THE MARINE ANGIOSPERMS, SEAGRASS


PROFESSOR DR. JAPAR SIDIK BUJANG

THE MARINE ANGIOSPERMS, SEAGRASS

PROFESSOR DR. JAPAR SIDIK BUJANG
B. Sc. (Hons), Ph.D., USM

23 MARCH 2012

Dewan Taklimat
Universiti Putra Malaysia

Universiti Putra Malaysia Press
Serdang • 2012
http://www.penerbit.upm.edu.my

First Print 2012

UPM Press is a member of the Malaysian Book Publishers Association (MABOPA)
Membership No.: 9802

Typesetting : Sahariah Abdol Rahim @ Ibrahim
Cover Design : Md Fairus Ahmad

Design, layout and printed by
Penerbit Universiti Putra Malaysia
43400 UPM Serdang
Selangor Darul Ehsan
Tel: 03-8946 8855 / 8854
Fax: 03-8941 6172
http://www.penerbit.upm.edu.my

Contents

ABSTRACT

Seagrasses are a group of marine flowering plants. They are under the sub-division of angiosperms classed within a family of the monocotyledonous plants, which also includes the freshwater aquatic macrophytes. Although totally submerged, seagrasses have all the structures of the terrestrial plants with a root system, a shoot system, a vascular system, and vegetative and sexual reproduction, with flowers fertilized by water borne pollen. These structures and functions are unique for plants in the sea.

Seagrasses occur in many areas along the coast of Malaysia and although small in area, form a significant component of the coastal ecosystem besides mangroves and coral reefs. Our research group field studies revealed that even though are seagrasses patchy in distribution, they constitute one of the common coastal ecosystem types. Those areas that were studied were those accessible ones. Many more areas, far and wide particularly in the off-shore islands in the territorial waters of Sabah are the most likely environments where extensive seagrasses occur. The structure of seagrass ecosystem can vary from a few or patches of plants to extensive seagrass beds by two or more mixed species. These beds are dynamic and productive, attract diverse grazers and predators, and often these are commercially important species. In some coastal areas, seagrasses are service provider i.e., support livelihood of coastal communities that depend on fisheries which are linked directly or indirectly to the environment and production created by seagrasses. These intrinsic roles of seagrasses although have been recognized have not been afforded the same priority as the mangroves and corals. One reason could be that seagrass ecosystem has historically been neglected and not been well-studied. With the growing concern and interest, this important system is based on what have been studied should be communicated. In this respect,

I am glad to have this opportunity to present this lecture personally than my numerous papers published on seagrasses alone could provide. In general, what are known about seagrasses in Malaysia? What differentiates seagrasses from other plants? Seagrasses together with seaweeds and phytoplankton form the important primary producers of a shallow marine environment. Seagrasses and seaweeds in particular share similar habitats e.g., mangroves, coral reef ecosystem, intertidal areas, lagoons and rocky shores. It is important to learn and be able to distinguish between them. "If you take seagrasses away to identify, make sure take the "whole plant" – a complete cluster of shoots with rhizomes, roots and if available the flowering plants. If just a shoot is collected, not only you may miss the flowering materials but you may find that you do not have all the information that you require". Accurate species identification in the field would be helpful and allow more people to understand and appreciate seagrasses. This is especially true where people now are very much aware on its unique natural values e.g., especially seagrass beds provide habitats and feeding ground for dugongs, green turtles, seahorses and other invertebrates. Are seagrasses merely green vegetation along the coastline? Seagrasses do much more than providing underwater spectacular scenes. The lush vegetation in a seagrass bed (e.g., Sungai Pulai estuary and its adjacent waters) may harbor hundreds of species and each is unique and interconnected in a food web. In this case the heart of a food web is the seagrasses, providing food and oxygen. A food web is strong when intact, yet easily disturbed and each disrupted connection weakening the web. We must recognize the value of all species and the hidden relationship between them. This lecture provides the basis for far more work on the seagrasses and their associates.

INTRODUCTION

Seagrasses are submerged monocotyledonous plants that form patches to dense extensive coastal beds or meadows. Seagrasses constitute complex and productive ecosystems occurring both in temperate and tropical seas (den Hartog 1970). In Malaysia, along its 4,800 km coastline, stretching along the Malay Peninsula, Sabah and Sarawak bounding much of the southern part of the South China Sea are environments with mangroves and coral reefs. Along the mainland coastal areas between mangroves and corals, from low tide level to the coral reef fringe, are habitats for seagrasses. Seagrasses are also found around off-shore islands with fringing corals. Here they inhabit the subtidal areas between the corals and the semi-open sea (Japar Sidik et al. 2006a).

Seagrass ecosystem in Malaysia is made up of a small portion of the marine ecosystem (Japar Sidik and Muta Harah 2011) compared to mangroves and coral reefs, yet it accounts for the high diversity of assortment of vertebrates and invertebrates (Arshad et al. 2001, 2002, 2006, 2008, Sasekumar et al. 1989), and seaweeds (Japar Sidik et al. 1996, 2001a). Seagrasses form the food and habitats for the vulnerable dugongs (*Dugong dugon*), seahorses (*Hippocampus* spp.) and endangered green turtles (*Chelonia mydas*), other fishes, crabs and feeding ground for seasonal migratory birds such as the *Egretta garzetta* (Japar Sidik et al. 2006a). Seagrasses, being rich in food resources, provide conditions for growth and abundance of fish and invertebrates that many local coastal inhabitants catch and collect for their daily livelihood (Japar Sidik and Muta Harah 2003a, Japar Sidik et al. 2006a, Muta Harah and Japar Sidik 2011). Seagrass ecosystems, with rich and diverse food resources, are continually being threatened by human activities causing their degradation and possibly habitat loss.

The information provided here are derived from published sources of the authors' own, his colleagues' and students' works in the Seagrass Group at UPM and references of which are included in the 'References' section. Other supporting sources of information pertaining to the period of 1904-1995 on the understanding of seagrass distribution, species composition and uses in Malaysia come from Ridley (1907, 1924), Burkill (1935), Henderson (1954), Holttum (1954), Sinclair (1956), den Hartog (1970), Sasekumar et al. (1989), Norhadi (1993) and Phang (2000), and dugong sightings from Jaaman (1999, 2000).

This inaugural lecture represents research contributions from various studies of the seagrass ecosystem in Malaysia. The assessment of the ecosystem in its previous and present status either in totality or in its major components may stimulate further research. It contains a review of the information on various aspects of the seagrasses forming the important basic materials for continuing research on seagrass resources. Unlike other terrestrial communities that can be lived in, managed or exploited, seagrasses offer only a few direct uses. However, given the importance of their ecological roles and importance of seagrasses as fisheries habitats, nurseries and feeding grounds, this neglected and relatively lesser known resource must be afforded the same priority as the well managed mangroves and corals. I believe that by knowing the resources, one will appreciate the tremendous contribution made by them, one good example is the seagrasses; "seagrasses may appear to be unimportant as it is not visible, being submerged plants, but they play an important role in the life of coastal resource-dependent families (e.g, in Sungai Pulai estuary, Johore). The livelihood of these coastal communities is linked with the seagrasses.

WHAT ARE SEAGRASSES?

Seagrasses are monocots that live in marine and estuarine habitats, structurally and functionally similar to terrestrial grasses, and as such, are differentiated into discrete morphological entities-leaves, stems, roots and reproductive structures (den Hartog 1970, Tomlinson 1974, Phillips and Menez 1988, Duarte et al. 1994, Japar Sidik et al. 1995, 1999a, 1999b). The horizontal stems known as rhizomes are well-developed, very extensive typically buried in the sandy or muddy substrate. Some seagrasses have also vertical stems. Leaves are produce on horizontal and vertical stems and usually only the leafy part, generally green, are the most obvious component of the plant appearing above the substrate. These range in shape from thin strips to oval structures and may be grouped into shoots with the older leaves on the outside. The stems, roots and leaves of seagrasses contain lignified conducting tissue (veins) and air channels named as lacunae. Seagrasses are flowering plants and as such produce flowers, fruits and seeds (Japar Sidik et al. 1999a, 2000, 2003, Muta Harah et al. 1998) though these do not necessarily resemble their terrestrial counterparts. The general structure of the plant is display in different forms as shown in Figure 1. Arber (1920) formulated a set of four properties indispensable for a marine water plant. These properties can be listed as follows: (i) the plant must be adapted to life in a saline medium, (ii) the plant must be able to grow fully submerged, (iii) the plant must have a secure anchoring system, and (iv) the plant must have a hydrophilous pollination mechanism. It is obvious that seagrasses fulfill these requirements. A full discussion on the origin of seagrasses and their limitation based on Arber's (1920) criteria and the eurysaline plants is given in Kuo and den Hartog (2000).

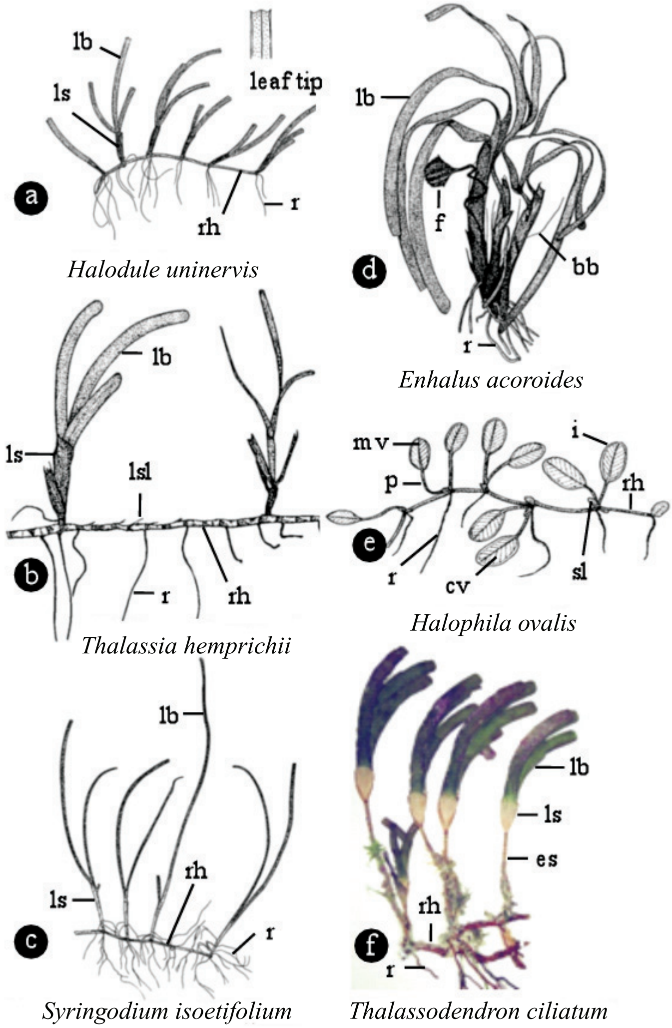

Figure 1 The general structure and terminology used to describe the various components of the seagrasses. a-Category 1, b-Category, 2, c-Category 3, d-Category 4, e-Category 5 and f-Category 6. lb-leaf blade, ls-leaf sheath, rh-rhizome, r-root, lsl-leaf scale, bb-black bristle, f-fruit, mv-mid vein, p-petiole, cv-cross vein, i-intra marginal vein and es-erect stem

SEAGRASSES SYNONYMOUS TO SEAWEEDS?

Seagrasses are not synonymous to seaweeds or macroalgae and, therefore have different vegetative and reproductive structures. The possibility of confusing with the other marine plant e.g., seaweeds for the most part is unlikely, nevertheless it must be regarded as a potential problem for the botanical novice. I know of at least two species of green macroalgae, *Caulerpa sertularoides* and *Caulerpa taxifolia* which could be mistaken for the 'fern-like' seagrass, *Halophila spinulosa*. There are a number of obvious morphological differences between seagrasses and seaweeds (Table 1). Only occasionally do seaweeds become large and complex with differentiation into organs that resemble leaves, stems and roots.

Table 1 The differences between seagrasses and seaweeds

Seagrasses	Seaweeds
Possess a prostrate stem or extensive rhizome networks buried in the substrate	Possess a prostrate axis, rarely extensive and almost always lie above the substrate
Have leaves that are generally green; produce on erect branches and usually only the leafy parts of the plant emerge from the substrate	Occasionally the body, thallus of various colours (green, brown, red) become large and complex, with differentiation into organs that resemble leaves, stems and roots
Produce flowers, fruits and seeds	Produce sporangium and spores, never produce flowers, fruits or seeds

If a seaweed does possess a prostrate axis, it is rarely extensive and almost always lies above the substrate. Leaflike organs, if present, never have lignified conducting tissue or air channels, though gas-filled floats (e.g., in *Sargassum*) may be produced. Seaweeds vary greatly in colour; some are green but many are brown or reddish; the colour may be uniform across the entire body called thallus. Seaweeds never form flowers, fruits or seeds, instead they have structures called sporangium that carry the spores.

WHAT MAKES A SEAGRASS PLANT?

The life of seagrass is initiated as a single fruit with seed/seeds produced by the mature plant. The fruit detached or remained with the plant, dispersing the seeds. A seed germinates and forms a pioneer shoot (Figure 2a), which produces a rhizome, then another shoot and so on (Figure 2b, Muta Harah et al. 1999, 2000, Japar Sidik et al. 2003). Each shoot however, is genetically identical to its predecessor. The production of new shoots is through vegetative propagation or asexual reproduction. As development continues, at some later stage, individual shoots may produce flowers, fruits, disperse seeds and ultimately seeds germinate. These give rise to separate, genetically different individual plants. What do we call this individual seagrass that reproduces in this way?, a shoot or a cluster of shoots? All seagrass species except *Enhalus* (Japar Sidik et al. 2003) and in some *Halophila* have differentiated vertical or a cluster of short shoots that are placed at different intervals along the horizontal creeping rhizome (Muta Harah et al. 1998, Japar Sidik et al. 2000). A shoot cluster is a group of shoots known as ramets attached as branches to a common rhizome axis (Harper 1977). The material produced by the original seed, regardless of whether all of the shoots are still connected, forms a group of genetically identical material. This is called a genet.

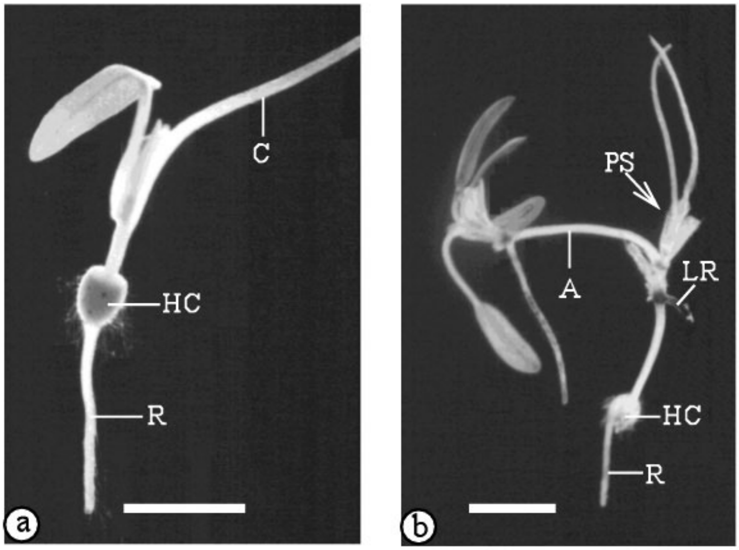

Figure 2 Seedling development of *Halophila beccarii*. a-a seedling showing a first true leaf, a cotyledon (C), hypocotyl (HC) and a radicle (R) emerging from the basal end. Scale bar, 3 mm; b-a seedling producing unilateral rhizome system with two shoots and nodes: a lateral rhizome (A) from the pioneer shoot (PS), lateral root (LR), Hypocotyl (HC) and radicle (R). Scale bar, 3 mm

Individual leaves are repeated units within each shoot, but they cannot exist alone. Shoots can be isolated and still survive, although they are usually connected to other shoots. These shoots are termed modules. A group of modules that are still joined together by their rhizomes can share nutrients. They are physiologically connected. This group of shoots is termed a ramet. The module and ramet form the basic architecture of seagrasses is illustrated in Figure 3. Thus organisms exhibiting the above characteristic are considered as modular organisms. They are different from many other organisms, including most familiar animals – fish, snails, barnacles, mussels, humans which are termed unitary organisms (Harper 1977).

