'	14
	d	0.62	d	1.05	d	–	d	–
	J	0.41	J	0.85	J	–	J	–

Table 4. Biological community characteristics index comparison table. (D_2 of benthonic organism has no observational data).

Island area (**Table 3**) and *wrinkles abalone* was rarely discovered. A site survey examined the average value of phytoplankton, zooplankter, and bentonic organisms from stations 1, 2, 3, and 4 found that the index of diversity (H') and degree of dominance (D_2) were increasing, abundance (d) was declining, and uniformity (J) was swinging between the two. There were slight fluctuations in phytoplankton and zooplankton; but the H', d, and J of benthonic organism have slight fluctuations and **Table 4** shows an upward trend.

3. Discussion

The analyses in Section 2.2 and 2.3 found that June, July, and August were the main periods of *Enteromorpha* cover of the Qianliyan Island area, when the July SST was between

20 and 25°C from 2009 to 2016. The longest *Enteromorpha* bloom in the Yellow Sea was the 106 days and the longest time off Qianliyan Island was 54 days in 2012. SSTs in June, July, and August were between 20 and 25°C, and suitable for the growth of *Enteromorpha*. **Figure 3** shows that *Enteromorpha* did not cover the research area, uniformly; nevertheless, it was still found that the July SST and its corresponding CHL were the highest observed for 3 months from 2009 to 2016 (**Figure 2a** and **c**). *Enteromorpha* blooms moved closer to the shore under the action of wind and waves in August (**Figure 2b** and **4**). Site observation data were from *Enteromorpha* covering Qianliyan Island before the blooms (February, March, or May), during the blooms (July) and after the blooms (August or October) in 2010–2016. The SAL of the research area was between 30 and 32 psu, levels most favorable for *Enteromorpha* spore dispersal. After *Enteromorpha* blooms, DO measurements were significantly lower than beforehand. The DIN in August 2015 was higher than that of May. In the INC measurements in August 2016, only the upper layer was higher than that of May. The pH of sea water from the research area from 2010 to 2016 ($8 < pH < 8.5$) was suitable for release of *Enteromorpha* spores; and after the *Enteromorpha* blooms, the pH and COD declined. *Enteromorpha* outbreaks have introduced heavy metals and petroleum pollution into the Qianliyan Island area and their concentrations have inhibited the growth of *Enteromorpha*. Benthos sampling in July 2013 found high levels of *Enteromorpha* on the seabed near the Qianliyan Island area. **Table 4** shows that the diversity index has generally increased, while the abundance value has decreased significantly. Uniformity has fluctuated from 2010 to 2016 (except in 2011), and this indicates that the environmental quality of the survey area has declined.

4. Conclusion

Sections 2 and 3, examining the remote sensing data and the site observation data analysis, show that the SST, SAL, pH of the Qianliyan Island area are suitable for *Enteromorpha* growth and spore release. There is a direct relationship between the SST and the strength or weakness of an *Enteromorpha* bloom. After a bloom, pH and COD decline. Results of benthos sampling in July 2013 confirm that *Enteromorpha* settled in the region during June–August. *Enteromorpha* decomposition is a threat to the survival and reproduction of shellfish and zooplankton, and it has an especially acute, lethal effect on abalone and *trepang*. In consecutive years, *Enteromorpha* has covered the Qianliyan Island area, bringing significant effects including DO depression, COD rise, RP, and heavy metals into the research area and polluting the environment. Comparison with the biogenesis characteristics index found that the environmental quality of the survey has declined. Number of *starfish* increased and shellfish, especially abalone, were damaged. This explains why *wrinkles abalone* is hardly to be found at present and *trepang* are decreasing yearly. The subsidence of the *Enteromorpha* and the rise in SSTs are two main reasons for the decline in the ecological environment off the Qianliyan Island area. To protect the national aquatic germ plasm resources of Qianliyan Island, we need to: (1) halt the growth in starfish numbers; (2) salvage the *Enteromorpha* blooms when they cover the Qianliyan Island area; (3) reduce human interference; and (4) improve fishery resources and revegetation of the eco-environment.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (No. 41576032), partially supported financially by international cooperation, CAS, Chinese-foreign cooperation in key projects ("The detection of oil spill and its ecological impact study" No. 133337KYSB20160002); and the "Strategic Priority Research Program" of the CAS (No. XDA11020305). Site monitoring data came from the Yantai Marine Environmental Monitoring Central Station, SOA.

