Coastal Marine Science 30(1): 184–188, 2006

Flowers and sexes in Malaysian seagrasses

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Received: 26 August 2005; Accepted: 10 November 2005

Abstract—Seagrasses are aquatic angiosperms growing in shallow coastal waters, although some species are found in deep waters. Similar to higher plants in terrestrial ecosystems, seagrasses are also flowering plants. Structurally, seagrass flowers are less complex and adapted for hydrophilous pollination and fertilization. Two modes of propagation typical of seagrasses are vegetative and sexual propagation. Vegetative propagation allows increase in ramet numbers and hence covers, while sexual reproduction through hydrophilous pollination and fertilization of flowers is a mechanism providing adaptability, maintenance and sustenance of the population. The flower morphology or structures, or their presence determine the sex of the plant. Seagrass plants can be monoecious or dioecious. Monoecious seagrass species have both male and female flowers on the same shoot or lateral shoots of the same plant. Dioecious seagrasses are those that have either male or female flowers borne on separate plants. In addition the pattern of growth, flowering and fruiting in the life cycle, whether continuous or periodic is a basis for separation of seagrass plants as perennial or annual respectively. In some cases, flower structures or their arrangement on the shoot of seagrass plants have been useful for taxonomic separation even to the level of species. Flowers in many seagrasses are rarely observed and encountered. We have been able to observe and record flowers from 12 seagrass species in Malaysia; *Enhalus acoroides, Thalassia hemprichii, Halophila beccarii, H. decipiens, H. minor, H. ovalis, H. spinulosa, Cymodocea rotundata, C. serrulata, Halodule pinifolia, H. uninervis* and *Syringodium isoetifolium* from Malaysia. This paper provides information on the structure and morphology of the male and female flowers from both gender (sexes-male and female) of seagrass plants. We hope this will be useful and of help to those who are not familiar with flowers and the sexes of seagrass species.

Key words: seagrasses, flowers, sexes, Malaysia

Introduction

Seagrasses can reproduce both sexually and asexually, through detached or drifting rhizome fragments. One of the characteristic of seagrass is its capability to reproduce in submerged condition and does not rely on animals for pollination (den Hartog, 1970). The sexual reproduction of seagrasses does not differ from reproductive modes of their land counterparts except with respect to the dispersal processes and frequencies of dioecious species (Ewanchuk and Williams, 1996). In Malaysia, of the twelve species, two species, *Halophila beccarii* and *H. decipiens* are monoecious (17%) where functionally male and female flowers are on the same plant while the rest; *Enhalus acoroides*, *Thalassia hemprichii*, *Halophila minor*, *H. ovalis*, *H. spinulosa*, *Cymodocea rotundata*, *C. serrulata*, *Halodule pinifolia*, *H. uninervis* and *Syringodium isoetifolium* are dioecious (83%). In dioecious seagrass, plants are separated into sexes, functionally female and male flowers are on separate plants which are relatively rare in land flowering plants. In Angiosperms, hermaphroditism occurs in plants where the individual bisexual flower (the reproductive organ) with both male and female equivalent parts (stamens and pistil) is common. Seventy percent (70%) of plants are hermaphroditic, while 5% are dioecious and 7% are monoecious. About 7% of species are gynodioecious (both female and hermaphrodite plants present) or androdioecious (both male and hermaphrodite plants present), while 10% plants that both unisexual and bisexual flowers (Molnar 2004). Worldwide, there is a high frequency of dioecious plants in seagrasses and has been interpreted to be important in the outcrossing mechanism (McConchie and Knox, 1989) or to avoid self-fertilization (Hemminga and Duarte, 2000). A whole range of flower diversities are shown in seagrasses at the genus level. Flowers can vary in structure, morphology and the orientation along the axis or the shoot of the plants. In this paper, the structure and morphological characteristics for the seagrass flowers, their sexes and the plant gender are discussed.

