

1 The distribution of large floating seagrass (*Zostera marina*) clumps in northern temperate zones of
2 Bohai Bay in the Bohai Sea, China

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20

21 **Abstract**

22 Seagrass meadows (*Zostera marina*) are important coastal ecosystems with high levels of
23 productivity and biodiversity. They are subject to considerable natural and anthropogenic threats in
24 China, such as oyster and snail aquaculture, wastewater discharge, electro-fishing, shellfish
25 collection, typhoons and floods. When seagrass communities are disturbed, they can become
26 removed from the sediment and converted into floating clumps, which then serve as marine hot spots
27 attracting a variety of marine organisms that then inhabit them. They are important nursery habitats
28 for many economic fish such as red drum (*Sciaenops ocellatus*), Atlantic cod (*Gadus morhua*),
29 queen conch (*Strombus gigas*), and blue crab (*Callinectes sapidus*). Thus, it is necessary to study the
30 distribution and biological characteristics of these floating seagrass clumps. In September 2016 we
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32

33 observed large scale floating *Z. marina* clumps in the northernmost area of Bohai Bay
34 (38°57'1.14"–39° 0'41.28" N, 118°45'23.22"–118°47'6.96" E), in the Bohai Sea, China. We
35 observed characteristics that precluded their origination from the nearby Caofidian seagrass
36 meadows. Two research cruises were undertaken, during which we did not observe other marine
37 organisms accompanying these floating *Z. marina* clumps. The dominant frond lengths were 40–50
38 cm, with less than 5% of the total number of fronds found in larger size categories (80–90 and
39 90–100 cm). We aim to pursue future research into the breakdown and dislodgement characteristics
40 of *Z. marina* clumps and the processes whereby they sink and integrate with the sediment.

41

42 **Keywords:** Seagrass meadow; floating seagrass clumps; *Zostera marina*; Xiangyun cove; Bohai
43 Bay

44

45 **Introduction**

46

47 Seagrass meadows are highly biodiverse and productive coastal ecosystems, covering
48 approximately 0.15% of the global ocean area and contributing 1% of the marine net primary
49 production [1]. Seagrass meadows are important nursery habitats for many economically valuable
50 fish and invertebrate species such as red drum (*Sciaenops ocellatus*), Atlantic cod (*Gadus morhua*),
51 queen conch (*Strombus gigas*), and blue crab (*Callinectes sapidus*) [1-2]. They also provide suitable
52 substrate for a variety of marine epiphytes and facilitate the sedimentation of suspended particulates
53 [3-4]. In the past half century, seagrass meadows have declined rapidly worldwide. For example,
54 approximately 2.6×10^4 km² of seagrass meadows, accounting for 15% of the estimated global total,
55 disappeared between 1993 and 2003 [5].

56 Floating seagrass clumps are an important method of transport for seagrass detritus from one
57 habitat to another [6]. As seagrass meadows age, senesce and interact physically with the
58 environment around them, leaves may break off from the beds and either sink to the surrounding
59 seafloor or float to the sea surface [6]. Due to the high primary productivity of seagrass meadows
60 [7], considerable volumes of leaves are continually shed and transported away from the beds by
61 currents and wave action [8-10]. Large aggregations of this floating vegetation called “seagrass
62 wrack” can form [11] and the biomass is ultimately exported to the seafloor or washed ashore on
63 beaches.

64 Floating at the sea surface, seagrass wracks can serve as habitat “hot spots” similar to other
65 floating vegetation such as floating macroalgae (e.g. *Sargassum* spp.). Thresher et al.[12] is one of
66 the only studies to report on the trophic impacts of floating seagrass wracks. Through indirect lines
67 of evidence, they reported that microbial decomposition of floating seagrass played a pivotal role in
68 the coastal planktonic food chain [12].

