

Overview of Red Tide Disasters in the Coastal Waters off Qinhuangdao

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Abstract:

As an important fishery and tourism resource city in northern China, Qinhuangdao has experienced frequent red tide disasters in recent years, which has had a serious impact on the marine ecological environment and human life. This paper first analyzes the characteristics, causes, and influencing factors of red tide disasters in Qinhuangdao waters then summarizes the existing coping strategies for red tide disasters and finally puts forward the coping strategies for red tide disasters in Qinhuangdao waters.

Keywords: Qinhuangdao; red tide; identification technology

Introduction

Qinhuangdao City is located in the northeast of Hebei Province, with a coastline of about 162.7 km. It is one of the first coastal open cities under its jurisdiction. Its coastal tourism, aquaculture, and port economy play vital roles in the local economic development. The sea area near Qinhuangdao is rich in resources, with 10,000 square kilometers of fishing grounds, 800,000 mu of shallow sea suitable for breeding, and 20,000 mu of intertidal zone^[1]. Therefore, the environmental quality and ecological protection of the Qinhuangdao sea area are particularly critical. However, in recent years, red tides have frequently occurred in Qinhuangdao waters, which has caused great damage to the local coastal economy. Nowadays, large-scale red tide disasters still occur in the waters of Qinhuangdao (such as the red tides in the waters from Jinshanzui to Shanhaiguan from April 27 to April 29, 2022, and the red tides in the coastal waters of Qinhuangdao from August 9 to August 18 and August 20 to September 20, 2022), which can be found that the red tide monitoring system in Qinhuangdao sea area is not perfect, which cannot effectively carry out timely monitoring and early warning of red tides. Therefore, it is of great significance to choose the appropriate red tide monitoring methods to prevent the red tides and protect the ecological environment and economic benefits of the Qinhuangdao Sea area.

1. Hydrological characteristics of the Qinhuangdao sea area

1.1 Data sources

The data in this paper are from the data of the Qinhuangdao Marine Environmental Monitoring Center Station of the State Oceanic Administration of China from April to September 2022.^[2] Due to the frequent precipitation and red tide during August, the water quality parameters fluctuated greatly; in order to accurately grasp the water quality situation, three water quality surveys were carried out in early, middle, and late August, and once a month in the rest of the months, and the water quality indicators of the surveys included the surface layer water temperature, salinity, dissolved oxygen.

1.2 Water temperature

According to the data, the sea temperature was lowest in April 2022 and increased to the highest from April until August; from August to September, the sea temperature decreased slowly and steadily (Figure 1).

1.3 Salinity

According to the data, salinity increased slowly and steadily from April to June 2022 but decreased rapidly from June to August 2022, while salinity fluctuated slightly from August to September 2022 but was generally stable (Figure 2).

