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Floating period of Sargassacean thalli estimated by the change in density

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Abstract The density (fresh weight/volume) of the detached thalli of four sargassacean species (*Myagropsis myagroides*, *Sargassum horneri*, *S. patens*, *S. siliquastrum*) was measured weekly to determine their floating period. Thalli of the four species were collected with respect to the difference in their reproductive stage, and their floating abilities at different stages were determined. Floating thallus was ballasted with pre-weighed leads until the final addition of a weight caused sinking. The density and floating period of sargassacean thalli were dependent on the species and the specimens' reproductive stage. The floating period of thalli detached before maturation was estimated to be between 4 and 14 weeks. However, thalli detached during maturation had a floating period of between 1 and 8 weeks, and those detached after maturation sank within 2 weeks. *Sargassum horneri* had the lowest density and the longest floating period among the four species investigated and this may explain the high abundance of *S. horneri* in floating seaweeds observed in the Sea of Japan.

Keywords Density of seaweed · Floating period · Floating seaweed · Sargassaceae

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Introduction

Forests of sargassacean seaweeds are among the most productive communities along temperate coasts (Taniguchi and Yamada 1978; Mann 2000; Yatsuya et al. 2005a). Most of the thalli produced are detached from the forests as floating seaweed (Yatsuya 2005), which is known to be an important food and habitat for fish larva and invertebrates (e.g., Senta 1965; Kingsford 1995).

Floating seaweeds usually originate from coastal seaweed beds and eventually sink to the bottom or are stranded on shore (Yoshida 1963); however, pelagic *Sargassum* on the surface of the central North Atlantic Ocean is adapted to survive over long periods of time (Parr 1939). In Japan, seasonal changes in the distribution and species composition of floating seaweeds have previously been investigated (Yoshida 1963; Ohno 1984; Yatsuya et al. 2005b). However, their floating period has rarely been examined, even though it should affect the ranges of dispersal of these seaweeds.

There have been rough estimates of the floating period of sargassacean thalli. Yoshida (1963) inferred from the recovery rate of labeled floating seaweeds that they kept afloat for 2 months. Ohno (1984) investigated the abundance of floating seaweeds and the deterioration of seaweed beds, suggesting a floating period of approximately 1 month. The floating period of seaweed is affected by its density; however, the change in the density during the floating period has never been investigated. In the present study, the density of four dominant sargassacean species was measured weekly to determine their floating ability (i.e., density and floating period) with respect to the differences in species and reproductive stage.

Materials and methods

Myagropsis myagroides (Mertens ex Turner) Fensholt, *Sargassum horneri* (Turner) C. Agardh, *Sargassum patens* C. Agardh, *Sargassum siliquastrum* (Turner) C. Agardh, used in this experiment, are dominant species in seaweed beds and floating seaweeds off the central part of Honshu Island facing the Sea of Japan (Ikehara and Sano 1986; Yatsuya 2005).

Attached thalli of the four sargassacean species were collected by a scuba diver from January to June 2004, according to their reproductive stages (Table 1), e.g., immature (sterile specimens without receptacles), during maturation (from receptacle formation to egg liberation), and post-mature (no egg and embryo on the receptacles). No collection was carried out in the other seasons, when floating seaweeds in this region are rarely observed (Yoshida 1963; Yatsuya et al. 2005a). *Myagropsis myagroides*, *Sargassum patens*, and *S. siliquastrum* were collected at a depth of 2 m on Yoro coast and *Sargassum horneri* was collected at a depth of 2 m on Odasyukuno coast. At each sampling, three individuals of similar size were collected for each species. The thalli were cut at the base of the main branches, since most of the thalli usually detach at that portion in the natural detaching process (Yatsuya 2005). The total length of the thalli collected for the experiments ranged from 1.7 to 3.7 m.