69 A broad seagrass meadow (39°00'N–39°05'N, 118°41'E–118°44'E), covering approximately
70 10 km² was discovered in the northwestern area of Longdao Island, Caofeidian, Bohai in October
71 2015 [13]. To date, it is the largest seagrass meadow discovered in the Bohai Sea and Yellow Sea
72 areas in China, and its composition is dominated by *Zostera marina* [13]. *Z. marina* is a species of
73 seagrass known by the common names ‘common eelgrass’ and ‘seawrack’, and is widely distributed
74 in the Northern Hemisphere. The plant is a rhizomatous herb which produces a long stem with
75 hair-like green leaves. The rhizome grows horizontally through the substrate, anchoring via clusters
76 of roots at nodes. In September 2016, a large area of floating *Z. marina* clumps was observed in the
77 area of Xiang-yun Island, the northernmost area of Bohai Bay in the Bohai Sea, China, nearby to the
78 Caofeidian area. We conducted two research cruises, a week apart, to survey the distribution of these
79 floating *Z. marina* clumps in September 2016. The present study is the first to report the distribution
80 of floating *Z. marina* clumps in temperate zones in the Bohai Sea, China.

81

82 Materials and methods

83 The field survey was approved by Institute of Oceanology, Chinese Academy of Sciences.

84 A survey of the distribution of floating *Z. marina* around Xiang-yun island, the northernmost
85 part of Bohai Bay, Bohai Sea was carried out using transect lines at a distance of approximately
86 0.5–1.0 km (Fig. 1). Sightings of drifting clumps are difficult unless the sea is calm, and only
87 clumps within 50 to 100 m of the vessel were observed. The first cruise was made on 6 September
88 2016 from ‘Point 1’ to ‘Point 8’, while the second cruise was made on 13 September 2016 from
89 ‘Point 8’ to ‘Point 15’ (Fig. 1). The research vessel kept a stable speed of six knots, and seagrass
90 clumps seen within each transect line were quantified as follows: none, frequent clumps and large
91 amounts (Fig. 2).

92 Based on previous literature [14-15], a dip net with a ring diameter of 50 cm and mesh size of
93 5.0 cm was selected for optimal sampling. The net was dipped under each clump, hauled up in one
94 quick sweep whenever possible, and emptied into a bucket containing seawater. Usually large
95 seagrass clumps encountered were collected randomly, and small fragments were ignored. In the

96 laboratory, the samples were thoroughly rinsed in water and species were identified and counted. *Z.*
97 *marina* frond lengths were measured from the bottom of the samples to the top of the longest
98 branches (± 1 cm) using a 30 cm ruler.

99

100 **Results and discussion**

101 A large area of floating *Z. marina* clumps was observed in our survey (marked in red, Fig. 1.).
102 The area between N 38°58.9358' E 118°50.1150' and 'Point 14' had frequent clumps, and the area
103 between 'Point 14' and 'Point 15' had large amounts of floating clumps. In the latter transect line,
104 we estimated the clumps to make up an area of approximately 80–100 m. The Caofeidian seagrass
105 meadows are located approximately 6,400 m away from Point 14, 10,000 m away from Point 15 and
106 13,500 m away from N 38°58.9358' E 118°50.1150'. We observed \sim 10 km² seagrass meadows and
107 large scale areas of floating *Z. marina* clumps around an artificial oil platform in Caofeidian sea
108 areas, near Long island (Fig. 3) in June 2018. Thus, we suggested that these floating seagrass clumps
109 originated from the Caofeidian seagrass meadows. Natural disturbances such as weather, tides and
110 the degree of bed exposure, as well as anthropogenic impacts such as dredging, fishing and
111 anchoring can destroy seagrass meadows and displace plants from the beds to distant locations
112 offshore [8-9, 16-19]. Dierssen et al. [11] found that strong southerly winter winds in Greater Florida
113 Bay advected considerable amounts of seagrass wracks comprised predominantly of *S. filiforme*
114 from the dense meadows in the area to oligotrophic Atlantic Ocean Waters. In our study, isolated *Z.*
115 *marina* leaves became more aggregated into patches between 'Point 14' and 'Point 15' and could be
116 found in long windrows produced by downwelling lobes of Langmuir circulation. Aggregations of
117 seagrass vegetation are common in shallow waters due to slow counter-rotating vortices at the
118 ocean's surface known as Langmuir circulation [20].

