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Fouling ascidians in the coastal waters of China - a review

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I. Introduction

Being important benthic species in marine ecosystems, ascidians are also one of the major fouling groups. If colonizing on aquaculture facilities, they can cause a series of problems such as competing food and settlement substrata with the cultivated species, blocking netting holes, increasing the weight of cages and retarding water flow, leading to the deterioration of the aquaculture environment. Finally growth and quality of those cultivated species will therefore be negatively affected. This review deals with the species composition, distribution and settlement characteristics of fouling ascidians based on previous investigations in China in order to provide a base for controlling marine fouling effectively and improving the understanding of coastal ecology.






II. Species and distribution

Bohai Sea: Bohai Sea is an inland sea, and consists of Liaodong Bay, Bohai Bay, Laizhou Bay, the central waters and Bohai Strait. Its area covers 7.7×10^4 km² and average depth is 18 m. There were seven species of fouling ascidians recorded. Of them, the dominant species are *Styela clava* and *Ciona intestinalis*, followed by *Molgula manhattensis* and *Diplosoma listerianum*. Common species is *Botrylloides violaceus*.

Yellow Sea: Yellow Sea is a semi-enclosed shallow sea. It is surrounded by North Jiangsu Plain, Shandong Peninsula, Liaodong Peninsula and Korean Peninsula and connects with East China Sea in the south. The area of Yellow Sea is about 3.8×10^5 km² and average depth is 44 m. Sixteen species of fouling ascidians were recorded. The dominant species are *Molgula manhattensis* and *Styela clava*, followed by *Diplosoma listerianum*, *Ciona intestinalis*, *Botryllus schlosseri* and *B. tsingtaoensis*. Common species are *Botrylloides violaceus*, *Styela canopus* and *Ascidia longistriata*. Endemic species are *Chelyosoma* sp. and *Botrylloides simodensis*.

East China Sea: At the northern end of East China Sea is the estuary of the Changjiang (Yangtze) River and at the southern end is Nan'ao Island in Guangdong Province. The area of East China Sea is about 7.7×10^5 km² and the average depth is 370 m. There were 23 species of fouling ascidians recorded with the dominant species being *Styela canopus*, *S. plicata*, *Trididemnum areolatum*, *Molgula manhattensis* and *Ascidia longistriata*. Common species were *Microcosmus australis*, *Ciona intestinalis* and *Diplosoma listerianum*.

South China Sea: South China Sea covers a subtropical and tropical area, with various geological environments and hydrological conditions. The overall area of South China Sea is about 3.6×10^6 km², and the average depth is 1 212 m. Twenty-eight species of fouling ascidians were recorded. Of them, *Styela canopus*, *Symplegma oceania*, *Microcosmus exasperates*, *Ascidia sydneiensis* and *Diplosoma listerianum* account for an absolute predominance, followed by *Styela plicata*, *Symplegma viride*, *Styela rectangularis* and *Botryllus schlosseri*. Common species are *Ciona intestinalis* and *Molgula manhattensis*.

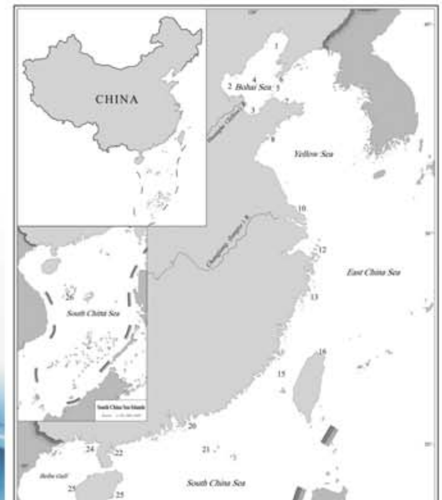

Fig.2 Investigation sites of acorn barnacles in Chinese waters

1. Liaodong Bay; 2. Bohai Bay; 3. Laizhou Bay; 4. Center waters of Bohai Sea; 5. Bohai Strait; 6. Dalian Bay and Lyshun Port; 7. Yantai Port; 8. Qingdao Port; 10. Lvsiyang waters; 12. Zhoushan Islands; 13. the coast of southern Zhejiang; 15. Taiwan Strait; 16. Badouzi Port; 20. coastal waters of Pearl River delta; 21. offshore area southeast of the Pearl River delta; 22. the coast of western Guangdong; 24. Beihai Port; 25. the coast of Hainan Island; 26. South China Sea Islands