However, most plants and a wide range of invertebrate animals e.g., sponges, corals, bryozoans, ascidians are modular.

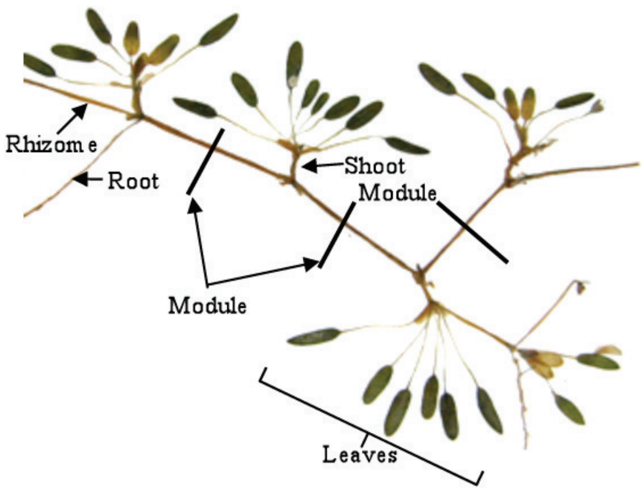

Figure 3 Seagrass ramets showing modular arrangement in *Halophila beccarii*. Each ramet is composed of a set of module i.e., a piece of rhizome which can be horizontal or vertical, a pair or a bundle of leaves attached to the rhizome and a root system

HOW DO THEY LOOK LIKE?

Seagrasses show a high degree of similarity in their external vegetative morphology and with respect to growth type with well-developed rhizomes bearing at each node a shoot of linear or strap-shaped leaves and branched or unbranched roots. However there are exceptions, in *Halophila* where leaves are ovate, lanceolate and petiolated. In general a closer inspection shows that seagrasses exhibit a considerable degree of diversity (refer to Figure 1). Based on mode of growth and the branching system introduced by den Hartog (1967), seagrasses in Malaysia can be subdivided into six categories.

A. Seagrasses with vegetative system monopodially branched; herbaceous, leaves linear or strap-shaped with air channels are categorized as;

Category 1. with fine linear leaves e.g., *Halodule.*

Category 2. with wide linear leaves; the sheaths either decay completely or remain membranous, but do not persist as a bunch of fibers e.g., *Cymodocea, Thalassia.*

Category 3. with long subulate leaves e.g., *Syringodium.*

Category 4. with leathery linear or coarse strap-shaped leaves; the remains of the sheaths form thick paintbrush-like fiber bundles at the base of the plant e.g., *Enhalus.*

Category 5. with leaves elliptic, ovate, lanceolate e.g., *Halophila.*

B. Seagrasses with vegetative system sympodially branched, lignified as;

Category 6. leaves distichously arranged along upright stems e.g., *Thalassodendron.*

Although in the genus *Halophila*, leaves are basically arranged in pairs, there are some variations on this theme e.g., *Halophila spinulosa* has caulescent stems with leaflets arranged in opposite pairs (den Hartog 1970, Kuo and McComb 1989, Posluszny and Tomlinson 1990) or has 2-3 leaflets per node in a whorled arrangement (Japar Sidik et al. 2000), and in *Halophila beccarii* the upright stems are crowned by a rosette consisting of three to thirteen leaves (Muta Harah et al. 2003a).

HOW ARE THEY IDENTIFIED?

The classification with respect to species separation has always been a fairly simple in terrestrial plants which centered on the flower structure. Characterization or species separation in seagrass has not. Reproductive structures comprising flowers and fruits have rarely been used as key characters since they tend to be similarly structured. In addition, flowers and fruits are also often inconspicuous and not obvious to the untrained eyes. Since the findings of seagrass flowers and fruits are infrequent or inconsistent, taxonomists focused to vegetative characters to identify sterile materials (den Hartog 1964, 1970, Fortes 1993, Lanyon 1986, Japar Sidik et al. 1995, 1999b, 2007, Japar Sidik and Muta Harah 1996, 2002). The organization of the vegetative organs of seagrass is peculiar and quite different from that of other flowering plants and hence can be used for identification of seagrass species. For taxonomic and descriptive purposes it is desirable to have a consistent terminology for the various vegetative organs (refer to Figure 1) and morphology of adult plants can be recognized through paired cross-vein numbers (*Halophila ovalis, H. minor,* Figure 4), rhizome characteristics (*Enhalus acoroides, Thalassia hemprichii*), blade tips and blade width (*Halodule uninervis, H. pinifolia,* Figure 5), leaf and arrangement of flowers (*Halophila beccarii, H. decipiens, H. spinulosa, Syringodium isoetifolium*) and leaf sheath characteristics (*Cymodocea serrulata, C. rotundata*). These characters are most obvious and found to be useful for field identifying species of seagrass in Malaysia.

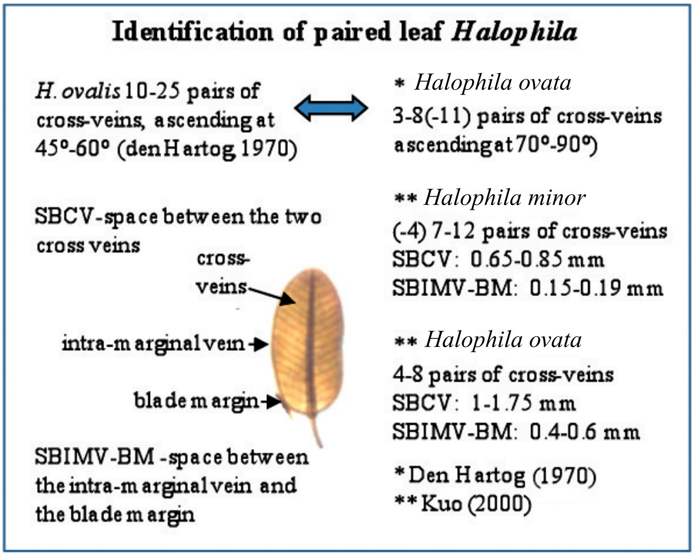

Figure 4 Species differentiation between *Halophila ovalis, H. ovata* and *H. minor* based on paired cross-veins numbers

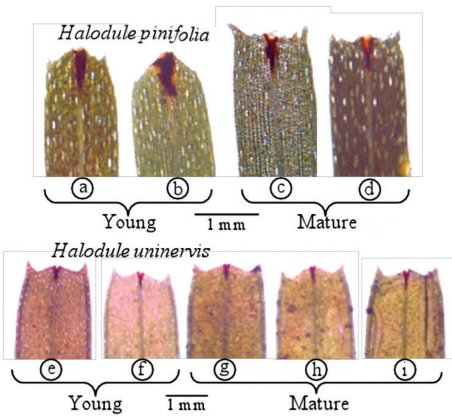

Figure 5 Leaf-tips of *Halodule pinifolia* (a-d) and *H. uninervis* (e-i). In *H. pinifolia*, young (a, b) leaf-tips are rounded or pointed while mature (c, d) leaf-tips are set with numerous small uneven serratures. In *H. uninervis* both young (e, f) and mature (g-i) leaf-tips are with 2 lateral teeth and obtuse or round median tooth

Another method for confirming identification is based on the epidermal cells features of the leaf surface (Figure 6). Epidermal cells features and keys adapted from Channells and Morrissey (1981) are useful and applicable when the plant specimen consists of damaged leaves or fragments. We have used this feature for the identification of seagrass plant tissues in gut of juvenile flower crab, *Portunus pelagicus* (Arshad et al. 2002).

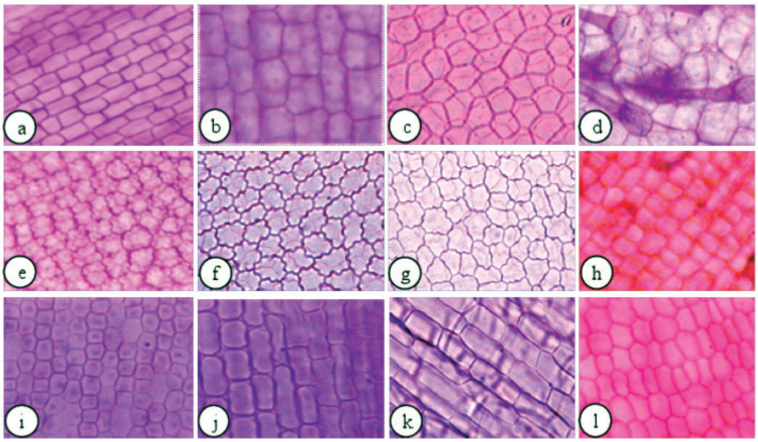

Figure 6 Leaf surface cells of a-*E. acoroides*, b-*T. hemprichii*, c-*H. beccarii*, d-*H. decipiens*, e-*H. minor*, f-*H. ovalis*, g-*H. spinulosa*, h-*C. rotundata,* i-*C. serrulata*, j-*H. pinifolia*, k-*H. uninervis* and l-*S. isoetifolium*

Other component of seagrass plants that has unique characteristics that can be used for species identification is the seed sculpturing feature particularly in *Halophila* (Figure 7, Japar Sidik et al. 2006b). *Halophila* seeds from different species showed diverse seed coats morphology with different sculpturing. Seeds of *H. beccarii*, *Halophila ovalis* and *H. decipiens* have coats with variations in micro sculpturing within the reticulations. *Halophila* seeds are sub-globose and bluntly beaked at both ends. With respect to gross morphology, *Halophila beccarii*, *H. decipiens*, *H. ovalis* have reticulate testa or seed coats. Detailed examination under scanning electron microscope indicated that seed coat of each *Halophila* species have distinct patterns or characters. The seed coat surface *H. beccarii* has reticulation with a pale short brown peg (appearing as brown dot as observed under light microscope) in the center of the reticulation. The surface within the reticulation is smooth.

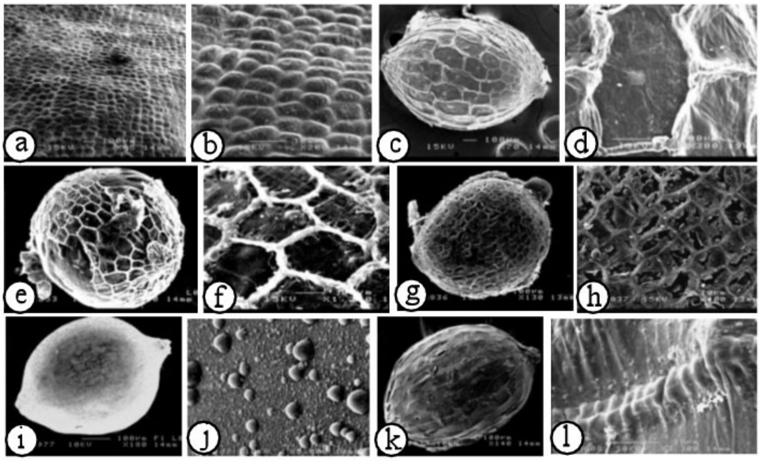

Figure 7 Seed coat morphology of seagrasses, (a-b)-*Enhalus acoroides* seed coat compared to the *Halophila*; (c-d)-*Halophila beccarii*, (e-f)-*H. decipiens*, (g-h)-*H. ovalis*, (i-j)-*Halophila* sp. and *Halophila* from Fiji, (k-l)-*H. stipulacea*

The seed coat of *H. decipiens* has hexagonal reticulation without peg at the center and smooth within the reticulation. In *H. ovalis*, the surface of the seed covering has a distinct isometric or rectangular reticulation and some micro sculptures within the reticulation. The seed of *Halophila* sp. is sub-globose in shape. The seed coat is without reticulation but verrucose in appearance sculptured with numerous small blunt projections. As a comparison *Halophila stipulacea* (a species not present in Malaysia, the one shown here is from Fiji) seed is also sub-globular with reticulate seed coat surface. The boundary of the reticulations has a peculiar fish bones sutures. *Halophila spinulosa* is characteristically sculptured with numerous long small peg-1ike projections (Birch 1981). It has been reported that the peculiar reticulate seed coat in Australian *H. ovalis* and *H. tricostata* probably facilitates floating by entrapment of air bubbles and dispersal of seeds (Kuo and Kirkman 1992, Kuo et al. 1993). However, field observation indicated that in *H. beccarii*, although the seed coat has reticulation, the seed is negative buoyant and may not promote floating and may not be conducive to the wide dispersal of seed (Muta Harah et al. 1999). Irrespective of species, the seed coat sculpturing has some functional significance in providing surface friction against the substratum whereby the seed coat loosened around the seed before emergence of the coiled cotyledon (Birch 1981) probably for the initiation of germination. Additional studies are needed to assess the effect of the difference of seed coats sculpturing in order to find out more on their functional roles.

Most seagrass plants are identified based on the classic reference “The Sea Grasses of The World” of den Hartog (1970) which is devoted on the use of vegetative characters and almost all taxonomy are based from herbarium specimens alone. Although seagrass plants can be separated into species following den Hartog (1970), they showed level of variation, often plastic in nature particularly with regard to the gross morphology. In Malaysia, distinct intraspecific variations in gross morphology have been observed namely *Halodule pinifolia* and *H. uninervis* (Japar Sidik et al. 1999a), *H. spinulosa* (Japar Sidik et al. 2000), *Halophila ovalis* (Japar Sidik et al. 2001b, c) and *Cymodocea serrulata* (Japar

Sidik et al. 2001c). For these species, we have introduced the term variant, understood as having characters that differed in a minor way from the usual characteristics of the species but plants have clearly defined geographical or ecological distribution.

Two morphological variants of *H. uninervis* (narrow- and wide-leaved) and *H. pinifolia* (short- and long-leaved) can be distinguished (Japar Sidik et al. 1999a). Both species adapt in the different environmental conditions through changes in morphology. Water depth (associated with ambient light), sediment type and sediment depth have an influence on the morphology of vegetative components e.g., leaf length, leaf width, erect stem length and rhizome growth pattern (Japar Sidik et al. 2008). In the case of *Halodule pinifolia* and *H. uninervis* plants or their variants, they have clearly defined ecological and geographical distribution. *Halodule uninervis* occurs around off shore islands or shoals and reef atoll. It rarely thrives in the coastal waters of the mainland. *Halodule pinifolia* tends to thrive in relatively calm coastal waters of the mainland, particularly in lagoons or bays and as isolated populations on shoals. It is rarely found around islands.

In *H. spinulosa*, two variants have been observed, those as described by den Hartog (1970), Phillips and Menez (1988) and (Kuo and McComb 1989, Posluszny and Tomlinson 1990, Japar Sidik et al. 1999b) as having opposite leaflets at each node along the erect shoot and, those with flowering shoot have 2 leaflets at each node and the same shoot possesses a rosette of 3 to (4) sessile leaflets at each node while supporting a male or female flower or developing fruit (Figure 8). This new variant is only for *H. spinulosa* from subtidal areas of Tg. Adang, Johore, Peninsular Malaysia and Police Beach, Pulau Gaya, Sabah (Japar Sidik et al. 2000).

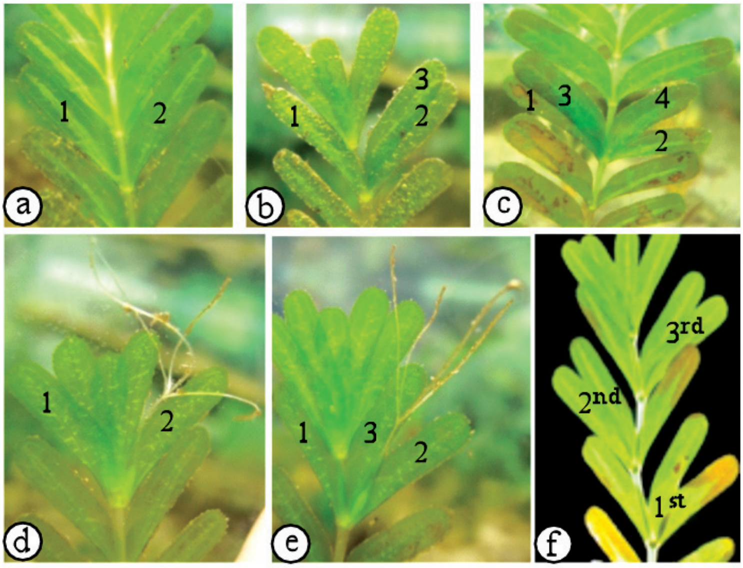

Figure 8 Sterile (a-c) shoot of *Halophila spinulosa* having opposite leaflets at each node along the erect shoot: a-2 leaflets; b-3 leaflets; c-4 leaflets and, flowering shoot having, d-2 leaflets; e-3 leaflets and f-alternately arrangement 3 leaflets per node

In *H. ovalis* five variants have been detected differing in basic folia characteristics; dimensions (small and big-leaved, Japar Sidik et al. 2001b, c), colour (green-, purplish red-, purple-leaved, Low et al. 2005; red blotches or dots in *Halophila* sp., Japar Sidik et al. 2010, Figure 9). The phenotypic plasticity of leaf size is related to depth and light variations. The survival under minimum light requires seagrass ability to respond to changes in light availability through a variety of morphological and physiological mechanisms. The primary adaptive morphological features towards decreased light include bigger leaf size, longer petiole length and erect stem length (Japar Sidik et al. 2001b). Similar respond has also been shown by *H. decipiens* which responded to the low light environment (shallow water depth) by having bigger leaves (Japar Sidik et al. 1995) compared to those small-leaved *H. decipiens* growing in deep waters (Japar Sidik et al. 1997, Muta Harah et al. 2003b).