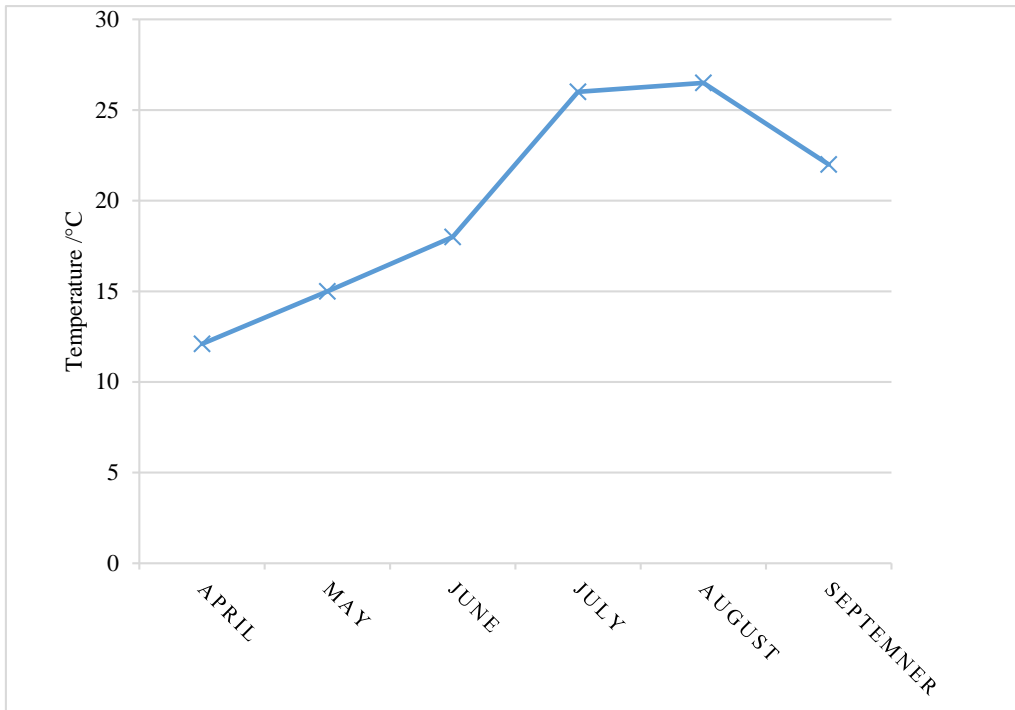


Fig. 1 Monthly description of water temperature in 2022

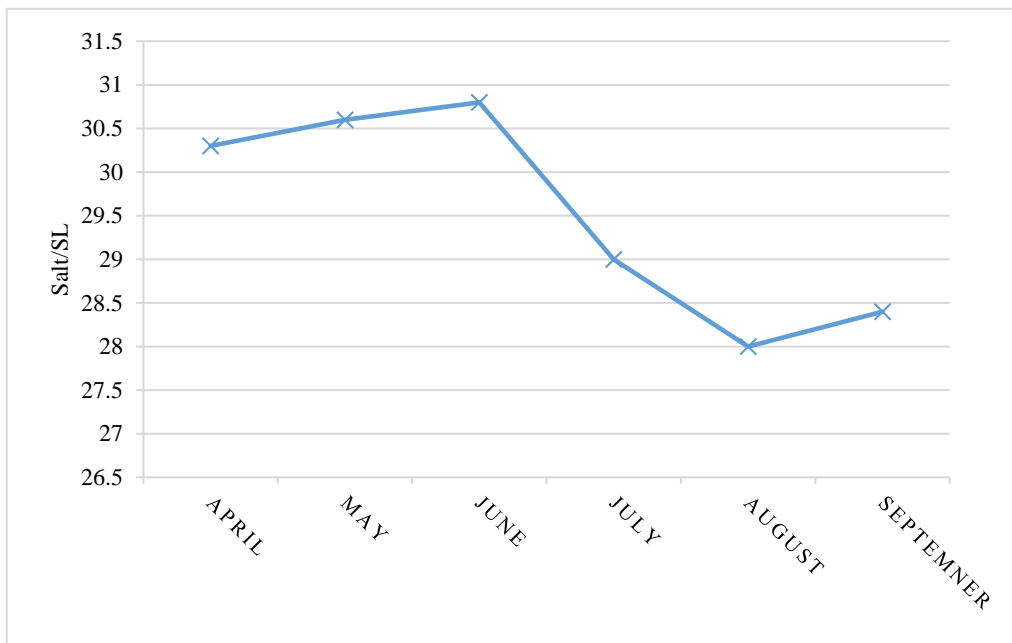


Fig. 2 Monthly mean description of salinity statistics in 2022

1.4 Dissolved oxygen

According to the data, from April to June 2022, the dissolved oxygen content in seawater was high. However, the proportion of dissolved oxygen in seawater decreases rapidly from June to July; from July to August, the amount of dissolved oxygen in seawater increases rapidly (probably due to the fact that the abundance of heterotrophs in sea-

water consumes a lot of oxygen at the beginning, and the later bloom of autotrophs in seawater makes it produce oxygen much faster than the rate at which heterotrophs consume oxygen). From August to September, the dissolved oxygen content in seawater decreased continuously. (Figure 3)