119 Generally floating seagrass wracks can be considered a relatively long-lived ecosystem "hot
120 spot", providing habitats for a wide variety of marine organisms [21]. As floating wracks travel, they
121 release dissolved organic carbon and colored dissolved organic material into surface waters which
122 results in enhanced bacterioplankton in the surrounding seawater. The diverse community supported
123 by floating wracks also serves as a resource for larger pelagic fish, which feed on the smaller
124 organisms living on and near the wracks. However, during the surveys in the present study, marine
125 organisms were not found accompanying the floating seagrass clumps. In addition, through trawling
126 surveys conducted in the sea areas surrounding 'Point 5', 'Point 6', 'Point 7' and 'Point 8', we
127 estimated 0.656–1.694 kg/m² (unpublished data) *Z. marina* debris to be laid down in the seabed.

128 Floating seagrass debris provides plentiful nutrition and is an important natural food source for an
129 economically important local aquaculture species, *Apostichopous japonicas*. Song et al. [22] found
130 that the specific growth rates, food utilizing efficiencies and energy budgets of *A. japonicas* were
131 strongly influenced by the ratio of *Z. marina* in their diets.

132 The dominant frond length category of isolated *Z. marina* leaves in the present study was
133 40–50 cm in both ‘Line A’ and ‘Line B’ (Fig. 4). In ‘Line A’, > 15% of fronds were in each of the
134 30–40, 40–50 and 50–60 cm categories. Whereas, in ‘Line B’, > 15% of fronds were in each of the
135 40–50, 50–60 and 60–70 cm categories. Less than 5% of fronds in both Lines were in the largest
136 size categories of 80–90 or 90–100 cm. In the Caofeidian *Z. marina* seagrass meadows, the canopy
137 height was 15.2 ± 5.84 to 62.1 ± 7.34 cm.

138 This study is the first survey to bridge the knowledge gap on floating *Z. marina* clumps in the
139 temperate zones along Chinas coastline. We precluded that the floating seagrass clumps in the
140 northernmost area of Bohai Bay ($38^{\circ}57'1.14''$ – $39^{\circ} 0'41.28''$ N, $118^{\circ}45'23.22''$ – $118^{\circ}47'6.96''$ E)
141 originated from the Caofeidian seagrass meadows. Our findings provide a greater understanding
142 about the life cycle of *Z. marina* including how it is transported to the seafloor and becomes organic
143 debris for benthic communities. The dislodgement and break-up characteristics of floating *Z. marina*
144 clumps and the transportation of their organic matter to the seafloor will be the subject of future
145 studies.