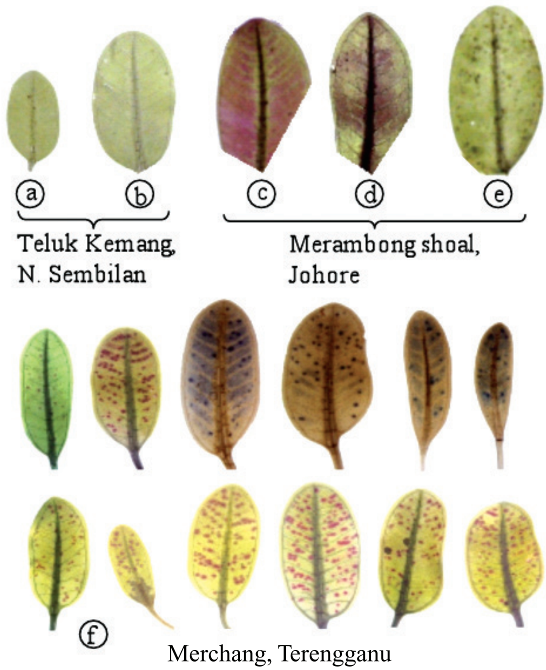

Figure 9 *Halophila* variants. The variability in *Halophila*'s leaf shapes in respond to the environment. Teluk Kemang, N. Sembilan: a-small-leaved *Halophila* occurred in shallow area, b-*Halophila* in relatively deeper water produced big-leaved variant; Merambong shoal, Johore: *Halophila* in this shoal possessed three leaf variants with respect to coloration, c-purplish red-, d-purple-, e-normal green-leaved. Merchang, Terengganu: f-*Halophila* in pure or mixed population, possessed different leaf shapes in respond to wide and frequent fluctuation in water salinity (9.4 to 34.5 psu) and coloration, red or purplish spots or spots to direct exposure to strong sun-light during the low tides

Halophila leaves possessing purplish coloration, red blotches or spots are as a form of response for protection of *Halophila* to direct exposure to strong sun-light during the low tides. It is believed that blotches are anthocyanin pigments (Low 2005) and serves as UV-blocking pigments (Hemminga and Duarte 2000). In a recent survey of the world's six seagrass bioregions, Novak and Short (2010) documented leaf reddening in 12 seagrass species from intertidal and shallow subtidal waters at 25 locations in the tropical Atlantic and tropical Indo-Pacific Oceans including additional observations of seagrasses with reddened leaves from Australia. The phenomenon is now documented in 15 seagrass species at 29 locations worldwide. Similar to terrestrial angiosperms, leaf reddening in seagrasses may relate to enhanced production and accumulation of anthocyanins, water soluble flavonoid pigments (Lee and Gould 2002) after exposure to one or more stressors (Novak and Short 2010).

Others *Halophila* species from Peninsular Malaysia and Sabah, East Malaysia (Annaletchumy et al. 2005, Japar Sidik et al. 2010, refer to the Figures 10 and 11) showed leaf shapes, dimension (cross vein number, SBCV-space between the two cross veins, SBIMV-BM-space between the intra-marginal vein), the blade margin and description that do not fit or conform to the description of den Hartog (1970) for *H. ovalis* and Kuo (2000) for *H. ovata* and *H. minor*. These small-leaved *Halophila* cannot be placed within the *H. ovalis*-*H. minor*-*H. ovata* complex as collective species, perhaps they can be treated under separate taxon.

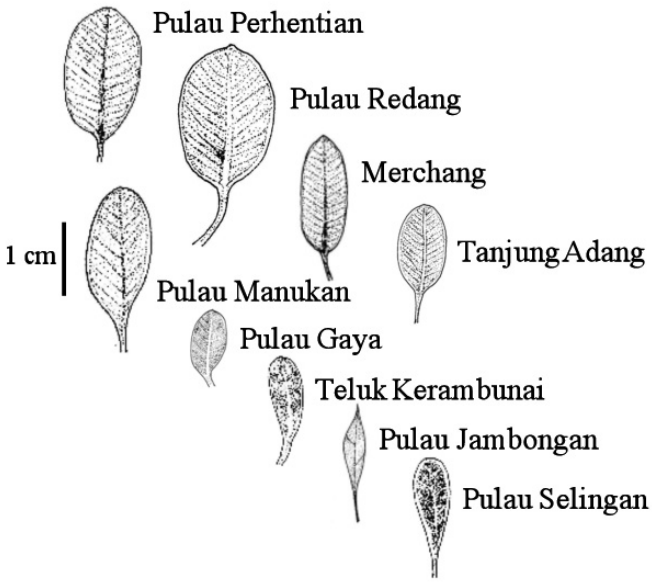

Figure 10 Variation in relative size and shape of *Halophila* leaves (drawn to scale) from nine locations along the coastlines of Peninsular Malaysia and Sabah, East Malaysia. The leaves are representative from plants of Pulau Perhentian, Terengganu; Pulau Redang, Terengganu; Merchang, Terengganu; Tanjung Adang, Johore; Pulau Manukan, Sabah; Pulau Gaya, Sabah; Teluk Kerambunai, Sabah; Pulau Jambongan, Sabah and Pulau Selingan, Sabah

In *Cymodocea serrulata*, two variants can be observed, distinguished by the presence or absence of the long, leaf-bearing erect stems. The long erect stem is directly related with the shading effect of the bigger and taller companion seagrasses, e.g., *Enhalus acoroides* or associated seaweeds e.g., *Sargassum* spp. or low light conditions and sedimentation (Japar Sidik et al. 2001c, Lam et al. 2004).

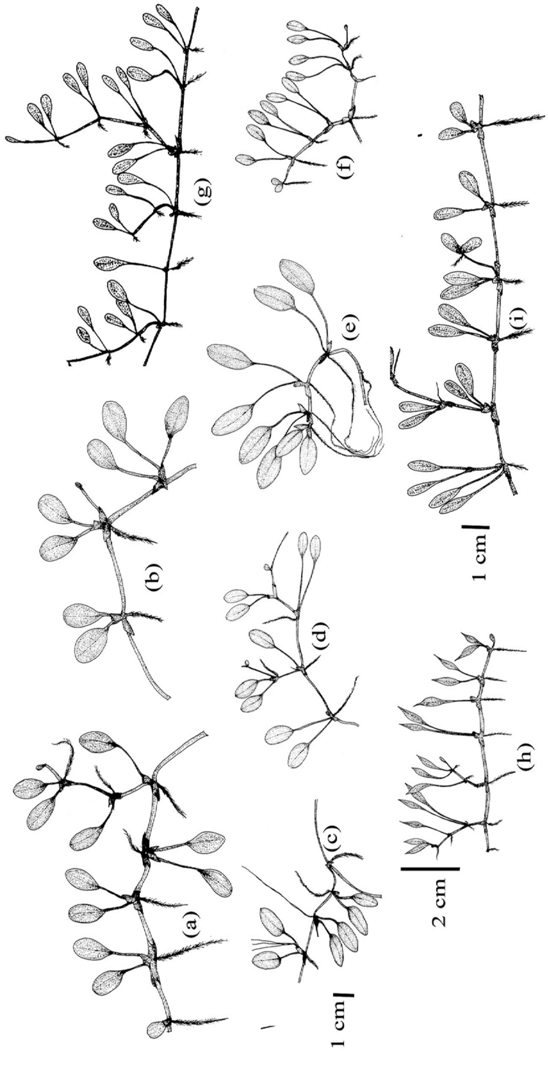

Figure 11 Variation in relative size of *Halophila* (drawn to scale) from nine locations. a-Pulau Perhentian, b-Pulau Redang, c-Merchang, d-Tanjung Adang, e-Pulau Manukan, f-Pulau Gaya, g-Teluk Karambunai, h-Pulau Jambongan and i-Pulau Selingan

Based on evidences, it is not realistic and practical to separate seagrass and their environment characteristics as they make some anatomical, physiological and morphological adjustments in order to complete their life. The true identity of seagrasses includes their ecological niche and morphological adaptation to their specific environments as explained above. Reliable visual morphological characters combined with molecular identification are now being used for identification of seagrasses.

Seagrass plants can also be identified based on their life cycle. The lives of seagrass plants, like those of all other organisms, are finite, having both a beginning and an end. The advanced groups of plants can be divided into three general categories based on their life cycle. Annuals complete their entire life cycle in one growing season. Biennials require two seasons to complete their life cycle; in the first season they are vegetative, and only flower and reproduce in their second year of life. Perennials continue to live and flower for some years after reaching maturity.

Studies clearly showed *H. beccarii* germinates from seed, grows into seedlings, juvenile plants, flowering and fruiting plants. They produce flowers and fruits continuously throughout the year (as in Kemaman, Terengganu,) or produce flowers, fruits and finally disappeared, all occurring within a period of approximately eight months (as in Pengkalan Nangka, Kelantan). The phenological cycles in the two studies suggest that *H. beccarii* can be both as perennial (Muta Harah et al. 1999) and an annual (Muta Harah et al. 2002) species (Figure 12).

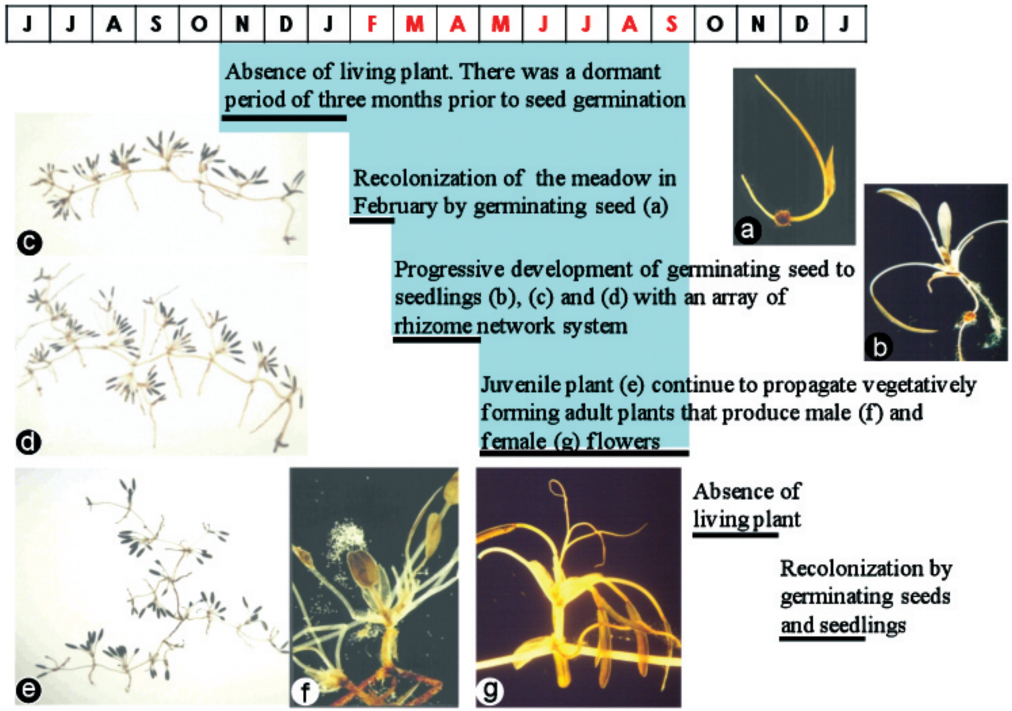

Figure 12 Growth cycle of annual *Halophila beccarii* (Source: Muta Harah et al. 2000)

Halophila ovalis from Malaysia, a dioecious is also an annual species (Japar Sidik et al. 2008, Figure 13). Other *Halophila*, such as dioecious *H. tricostata* at Fitzroy Island, in the Great Barrier Reef (Kuo et al. 1993) and monoecious *H. decipiens* in the estuaries of south western Australia (Kuo and Kirkman 1995) and from St. Criox in the U.S. Virgin Islands (Josselyn et al. 1986) are annual while dioecious *H. ovalis* (R. Br.) Hook. *f.* at Whitfords near Perth, south western Australia (Kuo and Kirkman, 1992), dioecious *H. johnsonii* in Indian Estuary, Florida (Jewett-Smith et al. 1997) and monoecious *H. decipiens* at Toro Point on the Caribbean coast of Panama (McMillan and Soong 1989) are perennial. Our studies have demonstrated that the identification of species must also consider the life cycle or covering series of observations of the species and not merely dependent on one-time collection.

FLOWERS AND GENDER IN SEAGRASSES

Seagrasses can reproduce both sexually and asexually, through detached or drifting rhizome fragments. One of the characteristics 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).

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

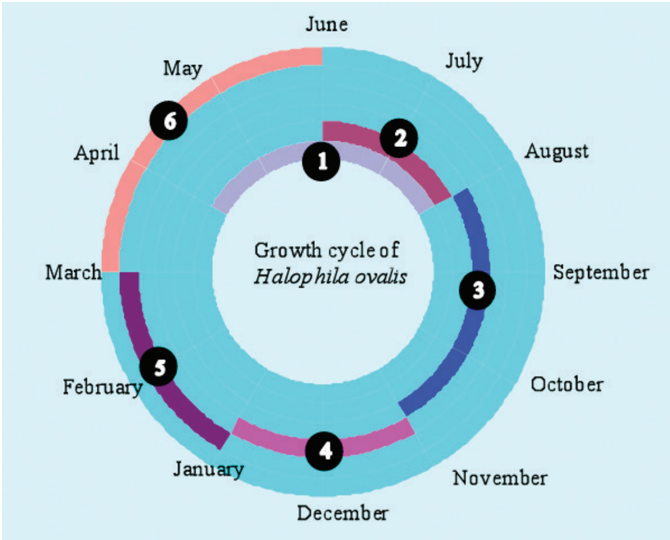

Figure 13 Growth cycle of annual *Halophila ovalis.* The stages from germinating seeds, seedlings, young to mature plants with the eventual death of *H. ovalis* plants take about 6 months
(Source: Japar Sidik et al. 2008)

1) Flowering (both male and female flowers in April and lasted for three months until July.
2) Fruiting occurred in June to July.
3) Decreasing in shoot density leading to the absence of living plants and dispersing seeds from August until November.
4) Different developmental stages from seeds, germinating seeds, seedlings, juvenile plants to formation of mature plants.
5) Flowering detected again in January.
6) Decreasing in shoot density started in early of March.

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 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* to minute flowers of *Halophila*. Of the thirteen flowering seagrasses two species, *Halophila beccarii* and *H. decipiens* (Table 2, Figure 14) are monoecious (15%) where functionally male and female flowers are on the same plant while the rest; *Enhalus acoroides*, *Thalassia hemprichii*, *Halophila beccarii, H. decipiens, H. ovalis*, *H. minor*, *H. spinulosa*, *Halophila* sp., *Cymodocea rotundata*, *C. serrulata*, *Halodule pinifolia*, *H. uinervis* and *Syringodium isoetifolium* are dioecious (85%).

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 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 out crossing mechanism (McConchie and Knox 1989) or to avoid self-fertilization (Hemminga and Duarte 2000).