Table 1 Fouling ascidians in the coastal waters of China

Species	Bohai Sea					Yellow Sea				East China Sea				South China Sea				
	Liaodong Bay	Bohai Bay	Laizhou Bay	Central Bohai	Bohai Strait	SE Liaoning	NE Shandong	Jiaozhou Bay	Lianyungang Port	Zhoushan Islands	NE Fujian	NE Taiwan	Taiwan Strait	Pearl River Delta	W Guangdong	Hainan Island	Beibu Gulf	South China Sea Islands
Ascidiidae																		
Ascidia longistriata							+					++	+	+				
A. sydneiensis													+			++	+	+
Cionidae																		
Ciona intestinalis	++			+		+	++	+				+	+	+			+	
Corellidae																		
Chelyosoma sp.							+											
Didemnidae																		
Didemnum fuscum																	+	
Didemnum sp.							+			+								
Diplosoma listerianum					++		+	++				+	+	++		++		
Trididemnum areolatum												+	++	+				
Molgulidae																		
Molgula manhattensis		++				++	++		++	+	++		+	+			+	
Polyclinidae																		
Amaroucium constellatum							+						+					
Polyclinum constellatum													++	+				
Styelidae																		
Botrylloides simodensis							+											
Botrylloides sp.										+								
B. violaceus					+		+	+	+				++					
Botryllus magnicoecus								+										
B. schlosseri						++		+	+					++		+		
Botryllus sp.						+							+		+	+		
B. tsingtaoensis							++											
B. tuberatus							+						+	+				
Cnemidocarpa sp.																++		
Eusynstyela sp.																	+	
Polyandrocarpa [illegible]																+		
P. sagamiensis													+		+			
Polyandrocarpa sp.													++					
Polycarpa sp.																		+
Styela canopus					+		+					++	++	++	+		++	++
S. clava	+	+		++	+	++	++	++	+									
S. plicata										+	+		++	++			+	
S. partita			+						+									
S. rectangularis																++		
Styela sp.										+						+	+	
Symplegma [illegible]																		+
S. oceania													+	++			++	
S. viride																++		
Pyuridae																		
Herdmania momus													+	+				
Microcosmus australis												+	+					
M. exasperatus													++	++	++		+	
Pyura sp.													+					
P. lignosa														+				
P. vittata																+		

SE Liaoning: Southeast coast of Liaoning Province; NE Shandong: Northeast coast of Shandong Province; NE Fujian: Northeast coast of Fujian Province; NE Taiwan: Northeast coast of Taiwan Province; W Guangdong: West coast of Guangdong Province

III. Fouling characteristics

Bohai Sea: The settlement period of most species was from June to September. In Liaodong Bay, the settlement peak time of the main species *Ciona intestinalis* was in summer and died with the drop of water temperature. In Bohai Bay, the dominant fouling species of ascidians colonizing on test panels deployed at the floating wharf was *Molgula manhattensis* and its settlement period is from May to October, especially from June to September. However, at the low tidal zone of sluice gates and wharf piles, the dominant species was *Styela clava*. In the central waters of Bohai Sea, offshore oil platforms were fouled by the ascidian *Styela partita*. In the Longkou port of Laizhou Bay, the main species of ascidians colonizing the autumn panels and 6-month ones was *Styela clava*. In Bohai Strait, *Diplosoma listerianum* was dominant species of ascidians and its settlement period is from July to September, the settlement peak time occurring from August to September.

Yellow Sea: In the waters off southeast coast of Liaodong Peninsula, the absolute dominant fouling ascidian on test panels was *Styela clava*, which mainly occurred on summer and annual panels and its settlement was from July to September. In Yantai Port, northeast Shandong Peninsula, the settlement of *Styela clava* was from June to November and the peak time was in June. In Qingdao Port located in Jiaozhou Bay, test panels were mainly fouled by *Diplosoma listerianum* in August. In Lianyungang Port the major ascidian was *Molgula manhattensis*. Its settlement period was from May to November peaking from July to September, particularly in September. Moreover, *Styela partita*, *S. clava* and *Botryllus schlosseri* only occurred on the summer, autumn and annual panels.

East China Sea: In the waters of Zhoushan Islands, no ascidians were found on test panels deployed in exposed waters off southeastern coast of Shengshan Island. However, the settlement of ascidians was observed during the period from April to May and September to November, respectively, on test panels deployed in the sheltered waters off west coast of Gouqi Island and the major species was *Molgula manhattensis*. In the waters of Daguanban reclamation area of Luoyuan Bay, the northern coast of Fujian, *Molgula manhattensis* was one of the dominant fouling ascidians. Their settlement occurred in May and reached peak time in June. The settlement density was still high in November. The Badouzi Harbour located in the north of Taiwan Island is surrounded by wharfs and Artificial embankment. Major fouling ascidians colonizing aquaculture facilities deployed there were *Styela canopus* and Ascidia longistriata. In the waters of Taiwan Strait, fouling ascidians was normally dominated by *Styela canopus* and the settlement peak occurred in summer.

South China Sea: In the coastal waters of the Pearl River Delta, the settlement period of fouling ascidians, for example *Styela plicata*, was normally in spring and summer. Additionally, the test panels deployed at a floating wharf in Qinglan port, northeastern Hainan Island, were fouled by the *Styela* and *Botryllus* ascidians only in autumn. However, in Yulin harbor, located in the southern Hainan Island, the dominant species of ascidians on the fouling test panels deployed at a wharf was *Ascidia sydneiensis* and only occurred in March. In the waters of Xisha Islands, the settlement of ascidians could be observed on all seasonal panels deployed in the sheltered waters and the peak settlement time was in summer. The dominant species of the ascidians was *Styela canopus*. More ascidians occurred in the fouling community on the test panels deployed on the wharf at the innermost end of the sheltered waters than at the entrance.

IV. Conclusion

A total of 40 ascidian species within 20 genera and 8 families are identified from fouling communities in the coastal waters of China - 7 species were found in the Bohai Sea, 16 in the Yellow Sea, 23 in the East China Sea and 28 in the South China Sea. The dominant species in the northern sea area of China are *Styela clava*, *Molgula manhattensis* and *Diplosoma listerianum*. However, *Styela canopus*, *S. plicata* and *Symplegma oceania* become dominant in southern waters. The characteristics of fouling ascidians are closely related to factors such as geographic location, immersion duration of substrata and local environmental conditions. The settlement period of fouling ascidians extends obviously with the decrease of latitude. In the Bohai Sea settlement takes place from June to September, however, in the South China Sea it takes place throughout the year. Furthermore, the species number also increases greatly from north to south.