The density of thalli was determined as follows. The mesh bag with the thalli inside was placed in seawater. Then the bag was ballasted with lead weights until a final addition of the weight caused sinking. Since buoyancy of the mash bag was preliminarily corrected, the combined weight of the immersed thalli plus the ballasts was equal to the weight of displaced seawater. Therefore, the density of ambient seawater (d_t) was derived in the following manner:

$$dt = \frac{Sw + bw}{Sv + bv} \quad (1)$$

where S_w=thallus weight (g), b_w=ballast weight (g), S_v= thallus volume (cm^3), and b_v=ballast volume (cm^3). The density of ambient seawater was measured by ACL215-DK (Alec Electronics, Kobe, Japan). The weight and volume of the ballast were known before measurement, therefore, the volume (S_v) was determined by the equation (1) and the density of the thallus (g cm^{-3}) was determined as (S_w/S_v).

After the measurement, each thallus was stored in a mesh plastic container (52 cm in length×77 cm in width×41 cm in depth, mesh size approximately 1 cm), floated and moored at a pier. The density and weight of stored thalli were measured every week until they sank, and these measurements were expressed by the mean of three individuals. Water temperature in the container was measured at 60 minute intervals by RMT thermometer (Rigo, Tokyo, Japan).

Table 1 Density and maturation stages of attached sargassacean thalli used in the experiments (n=3)

Species	Sampling date				
	January 28	March 10	April 20	May 19	June 18
Myagropsis myagroides	0.929[a]	0.941[b]	0.952[c]	N.D.	N.D.
Sargassum siliquastrum	0.929[a]	N.D.	0.973[c]	0.987[c]	N.D.
S. patens	0.906[a]	N.D.	0.993[b]	0.916[c]	0.992[c]
S. horneri	0.761[a]	0.874[b]	N.D.	0.987[c]	N.D.

See the text for the definition of the maturation stages
N.D.: no data
[a] Immature, [b] mature, [c] post-mature

Results

The temperature of surface water was lowest in February and early March, varying around 11°C, and had increased gradually to 23–25°C in late June. Although the density of water deeper than 2 m was almost constant at 1.025, the density of surface water occasionally decreased to 1.016.

The density of attached sargassacean thalli was different according to species and their reproductive stage (Table 1). On 28 January, the density of immature *Sargassum horneri* was 0.761, the lowest density measured in this study. The density of attached thalli increased as they matured, ranging from 0.761 to 0.929 for immature thalli, 0.874 to 0.941 for mature thalli, and 0.916 to 0.992 for post-mature thalli (Table 1).

Figure 1 shows the changes in the density and fresh weight of detached thalli. The density of all sargassacean species continuously increased through the time. Increase in the density of thalli detached before maturation was slower than those detached during or after maturation. In all cases, except for Experiment 5, which was started on 18 June, the fresh weight of thalli gradually increased from the start of the experiments, and it decreased for the latter part of the floating period (Fig. 1). In Experiment 5, the weight of thalli rapidly decreased from the start of the experiment, due to deterioration of the thalli in the water of higher temperature.

Discussion

Floating ability is a well-known characteristic of sargassacean species, which aids the dispersal of those species (Paula and Eston 1987). This study reports quantitative information on this characteristic with respect to the