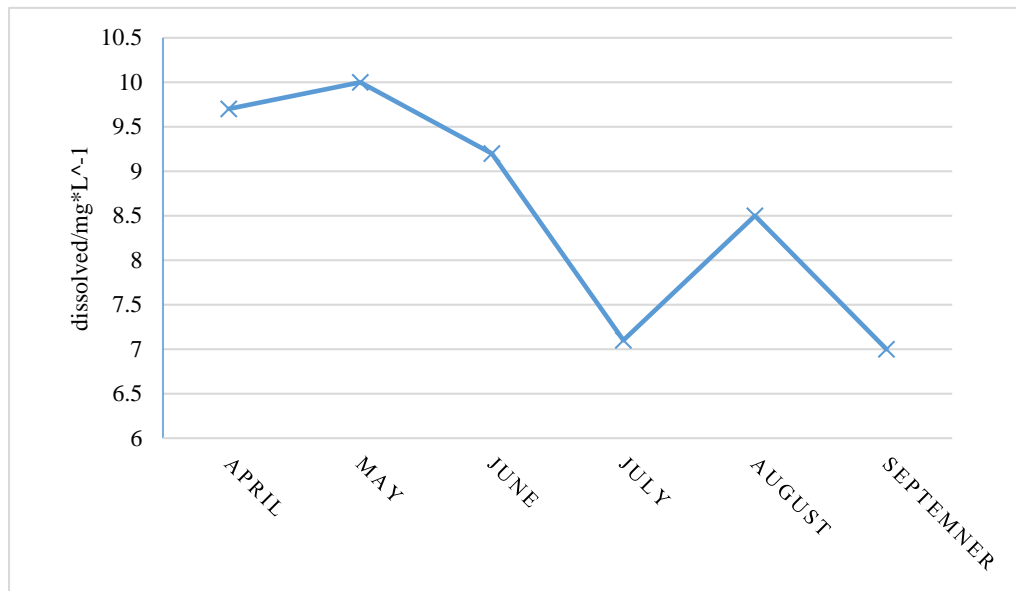


Fig. 3 Statistical results of monthly average dissolved oxygen in 2022

2. Analysis of the occurrence of red tide in Qinhuangdao waters

According to the marine environmental report of Qinhuangdao City from 2005 to 2022, the red tide events in the waters of Qinhuangdao were recorded as follows: In 2005^[3], no red tide was found in the sea area of Qinhuangdao, in 2006, two red tide occurrences were recorded, located in the eastern waters of Shanhaiguan and the waters near Beidaihe and Qinhuangdao ports, involving 180.5 square kilometers and 250 square kilometers, respectively^[4], and in 2007, there were four red tides, all in the waters near Shanhaiguan and the harbor area, concentrated from July to September, three of which were confirmed to contain toxic substances^[5]. In 2008, no red tide events were recorded^[6]. In 2009, two red tides occurred in the waters of Qinhuangdao, covering an area of 460 square kilometers and 1,000 square kilometers, respectively, which had a serious impact on the marine environment^[7], and in 2010, a total of three red tides occurred, the largest was caused by *Prorocentrum minimum*, which covered an area of 3,350 square kilometers, and *Noctiluca scintillans* caused the other two smaller ones. Respectively, in *Meso-*

dinium rubrum, four red tides occurred along the coast of Qinhuangdao^[8]. In 2011, four red tides occurred along the coast of Qinhuangdao City^[9]. In 2012, one lasting more than two months, covering an area of 3,400 square kilometers^[10], and in 2013, Six red tides occurred, the largest of which covered an area of 1,450 square kilometers and occurred along the coast from Tangshan City to Suizhong in Liaoning^[11]. In 2014, six red tides occurred along the coast from Tangshan to Suizhong, Liaoning Province, two of which exceeded 100 square kilometers^[12]. In 2015, six red tides occurred in the coastal area, especially caused by *Aureococcus anophagefferens*^[13], and in 2016, There were six red tides along the coast^[14]. In 2017, five red tides were detected in coastal waters, especially in the waters near Jinneng Bay, four of which included this area^[15]. In 2008, no red tide events were recorded^[16]. In 2019, a total of two red tides were found in Qinhuangdao, with an area of 0.1 square kilometers and 0.18 square kilometers, respectively^[17]. In 2020 and 2021, no red tide events were recorded^{[18] [19]}. In 2022, there were ten red tides in the waters of Qinhuangdao, the largest of which reached 348 square kilometers^[20]. (Figure 4), (Figure 5) (Table 1)

Table 1. The specific occurrence of red tides from 2005 to 2022

Number	date	Occurring sea area	Area/km ²	main red-tide species organisms
1	In 2005,	not have	0	not have
2	From May 11-17,2006	East Sea of Shanhaiguan	180.5	Noctiluca scintillans
3	June 2-4,2006	Sea areas near Beidaihe and Qinhuangdao ports	250	Noctiluca scintillans Prorocentrum minimum *