Materials and Methods

Field surveys were undertaken in the various locations around Malaysia and East Malaysia (Fig. 1) either by direct collection during low tide or by snorkelling and SCUBA div-

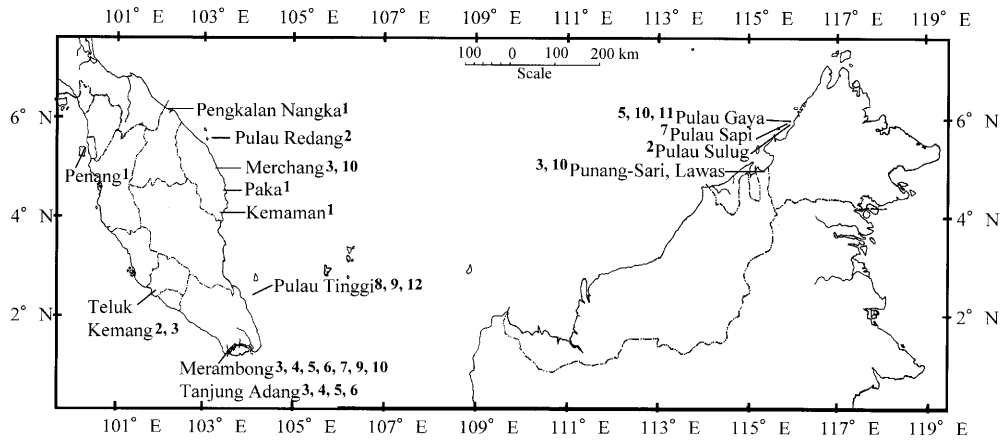

Fig. 1. The study locations: Peninsular Malaysia-Penang; Teluk Kemang, Negri Sembilan; Merambong shoal, Johore; Tanjung Adang shoal, Johore; Pulau Tinggi, Johore; Kemaman, Terengganu; Paka, Terengganu, Merchang, Terengganu; Pulau Redang, Terengganu; Pengkalan Nangka, Kelantan; Sabah, East Malaysia-Pulau Gaya; Pulau Sapi, Pulau Sulug and Sarawak, East Malaysia-Punang-Sari, Lawas. 1-*Halophila beccarii*, 2-*H. decipiens*, 3-*H. ovalis*, 4-*H. minor*, 5-*H. spinulosa*, 6-*Enhalus acoroides*, 7-*Thalassia hemprichii*, 8-*Cymodocea rotundata*, 9-*C. serrulata*, 10-*Halodule pinifolia*, 11-*H. uninervis*, 12-*Syringodium isoetifolium*.

ing over 10 years (1994–2004) as part of the inventory of marine plants under the Intensification in Priorities Research 7 & 8. Flowering plant materials were cleaned of adhering debris, preserved in 4% formalin in saline water and stored in plastic containers. Characteristics that den Hartog (1970) used in describing reproductive structures of seagrasses were observed, measured and recorded as digital images.

Observations and Discussion

Seagrasses are modular plants composed of units or ramets, which are repeated during clonal growth (Harper 1977, Hemminga and Duarte 2000). Each ramet is composed of a set of module; a piece of rhizome which can be horizontal or vertical, a pair or a bundle of leaves attached to the rhizome and a root system. In addition the ramet may hold flowers or fruits depending on the timing of observation. In spite of the necessary presence of all other modules, most seagrasses e.g. *Cymodocea rotundata*, *C. serrulata* and *Syringodium isoetifolium* shoots rarely produce flowers or fruits. Species such as some *Halophila* and *Enhalus acoroides* flower frequently. These species are able to produce a flower or more for every rhizome node formed. In higher plants, flowers are essential as a structure and mechanism for propagation. The flowers of seagrasses are simple when compared to the land plants. The typical flowers of land plants are complex, having sepals, petals and the essential components the stamen and pistil. Seagrass flowers are often inconspicuous, relatively simple and reduced in forms usually as separate sexes male and female. Seagrass flowers are diverse morphologically and range in size from the large flowers of *Enhalus* (Fig. 2a–b) to minute flowers of *Halophila* (Fig. 2c–h, 3e–f). The structure and morphology of the Malaysian seagrass flowers are illustrated in Figs. 2 and 3.