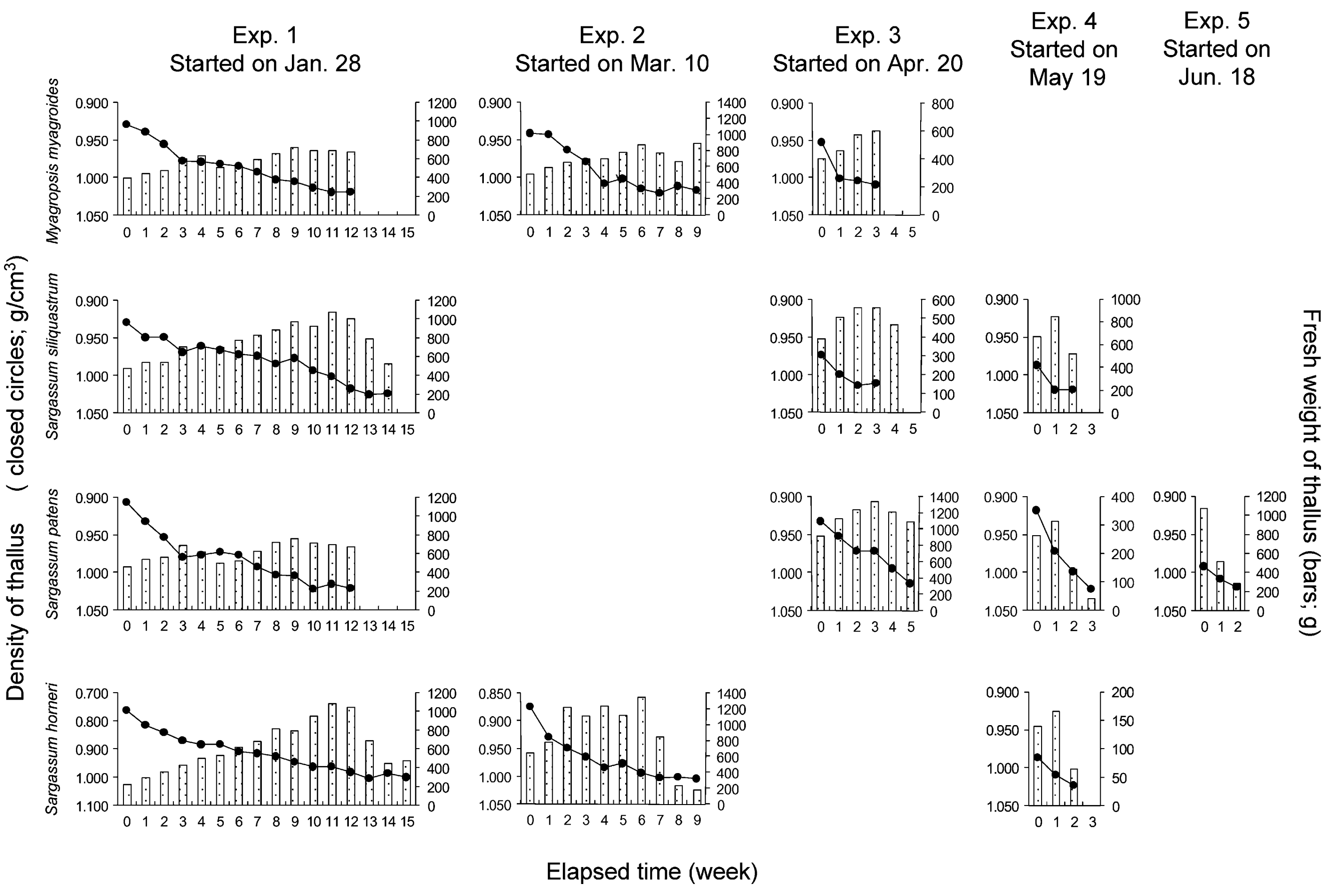

Fig. 1 Changes in density (*closed circles*) and fresh weight (*bars*) of sargassacean thalli, measured weekly in the experiments (n=3)

differences in species and reproductive stage of floating seaweeds.

At first, the floating period of sargassacean thalli was estimated as follows. Woodcock (1950) showed that floating seaweeds were concentrated at convergence lines in which water was descending during higher wind speed. He inferred that a descending current of 3 cm/s would carry downward any plants with a density higher than 1.0. Thalli with a density higher than 1.005 in the experiments of the present study were so fragmented and damaged that most of the leaves and vesicles on the thalli were lost. Such fragmented and deteriorated thalli have never been observed in floating seaweed in this region (K. Yatsuya, unpublished data 2004). Therefore, the density of thalli when they start sinking was tentatively supposed to be 1.005 in this study.