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Number	date	Occurring sea area	Area/km ²	main red-tide species organisms
4	From July 13-15,2007	Qinhuangdao West Baths	3	Heterosigma akashiwo*
5	August 6-7,2007	Sea near Dongshan Bathbeach	2	Nitzschia delicatissima Noctiluca scintillans
6	On August 23, 2007	Qinhuangdao Shanhaiguan shipyard near the anchorage	30	Gymnodinium catenatum*
7	August 24-September 6,2007	Qinhuangdao West bath to Beidaihe Pigeon Park near the sea area	30	Karenia mikimotoi*
8	In 2008,	not have	0	not have
9	On May 25-31,2009	Sea area near Changli new mouth	460	Noctiluca scintillans
10	Late June-early September, 2009	Qinhuangdao city sea area, involving Shanhaiguan District, Haigang District, Beidaihe District, Funing County coastal sea area	1 000	Dinoflagellate minimum
11	On May 14, 2010	The ocean estuary starts in the north to the artificial estuary in the south	About 4.5	Noctiluca scintillans
12	On June 24th, 2010	Qinhuangdao- Liaoning Suizhong coastal waters	3 350	Prorocentrum minimum
13	From July 24-26,2010	From the Yang Estuary to the Dai Estuary near the shore	Small area	Mesodinium rubrum
14	Late May-late July, 2011	Qinhuangdao waters	About 180	Prorocentrum minimum
15	May 50-June 4,2011	Changli's new opening waters	About 20	Rhizosolenia delicatula
16	On June 17th, 2011	Ocean estuary to the artificial river coastal sea	About 0.02	Gymnodinium sp.
17	On August 17, 2011	Beidaihe Zhongzhi bath near the sea	About 40	Noctiluca scintillans, Chattonella antique
18	On May 18-28,2012	The sea near the Tang River estuary	16	Aureococcus anophagefferens
19	From June 8-20,2012	Tangshan Daqing estuary to Liaoning Suizhong coastal waters	3 400	Aureococcus anophagefferens
20	On August 10, 2012	The coastal waters of Beidaihe	0.1	Chaetoceros siamense
21	August 28-29,2012	Sea near Dongshan Bathbeach	1.3	Noctiluca scintillans
22	August 30-31,2012	Shanhaiguan Sea near the river mouth	5	Gonyaulax spinifera, Prorocentrum micans
23	October 4-10,2012	Sea near Dongshan Bathbeach	30	Gonyaulaxpoly gramma
24	From May 25-26,2013	Qinhuangdao Daihekou to Jinshanzui sea area	2	Noctiluca scintillans

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Number	date	Occurring sea area	Area/km ²	main red-tide species organisms
25	From June 3-4,2013	Qinhuangdao Daihekou to Jinshanzui sea area	10	Noctiluca scintillans
26	From June 9-12,2013	Qinhuangdao Daihekou to the west anchorage sea area	16	Noctiluca scintillans
27	From June 18-22,2013	Qinhuangdao Dongshan Bath beach to Jinshanzui sea area	7	Noctiluca scintillans, Prorocentrum minimum
28	From June 23-27,2013	Qinhuangdao near the east anchorage sea area	4	Noctiluca scintillans
29	June 20-August 31,2013	Tangshan City Leting to Liaoning Suizhong coast	1 450	Aureococcus anophagefferens
30	May 15-August 7,2014	Qinhuangdao to Liaoning Suizhong six stock estuary coastal waters	2 000	Aureococcus anophagefferens
31	May 31-June 1,2014	Qinhuangdao Dongshan Bath Sea area	0.1	Noctiluca scintillans
32	From June 11-12,2014	Qinhuangdao Shanhaiguan customs grain unloading port to Qinhuangdao port sea area	75	Noctiluca scintillans
33	From June 13-15,2014	Qinhuangdao Beidaihe sea area	228	Noctiluca scintillans, Prorocentrum minimum
34	September 1-4,2014	Qinhuangdao shallow bay bath to the west bathing area	8	Karenia mikimotoi*
35	From September 15-19,2014	Qinhuangdao West Bath near the sea area	1.1	Scrippsiella trochoidea, Ceratium furca
36	May 20-August 13,2015	Liaoning Suizhong to Luanhe hekou waters	825	Aureococcus anophagefferens
37	From June 14-16,2015	Qinhuangdao nearshore waters	5	Noctiluca scintillans
38	From June 23-24,2015	Qinhuangdao west anchorage outside the sea area	3	Noctiluca scintillans
39	August 6-9,2015	Qinhuangdao Dongshan bath near the sea area	60	Skeletonema costatum
40	August 11-19,2015	Qinhuangdao west bath to the east bath near the sea area	40	Fibrocapsa japonica
41	April 30-May 4, 2016	Qinhuangdao nearshore waters	4.5	Alexandrium tamarense, Noctiluca scintillans
42	June 6-9,2016	Qinhuangdao Dongshan bath near the coastal waters	2.3	Heterosigma akashiwo*
43	July 5-11,2016	Qinhuangdao Shanhaiguan customs to the port area sea area	18.5	Noctiluca scintillans
44	From July 18-19,2016	Qinhuangdao Dongshan bath near the coastal waters	3	Chattonella antique*
45	From July 23-24,2016	Qinhuangdao Beidaihe tiger stone bathing beach near the sea area	0.5	Heterosigma akashiwo *Noctiluca scintillans