In *Halophila* irrespective whether they are monoecious or dioecious e.g. in *H. beccarii*, *H. decipiens*, *H. minor*, *H. ovalis*, *H. spinulosa*, a male flower comprises a pedicel, three tepals (sepal and petal being reduced to a structure called tepal) while still retaining the stamen comprising 3 anthers which housed the pollen (Fig. 2c). A female flower is also reduced in form having an ovary, a hypanthium and three styles that lack stigma (Fig. 2d). However, female flowers of *H. ovalis* (Fig. 2e) although rare can have four styles and female flowers with four styles are common in populations of *H. decipiens* (Figs. 2f, 2h) from Teluk Kemang, Negri Sembilan, Pulau Redang, Terengganu and Pulau Sulug, Sabah (Japar Sidik et al. 1997; Japar Sidik et al. 2000, Muta Harah et al. 2003). Similarity in flowers' structure and morphology are also observed in other *Halophila*; *H. australis* Doty & Stone (Doty and Stone 1966, den Hartog 1970), *H. hawaiiana* Doty & Stone (Doty and Stone 1966, Herbert 1986), *H. johnsonii* Eiseman (Eiseman and McMillan 1980), *H. ovata* Gaud (Ostenfeld, 1909), *H. stipulacea* (Forssk.) Aschers. (den Hartog 1970, Lipkin 1975), *H. baillonis* Aschers. ex Dickie in Hook. *f.* (den Hartog 1970, Oliveira et al. 1983), *H. engelmannii* Aschers. (den Hartog 1970, Short and Cambridge, 1984) and *H. tricostata* Greenway (Greenway 1979, Kuo et al. 1993).

Of the twelve seagrass species, *Enhalus acoroides* (male plant), *S. isoetifolium* (both male and female plants), *H. spinulosa* (both male and female plants) do not develop solitary terminal flowers on their vertical shoots. In *E. acoroides* a single male inflorescence comprises numerous male flowers enclosed by spathal leaves (Fig. 2a). *Syringodium. isoetifolium* (Fig. 3a–b) has a cyme inflorescence or many single flowers in a branch array on the vertical shoot). In *H. spinulosa*, flowers are laterally arranged in alternate and acropetal

