INVESTIGATION ON SALTERN PLANKTON IN TANGGU SALTWORKS, TIANJIN, CHINA

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Abstract: Plankton plays an important role in saltern ecosystem. In this paper, the species composition and distribution of phytoplankton and zooplankton in Tanggu Saltworks, Tianjin, China was recorded during 2004 and 2005. Compared with the survey results obtained in 2002, community structures of the phytoplankton were similar; while the variety of diatoms decreased and an increase of green algae species were observed. Additionally, a new species Aphanothece sp. was found, which was not recorded in the survey of 2002. The kinds of zooplankton decreased slightly, but the community structure was basically the same. A kind of protozoa Noctiluca scintillans, an indicator for red-tide and eutrophication of the sea, was discovered in the summer survey. The survey revealed that the saltern ecosystem in Tanggu saltworks is being on the way to imbalance, thus the biological management was emphasized towards the end of the paper.

Keywords: Saltworks; Phytoplankton; Zooplankton

INTRODUCTION

Tanggu saltworks is located in Bohai Bay, China (38° 54'~ 38° 56' N and 117° 30'~ 117° 38'E), covering an area of about 170 sq km. It has sub-continental monsoon climate with distinct four seasons. The average annual temperature is 13.0 °C, with the maximum temperature of 41.9°C and the minimum temperature of -15.4 °C. The average evaporation reaches 1986.6 mm and the average annual rainfall is 522 mm. Salt production capacity is 1.2 million tons per year.

The concept of the saltern ecosystem and the relationship between the saltern ecosystems and salt production was first proposed by Carpelan in 1950s [1]. It has been proved that the biological management and process control of solar salt production at all levels of the production area ensure the balance of the concentrations and volume of brine, and maintain the balance of the entire saltern ecosystem. In this way, the maximum benefit from solar salt production fields in terms of salt quantity and quality can be reached [2].

In this paper, two-year consecutive ecological survey in Tanggu Saltworks was conducted in year 2004 and 2005. The aim of the survey was to investigate the ecological conditions in recent years, and provide some basic information to the saltwork managers.

MATERIALS AND METHODS

Three investigations were conducted during 2004 and 2005. Brine samples were taken from nine sampling points including seawater intake canal, evaporation pond, adjustment pond and crystallization pond on Jul. 7th, 2004, Oct. 13th, 2004 and Apr. 21th, 2005, respectively. The species and densities of phytoplankton and zooplankton were determined according to the following procedures:

Phytoplankton

1L brine was collected at each sample point by a sampling bottle. 6-8mL saturated iodine solution were added to immobilize the phytoplankton. The phytoplankton in the sample was precipitated and settled in a cylinder funnel for 24h. The supernatant was taken out through a thick-walled capillary until around 20mL solution was remained, which was then transferred into a bottle with calibrated scale. The cylinder funnel was rinsed three times with the supernatant to make sure that all phytoplankton was transferred into the bottle. The volume of concentrated solution in the scaled bottle was adjusted to 30mL for counting the number of phytoplankton. Each sample was counted two times using blood cell counter. The deference between the two results should be no more than 15%.

Zooplankton

20L brine was taken from the sampling location and filtered with a net which has mesh diameter of 0.064 mm. The obtained zooplankton was collected into a bottle, and 10mL 5% formaldehyde solution was added for immobilization. The kinds of and zooplankton and number of each kind of zooplankton were determined.

RESULTS AND DISCUSSION

Species composition and distribution of phytoplankton

The results of phytoplankton were given in Table 1-3.As shown in Table 1, the results obtained from July, 2004 indicated that phytoplankton collected from Tanggu Saltworks is consisted of five primary phyla and twenty-four species, including one specie of pyrrophyta, one specie of cryptomonas, ten species of diatom, four species of cyanophyta and eight species of chlorophyta. The dominant species are cryptophyta such as Cryptomonas ovata, bacillariophyta such as Cymbella sp., Naricula sp., Cradiatus, cyanophyta such as Oscillatoria agardhii, Lyngbya sp., chlorophyta such as Dunaliella salina and Dunaliella viridis.