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Number	date	Occurring sea area	Area/km ²	main red-tide species organisms
46	July 28-August 20,2016	The waters near Qinhuangdao	75	Thalassiosiranorden skioldii Hakashiwosanguineum Chaetocero scurvisetus
47	From June 22-27,2017	Qinhuangdao Dongshan bath near the sea area	1.8	Heterosigma akashiwo
48	From July 4-12,2017	Qinhuangdao nearshore waters	1.6	Noctiluca scintillans
49	July 20-24,2017	Qinhuangdao Jinneng Bay near the sea area	0.0015	Thalassiosira nordenskioldii
50	August 9-26,2017	Qinhuangdao Dai Hekou to jinneng Bay near the sea	50	Heterosigma akashiwo
51	From September 14-23,2017	Qinhuangdao Tangshan estuary to Jinshan Mouth near the sea	18	Gonyaulax Verior
52	From July 24-27,2019	Qinhuangdao Jinneng Bay bathing beach shore, pigeon nest shore, tiger stone around the sea area	0.1	Chattonella antique*Leptocylindrusd anicus
53	From August 31 to September 4, 2019	Qinhuangdao West Port Garden Port pool sea area	0.18	Scrippsiella trochoidea
54	April 27-29,2022	Qinhuangdao Jinshan mouth to Shanhaiguan sea area	48	Noctiluca scintillans
55	From May 9-10,2022	The sea area near the ocean estuary of Qinhuangdao	1.5	Noctiluca scintillans
56	On May 14-15,2022	Qinhuangdao Shanhaiguan near the sea area and Beidaihe outside the sea	17	Noctiluca scintillans
57	From June 17-18,2022	land within certain boundaries	0.6	Noctiluca scintillans
58	June 20-26,2022	Qinhuangdao Dongshan Bath beach to Qinhuangdao Port nine Company wharf	1	Noctiluca scintillans
59	July 31-August 5,2022	sea area	150	Skeletonema costatum
60	August 9-18,2022	Qinhuangdao Xigang Garden to beidaihe coastal part of the sea	150	Scrippsiella trochoidea
61	August 20-September 20,2022	Qinhuangdao Dongshan Bath to Dai hekou sea	348	Ceratium furca