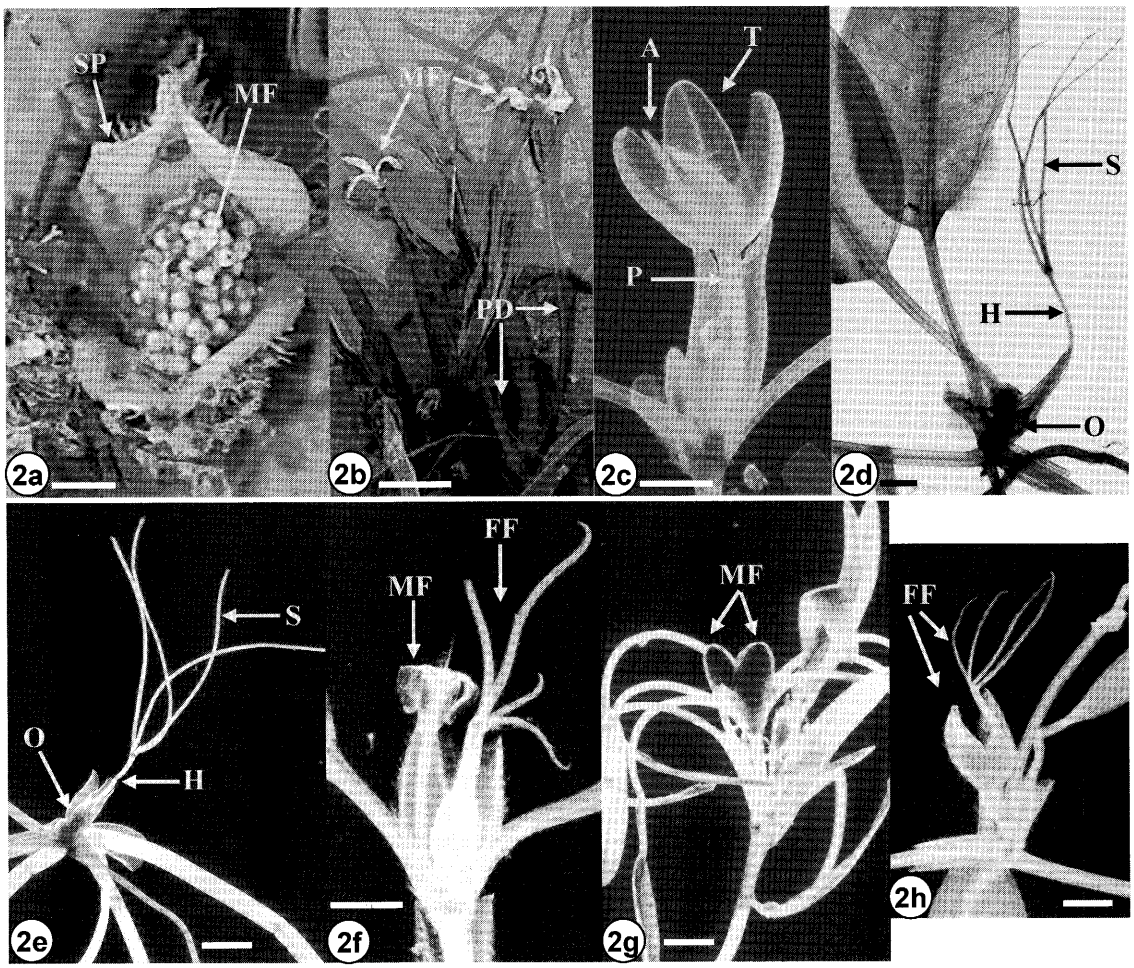

Fig. 2. Flowers and sexes in seagrasses.
2a–the numerous white male flowers (MF) in *Enhalus acoroides* enclosed by spathal leaves (SP), scale bar=1.5 cm; 2b–the female flowers (MF) in *E. acoroides* borne by a long peduncle (PD), scale bar=10 cm; 2c–the male flower in *Halophila* comprises a pedicel (P), three tepals (T) and alternating three anthers (A), scale bar=2 mm; 2d–the female flower in *Halophila* comprises an ovary (O), a hypanthium (H) and three styles (S), scale bar=5 mm; 2e–the female flower in *H. ovalis* can have four styles (S), a rare observation, scale bar=5 mm; 2f–in monoecious *H. decipiens*, a single shoot bears flowers pair of opposite sex, male flower (MF) and female flower (FF). The presence of four styles in a female flower of *H. decipiens* is common in Malaysia. Those reported for *Halophila* species including *H. decipiens* elsewhere have three styles, scale bar=5 mm; 2g–in monoecious *H. beccarii*, a single shoot bears a pair of opposite sex, male and female flowers (refer to Fig. 3e) but rarely a pair of the same sex male flowers (MF), scale bar=5 mm; 2h–similarly, in monoecious *H. decipiens* as in 2f, a single shoot bears a pair of opposite sex, male and female flowers but rarely a pair of the same sex female flowers (FF), scale bar=5 mm.