As shown in Table 2, the results obtained from October, 2004 indicated that phytoplankton collected from Tanggu Saltworks was consisted of four primary phyla and fifteen species, including one specie of cryptomonas, five species of diatom, three species of cyanophyta and six species of chlorophyta. The dominant species are cryptophyta such as Cryptomonas orb, bacillariophyta such as Cymbella sp., Pleurosigma, cyanophyta such as Oscillatoria agardhii, chlorophyta such as Dunaliella salina and Dunaliella viridis.

As shown in Table 3, the results obtained from April, 2004 indicated that phytoplankton collected from Tanggu Saltworks was consisted of five primary phyla, and eighteen species, including one specie of pyrrophyta, one specie of cryptomonas, seven species of diatom, three species of cyanophyta and six species of chlorophyta. The dominant species are cryptophyta such as Cryptomonas ovata, bacillariophyta such as Nitzschia longissima, Cymbella sp., Naricula sp., cyanophyta such as Chroococcus sp., Lyngbya sp., chlorophyta such as Dunaliella salina, Dunaliella viridis and Chlorella sp..

Species composition and distribution of zooplankton

The results of zooplankton were given in Table 4-6. As shown in Table 4, the results obtained from July, 2004 indicated that zooplankton collected from Tanggu saltworks was consisted of fifteen species, including two species of protozoa, one specie of coelenterate, one specie of nematode, seven species of crustacea, one specie of polychaeta, one specie of mollusk, one specie of aquatic insects, one specie of bivalve. The dominant species are crustacea such as Artemia adult, Calanus sinicus and Acartia bifilosa.

As shown in Table 5, the results obtained from October, 2004 indicated that zooplankton collected from Tanggu Saltworks was consisted of ten species, including eight species of crustacea, one specie of polychaeta, one specie of aquatic insects. The dominant species are crustacea such as Artemia adult, Paracalanus crassirosteris, Copepodite and Acartia bifilosa.

As shown in Table 6, the results obtained from April, 2005 indicated that zooplankton collected from Tanggu Saltworks was consisted of sixteen species including thirteen species of crustacea, one specie of mollusk, two species of aquatic insects. There were also many Artemia cysts in V station. The dominant species are crustacea such as Paracalanus crassirosteris, Oithina similes, Acatia bifilosa, and aquatic insects such as Ephedra larva.

Table 1 Species composition and distribution of phytoplankton (July, 2004)

Phytoplankton	Distribution and specific gravity($^0Be'$)								
	I	II	III	IV	V	VI	VII	VIII	IX
	3.24	4.13	6.24	10.35	15.04	19.10	23.80	26.87	29.14
Pyrrophyta									
Glenodinium sp.	+	+	+	+					
Cryptophyta									
Cryptomonas ovata	+++	+++	++	+++	+	+			
Bacillariophyta									
C.radiatus	+++	+	++						
Coscinodiscus oeulusiridis	++								
Coscinodiscus asteromphalust	+								
Pleurosigma pelagicum	+	+++							
P.affine	+	+	++						
Nitzschia longissima		+							
Nitzschia sp.		+	+++						
Naricula sp.		+++	++	+++	+++				
Cymbella sp.	+	+++	+++	+++	+++				
Cyclotella sp.		+			+				
Cyanophyta									
Aphanothece sp.		+			+				
Lyngbya sp.		+++	++	+		+			
Oscillatoria agardhii		+++	+	+	+++	+			
Chroococcus sp.		+++							
Chlorophyta									
Dunaliella salina				+	+	+	+++	+++	
Dunaliella viridis				++	++	++	+++	+++	
Pallmella sp.			+						
Chlorella sp.			+++		++				
Schroederia		+							
Volvox sp.			+						
Kirchneriella sp.			+						
Platymonas sp.				++					

Notes: "+" means much; "++" means more; "+++" means the most. The same symbols were presented in the following tables.