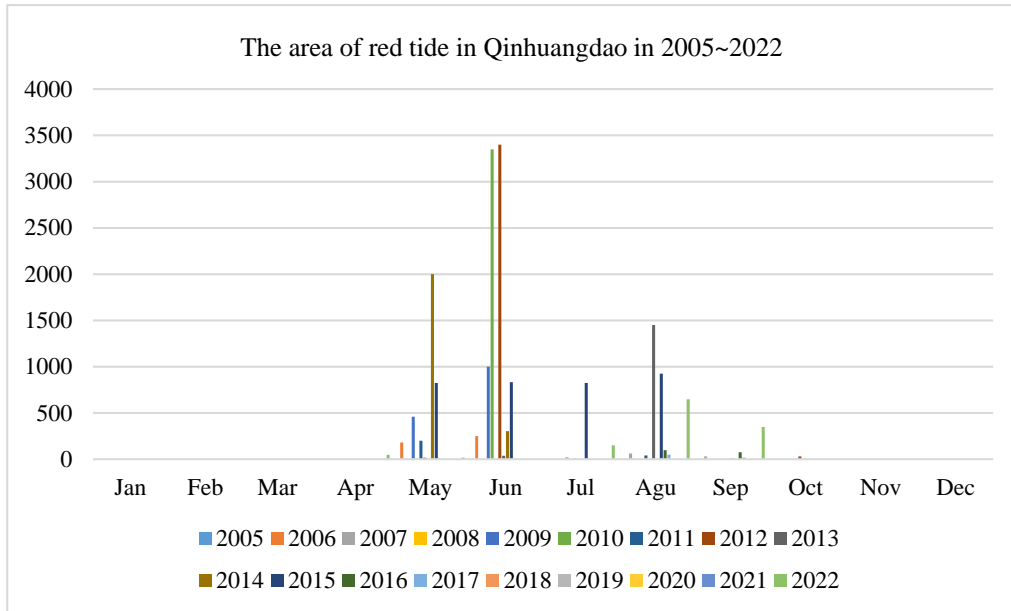


Fig. 4 The area of red tide in Qinhuangdao in 2005~2022

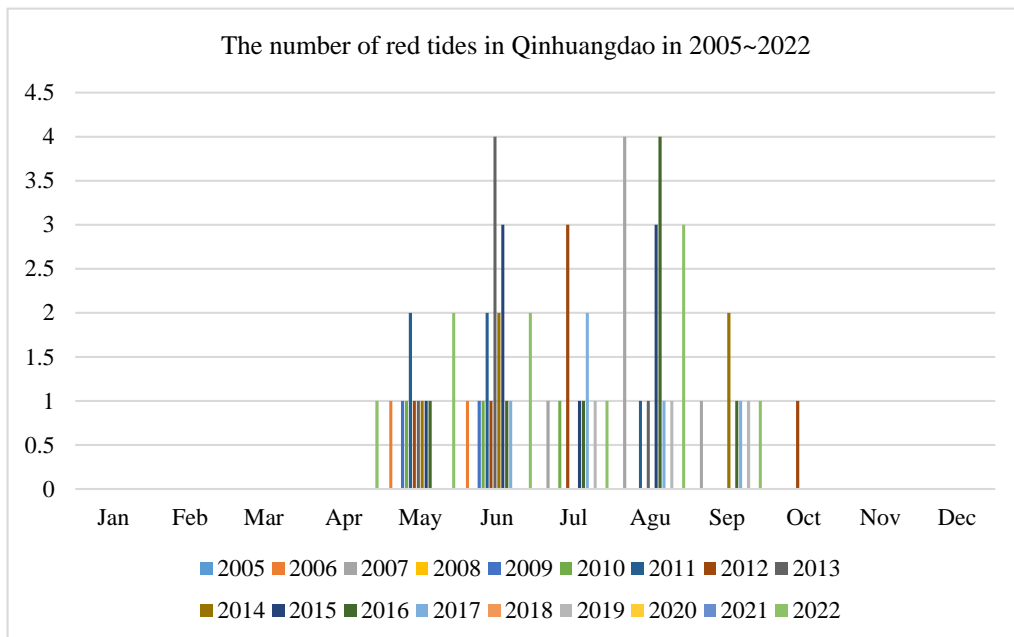


Fig.5 The number of red tides in Qinhuangdao in 2005~2022

***Toxic algae**

Through the analysis of red tide events in the waters of Qinhuangdao from 2005 to 2022, we can draw the following conclusions:

In the waters of Qinhuangdao City, *Noctiluca scintillans* are the most common algae that cause red tides, triggering a total of 22 red tide events. Still, these are usually short-lived, only in 2006, 2009, 2014, and 2022, when the size of these four red tides exceeded 100 square kilometers. In addition to this, *Aureococcus anophagefferens* is also one

of the frequent algae. Since 2009, when the first red tide was triggered in the waters of Qinhuangdao, *Aureococcus anophagefferens* has been the main factor of red tide for seven consecutive years, and a large area and long duration characterize the red tide caused by it. In the last 17 years, there have been 12 major red tide events, basically all caused by *Noctiluca scintillans* and *Aureococcus anophagefferens*. Toxic algae in the waters of Qinhuangdao also contributed to the high frequency of red tides, with a total of 21 occurrences. Of these, *Prorocentrum minimum*

and *Heterosigmaakashiwo* are the two most common toxic algae, causing 6 and 5 red tide events, respectively. 2016 and 2022 were the two years with the highest number of red tide algae species and occurrences. In 2005, 2008, 2018, 2020, and 2021, there were no red tide events in the waters of Qinhuangdao, and small-scale red tide events occurred in 2019. From 2018 to 2021, red tide control in Qinhuangdao was very effective. Still, in 2022, there were eight consecutive red tide events in Qinhuangdao waters, three of which exceeded 100 square kilometers, and the dominant species in five of the eight red tide disasters was *Noctiluca scintillans*.