146

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148

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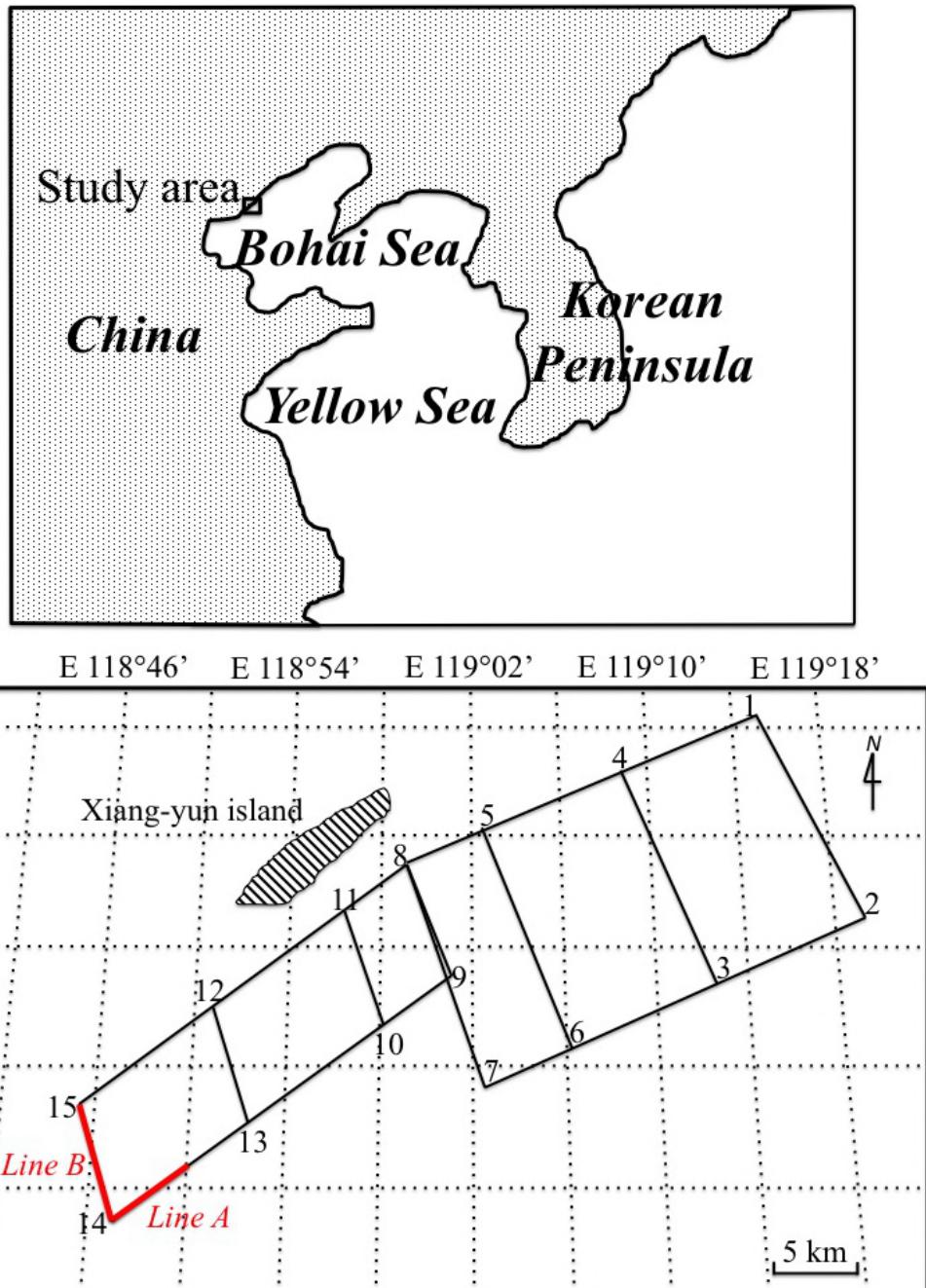
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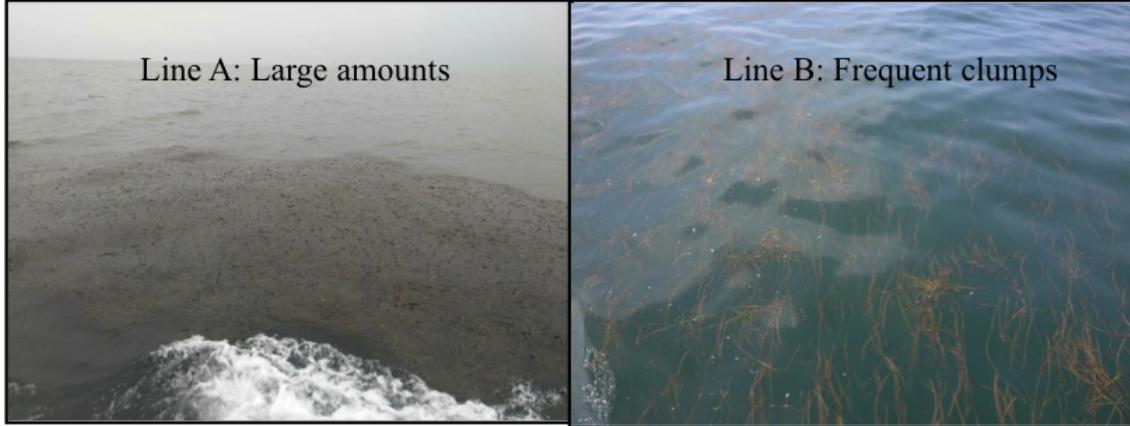
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226 **Fig. 1.** Schematic map showing the route of two research cruises to survey the distribution of floating
227 *Zostera marina* clumps in the waters off Xiang-yun Island, Tangshan in the northernmost area of Baihai
228 Bay in the Bohai Sea, China. On 6 and 13 September 2016 the vessel travelled from 'Point 1' to 'Point 8'
229 and from 'Point 8' to 'Point 15', respectively. The red lines ('Line A' and 'Line B') indicate the locations
230 of floating *Z. marina* clumps. Line A was from N 38°58.9358' E 118°50.1150' to 'Point 14', and Line
231 B was from 'Point 14' to 'Point 15'. The Caofidian seagrass meadows are located approximately