Table 2 Species composition and distribution of phytoplankton (October, 2004)

Phytoplankton	Distribution and specific gravity($^0Be'$)								
	I	II	III	IV	V	VI	VII	VIII	IX
	3.28	4.51	8.45	10.21	16.09	19.67	24.23	27.30	29.11
Cryptophyta									
Cryptomonas orb		++			+				
Bacillariophyta									
Pleurosigma	+		+++	+					
Nitzschia sp.			++	+					
Naricula sp.	+				++				
Cymbella sp.	+	+++	++	+	++				
Cyclotella sp.		++							
Cyanophyta									
Aphanothece sp.		+++							
Lyngbya sp.			++						
Oscillatoria agardhii			++	+	+++				
Chlorophyta									
Dunaliella salina	+					++	++	++	
Dunaliella viridis	+			+	+	+++	+++	+++	
Chlorella sp.		+++							
Carteria		++							
Tetraspore		++							
Volvox sp.			+	+					

Table 3 Species composition and distribution of phytoplankton (April, 2005)

Phytoplankton	Distribution and specific gravity($^0Be'$)								
	I	II	III	IV	V	VI	VII	VIII	IX
	4.05	4.46	5.70	13.70	17.99	19.18	23.75	27.55	28.10
Pyrrophyta									
Glenodinium sp.	+	+	+						
Cryptophyta									
Cryptomonas ovata	+++	+++	+++	++	+				
Bacillariophyta									
Pleurosigma pelagicum	+	+							
P.affine	+	+	+						
Nitzschia longissima	+	+	+++						
Nitzschia sp.	+	+	+						
Naricula sp.	+	+	+						
Cymbella sp.	+	+	+						
Pinnularia sp.	+	+							
Cyanophyta									
Aphanothece sp.					+				
Lyngbya sp.	+	+	+	+					
Chroococcus sp.	+	+	+	+					
Chlorophyta									
Dunaliella salina					+	+	+	+	
Dunaliella viridis			+	++	++	++	+++	++	
Pallmella sp.			+						
Chlorella sp.			+++	+	+				
Volvox sp.			+	+	+				
Kirchneriella sp.			+						

Table 4 Species composition and distribution of zooplankton (July, 2004)

Zooplankton	Distribution and specific gravity($^{0}Be'$)								
	I	II	III	IV	V	VI	VII	VIII	IX
	3.24	4.13	6.24	10.35	15.04	19.10	23.80	26.87	29.14
Protozoa									
Noctiluca scintillans	+								
Tininnopsis	+	+							
Coelenterata									
Brachionus plicatilis		+++							
Nematoda									
Nematoda		+							
Crustacea									
Artemia adult			+++	+++	+++	+++	+++	+++	
Calanus sinicus	+++	+++							
Microsetella Norvegica	+	+							
Acartia bifilosa	+++	+++							
Nauplius	+	+++							
Copepodite	+	+++							
Neomusis awatschensis	+								
Polychaeta									
Polychaeta larva	+	+++							
Mollusk									
Gastropoda larva	++	+++							
Aquatic Insects									
Ephedra larva				+	+	+	+	+	
Bivalve									
Juvenile bivalve	+	+							

Table 5 Species composition and distribution of zooplankton (October, 2004)

Zooplankton	Distribution and specific gravity($^0Be'$)								
	I	II	III	IV	V	VI	VII	VIII	IX
	3.28	4.51	8.45	10.21	16.09	19.67	24.23	27.30	29.11
Crustacea									
Artemia adult		+++	+++	+++	+++	+++	+++	+++	
Paracalanus crassirosteris	+++	+++	+						
Microsetella norvegica	+	+	+						
Acartia bifilosa	+	+++	+						
Oithina similis	++								
Acatia bifilosa	++								
Balanus larva	+								
Copepodite	+++	+++	+						
Polychaeta									
Polychaeta larva	+++	+++	+++						
Aquatic Insects									
Ephedra			+	+	+	+	+		