3. Causes of red tides in Qinhuangdao Sea — Take the causes of red tide outbreak in 2022 as an example

According to the data from the Qinhuangdao Marine Environmental Monitoring Center Station of the State Oceanic Administration, in 2022, the waters near Qinhuangdao experienced three different types of red tide events, which can be distinguished according to the different species of red tide algae and the difference in the time of occurrence. A total of eight red tides occurred over an area of 716.1 square kilometers, mainly between April and September^[21]. The main red tide organisms involved include *Noctiluca scintillans*, *Skeletonema costatum*, *Thalassiosira nordenskioldii*, *Scrippsiella trochoidea*, and *Ceratium furca*, among others^[22]. At the same time, we will use the above annual environmental factor data from April to September 2022 to compare the characteristics of red tide disasters in different periods in 2022 to obtain the dominant species of red tide in different environments.

3.1 Noctiluca scintillans

From the above data, it can be seen that since April 27, the coastal waters of Qinhuangdao have experienced red tide events caused by *Noctiluca scintillans*, mainly in Yanghekou, Jinshanzui, Dongshan Bathing Beach, and Shanhaiguan, and this phenomenon has continued until the end of June. Between the end of April and the end of June, the sea temperature ranges from 12.1 to 18 degrees Celsius, the dissolved oxygen content in the sea water is high during the year, at 9 to 10 mg per liter of dissolved oxygen, and the salinity is also high during the year, between 30 and 31.

3.2 Euglena and Diatom

From the above data, it can be seen that since late July, the coastal waters of Qinhuangdao have experienced compound red tides caused by a variety of diatoms and euglena. *Skeletonema costatum* was the dominant population of this red tide, but the duration of this red tide was relatively

short, only about six days. During the Diatom-Euglena red tide, the salinity of the seawater ranges from 29 to 27.8, the sea temperature ranges from 28 to 28.6, and the dissolved oxygen content of the seawater ranges from 7.1 mg per liter to 9 mg per liter.

3.3 Dinoflagellate red tide

Since August 9, the coastal waters of Qinhuangdao have suffered two more serious dinoflagellates red tide events. The first red tide occurred from 9 to August 18 and was dominated by *Scrippsiella trochoidea*. From August 20 to September 20, the region experienced a 32-day red tide of *Ceratium furca*. During this period, the sea temperature ranges from 28.6 to 22 degrees Celsius and gradually decreases: the salinity ranges from 27.8 to 28.4. The amount of dissolved oxygen in seawater varies from about nine mg/L to about seven mg/L and gradually decreases.

4. Summary

Through the analysis of the above data, the characteristics of the red tide outbreak in the Qinhuangdao Sea area can be obtained.

4.1 Temporal characteristics

Through the analysis of the area and frequency of red tide occurrence in Qinhuangdao from 2007 to 2022, it can be found that the outbreak time of red tide in Qinhuangdao is generally between May and September, among which red tide disasters are more likely to occur in June, July, and August, while large-scale red tide disasters are more likely to occur in May and June.

4.2 Spatial characteristics

Through the analysis of the area, frequency, and location of red tide in Qinhuangdao from 2007 to 2022, it can be found that some sea areas in Qinhuangdao are more prone to red tide disasters. For example, *Noctiluca scintillans* is prone to occur in the waters of Shanhaiguan in Qinhuangdao. The occurrence time is often from early May to mid-May, and the waters near Dongshan Bathing Beach and Daihekou are also prone to red tide disasters, and the outbreak time is often from the end of July to the end of August.

4.3 Environmental characteristics of different red tide species

By comparing the red tide occurrence data in Qinhuangdao in 2022 with the environmental factors in 2022, it can be seen that the environmental factors in the sea area are also quite different when different red tide species erupt. For example, the water temperature is usually 12.1 to 18 degrees Celsius during the outbreak of *Noctiluca scintillans*. Still, the sea temperature is usually above 25 degrees

Celsius during the eruption of Euglena and Diatom. At the same time, it can be seen from this data that the salinity of Qinhuangdao is lower when Dinoflagellate red tide is enriched, while the oxygen content of Qinhuangdao is higher when Euglena and Diatom are abundant.

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