Table 2 Flowering forms in Malaysian seagrasses

No.	Seagrass species	Gender	
1	*Halophila beccarii*	Monoecious	Andromonoecious
2	*H. decipiens*	Monoecious	Gynomonoecious
3	*Enhalus acoroides*	Dioecious	-
2	*Thalassia hemprichii*	Dioecious	-
5	*H. minor*	Dioecious	-
6	*H. ovalis*	Dioecious	-
7	*H. spinulosa*	Dioecious	-
8	*Halophila* sp.	Dioeciuos	-
9	*Cymodocea rotundata*	Dioecious	-
10	*C. serrulata*	Dioecious	-
11	*Halodule pinifolia*	Dioecious	-
12	*H. uninervis*	Dioecious	-
13	*Syringodium isoetifolium*	Dioecious	-
14	*Thalassodendron ciliatum*	No flower observed	
15	*Ruppia maritima*	No flower observed	

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 of the shoot of the plants. The structure and morphology of the Malaysian seagrass flowers are illustrated in Figures 14 and 15.

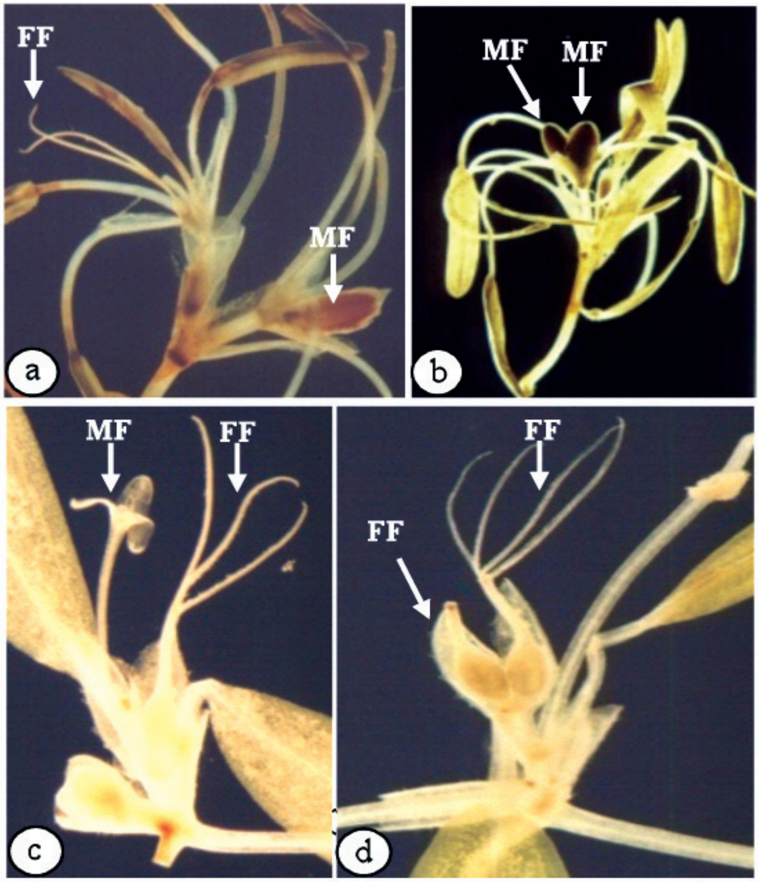

Figure 14 Flowers and sexes in seagrasses. a-in monoecious *H. beccarii*, a single shoot bears a pair of opposite sex, male and female flowers; b- Andromonoecious, a rare observation on a pair of the same sex male flowers (MF); c-similarly, in monoecious *H. decipiens*, a single shoot bears a pair of opposite sex, male and female flowers and; d- Gynomonoecious, a pair of the same sex female flowers (FF) Source: Japar Sidik et al. (2006c)

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 (Figure 15a). A female flower is also reduced in the form of having an ovary, a hypanthium and three styles that lack stigma (Figure 15b). 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), *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).

Enhalus acoroides (male plant), *H. spinulosa* (both male and female plants) and *S. isoetifolium* 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 (Figure 15c). In *H. spinulosa*, flowers are laterally arranged in alternate and acropetal (Figure 15e, f) succession (Japar Sidik et al. 1999b, Japar Sidik et al. 2000) along the shoot.

In some seagrasses, mostly dioecious species, their individual shoots carry flowers pair of the same sex-female e.g., in *E. acoroides* (Figure 15d, female plant), *S. isoetifolium, H. pinifolia*, *Halodule uninervis*, *C. rotundata*, *C. serrulata* and, the same sex-male e.g., in *T. hemprichii* (Figure 15g, male plant). A female plant of *T. hemprichii* (Figure 15h) has a single flower in a shoot. In temperate species, *Thalassia testudinum* Banks ex Konig have more than one flower in a shoot for a male plant which has been reported by William and Mark (1978). Male plants of *S. isoetifolium*, *H.*

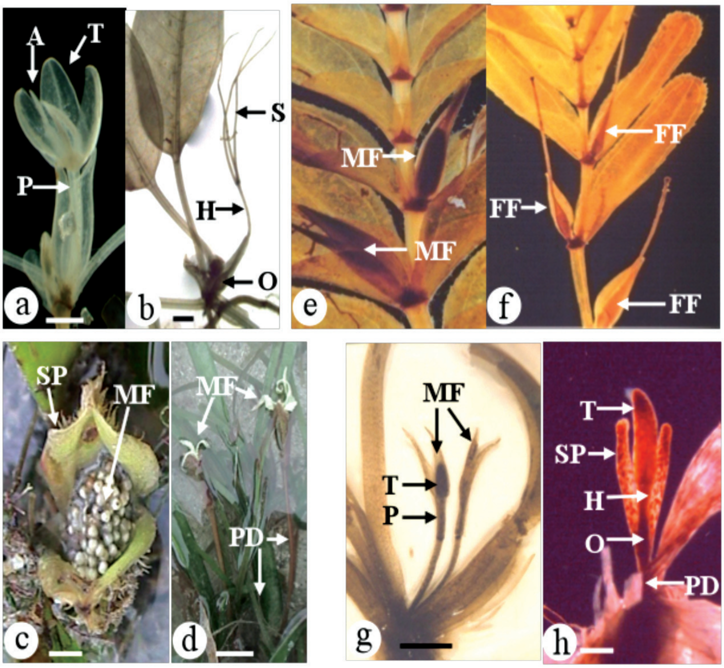

Figure 15 Flowers and sexes in seagrasses. a-The male flower in *Halophila* comprises a pedicel (P), three tepals (T) and alternating three anthers (A), scale bar=2 mm; b-the *Halophila* female flower in comprises an ovary (O), a hypanthium (H) and three styles (S), scale bar=5 mm; c–the numerous white male flowers (MF) in *Enhalus acoroides* enclosed by spathal leaves (SP), scale bar=1.5 cm; d-the female flowers (MF) in *E. acoroides* borne by a long peduncle (PD), scale bar=10 cm; e, f-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; g-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; h-the female plant of *T. hemprichii* bears only a single female flower (FF) by a pair of spathal leaves (SP) in a shoot. A female flower comprises a conical ovary (O) supported by a short peduncle (PD), a persistent hypanthium (H) and three tepals enclosing six styles with 11 stigmas

pinifolia, *H. uninervis*, *C. rotundata*, and *C. serrulata* borne a single flower at each shoot node (Japar Sidik et al. 2006c). The information and illustrations presented (Figures 14 and 15) 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 plant ramet. The sexes for seagrass plants are determined by the presence of both male and female flowers on the same plant (monoecious) or separate male and female flowers on different plants (dioecious).

WHERE DO WE FIND SEAGRASSES?

Seagrass beds are patchy throughout the Peninsular and East Malaysia. The major important seagrass beds and area are shown in Figure 16. The coasts of Peninsular Malaysia are relatively extensive and environmental conditions available are different on the east and west coasts. On the west coast, seagrasses occur in coastal waters of open sea while in the east coast, seagrasses inhabit the calm lagoons, behind the sand ridges sheltered from the open sea. The general suitability of the coastline in the east coast with inland coastal lagoons sheltered from waves make the area available for colonization. During the monsoon season, the physical features fluctuate along with the water quality conditions and create a highly dynamic and fluctuating environment and hence seagrasses are rarely found in the open sea. Records (Japar Sidik 1994) indicated that in Peninsular Malaysia, *Enhalus acoroides* and *Halophila ovalis* are common around the coast, on muddy shores, and in areas exposed at low tide as documented by Ridley (1924), Burkill (1935), Henderson (1954) and Holttum (1954). Seagrass beds of considerable sizes (Japar Sidik et al. 1996) are found in Johore (south-west and east coasts), Peninsular Malaysia and much of the habitats have been utilized or deteriorated due to coastal development (Japar Sidik and Muta Harah 2003b).

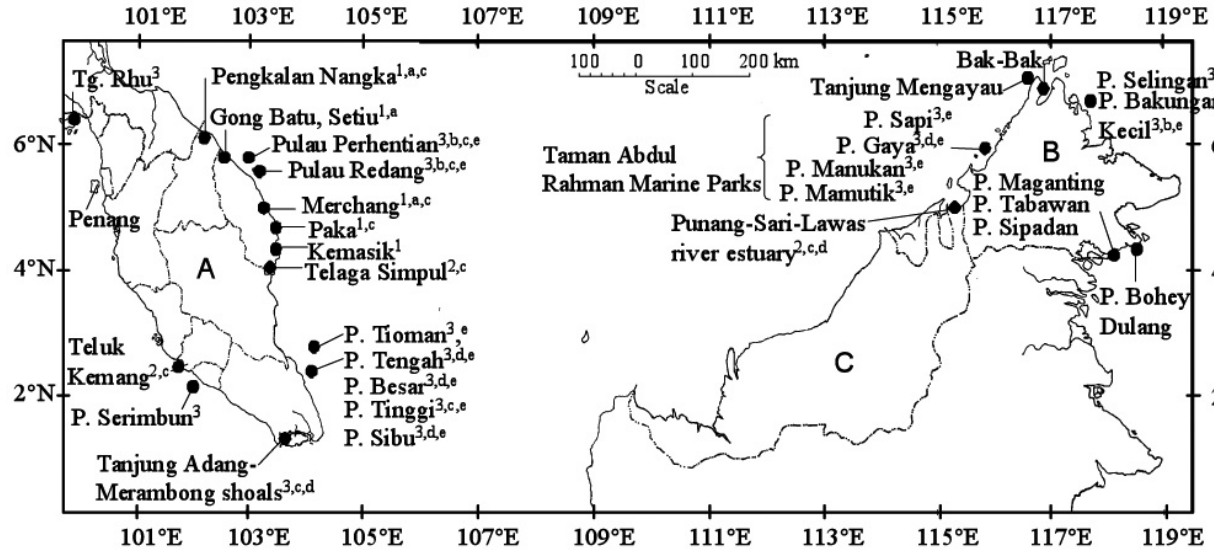

Figure 16 The major seagrass areas, associated habitats, utilization by coastal communities and other users in Peninsular Malaysia (A) and east Malaysia- Sabah (B) and Sarawak (C). Lagoon[1], intertidal[2], subtidal[3]. Aquaculture[a], turtle sanctuary[b], traditional capture fisheries[c], dugong feeding ground[d] and marine park[e]

Norhadi (1993) described seagrass habitats that are already degraded by human activities in Sabah, East Malaysia. This may explain the observed geographical distribution and areas of seagrasses patchy distribution that is no longer extensive along the Malaysian coastline (Japar Sidik et al. 2006a, Japar Sidik and Muta Harah 2011).

The most natural and extensive communities occur in the south-west coast and east coasts of Peninsular Malaysia, Sabah and Sarawak where urbanization is minimal. Along the west coast of peninsular Malaysia, patches of mixed species seagrass beds grow on substrates from the sandy-mud of Tanjung Rhu in the extreme northern region along the coast of P. Langkawi, Kedah to sand-covered corals of Teluk Kemang, Negri Sembilan extending to as far as P. Serimbun, Malacca. The Teluk Kemang is the only area in mainland Peninsula that has an intertidal seagrass bed on a reef platform (Japar Sidik et al. 2006a). In the southern region, the calcareous sandy-mud subtidal shoals of Tanjung Adang Darat, Tanjung Adang Laut and Merambong (Figure 17) at depths of 2 to 2.7 m support ten species of seagrases, the highest species number for any locality in Peninsular Malaysia or Malaysia (Japar Sidik and Muta Harah 2003a).

Most of the intertidal areas of the eastern coastline are fringed with sandy to rocky areas and therefore are not suitable habitats for seagrasses. Beds of two species, *Halophila beccarii*-*Halodule pinifolia* inhabit the fine sand substrate of the shallow inland coastal lagoons from Pengkalan Nangka, Kelantan to Paka, Terengganu while *H. pinifolia*-*H. ovalis* inhabit similar substrate type at Gong Batu and Merchang. A monospecific bed of *H. pinifolia* is found at Kemasik, Terengganu.

Figure 17 In the southern region, the calcareous sandy-mud subtidal shoal of Merambong, Johore, visible only during the extreme low tides supports diverse species of seagrasses

Monospecific beds of *H. pinifolia* or *H. minor* or *H. decipiens* (e.g., at P. Redang, Muta Harah et al. 2003a) to mixed species seagrass beds occur in the waters of the off-shore islands with fringing coral reefs of P. Sibu, P. Tengah, P. Besar and P. Tinggi, P. Redang and P. Perhentian (Japar Sidik et al. 2006a, Japar Sidik and Muta Harah 2003a, Muta Harah et al. 2003a) and P. Tioman (Zelina et al. 2000). Seagrasses usually inhabit the outer region between the corals and the semi-open sea. With different species forming distinct communities and environmental parameters, seagrass beds are site specific.

The west and south-eastern coasts of Sabah harbor mixed species seagrass beds in substrates ranging from sand, muddy-sand to coral rubble of the intertidal zone down to a depth of 2.5 m. There are six areas of intertidal mixed associations of seagrass and coral reef along the west coast at Bak-Bak, Tanjung Mengayau, Sepangar Bay and Pulau Gaya. The four off-shore islands of P. Maganting, P. Tabawan, P. Bohey Dulang and P. Sipadan along the south-eastern coast have subtidal seagrasses growing on coral rubble (Norhadi 1993, Japar Sidik et al. 1997, 1999a, 1999b, 2000, Josephine and De Silva 2007).

In Sarawak, records of the presence of seagrasses are those of *H. beccarii*, collected in Sungai Bintulu (Beccari 1904, den Hartog 1970) and *H. decipiens* at P. Talang Talang, Semantan (Phang 2000). A survey in 2003 discovered an extensive intertidal beach front of Punang-Sari-Lawas river estuary, Sarawak, comprising sandy flatland traversed by shallow channels, intermittent pockets of pools and mangrove mud flats harbouring seven seagrass species: *E. acoroides*, *Thalassia hemprichii*, *H. ovalis*, *H. beccarii*, *Cymodocea rotundata*, *H. pinifolia* and *H. uninervis* (Muta Harah and Japar Sidik 2004, 2005). A survey in 2009 at Kuala Similajau, Bintulu, recorded three species of seagrasses; *H. decipiens* inhabiting the deeper subtidal area while *T. hemprichii* and *H. pinifolia* occurred in the intertidal sandy rocky shore.

SEAGRASS SPECIES AND DIVERSITY

Information on seagrass diversity from as early 1904 to 1990 was based on accounts and records that appeared in the publications of Ridley (1907-Materials for a flora of the Malay Peninsula Part 1, pp. 5-6; 1927), Burkill (1935), Henderson (1954), Holttum (1954), Sinclair (1956), Keng (1969) and den Hartog (1970). These were on seagrass brief plant's descriptions and habitat lists of 7 species of seagrasses; *E. acoroides* (then referred to as *Enhalus koenigii* by Holttum 1954), *H. ovalis*, *H. minor* (*H. ovata* as written by

Henderson 1954), *H. spinulosa, Halodule uninervis* (*Diplanthera uninervis*), *T. hemprichii* and *Ruppia maritima* (*R. rostellata* as identified by Burkill, Herbarium specimen no. 6234, Flora of Province Wellesley, Royal Botanic Gardens, Kew-England). Early records on the distribution of the seagrass communities in Sabah were made by den Hartog (1970) in three areas; Labuan Island, Sandakan, and Lahad Datu. *Halophila beccarii* was the only species recorded for Sarawak (Beccari 1904, den Hartog 1970). Based on the available records in the form of herbarium specimens deposited at the herbaria of Royal Botanic Gardens, Kew-England, British Natural History Museum-England, Universitatis Florentinae-Instituto Botanico-Italy, Rijksherbarium, Leyden-the Netherlands, Herbarium of the Botanic Gardens-Singapore and the University of Malaya and actual collection by the author, collegues and students, Malaysia has 15 species belonging to 8 genera from 3 families (Table 3, Japar Sidik and Muta Harah 2011) of seagrasses sparsely distributed over wide areas covering the west, east coasts and southern part of Peninsular Malaysia (Figure 18), Sabah and Sarawak (Figure 19) of East Malaysia. Three other species, *T. ciliatum* (Phang 2000), *R. maritima* (Burkill 1935) and *Halophila* sp. (Japar Sidik and Muta Harah 2011) are rare in occurrence. Several localities along the coasts of Malaysia support well-developed seagrass communities and a large proportion (40%-71%) of all known seagrass species in Malaysia. The Teluk Kemang and Tanjung Adang-Merambong shoals of the Peninsular Malaysia, P. Gaya, Sabah and Punang-Sari-Lawas river estuary, Sarawak has a greater diversity of seagrasses.