(i.e. the lower flowers are older than the upper flowers) succession (Fig. 3c–d) along the shoot. Seagrass also produces flowers in pairs in a shoot. Depending on species, at any one time, in a shoot the flowers pair can be of opposite sex-male and female e.g. in *H. beccarii* (Fig. 3e, however there is exception as well where male and female flowers are borne on separate shoots, Fig. 3f). In some seagrasses, mostly dioecious species, their individual shoots carry flowers pair of the same sex-male e.g. in *T. hemprichii* (Fig. 3g, male plant) or the same sex-female e.g. in *E. acoroides* (Fig. 2b, female plant), *S. isoetifolium* (Fig. 3b, female plant), *Halodule pinifolia* (Fig. 3j, female plant), *H. uninervis* (similar to *H. pinifolia*), *C. rotundata* (Fig. 3k, female plant), *C. serrulata* (Fig. 3l, female plant). *Thalassia testudinum* Banks ex Konig having more than one flower in a shoot for a male plant has been reported by William and Mark (1978). Male plants of *S. isoetifolium* (Fig. 3a, a single flower at each shoot node), *H. pinifolia* (Fig. 3i), *H. uninervis*, *C. rotundata*, *C. serrulata* and female plant of *T. hemprichii* (Fig. 3h) all have a single flower in a shoot. In monoecious species, although flowers pair of the same sex in the same shoot are rarely encountered, two *Halophila* from Malaysia have flowers pair in the same shoot of the same sex-male e.g. in *H. beccarii* (Fig. 2g) or the same sex-female e.g. in *H. decipiens* (Fig. 2h).

The information above and illustrations presented (Figs. 2 and 3) demonstrate the possible diverse range of variation with respect to flowers' sexes (gender-male or female), morphology, structure, size, number and their arrangement on the