232 6,400 m away from Point 14, 10,000 m away from Point 15 and 13,500m away from N 38°58.9358'
233 E 118°50.1150'.
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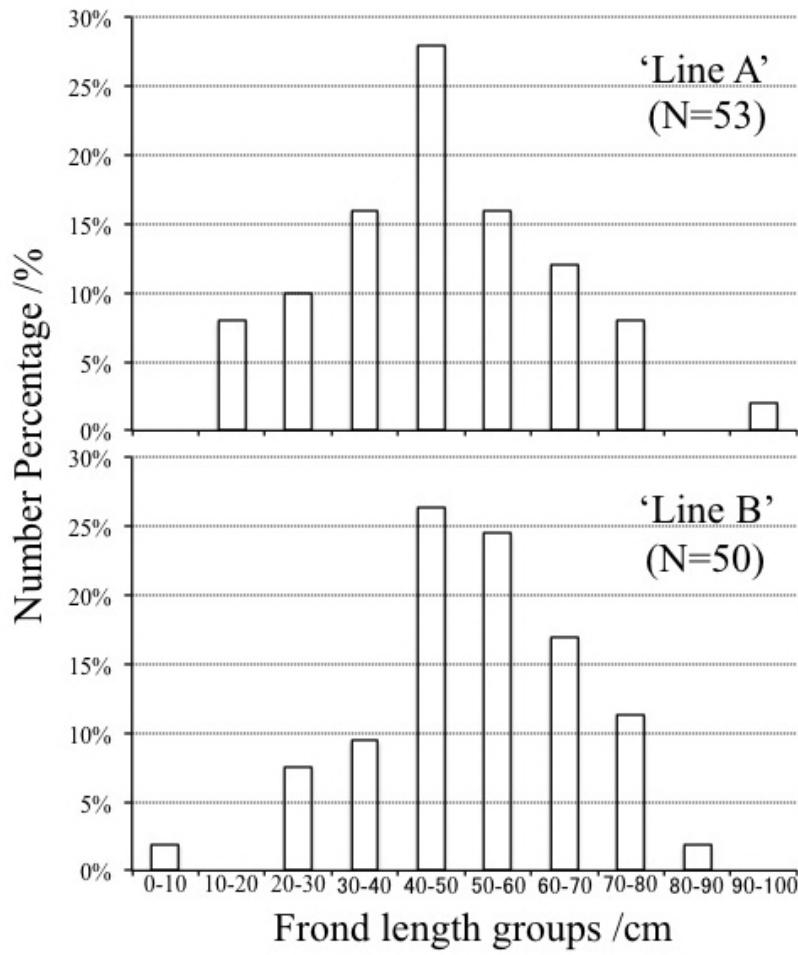
236 **Fig. 2.** Left: An example of 'large amounts' of *Zostera marina* observed in 'Line A'. Right: An example
237 of floating *Z. marina* leaves observed in 'Line B'.

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240 **Fig. 3.** Left: Floating *Zostera marina* clumps found in Caofeidian seagrass meadows; Right: ~10 km²
241 Caofeidian seagrass meadows observed on June 1st 2018.



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243 **Fig. 4.** Number percentage (%) of floating *Zostera marina* leaves within different frond length categories
244 (cm) in 'Line A' (N = 53) and 'Line B' (N = 50).

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