The previous low diversity of seagrasses is due to; (i) undiscovered habitats where seagrass thrive e.g., river system, coastal lagoon, coral reefs, mangrove areas, subtidal shoals and seagrasses are not confined to the sea alone, (ii) seagrasses are often overlooked by low tide collectors and by collectors using

Table 3 Seagrass species in Peninsular Malaysia (Wc-west coast, Ec-east coast, S-southern) and in East Malaysia (SWc-Sabah east coast, SNc-Sabah north coast, SSE-Sabah south eastern, SA-Sarawak)

Family and Species	**Peninsular Malaysia**			**East Malaysia**			
	Wc	**Ec**	**S**	**SWc**	**SNc**	**SSE**	**SA**
Hydrocharitaceae							
1. *Enhalus acoroides* (L.*f.*) Royle	+	+	+	+	+	+	+
2. *Thalassia hemprichii* (Ehrenb.) Aschers.	+	+	+	+	+	+	+
3. *Halophila beccarii* Aschers.	+	+	+				+
4. *Halophila decipiens* Ostenfeld	+	+		+	+	+	+
5. *Halophila minor* (Zoll.) den Hartog	+	+	+	+	+	+	+
6. *Halophila ovalis* (R. Br.) Hook. *f.*	+	+	+	+	+	+	+
7. *Halophila spinulosa* Aschers.		+	+	+			
8. *Halophila* sp.						+	
Cymodoceaceae							
9. *Cymodocea rotundata* Ehrenb. & Hempr. ex Aschers.	+	+	+	+	+	+	+
10. *Cymodocea serrulata* (R. Br.) Aschers. & Magnus	+	+	+	+	+	+	
11. *Halodule pinifolia* (Miki) den Hartog	+	+	+	+	+	+	+
12. *Halodule uninervis* (Forssk.) Aschers.	+	+	+	+	+	+	
13. *Syringodium isoetifolium* (Aschers.) Dandy	+	+	+	+	+	+	
14. *Thalassodendron ciliatum* (Forssk.) den Hartog				+			
Ruppiaceae							
15. *Ruppia maritima* L.	+						
Total	12	12	11	12	10	11	8

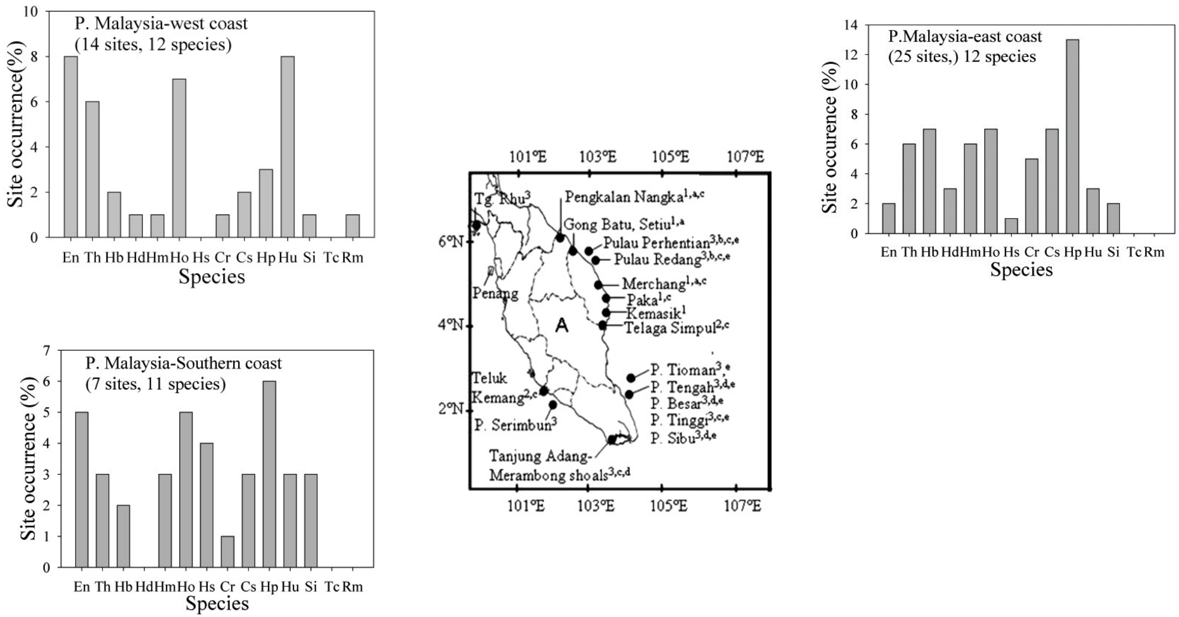

Figure 18 The diversity and site occurrence (%) of seagrass species in Peninsular Malaysia

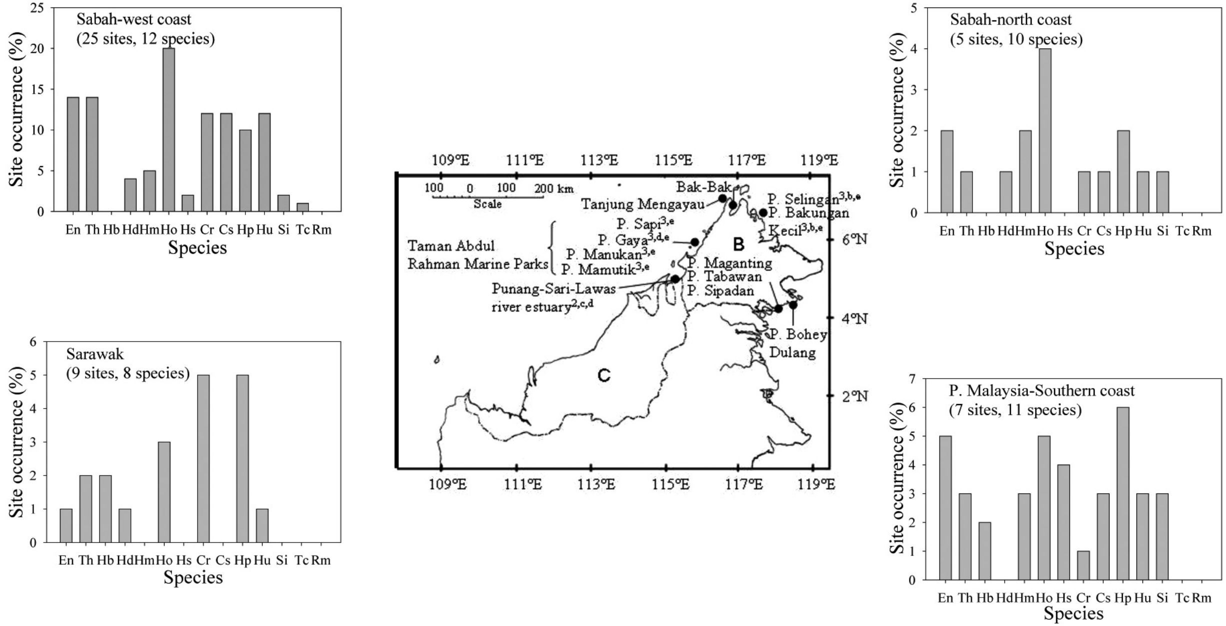

Figure 19 The diversity and site occurrence (%) of seagrass species in Sabah and Sarawak, East Malaysia

only snorkel gear, except in habitats where the water has a low transparency. Certain seagrass species e.g., *H. decipiens, H. minor*, *H. ovalis*, *H. spinulosa* and *Halodule pinifolia* are found at deeper depths (Figure 20) and this is normally discovered by scuba divers or by dredging.

Based on those documentation and researches, now we have a reasonable understanding of the species composition, distribution and plant description especially in Peninsular and Sabah, East Malaysia (Japar Sidik 2001, Japar Sidik et al. 2006a, Japar Sidik et al. 2007).

SEAGRASS ASSOCIATES AND THEIR IMPORTANCE

Seagrass beds support a diverse assemblage of aquatic lives especially to shallow marine ecosystem. Several characteristics of seagrass beds allow them to perform this role. Among them as mentioned by Kikuchi (1980) are; (i) where seagrass form dense vegetation, they increased the available substrate surface for epiphytic biota. The differentiation of the plant into leaves, stems, rhizomes and roots increase the heterogeneity resulting in a greater diversity of animals, some of them feeding directly upon seagrasses, (ii) dense vegetation retards water movement, thus offering calm underwater space within the bed for many animals, such as mysids, hydromedusae and juvenile fishes, (iii) the relatively less disturbed hydrodynamic conditions, settlement of minerals and organic particles, deposition of decayed leaves and sedimentation of fine, suspended particle occur, providing eutrophic environment for benthic animals and (iv) reduction of excessive illumination in daytime permits the developments of a shaded microenvironment that is beneficial to animals. They provide food and shelter for many fishes, crustaceans, and they protect juvenile and small fish from predation. Due to this, species richness in seagrass ecosystem is equivalent if not richer than the mangroves or coral reefs.

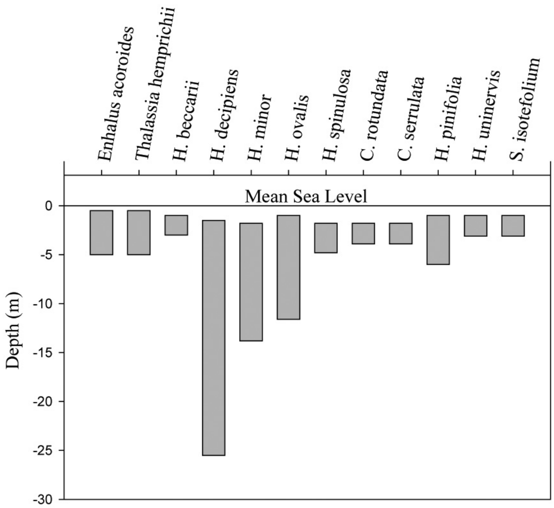

Figure 20 Depth distribution of the different seagrasses in Malaysia

Fishes are by far the most diverse and abundant vertebrates. The dense seagrass beds of sub-tidal shoals of Tanjung Adang-Merambong, south-west Johore, Pengkalan Nangka, Kelantan and Paka shoal, Terengganu support many juvenile to adult fishes and prawns. In Tanjung Adang-Merambong seagrass areas, approximately 70-76 species of fish in 41 families have been observed in seagrass beds and the adjacent mangrove areas (Sasekumar et al. 1989). Thirty five (35) fish species are of commercial important, among them *Ilisha* spp., *Stolephorus indicus*, *Thryssahamiltoni*, *Hippocampus* spp., *Lates calcarifer*, *Lutjanu schrysotaenia*, *Plotosus canius*, *Apolynemus sextarius*, *Rastrelliger kanaqurta, Siganus guttatus*, *S. javus*, *Siganus* sp. *Epinephalus* sp. and *Therapon* spp. (Arshad et al. 2001). The rest are low-grade fish which are consumed locally. Seahorses species (e.g., *Hippocampus kuda*, status: vulnerable VU A4cd) are very much in demand locally and abroad for the Chinese traditional medicine. Species of commercially important prawns e.g., *Penaeus indicus*, *Penaeus merguiensis*, *Penaeus monodon*, *Penaeus semisculcatus*, *Parapeneopsis* sp., *Metapeneopsis barbeensis*, *Metapenaeus* sp., *Lucifer* sp. and *Acetes* sp. and stomatopods (*Oratosquilla* sp.) have been recorded from the seagrass areas (Japar Sidik et al. 2006a). Other crustaceans include crabs e.g., *Hemigrapsus* sp., *Portunus pelagicus*, *Scylla serrata*, *Thalamita* sp., and horse-shoe crab, *Carcinoscorpius rotundicauda* have been observed (Arshad et al. 2001). In Kelantan and Terengganu, fishes such as *Caranx sexfasciatus*, *Leiognathus equulus*, *Lutjanus russelli*, *Mugil cephalus*, *Periophthalmus* sp., *Scatophagus argus*, *Tylosurus crocodilus* and *Scomberoides lysan* are found in abundance in seagrass beds (Muta Harah, 2001).

Many infaunal organisms i.e., animals living in soft sea bottom sediments also utilize and live within seagrass beds. Species such as gastropods (*Lambis lambis*, *Strombus canarium, Cypraea felina*), bivalves (*Gafrarium* sp., *Geloina coaxans*, *Meretrix meretrix*, *Modiolus* sp., *Modiolus senhausii*, *Hiatula solida*), echinoderms e.g., *Archaster* sp., *Astropecten* sp., *Protoreaster nodusus*, *Macrophiothrix* sp. and sea cucumbers; *Phyllophorus* sp., *Pentacta quadrangularis* and *Mensamaria intercedens* use the buffering capabilities of seagrasses to provide a refuge from strong currents. In Sabah, most seagrass and coral reef associated ecosystems are fishing and gleaning sites for food collection such as *Caulerpa* spp., *Gracilaria* sp. and fauna such as sea cucumbers, gastropods and bivalves (Japar Sidik and Muta Harah 2011). Illegal fishing methods with explosives (e.g., at Pulau Selingan, Pulau Bakungan Kecil) are among the major causes of damage to coral reefs and associated seagrasses.

Many bird species occasionally land on exposed seagrass area along the shores, though only a few are highly adapted to use this habitat to any great extent. Wading birds, the herons and egrets, *Egretta garzetta* are occasionally seen in seagrass areas (e.g., Pengkalan Nangka, Kelantan, Tanjung Adang-Merambong shoals, Johore), but they much prefer shallow floodplain waters vegetated shore or mudflats of mangroves where it is easier for them to catch prey and where they find more appropriate perching sites in the areas.

Very rarely is the seagrass ecosystem has a large number of mammals or reptiles. *Dugong dugon* (status: vulnerable, VU A1cd) and *Chelonia mydas* (green turtle, status: endangered, EN A1bd) are found associated and feed on seagrasses. Dugongs are common in the 50's and later became rare because they were hunted for meat and hide (Holttum 1954). Presently dugongs are found in areas with abundant seagrasses such as Pulau Sibu, Pulau Tengah, Pulau Besar and Pulau Tinggi on the east coast and around Tanjung Adang-Merambong shoals of Sungai Pulai, Johore (Japar Sidik et al. 2006a). In Sabah, sightings reports and surveys indicated that dugongs have been encountered occasionally in Tunku Abdul Rahman Marine Park (Jaaman 2000). Other areas with possible viable populations are the shallow coastal waters from Semporna, Kudat, Kota Kinabalu, Sepangar bay, Sabah to Lawas, Sarawak. Green turtles are abundant at Cagar Hutang, Pulau Redang, Peninsular Malaysia and in Pulau Selingan and Pulau Bakungan Kecil, Sabah. These areas are the nesting ground of turtles and the presence of seagrass meadows in the vicinity may serve as feeding ground.