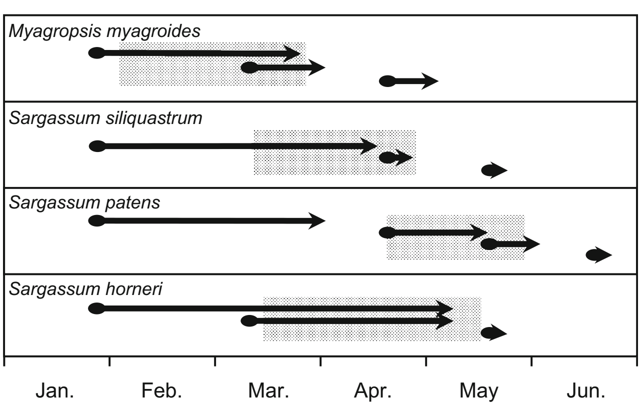

Fig. 2 Estimated floating periods (*arrows*) of four sargassacean species that were detached at different maturation stages. Their maturation period is expressed by the shading

Estimated floating periods ranged from less than 1 week to 14 weeks, varying among species and reproductive stages (Fig. 2, Table 2). Thalli of *S. horneri*, detached on 10 March, had an 8-week floating period, while those of *M. myagroides* floated for 3 weeks (Table 2). For thalli

Table 2 Estimated floating period (weeks) of sargassacean thalli

Species	Date of detachment				
	28 January	10 March	20 April	19 May	18 June
Myagropsis myagroides	8	3	2	N.D.	N.D.
Sargassum siliquastrum	11	N.D.	1	<1	N.D.
S. patens	9	N.D.	4	2	<1
S. horneri	14	8	N.D.	<1	N.D.

N.D.: no data, <1: less than 1 week

detached on 20 April, the estimated floating period of *S. patens* was longer than that of the other two species (Table 2). The longest floating period (14 weeks) was estimated for *S. horneri*, which detached on 28 January. The estimated floating periods decreased as the maturation stage progressed. The thalli detached before maturation were estimated to float for 8–14 weeks, while those detached during and after maturation floated for 3–8 weeks and 2 weeks or less respectively (Fig. 2, Table 2). Immature thalli, except for *S. patens,* detached on 28 January, formed receptacles during their floating period.

The weight and density of floating thalli varied with the time. A gain in the weight may be due to an increase in water content, because few epizoa and epiphytes were attached, and little growth was observed. A decrease in the weight was attributed to fragmentation and deterioration of the thalli. An increase in the density may be the result of degradation and detachment of vesicles and of an increase in the water content of thalli.

Our results show that the floating period of sargassacean thalli is species-specific. *Sargassum horneri* has the lowest density and the longest floating period among the four sargassacean species investigated. The high floating ability of *S. horneri* may support the frequent observations and high abundance in floating seaweeds in the Sea of Japan (Yoshida 1963; Ikehara and Sano 1986; Yatsuya et al. 2005b). *Sargassum horneri* is an annual seaweed, while the other three species are perennials. Annual seaweeds have to settle on a new substratum every year; thus *S. horneri* has the advantage of having propagules with a high dispersal ability.

The floating ability (i.e., thallus density and floating period) of sargassacean thalli seems to decrease as the reproductive stage progresses. The relative abundance of vesicles and receptacles may be related to the change in the floating ability. Yatsuya et al. (2005a) showed that the weight ratio of vesicles to whole thalli was constant before and during maturation, while those of receptacles increased for the same period. This result suggests that buoyancy provided by vesicles was constant, while the formation of receptacles would lead to an increase in the density of the thalli. After maturation, the deterioration of the thalli, especially vesicles, should also increase density.

According to the estimated floating period of the thalli detached at various reproductive stages, quantitative aspects of floating seaweeds could be inferred. In *Sargassum* beds in the Sea of Japan, most thalli detach after maturation, while few thalli detach before maturation (Taniguchi and Yamada 1978; Murase et al. 2000; Yatsuya et al. 2005a). This implies that most of the detached sargassacean thalli in nature will float for 2 weeks or less, and that few of them have more than 8 weeks longevity in floating conditions. On the basis of the fact that floating seaweeds in the Sea of Japan are transported a maximum of 17 km/day (Yoshida 1963), it may be possible for floating seaweeds to be transported such long distances as from Kyusyu Island to Tohoku district (approximately 1,000 km); however, this may be on rare occasions since those thalli must be detached before maturation and be floating for more than 8 weeks.

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