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References

[1] Hu C, He MX. Origin and offshore extent of floating algae in Olympic sailing area. Eos Transactions American Geophysical Union. 2008;**89**:302-303

[2] Hu C, Li D, Chen C, Ge J, Muller-Karger FE, Liu J, He MX. On the recurrent *Ulva prolifera* blooms in the Yellow Sea and East China Sea. Journal of Geophysical Research. 2010; **115**:C05017. DOI: http://dx.doi.org/10.1029/2009JC005561

[3] Xing Q, Zheng X, Shi P, Hao J, Yu D, Liang S, Zhang Y. Monitoring "GreenTide" in the Yellow Sea and the East China Sea using multi-temporal and multi-source remote sensing images. Spectroscopy and Spectral Analysis. 2011;**31**:1644-1647

[4] Xing Q, Tosi L, Braga F, Gao X, Gao M. Interpreting the progressive eutro-phication behind the world's largest macroalgal blooms with water quality and ocean color data. Natural Hazards. 2015;**78**:7-21

[5] Liu D, Keesing J K, Xing Q, Shi P. World's largest macro algal bloom caused by expansion of seaweed aquaculture in China. Marine Pollution Bulletin. 2009;**58**(6):888-95. DOI: http:// dx.doi.org/10.1016/j.marpolbul.2009.01.013

[6] Zhang Z, Chen YL, Luo F. Temporal and spatial distribution characteristics of *Enteromorpha prolifera* in the south Yellow Sea based on remote sensing data of 2014. Journal of Huaihai Institute of Technology (Natureal Science Edition). 2016;**25**(1):80-85

[7] Zhao WJ, Zhang J, Cui TW, Hao YL, Sun L. *Enteromorpha prolifera* underwater spectral research based on simulation of radiation transmission. Spectroscopy and Spectral Analysis. 2009;**23**(4):617-626

[8] Tang JW, Wang XM, Song QJ, Li TJ, Chen JZ, Huang HJ, Ren JP. The statistic inversion algrithms of water constituents for the Huanghai Sea and the East China Sea. Acta Oceanologica Sinica. 2004;**23**(4):617-626

[9] Li Y, Liang G, Yu SM, Chen P. Selection of microwave remte sensing data of monitoring of *Entermorpha prolifera* disaster. Marine Environmental Science. 2011;**30**(5):739-742

[10] Guo J, Guo S. Status and trend of remote sensing study to monitor sea surface oil spill and *enteromorpha*. Journal of Guangxi Academy of Sciences. 2016;**32**(2):73-82

[11] Shen H, William P, Liu QR, He YJ. Detection of macroalgae blooms by complex SAR imagery. Marine Pollution Bulletin. 2014;**78**(1/2):190-195

[12] Wang JW, Yan BL, Lin AP, Hu JP, Shen SD. Ecological factor research on the growth and induction of spores release in *Enteromorpha prolifera* (Chlorophyta). Marine Science Bulietin. 2007;**26**(2):60-65

[13] Zhang XH, Wang ZL, Li RX, Li Y, Wang X. Microscopic observation on population growth and reproduction of *Entromorphra prolifera* under different temperature and salinity. Advances in Marine Science. 2012;**30**(2):276-283

[14] Wang C. Primary Studies on the Harmful Effects and Mechanisms of Ulvaprolifera Green Tide [Thesis]. Qingdao: Institute of Oceanology Chinese Academy of Sciences; 2010

[15] Wang C, Yu RC, Zhou MJ. Effects of the decomposing green macroalga *Ulva* (*Enteromorpha*) *prolifera* on the growth of four red-tide species. Chinese Journal of Oceanology and Limnology. 2011;**29**(3):541-546

[16] Hu CM. A novel ocean color index to detect floating algae in the global oceans. Remote Sensing of Environment. 2009;**113**(10):2118-2129

[17] Sun XX, Du M, Pu YL. A study on interval taking out to extend the life of the electroless nickel plating solution. Periodical of Ocean University of China. 2006;**36**(2):287-290

[18] Norkko A, Bonsdorff E. Altered benthic prey-availability due to episodic oxygen deficiency caused by drifting algal mats. Marine Ecology. 1996;**17**:355-372

[19] Liu Q. The Interactions Study between Bloom-Forming *Ulva prolifera* and Phytoplankton in the Yellow Sea [Thesis]. Qingdao: Institute of Oceanology Chinese Academy of Sciences; 2015

[20] Wu LW, Han XR, Wu T. Effects of heavy metals on the uptake of nitrate by *Ulva prolifera*. China Environmental Science. 2016;**36**(4):1173-1180