Seagrass ecosystems teem with life, providing habitats for associated fauna (Figure 21, Arshad et al. 2005) and algal (Japar Sidik et al. 2001a, Japar Sidik and Muta Harah 2011). A number

Figure 21 Diversity of life associated with seagrass ecosystem; a-*Dugong dugon,* b-*Chelonia mydas,* c-*Portunus pelagicus*, d-*Epinephalus* sp., e-*Acreichthys tomentosus*, f-*Dasyatis* sp., g-*Meretrix meretrix*, h-*Strombus canarium*, i-*Actinopyga* sp., j-*Pseudocolochirus* sp., k-*Phyllophorus* sp., *Protoreaster nodosus*, m-*Goniodiscaster scaber*, n-*Asthenosoma* sp. and o-*Astropyga* sp.

of problems affect the long-term survival and health of seagrass populations in our coastal zone. More than half the nation's population lives within the coast, and more new residents move in coastal areas each year. This growing population places increasing stress on coastal environments that harbor the biological diversity. Where seagrasses are found, human benefit directly or indirectly from the presence of this vegetation and at the same time, it has also become evident that seagrasses are a vulnerable resource, easily lost in coastal areas facing environmental changes. In recent years the rate and variety of human induced influences have increased, exerting pressures on coastal resources such as seagrasses (Japar Sidik et al. 2006a). However, the nature itself can also threats seagrasses like storms hit that caused shifting sand burying seagrasses. Long rainy season e.g., in the east coast of Peninsular Malaysia also give impact to seagrasses by reduce salinity and change in water levels. The serious threats are those from the external sources-human and coastal development activities (Muta Harah and Japar Sidik 2011). While we know what the various components of seagrass ecosystem are, we still do not understand the processes and mechanisms of its function. For example, although we have evidence to say that seagrass ecosystem is productive as other natural ecosystem e.g., mangroves, coral reefs, we do not really know how much this productivity contributes to the fisheries and to the adjacent coastal ecosystem. This information is important in terms of rational use and management of this ecosystem. In addition given the importance of seagrass as fisheries habitat, nursery and feeding ground, this resource must be afforded the same priority as well-managed as mangroves and corals to provide for future renewable resource utilization, education and training, science and research, conservation and protection. Future priority of initiatives or seagrass research should look at how best to manage open-access, multi-user seagrass systems mentioned above to ensure their sustainable use to conserve biodiversity.

REFERENCES

Annaletchumy L., B. Japar Sidik, Z. Muta Harah and A. Arshad. 2005. Morphology of *Halophila ovalis* (R. Br.) Hook *f.* from Peninsular and East Malaysia. *Pertanika J. Trop. Agric. Sci.* 28(1): 1-11.

Arber A. 1920. Water plants. A study of aquatic angiosperms. Cambridge University Press, Cambridge (reprint 1972 J. Cramer Weinheim Historiae Naturalis Classica. Tomus xxiii).

Arshad A, B. Japar Sidik and Z. Muta Harah. 2002. Changes in diet of juvenile flower crab *Portunus pelagicus* (Crustacea: Decapoda). *Science Putra* 10(2): 13-17.

Arshad A., A. Jimmy, S.M. Nurul Amin, B. Japar Sidik and Z. Muta Harah. 2008. Length-weight and length-length relationships of five fish species collected from seagrass beds of the Sungai Pulai estuary, Peninsular Malaysia. *Journal of Applied Ichthyology* 24: 328-329.

Arshad A., B. Japar Sidik and Z. Muta Harah. 2005. Biodiversity of the Malaysian seagrass fauna: A state of realization and anxiety. Poster for Exhibition of Invention & Research, 2005, Faculty of Science, UPM Serdang, 16 March 2005.

Arshad A., B. Japar Sidik and Z. Muta Harah. 2001. Fishes associated with seagrass habitat. *In* Aquatic Resource and Environmental Studies of the Straits of Malacca: Current Research and Reviews. Japar Sidik B., A. Arshad, S.G. Tan, S.K. Daud, H.A. Jambari and S. Sugiyama, (eds.), p. 151-162. Malacca Straits Research and Development Centre (MASDEC), Universiti Putra Malaysia, Serdang, Malaysia.

Arshad A., B. Japar Sidik, Z. Muta Harah, Y. Suryana and A.G. Mazlan. 2006. Fish Communities from Seagrass Bed of Merchang Lagoon, Terengganu, Peninsular Malaysia. *Coastal Marine Science* 30(1): 268-275.

Beccari O. 1904. Wanderings in the great forests of Borneo. Oxford University Press, Oxford, New York.

Birch W.R. 1981. Morphology of germinating seeds of the seagrass *Halophila spinulosa* (R. Br.) Aschers. (Hydrocharitaceae). *Aquatic Botany* 11: 79–80.

Burkill I.H. 1935. A dictionary of the economic products of the Malay Peninsula. Government of Malaysia and Singapore. Ministry of Agriculture and Co-operatives, Kuala Lumpur, Malaysia. Vol. 1 and Vol. 2.

Channells P. and J. Morrissey. 1981. Technique for analysis of seagrass genera present in dugong stomachs, including a key to North Queensland seagrasses based on cell details. *In* The Dugong. Proceedings of Seminar/Workshop held at James Cook University 8-13 May 1979. Marsh H. (ed.), p. 176-179. Dept. Zoology, James Cook University.

Den Hartog C. 1964. An approach to the taxonomy of the sea-grass genus *Halodule* Endl. (Potamogetonaceae). *Blumea* 12: 19-312.

Den Hartog C. 1967. The structural aspect in the ecology of seagrass communities. Helgolanderwiss. *Meresunters* 15(1-4): 648-659.

Den Hartog C. 1970. The Sea Grasses of the World. Tweede Reeks, Deel 59, No. 1. North-Holland Publishing Company, Amsterdam, London, 275 p.

Doty M.S. and B.C. Stone 1966. Two new species of *Halophila* (Hydrocharitaceae). *Brittonia* 18: 303-306.

Duarte C.M., N. Marba, N. Agawin, J. Cebrian, S. Enriquez, M.D. Fortes, M.E. Gallegos, M. Merino, B. Olesen, K. Sand-Jansen, J. Uri and J.E. Vermaat. 1994. Reconstruction of seagrass dynamics: age determinations and associated tools for the seagrass ecologist. *Mar. Ecol. Prog. Ser.* 107: 195-209.

Eiseman N.J. and C. McMillan. 1980. A new species of seagrass, *Halophila johnsonii*, from the Atlantic coast of Florida. *Aquatic Botany* 9: 15-19.

Ewanchuk P.S. and S.L. Williams. 1996. Survival and re-establishment of vegetative fragments of eelgrass (*Zostera marina*). *Canadian J. Bot.* 74: 1584–1590.

Fortes M.D. 1993. Seagrasses: their role in marine ranching. *In* Seaweed Cultivation and Marine Ranching (1st edition). Ohno M. and A.T. Critchle (eds.), p. 131-151. Kanagawa International fisheries Training Centre, Japan International Co-operation Agency (JICA).

Greenway M. 1979. *Halophila tricostata* (Hydrocharitaceae), a new species of seagrass from the Great Barrier Reef region. *Aquatic Botany* 7: 67-70.

Harper J.L. 1977. Population biology of plants. Academic Press. London, New York.

Hemminga M.A. and C.M. Duarte. 2000. Seagrass ecology. Cambridge University Press. Cambridge.

Henderson M.R. 1954. Malayan wild flowers. Monocotyledon. The Malayan Nature Society, Kuala Lumpur.

Herbert D.A. 1986. Staminate flowers of *Halophila hawaiiana*: Description and notes on its flowering ecology. *Aquatic Botany* 25: 97-102.

Holttum R.E. 1954. Plant life in Malaya. Longman Group Limited, London.

Jaaman S.A. 1999. Marine mammals and whale shark recorded in Malaysia. Paper presented in Training Workshop on Marine Mammals and Whale Shark Research and Management, 15-18 March 1999, Universiti Malaysia Sabah, Kota Kinabalu (In Bahasa Malaysia).

Jaaman S.A. 2000. Malaysia's endangered species (Marine mammals and whale shark). Paper presented in Maritime Awareness Programme Forum Series 2000, Maritime Institute of Malaysia, Kuala Lumpur.

Japar Sidik B. 1994. Status of seagrass resources in Malaysia. *In* Wilkinson C.R., S. Sudara and L.M. Chou (eds.), Proceedings, Third ASEAN Australia Symposium on Living Coastal Resources, Chulalongkorn University, Bangkok, Thailand. Status Reviews 1: 283-290.

Japar Sidik B. and Z. Muta Harah. 2003a. Seagrasses in Malaysia. *In* World Atlas of Seagrasses. Green E.P. and Short F.T. (eds.), Chapter 14, p. 152-160. University of California Press, Berkeley, Los Angeles, London.

Japar Sidik B. and Z. Muta Harah. 2003b. Seagrasses: A threatened coastal resource. Fishmail 12(2): 6-14.

Japar Sidik B. and Z. Muta Harah. 2011. Seagrasses in Malaysia. *In* Seagrasses: Resource status and trends in Indonesia, Japan, Malaysia, Thailand and Vietnam. Ogawa H., Japar Sidik B. and Muta Harah Z. (eds.), p. 22-37. Seizando-Shoten Publishing Co., Ltd., Tokyo.

Japar Sidik B., Z. Muta Harah, I. Mohd Fakhrulddin, M.S. Khairul Anuar and A. Arshad. 2010. Growth performance of Malaysian's spoongrass, *Halophila ovalis* (R. Br.) Hooker *f.* under different substrate, salinity and light regime. *Coastal Marine Science* 34(1): 103-107.

Japar Sidik B., A. Arshad, O. Hishamuddin and A. Shamsul Bahar. 1995. *Halophila decipiens* Ostenfeld (Hydrocharitaceae): A new record of seagrass for Malaysia. *Aquatic Botany* 52: 151-154.

Japar Sidik B., A. Arshad, O. Hishamuddin, Z. Muta Harah and S. Misni. 1996. Seagrass and macroalgal communities of Sungai Pulai estuary, south-west Johore, Peninsular Malaysia. *In* Seagrass Biology: Scientific discussion from an International Workshop, Rottnest Island, Western Australia. Kuo J., D.I. Walker and H. Kirkman (eds.), p. 3-12. Faculty of Science, The University of Western Australia, Nedlands, Western Australia.

Japar Sidik B., A.N. Norhapizah, Z. Muta Harah, A. Arshad and H. Ogawa. 2008. Morphological plasticity of *Halodule* species in response to different environments. *Mar. Res. Indonesia* 33(1): 11-16.

Japar Sidik B., L. Ali, Z. Muta Harah, S. Muhamad Saini, A. Mansoruddin, G. Josephime and A.R. Fazrullah Rizally. 1997. *Halophila decipiens* (Hydrocharitaceae), a new seagrass record for Sabah. *Sandakania* 9: 67–75.

Japar Sidik B., Z. Muta Harah and A. Arshad. 2003. The Occurrence of *Enhalus acoroides* fruits, seeds and seedlings. *In* Aquatic Resource and Environmental Studies of the Straits of Malacca: Managing the Straits through Science and Technology. Japar Sidik Bujang, Aziz Arshad, Muta Harah Zakaria and Akito Kawamura (eds.), p. 111-116. Malacca Straits Research and Development Centre (MASDEC), Universiti Putra Malaysia, Serdang, Malaysia.

Japar Sidik B., Z. Muta Harah and A. Arshad. 2006a. Distribution and significance of seagrass ecosystems in Malaysia. *Aquatic Ecosystem Health and Management* 9(2): 203-214.

Japar Sidik B., Z. Muta Harah, A. Suzalina Akma, N. Satoshi and H. Ogawa. 2006b. Seed coat sculpturing in *Halophila*. *Coastal Marine Science* 30(1): 240-242.

Japar Sidik B., Z. Muta Harah, A. Arshad, S.L. Lam and H. Ogawa. 2006c. Flowers and sexes in Malaysian seagrasses. *Coastal Marine Science* 30(1): 184-18.

Japar Sidik B., Z. Muta Harah and A. Arshad. 2010. Morphological characteristics, shoot density and biomass variability of *Halophila* sp. in a coastal lagoon of the east coast of Malaysia. *Coastal Marine Science* 34(1): 108-112.

Japar Sidik B., O. Salomao and N.A. Milchakova. 2001a. Methods to measure macroalgal biomass and abundance in seagrass meadows. *In* Global Seagrass Research Methods, F.T. Short and R.G. Coles (eds.), Chapter 11, p. 223-235. Elsevier Science B.V., Amsterdam.

Japar Sidik B., Z. Muta Harah, Z. Kanamoto and A. Mohd. Pauzi. 2001b. Seagrass communities of the Straits of Malacca. *In* Aquatic Resource and Environmental Studies of the Straits of Malacca: Current Research and Reviews. Japar Sidik B., A. Arshad, S.G. Tan, S.K. Daud, H.A. Jambari and S. Sugiyama (eds.), p. 81-98. Malacca Straits Research and Development Centre (MASDEC), Universiti Putra Malaysia, Serdang, Malaysia.

Japar Sidik B., Z. Muta Harah, A. Arshad and A. Mohd Pauzi. 2001c. Responses of *Halophila ovalis* and *Cymodocea serrulata* under the shade of *Enhalus acoroides*. *In* Aquatic Resource and environmental Studies of the Straits of Malacca: Current Research and Reviews. Japar Sidik B., A. Arshad, S.G. Tan, S.K. Daud, H.A. Jambari and S. Sugiyama (eds.), p. 111-115. Malacca Straits Research and Development Centre (MASDEC). Universiti Putra Malaysia, Serdang, Malaysia.

Japar Sidik B., Z. Muta Harah, A. Mohd. Pauzi and M. Suleika. 1999a. *Halodule* species from Malaysia-distribution and morphological variation. *Aquatic Botany* 65: 33-46.

Japar Sidik B., Z. Muta Harah, L. Ali, F. Liew, G. Josephine and A.R. Fazrullah Rizally. 1999b. *Halophila spinulosa* (R. Brown) Ascherson: An unreported seagrass in Sabah. *Sabah Parks Nature Journal* 2: 1-9.

Japar Sidik B., Z. Muta Harah, A.R. Fazrullah Rizally and B. Kamin. 2000. New observations on *Halophila spinulosa* (R. Br.) Aschers. In Neumayer, Malaysia. *Biologia Marina Mediterranea* 7(2): 75-78.

Japar Sidik B., Z. Muta Harah, M. Kusnan and H. Omar. 2000. The seagrass, *Halophila decipiens* (Hydrocharitaceae) from Teluk Kemang, Negeri Sembilan: an update. *In* Towards Sustainable Management of the Straits of Malacca. Shariff, M., F.M. Yusoff, N. Gopinath, H.M. Ibrahim and R.A. Nik Mustapha (eds.), p. 233–238. Malacca Straits Research and Development Centre (MASDEC), Universiti Putra Malaysia, Serdang, Malaysia.

Japar Sidik B. and Z. Muta Harah. 1996. Manual on Introduction to Taxonomy of Malaysian Seagrasses. Courses and workshop on coral reefs' organisms. Borneo Marine Research Unit, Universiti Malaysia Sabah, Semporna, Sabah, 14-20 December 1996. 58 p.

Japar Sidik B. and Z. Muta Harah. 2002. Seagrasses: Module of Slide Shows and Lecture Notes, Instructor Guide for Third Country Training Programme 2002 on Marine Ecosystem and Pollution Management. 12 July 2002. MASDEC-JICA. 174 p.

Japar Sidik B., Z. Muta Harah and A. Arshad. 2007. Mangroves ecosystem and associated plant resources. *In* Forest Biodiversity Series 4. Sustainable Management of Matang Mangroves: 100 Years and Beyond. Shahruddin Mohamad Ismail, Azahar Muda, Razani Ujang, Kamaruzaman Ali Budin, K.L. Lim, Suhaili Rosli, Jalil Md. Som and A. Latiff (eds.), p. 391-410. Jabatan Perhutanan Semenanjung Malaysia, Kuala Lumpur.

Japar Sidik B., Z. Muta Harah and H. Ogawa. 2007. Manual for JSPS-VCC Regional Training Course and Workshop on Taxonomy and Ecology of Seagrasses and Macroalgae in Bintulu, Malaysia. 24-29 October 2007. Faculty of Agriculture and Food Sciences, Universiti Putra

Malaysia Bintulu Campus, Sarawak, Malaysia and Japan Society for the Promotion of Science. PDF Format in CD. 360 p.

Japar Sidik B. 2001. Seagrasses. *In* The Encyclopedia of Malaysia. Volume 7. The Seas. J.E. Ong and W.K. Gong (eds.), p. 48-49. Editions Didier Millet, Archipelago Press. Kuala Lumpur.

Jewett-Smith J., C. McMillan, W.J. Kenworthy and K. Bird. 1997. Flowering and genetic banding patterns of *Halophila johnsonii* and conspecifics. *Aquatic Botany* 59: 323–331.

Josephine G. and M.W.R.N. De Silva. 2007. Issues and Challenges of seagrass. With special reference to Sabah, Malaysia. Universiti Malaysia Sabah.