Table 6 Species composition and distribution of zooplankton (April, 2005)

Zooplankton	Distribution and specific gravity($^0Be'$)								
	I	II	III	IV	V	VI	VII	VIII	IX
	4.05	4.46	5.70	13.70	17.99	19.18	23.75	27.55	28.10
Crustacea									
Artemia adult			+++						
Artemia pre-adult			++						
Artemia nauplius			+++						
Paracalanus crassirosteris	++	+	+++		+		++		
Oithina similis	++	++	+				++		
Megalopa larva	++								
Acatia bifilosa	+	+	++				+		
Tortanus soinicaudatus	+								
Acartia bifilosa	+	+							
Nauplius		+				+	+		
Copepodite		++					++		
Microsetella norvegica		+					+		
Calanus sinicus			+				+		
Mollusk									
Gastropoda larva		+							
Aquatic Insects									
Ephedra							+		
Ephedra larva	+ + +	++	+++	+	+	+	+		

CONCLUSIONS

Phytoplankton

The saltern phytoplankton is originally from seawater, it gradually adapts to the high salinity as the concentration of the brine increasing. The species and density of phytoplankton decreased as the concentration of the brine increased from sample point I to IX. However, the halophilic microalgae, D. salina and D.viridis, could tolerant extreme high salinity, therefore they became the dominant species in the high salinity area of the salt fields. The fact that these two kinds of microalgae are beneficial to the salt production is has been confirmed [2-4].

The richness of phytoplankton in species are related to the seasons, The species of phytoplankton in Tanggu Saltworks were richer in spring and summer than that in autumn, eand were dominated by diatom and green algae. Moreover, there were more species in high-temperature season than that in low-temperature season.

The main algae composition in current survey was in accordance with the result in 2002, except for that the species of diatom have decreased, and the species of green algae have increased. The current investigation also discovered Aphanothece sp. which has not been observed in 2002. Aphanothece sp. can produce polysaccharides organic matters, cause the viscosity of brine increased, hinder evaporation of brine and crystallization of sodium chloride, thus it is considered as a symbol of an unbalanced salt field ecosystem. It is suggested that more attention must be paid on the saltern ecosystem [5-8].

Zooplankton

The species of zooplankton decreased as the brine concentration increased from sample point I to IX. Artemia is the dominant species of zooplankton in middle and high salinity area. As an important species in the salt field, the density of Artemia plays a very important role in salt production. The density of Artemia observed in current survey was similar to that in 2002, but 10 times lower than that in 1989. Over fishing on Artemia for the aquaculture purpose during last 20 years could attribute to this remarkable reduction. And it should be mentioned that the reducing density of Artemia could be a sign of an unbalanced development of saltern ecosystem.

The species of zooplankton in Tanggu Saltworks are richer in spring and summer than that in autumn, and were dominated by crustaceans in all reasons. Moreover, there were more species in high-temperature season than that in low-temperature season.

The composition of community and fauna of zooplankton was the similar to the results obtained in 2002, but the variety and quantities have decreased slightly. One kind of protozoan named Noctiluca scintillans was first discovered in this summer investigation. Noctiluca scintillans is the bio-indicator of red tides and eutrophication, thus the appearance of this species might reflect the ecological changes in Bohai bay. Its effect on the ecological environment of salt field is needed in future research. In the summer investigation, we also found plenty of Brachionus plicatilis in sample point II, which became the dominant species in the lower salinity pond (with density up to 36 ind/L). The Brachionus plicatilis inhibit extremely high tolerant to the eutrophication, it consumes microalgae and proliferates quickly in the water, thus it competes food with Artemia and hinder the growth and reproduction of Artemia.

In Summary, the current survey revealed that saltern ecosystem in Tanggu saltworks is being on the way to imbalance, thus the biological management was emphasized towards the end of the paper.

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