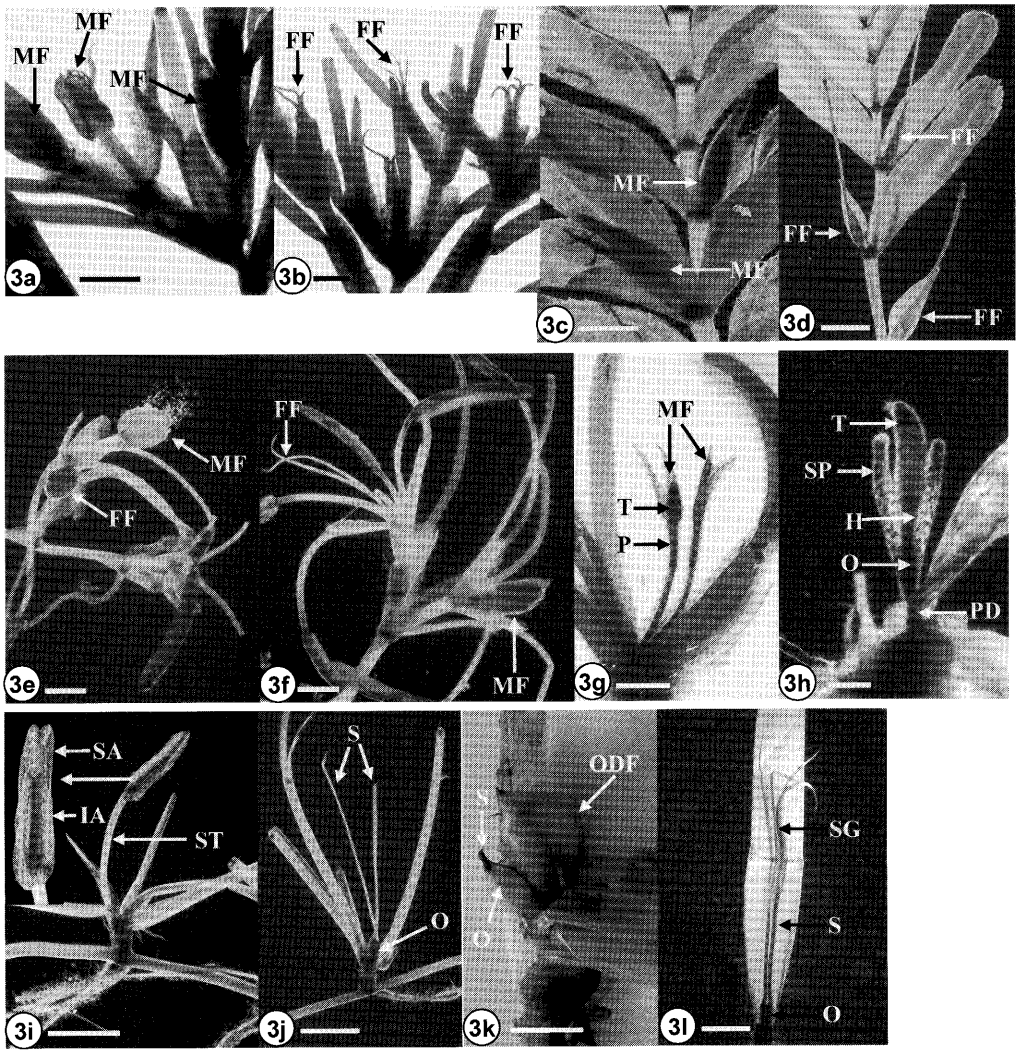

Fig. 3. Flowers and sexes in seagrasses.
3a–*Syringodium. isoetifolium* has a cyme inflorescence or many single flowers (MF) in a branch array on the vertical shoot. A male flower structure is similar to the *Halophila* male flower, scale bar=5 mm; 3b–a cyme inflorescence or many female flowers (FF) in a branch array on the vertical shoot. At each node of the vertical shoot, there is always a pair of female flowers (FF), each female flower comprises an ovary, a hypanthium and two styles, scale bar=5 mm; 3c,d–in *H. spinulosa*, male flowers (MF) and female flowers (FF) are laterally arranged in alternate and acropetal (i.e. the lower flowers are older than the upper flowers) succession along the shoot, scale bar=3 mm; 3e–in monoecious *H. beccarii*, a single shoot bears a pair of opposite sex, male flower (MF) and female flower (FF), scale bar=5 mm; 3f–in *H. beccarii*, monoecy can also exists where male flower (MF) and female flower (FF) are borne on separate shoots but on the same plant, scale bar=5 mm; 3g–in male plant of *T. hemprichii*, a shoot bears a pair of male flowers (MF). The male flower comprises a pedicel (P), three tepals (T) which house the anthers containing pollen, scale bar=10 mm; 3h–the female plant of *T. hemprichii* bears only a single female flower in a shoot. The female flower comprises a conical ovary (O) supported by a short peduncle (PD), a persistent hypanthium (H) and three tepals (T) enclosing six styles with 11 stigmas. Young female flower bud is enclosed by a pair of spathal leaves (SP), scale bar=5 mm; 3i–a single male flower in a shoot of *H. pinifolia* (*H. uninervis* has a similar single male flower) male plant, comprising the stalk (ST), inferior anther (IA) and superior anther (SA) which house the pollen, scale bar=4 mm; 3j–there is always a pair of female flowers of unequal sizes in a shoot of *H. pinifolia* (*H. uninervis* has a similar pair of female flowers) female plant. Each female flower comprises an ovary and a style, scale bar=4 mm; 3k–in female plant of *C. rotundata*, there is always a pair of female flowers of unequal sizes in a shoot. A female flower comprises an ovary (O) and a persistent style (S). The older female flower after fertilization developed into developing fruit (ODF). In comparison, a male plant has a single male flower in a shoot, scale bar=5 mm; 3l–in female plant of *C. serrulata*, there is always a pair of female flowers of unequal sizes in a shoot. A female flower comprises an ovary (O) and a style (S) which carries two stigmas (SG). Comparatively a male plant has a single male flower in a shoot. Scale bar=10 mm.

plant ramet. The sexes for seagrass plants is determined by the present of both male and female flowers on the same plant (monoecious) or separate male and female flowers on different plants (dioecious).

Acknowledgements

We would like to thank Vice-Chancellor, Universiti Putra Malaysia, for encouragement and facilities. This research is funded by the Ministry of Science, Technology and Environment Malaysia,

under the 'Intensification of Research in Priority Areas' programme entitled "Seagrass taxonomy, biology and habitat characteristics: EA-001-09-02-04-0679" and, some financial and travel supports from Japan Society for the Promotion of Science (JSPS) are acknowledged.

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