Josselyn M., M. Fonseca, T. Niesen and R. Larson. 1986. Biomass, production and decomposition of a deep water seagrass, *Halophila decipiens* Osten. *Aquatic Botany* 25: 47–61.

Keng H. 1969. Orders and families of Malayan seed plants. Synopsis of orders and families of Malayan gymnosperms, dicotyledons and monocotyledons. Singapore University Press.

Kikuchi T. 1980. Faunal relationships in temperate seagrass beds. *In* Handbook to Seagrass Biology. Phillips R.C. and C.P. McRoy (eds.), p. 153-172. New York: Garland STPM Press.

Kuo J. 2000. Taxonomic notes on *Halophila ovata* and *Halophila minor*. *Biologia Marina Mediterranea* 7(2)**:** 79-82.

Kuo J. and A.J. McComb. 1989. Seargrass taxonomy, structures and development. *In* Biology of seagrasses-A treatise on the biology of seagrasses with special reference to the Australian region. Larkum A.W.D., A.J. McComb and S.A. Shepherd (eds.), p. 6-67 in Elsevier, Amsterdam.

Kuo J. and C. den Hartog. 2000. Seagrasses: A profile of an ecological group. *Biologia Marina Mediterranea* 7(2): 3-17.

Kuo J. and H. Kirkman. 1992. Fruits, seeds and germination in the seagrass *Halophila ovalis* (Hydrocharitaceae). *Botanica Marina* 35: 197-204.

Kuo J. and H. Kirkman. 1992. Fruits, seeds and germination in the seagrass *Halophila ovalis* (Hydrocharitaceae). *Botanica Marina* 35: 197-204.

Kuo J. and H. Kirkman. 1995. *Halophila decipiens* Ostenfeld in estuaries of southwestern Australia. *Aquatic Botany* 51: 335-340.

Kuo J., W.J. Lee Long and R.G. Coles. 1993. Occurrence and fruit and seed biology of *Halophila tricostata* Greenway (Hydrocharitaceae). *Australian J. Mar. and Freshwater Res*. 44: 43–57.

Lam S.L., B. Japar Sidik, Z. Muta Harah and A. Arshad. 2004. Adaptability of *Cymodocea serrulata* (R. Br.) Aschers. & Magnus to different environment. *Science Putra* 12(2): 12-16.

Lanyon J. 1986. Seagrasses of the Great Barrier Reef.Great Barrier Reef Marine Park Authority. Special Publication Series (3). Nadicprint Services Pty. Ltd., Townsville, Queensland.

Lee D.W. and K.S. Gould. 2002. Anthocyanins in leaves and other vegetative organs: an introduction. *In* Anthocyanins in leaves. Adv. Bot. Res. 37. Gould K.S. and D.W. Lee (eds.), p. 1-16. Academic Press, London.

Low K.L. 2005. Chlorophyll and pigment profile of *Halophila.* Final year project. Department of Biology of Science and Environmental Studies, UPM Serdang.

Low K.L. B. Japar Sidik, K. Misri, Z. Muta Harah and S.L. Lam. 2005. Chlorophylls and carotenoids of seagrass, *Halophila*. *Bulletin of Pure and Applied Sciences* 24B (1): 41-50.

McConchie C.A. and R.B. Knox. 1989. Pollination and reproductive biology of seagrasses. *In* Biology of Seagrasses. A treatise on the biology with special reference to the Australian region. Larkum A.W.D., A.J. McComb and S.A. Shepherd (eds.), p. 74-111, Elsevier, Amsterdam.

McMillan C. and K. Soong. 1989. An annual cycle of flowering, fruiting, fruiting and seed reserve for *Halophila decipiens* Ostenfeld (Hydrocharitaceae) in Panama. *Aquatic Botany* 34: 375–379.

Molnar S. 2004. Plant reproductive system. Internet version posted February 17, 2004. http://www.geocities.com/we_evolve/ Plants/ breeding_sys.html.

Muta Harah Z. 2001. Ecology and biology of seagrass, *Halophila beccarii* Aschers. in Peninsular Malaysia. PhD Thesis, Universiti Putra Malaysia.

Muta Harah Z. and B. Japar Sidik. 2004. Seagrass communities of Punang-Bt. Sari-Lawas river estuary, Sarawak, East Malaysia. *Bio-Science Research Bulletin* 20(1): 1-8.

Muta Harah Z. and B. Japar Sidik. 2005. Morphometrics of seagrasses in relation to their distribution at Punang-Bt. Sari-Lawas river estuary, Sarawak, east Malaysia. *Bulletin of Pure and Applied Sciences* 24B(1): 15-23.

Muta Harah Z., B. Japar Sidik and A. Arshad. 2002. Flowering, fruiting and seedling of annual *Halophila beccarii* Aschers. in Peninsular Malaysia. *Bulletin of Marine Science* 71(3): 1199-1205.

Muta Harah Z., B. Japar Sidik and O. Hishamuddin. 1998. The seagrass *Halophila beccarii* Ascherson. *Fisheries Journal Garing* 7(2): 19-25.

Muta Harah Z., B. Japar Sidik and O. Hishamuddin. 1999. Flowering, fruiting and seedling of *Halophila beccarii* Aschers. (Hydrocharitaceae) from Malaysia. *Aquatic Botany* 65: 199-207.

Muta Harah Z., B. Japar Sidik, A.T. Law and O. Hishamuddin. 2000. Seedling of *Halophila beccarii* Aschers. in Peninsular Malaysia. *Biologia Marina Mediterranea* 7(2): 99-102

Muta Harah Z., B. Japar Sidik, A.T. Law and O. Hishamuddin. 2003a. The Seagrass, *Halophila beccarii* (Hydrocharitaceae) and its distribution in Peninsular Malaysia. *In* Aquatic Resource and Environmental Studies of the Straits of Malacca: Managing the Straits through Science and Technology. Japar Sidik Bujang, Aziz Arshad, Muta Harah Zakaria and Akito KAWAMURA (eds.), p. 165-174. Malacca Straits Research and Development Centre (MASDEC), Universiti Putra Malaysia, Serdang, Malaysia.

Muta Harah Z., B. Japar Sidik, and A.R. Fazrullah Rizally. 2003b. Occurrence and morphological description of seagrasses from Pulau Redang, Terengganu, Malaysia. *Jurnal Teknologi* 38(C): 29-39.

Norhadi I. 1993. Preliminary study of seagrass flora of Sabah, Malaysia. *Pertanika Jour. of Tropical Agriculture Science* 16(2): 111-118.

Novak A.B. and F.T. Short. 2010. Leaf reddening in seagrasses. *Botanica Marina* 53: 93–97.

Oliveira F.E.C. de, J.R. Pirani and A.M. Giulietti. 1983. The Brazillian seagrasses. *Aquatic Botany* 16: 251-267.

Ostenfeld C.H. 1909. On *Halophila ovata* Gaudichaud, a neglected species. *Philippine J. Sci*. IV: 67.

Phang S.M. 2000. Seagrasses of Malaysia. Universiti Malaya, Botanical Monographs No. 2. Institute of Biological Sciences, Universiti Malaya, Kuala Lumpur.

Phillips R. and E.G. Menez. 1988. Seagrasses. Smithsonian Contributions to the Marine Sciences No. 34. Smithsonian Institution Press, Washington: 105 p.

Posluszny U. and P.B. Tomlinson. 1990. Shoot organization in the seagrass *Halophila* (Hydrocharitaceae). *Canadian Journal of Botany* 69: 1600-1615.

Ridley H.N. 1907. Materials for a flora of the Malay Peninsula Part 1. Methodist Publishing House, Singapore.

Ridley H.N. 1924. The flora of the Malay Peninsula. Monocotyledons. The Authority of the Government of the Straits Settlements and Federated Malay States. A. Asher & Co. Amsterdam, Holland, L. Reeve & Co. Brook Nr. Ashford, Great Britain. Vol. IV.

Sasekumar A., C.M.U. Leh, V.C. Chong, D. Rebecca and M.L. Audery. 1989. The Sungai Pulai (Johore): A unique mangrove estuary. *In* Proceedings 12th. Annual Seminar of the Malaysian Society of Marine Sciences. Research Priorities for Marine Sciences in the 90's. Phang, S.M., A. Sasekumar, and S. Vickineswary (eds.), p. 191-211. Malaysian Society of Marine Science, Kuala Lumpur.

Short F.T. and M.L. Cambridge. 1984. Male flowers of *Halophila engelmannii*: Description and flowering ecology. *Aquatic Botany* 18: 413-416.

Sinclair J. 1956. Additions to the flora of Singapore II. *Gardens Bulletin Singapore* 15: 22-30.

Tomlinson P.B. 1974. Vegetative morphology and meristem dependence-the foundation of productivity in seagrasses. *Aquaculture* 4: 107-130.

William F.G. and D.M. Mark. 1978. Flowering of the seagrass *Thalassia testudinum* (Hydrocharitaceae) in the Tampa Bay, Florida. *Aquatic Botany* 5: 251–259.

Zelina Z.I., A. Arshad, S.C. Lee, B. Japar Sidik, A.T. Law, R.A. Nik Mustapha and M. Maged Mahmoud. 2000. East coast of Peninsular Malaysia. *In* Seas at the Millennium. Vol. 2. Sheppard, C. (ed.), p. 345-359. Pergamon, Amsterdam.

BIOGRAPHY

Japar Sidik bin Bujang was born in Miri, Sarawak, Malaysia on 15 November 1954. He obtained his early education at Saint Columbas Secondary School and Kolej Tunku Haji Bujang in Miri, Sarawak. He graduated with B.Sc. (Hons.) in Aquatic Biology at Universiti Sains Malaysia, Penang, Malaysia in 1982. He was awarded an Academic Staff Training Fellowship and received his Ph.D from the School of Biological Sciences from the same University in 1989.

Dr. Japar Sidik Bujang started his lectureship in the School of Biological Sciences USM in 1989 after which in 1991 he joined the Faculty of Fisheries and Marine Sciences, Universiti Pertanian Malaysia, Serdang, Selangor and transferred to the Department of Biology, Faculty of Science and Environmental Studies (now Faculty of Science), Universiti Putra Malaysia in 1996. He was also a visiting lecturer at the Department of Marine Sciences, Faculty of Science and Natural Resources, Universiti Kebangsaan Malaysia, Sabah Campus. He was promoted to Associate Professor in August 2000 and later received his Professorship in Aquatic Biology from the Faculty of Science in October 2008. In May 2000 he was appointed as the Head of Department of Biology, as the Deputy Dean of Academic at the Faculty of Science in January 2003 and Faculty of Agriculture and Food Sciences, UPMKB in Febuary 2006. Since January 2008 till present he is the Dean of Faculty of Agriculture and Food Sciences, UPMKB, Sarawak.

For more than 21 years of career as an academician, he has experienced a broad-based teaching as well as learning experiences from terrestrial ecology to marine and botany related subjects. Since his appointment in 1991 at Universiti Putra Malaysia, he has secured research field in aquatic biology (seagrasses and mangroves) and taught subjects in both fields in courses such as Aquatic Ecology, Aquatic Botany, The Ecology of Estuaries and Mangroves, Biology of Mangroves, Wetland Ecosystems Management, Aquatic Living Resources, Anatomy and Morphology of Vascular Plants, Plant Structure and Function, and Biodiversity I: Monera, Protista, Fungi and Plantae. Further he introduced an elective course "The Ecology and Biology of Seagrasses" at the Department of Biology, Faculty of Science. The course received very good response from students since its introduction in 1997. To his credit, he has supervised and co supervised more than 30 postgraduate and 145 undergraduate students. In general he has been involved in both teaching as well as supervision of students where those experiences together with his involvement in research and association with scientists in other parts of the world in related field have nurtured his academic career.

He was actively involved in research activities in the field of seagrasses and mangroves either as a team member in the Department of Biology or collaborated with other scientists from other local research institutions e.g., Universiti Sains Malaysia, Penang: Universiti Malaya, Kuala Lumpur, Sabah Parks, Sabah and officers from Federal Government Agency e.g., Department of Fisheries Malaysia and Department of Environment Malaysia, Federal Department of Town and Country Planning Peninsular Malaysia, Ministry of Housing and Local Government Malaysia and non-governmental organizations e.g., World Wide Fund (WWF) for Nature Malaysia, Petronas Penapisan Sdn. Berhad. Internationally, he was involved with multi-lateral research projects, ASEAN-Australia Co-operative Programme in Marine Science, Coastal Living Resources and United Nation Environmental Programme (UNEP)-East Asian Seas 35. He was involved in Seagrass Ecology of a research project on Aquatic Resources and Environmental Studies of the Straits of Malacca under the Japan International Co-operation Agency (JICA) and SeagrassNet Western Pacific Seagrasses Monitoring Program at Kg. Tanjung Balang, Pulau

Tinggi Marine Park, Mersing, Johore funded by David and Lucile Packard Foundation and Jackson Estuarine Laboratory, University of New Hampshire, USA. He was also involved in a Multilateral Core University Program on Coastal Oceanography, a research project on Biodiversity of Seaweeds and Seagrasses partially funded by Japan Society for the Promotion of Science (JSPS). Currently he is doing a research project on Identification of Seagrasses using Morphology and Molecular Approach with Kitasato University and Atmosphere and Ocean Research Institute, the University of Tokyo under the JSPS Asian Core Project: Establishment of Research Education Network on Coastal Marine Science in Southeast Asia.

Based on his, co-authors and students' research activities, out of which more than 250 papers have been published in international and local journals, proceedings, books, chapters in Books, chapters in Bulletins, monographs/Training modules/magazines and reports. His expertise and interests are generously shared with the public, government departments and scientists in his field of expertise. The seagrass plants in particular have been processed as herbarium specimens for reference purposes, teaching materials and have been on loaned to outside countries (e.g., Australia, Japan, Smithsonian Institute, Washington) for taxonomic studies. The publications, herbarium specimens, data, photographic records (prints and slides) acquired during research have formed into valuable resources. Prints, slides and data records of seagrasses and mangroves flora and fauna have been used in articles for educational magazines. Those on seagrasses are illustrations and invited chapters as in - J.E. Ong and W.K. Gong (eds.) 2001. Seagrasses, The Encyclopaedia of Malaysia The Malaysian Seas (Didier Millet), Mangroves and Seagrasses of the Indian Ocean-*Halodule pinifolia* seagrass bed, male and female flowers by Charles Sheppard, The University of Warwick, Guide to the Seagrasses specifically on *Halophila* by

NOAA Coastal Services Center; in books, Hemminga M.A. and C.M. Duarte. 2000. Seagrass ecology (Cambridge University Press), Short F.T. and R.G. Coles (eds.) 2001. Global Seagrass Research Methods (Elsevier Science B.V., Amsterdam), Green E.P., F.T. Short and M.D. Spalding (eds.) 2003. World Atlas of Seagrasses, California University Press, Waycott M., K. McMahon, J. Mellors, A. Calladine and D. Kleine. 2004. A Guide to Tropical Seagrasses of the Indo-West Pacific, James Cook University, Townsville and, Dewan Bahasa dan Pustaka-Universiti Teknologi Malaysia and Ministry of Education Malaysia. 2005. The Encyclopaedia of Agriculture and Forestry Technology. His seagrass group research findings have been incorporated in the country's national reports and manuals, for examples; Introduction to taxonomy of Malaysian seagrasses; Seagrasses: Module of Slide Shows and Lecture Note, Instructor Guide for Third Country Training Programme 2001-2003 on Marine Ecosystem and Pollution are used as teaching materials in workshops organised by Universiti Malaysia Sabah, JICA and JSPS in Indonesia, Japan, Thailand, Malaysia, Philippines and Vietnam.

His active research in seagrasses has led him to being invited as a resource person in lecturing assignments, workshops, awareness programs locally and internationally e.g., ASEAN-Australia Database on Living Coastal Resources, Coral Reef Organisms Workshop, Universiti Malaysia Sabah-Introduction to Malaysian seagrass taxonomy, JICA Third Country Training Programme-Seagrasses and Mangroves, Marine Education Kit under the Government and non-Government Organisation) and consultant for several projects (World Wild Life Fund for Nature Malaysia, Petronas, ESSO Malaysia). He is involved still with the Department of Environment, the Department of Environment, Ministry of Science, Technology and Environment Malaysia; Department of Fisheries Malaysia, Ministry of Agriculture Malaysia; Federal

Department of Town and Country Planning Peninsular Malaysia, Ministry of Housing and Local Government Malaysia and, frequently being consulted on matters pertaining to seagrass and mangroves current status on distribution and conservation in Malaysia. Finally through involvement of his work, research and expertise assignments, he has established linkages benefiting both the Universiti Putra Malaysia and the counterparts local and other Universities, government departments, non-governmental organisation such as JICA and JSPS.

His latest contribution to the world of seagrasses is serving as a member of the IUCN/Species Survival Commission (SSC) Seagrass Red List Authority.

ACKNOWLEDGEMENT

In the name of ALLAH the Most Gracious and the Most Merciful

I am most grateful to ALLAH SWT for His Blessings and Guidance. This is the most gratifying moment to thank and acknowledge the tremendous assistance and great contributions from individuals, organizations and institutions throughout my career for the past 21 years in UPM.

My sincere appreciation and gratitude to all staff, students of both undergraduates and postgraduates and colleagues whose names are impossible to list at the Department of Fish Biology, Faculty of Fisheries and Marine Science, Department of Biology, Faculty of Science, Department of Animal Science and Fishery, Faculty of Agriculture and Food Sciences, UPMKB, Department of Fisheries, Malaysia, Sabah Marine Park, and others from all over the country.

The sponsors for the research grants from Ministry of Science, Technology and Innovation Malaysia (MOSTI) through the Intensified Research for Priority Areas IRPA-7: Seagrass Resources Utilization and Development, Ecology, Distribution and Systematic of Seagrass Resources in Malaysia, IRPA-8: Seagrass Taxonomy, Biology and Habitat Characteristics, scienceFund: Laboratory Culture Studies of *Halophila ovalis*), Ministry of Higher Education, Malaysia (FRGS), Department of Fisheries, Malaysia, Department of Forestry Peninsular Malaysia, World Wide Fund (WWF) for Nature Malaysia, ASEAN Australia, Japan International Cooperation Agency (JICA), Japan Society for Promotion of Science (JSPS), United Nation Environmental Protection (UNEP), World Seagrass Association (WSA), SeagrasseNet, World Conservation Monitoring Centre (WCMC) are gratefully acknowledged.

I am greatly indebted to Vice Chancellors, Deputy Vice Chancellors of UPM, Prof. Dato' Dr. Wan Md. Zin Wan Yunus (former Dean, Faculty of Science), Prof. Tan Soon Guan (former Head, Department of Biology), my co-researchers Assoc. Prof. Dr. Muta Harah Zakaria, Prof. Dr. Aziz Arshad, Prof. Dr. Mazlan Abd. Ghaffar, Dr. Hishamuddin Omar, Mr. Fazrullah Rizally Abdul Razak, the late Prof. Dr. Law Ah Theem, Dato' Lamri Ali, Mr. Francis Liew and other Marine Scientists, Prof. Dr. John Kuo, Prof. Dr. Miguel Fortes, Dr. Hisao Ogawa, Prof. Dr. Frederick Short, Prof. Dr. Masahiro Nakaoka, Assoc. Prof. Kenichi Hayashizaki for their support. Last but not least to my late mother Mastura binti Sidik, father Bujang bin Sulaiman, my wife Aini Hj. Kuntom and wonderful daughter Nur Jannah for your undying love, invaluable support, inspirations, sacrifices, understanding and constant prayers, thank you so much.

To All – Thank You and May ALLAH SWT Bless all of You.

LIST OF INAUGURAL LECTURES

1. Prof. Dr. Sulaiman M. Yassin
   The Challenge to Communication Research in Extension
   22 July 1989

2. Prof. Ir. Abang Abdullah Abang Ali
   Indigenous Materials and Technology for Low Cost Housing
   30 August 1990

3. Prof. Dr. Abdul Rahman Abdul Razak
   Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops
   30 January 1993

4. Prof. Dr. Mohamed Suleiman
   Numerical Solution of Ordinary Differential Equations: A Historical Perspective
   11 December 1993

5. Prof. Dr. Mohd. Ariff Hussein
   Changing Roles of Agricultural Economics
   5 March 1994

6. Prof. Dr. Mohd. Ismail Ahmad
   Marketing Management: Prospects and Challenges for Agriculture
   6 April 1994

7. Prof. Dr. Mohamed Mahyuddin Mohd. Dahan
   The Changing Demand for Livestock Products
   20 April 1994

8. Prof. Dr. Ruth Kiew
   Plant Taxonomy, Biodiversity and Conservation
   11 May 1994

9. Prof. Ir. Dr. Mohd. Zohadie Bardaie
   Engineering Technological Developments Propelling Agriculture into the 21st Century
   28 May 1994

10. Prof. Dr. Shamsuddin Jusop
    Rock, Mineral and Soil
    18 June 1994

11. Prof. Dr. Abdul Salam Abdullah
Natural Toxicants Affecting Animal Health and Production
29 June 1994

12. Prof. Dr. Mohd. Yusof Hussein
Pest Control: A Challenge in Applied Ecology
9 July 1994

13. Prof. Dr. Kapt. Mohd. Ibrahim Haji Mohamed
Managing Challenges in Fisheries Development through Science and Technology
23 July 1994

14. Prof. Dr. Hj. Amat Juhari Moain
Sejarah Keagungan Bahasa Melayu
6 Ogos 1994

15. Prof. Dr. Law Ah Theem
Oil Pollution in the Malaysian Seas
24 September 1994

16. Prof. Dr. Md. Nordin Hj. Lajis
Fine Chemicals from Biological Resources: The Wealth from Nature
21 January 1995

17. Prof. Dr. Sheikh Omar Abdul Rahman
Health, Disease and Death in Creatures Great and Small
25 February 1995

18. Prof. Dr. Mohamed Shariff Mohamed Din
Fish Health: An Odyssey through the Asia - Pacific Region
25 March 1995

19. Prof. Dr. Tengku Azmi Tengku Ibrahim
Chromosome Distribution and Production Performance of Water Buffaloes
6 May 1995

20. Prof. Dr. Abdul Hamid Mahmood
Bahasa Melayu sebagai Bahasa Ilmu- Cabaran dan Harapan
10 Jun 1995

21. Prof. Dr. Rahim Md. Sail
Extension Education for Industrialising Malaysia: Trends, Priorities and Emerging Issues
22 July 1995

22. Prof. Dr. Nik Muhammad Nik Abd. Majid
The Diminishing Tropical Rain Forest: Causes, Symptoms and Cure
19 August 1995

23. Prof. Dr. Ang Kok Jee
The Evolution of an Environmentally Friendly Hatchery Technology for Udang Galah, the King of Freshwater Prawns and a Glimpse into the Future of Aquaculture in the 21st Century
14 October 1995

24. Prof. Dr. Sharifuddin Haji Abdul Hamid
Management of Highly Weathered Acid Soils for Sustainable Crop Production
28 October 1995

25. Prof. Dr. Yu Swee Yean
Fish Processing and Preservation: Recent Advances and Future Directions
9 December 1995

26. Prof. Dr. Rosli Mohamad
Pesticide Usage: Concern and Options
10 February 1996

27. Prof. Dr. Mohamed Ismail Abdul Karim
Microbial Fermentation and Utilization of Agricultural Bioresources and Wastes in Malaysia
2 March 1996

28. Prof. Dr. Wan Sulaiman Wan Harun
Soil Physics: From Glass Beads to Precision Agriculture
16 March 1996

29. Prof. Dr. Abdul Aziz Abdul Rahman
Sustained Growth and Sustainable Development: Is there a Trade-Off 1 or Malaysia
13 April 1996

30. Prof. Dr. Chew Tek Ann
Sharecropping in Perfectly Competitive Markets: A Contradiction in Terms
27 April 1996

31. Prof. Dr. Mohd. Yusuf Sulaiman
Back to the Future with the Sun
18 May 1996

32. Prof. Dr. Abu Bakar Salleh
Enzyme Technology: The Basis for Biotechnological Development
8 June 1996

33. Prof. Dr. Kamel Ariffin Mohd. Atan
The Fascinating Numbers
29 June 1996

34. Prof. Dr. Ho Yin Wan
Fungi: Friends or Foes
27 July 1996

35. Prof. Dr. Tan Soon Guan
Genetic Diversity of Some Southeast Asian Animals: Of Buffaloes and Goats and Fishes Too
10 August 1996

36. Prof. Dr. Nazaruddin Mohd. Jali
Will Rural Sociology Remain Relevant in the 21st Century?
21 September 1996

37. Prof. Dr. Abdul Rani Bahaman
Leptospirosis-A Model for Epidemiology, Diagnosis and Control of Infectious Diseases
16 November 1996

38. Prof. Dr. Marziah Mahmood
Plant Biotechnology - Strategies for Commercialization
21 December 1996

39. Prof. Dr. Ishak Hj. Omar
Market Relationships in the Malaysian Fish Trade: Theory and Application
22 March 1997

40. Prof. Dr. Suhaila Mohamad
Food and Its Healing Power
12 April 1997

41. Prof. Dr. Malay Raj Mukerjee
A Distributed Collaborative Environment for Distance Learning Applications
17 June 1998

42. Prof. Dr. Wong Kai Choo
Advancing the Fruit Industry in Malaysia: A Need to Shift Research Emphasis
15 May 1999

43. Prof. Dr. Aini Ideris
Avian Respiratory and Immunosuppressive Diseases- A Fatal Attraction
10 July 1999

44. Prof. Dr. Sariah Meon
Biological Control of Plant Pathogens: Harnessing the Richness of Microbial Diversity
14 August 1999

45. Prof. Dr. Azizah Hashim
The Endomycorrhiza: A Futile Investment?
23 Oktober 1999

46. Prof. Dr. Noraini Abdul Samad
Molecular Plant Virology: The Way Forward
2 February 2000

47. Prof. Dr. Muhamad Awang
Do We Have Enough Clean Air to Breathe?
7 April 2000

48. Prof. Dr. Lee Chnoong Kheng
Green Environment, Clean Power
24 June 2000

49. Prof. Dr. Mohd. Ghazali Mohayidin
Managing Change in the Agriculture Sector: The Need for Innovative Educational Initiatives
12 January 2002

50. Prof. Dr. Fatimah Mohd. Arshad
Analisis Pemasaran Pertanian di Malaysia: Keperluan Agenda Pembaharuan
26 Januari 2002

51. Prof. Dr. Nik Mustapha R. Abdullah
Fisheries Co-Management: An Institutional Innovation Towards Sustainable Fisheries Industry
28 February 2002

52. Prof. Dr. Gulam Rusul Rahmat Ali
Food Safety: Perspectives and Challenges
23 March 2002

53. Prof. Dr. Zaharah A. Rahman
Nutrient Management Strategies for Sustainable Crop Production in Acid Soils: The Role of Research Using Isotopes
13 April 2002

54. Prof. Dr. Maisom Abdullah
Productivity Driven Growth: Problems & Possibilities
27 April 2002

55. Prof. Dr. Wan Omar Abdullah
Immunodiagnosis and Vaccination for Brugian Filariasis: Direct Rewards from Research Investments
6 June 2002

56. Prof. Dr. Syed Tajuddin Syed Hassan
Agro-ento Bioinformation: Towards the Edge of Reality
22 June 2002

57. Prof. Dr. Dahlan Ismail
Sustainability of Tropical Animal-Agricultural Production Systems: Integration of Dynamic Complex Systems
27 June 2002

58. Prof. Dr. Ahmad Zubaidi Baharumshah
The Economics of Exchange Rates in the East Asian Countries
26 October 2002

59. Prof. Dr. Shaik Md. Noor Alam S.M. Hussain
Contractual Justice in Asean: A Comparative View of Coercion
31 October 2002

60. Prof. Dr. Wan Md. Zin Wan Yunus
Chemical Modification of Polymers: Current and Future Routes for Synthesizing New Polymeric Compounds
9 November 2002

61. Prof. Dr. Annuar Md. Nassir
Is the KLSE Efficient? Efficient Market Hypothesis vs Behavioural Finance
23 November 2002

62. Prof. Ir. Dr. Radin Umar Radin Sohadi
Road Safety Interventions in Malaysia: How Effective Are They?
21 February 2003

63. Prof. Dr. Shamsher Mohamad
The New Shares Market: Regulatory Intervention, Forecast Errors and Challenges
26 April 2003

64. Prof. Dr. Han Chun Kwong
Blueprint for Transformation or Business as Usual? A Structurational Perspective of the Knowledge-Based Economy in Malaysia
31 May 2003

65. Prof. Dr. Mawardi Rahmani
Chemical Diversity of Malaysian Flora: Potential Source of Rich Therapeutic Chemicals
26 July 2003

66. Prof. Dr. Fatimah Md. Yusoff
An Ecological Approach: A Viable Option for Aquaculture Industry in Malaysia
9 August 2003

67. Prof. Dr. Mohamed Ali Rajion
The Essential Fatty Acids-Revisited
23 August 2003

68. Prof. Dr. Azhar Md. Zain
Psychotheraphy for Rural Malays - Does it Work?
13 September 2003

69. Prof. Dr. Mohd. Zamri Saad
    Respiratory Tract Infection: Establishment and Control
    27 September 2003

70. Prof. Dr. Jinap Selamat
    Cocoa-Wonders for Chocolate Lovers
    14 February 2004

71. Prof. Dr. Abdul Halim Shaari
    High Temperature Superconductivity: Puzzle & Promises
    13 March 2004

72. Prof. Dr. Yaakob Che Man
    Oils and Fats Analysis - Recent Advances and Future Prospects
    27 March 2004

73. Prof. Dr. Kaida Khalid
    Microwave Aquametry: A Growing Technology
    24 April 2004

74. Prof. Dr. Hasanah Mohd. Ghazali
    Tapping the Power of Enzymes- Greening the Food Industry
    11 May 2004

75. Prof. Dr. Yusof Ibrahim
    The Spider Mite Saga: Quest for Biorational Management Strategies
    22 May 2004

76. Prof. Datin Dr. Sharifah Md. Nor
    The Education of At-Risk Children: The Challenges Ahead
    26 June 2004

77. Prof. Dr. Ir. Wan Ishak Wan Ismail
    Agricultural Robot: A New Technology Development for Agro-Based Industry
    14 August 2004

78. Prof. Dr. Ahmad Said Sajap
    Insect Diseases: Resources for Biopesticide Development
    28 August 2004

79. Prof. Dr. Aminah Ahmad
The Interface of Work and Family Roles: A Quest for Balanced Lives
11 March 2005

80. Prof. Dr. Abdul Razak Alimon
Challenges in Feeding Livestock: From Wastes to Feed
23 April 2005

81. Prof. Dr. Haji Azimi Hj. Hamzah
Helping Malaysian Youth Move Forward: Unleashing the Prime Enablers
29 April 2005

82. Prof. Dr. Rasedee Abdullah
In Search of An Early Indicator of Kidney Disease
27 May 2005

83. Prof. Dr. Zulkifli Hj. Shamsuddin
Smart Partnership: Plant-Rhizobacteria Associations
17 June 2005

84. Prof. Dr. Mohd Khanif Yusop
From the Soil to the Table
1 July 2005

85. Prof. Dr. Annuar Kassim
Materials Science and Technology: Past, Present and the Future
8 July 2005

86. Prof. Dr. Othman Mohamed
Enhancing Career Development Counselling and the Beauty of Career Games
12 August 2005

87. Prof. Ir. Dr. Mohd Amin Mohd Soom
Engineering Agricultural Water Management Towards Precision Framing
26 August 2005

88. Prof. Dr. Mohd Arif Syed
Bioremediation-A Hope Yet for the Environment?
9 September 2005

89. Prof. Dr. Abdul Hamid Abdul Rashid
The Wonder of Our Neuromotor System and the Technological Challenges They Pose
23 December 2005

90. Prof. Dr. Norhani Abdullah
Rumen Microbes and Some of Their Biotechnological Applications
27 January 2006

91. Prof. Dr. Abdul Aziz Saharee
Haemorrhagic Septicaemia in Cattle and Buffaloes: Are We Ready for Freedom?
24 February 2006

92. Prof. Dr. Kamariah Abu Bakar
Activating Teachers' Knowledge and Lifelong Journey in Their Professional Development
3 March 2006

93. Prof. Dr. Borhanuddin Mohd. Ali
Internet Unwired
24 March 2006

94. Prof. Dr. Sundararajan Thilagar
Development and Innovation in the Fracture Management of Animals
31 March 2006

95. Prof. Dr. Zainal Aznam Md. Jelan
Strategic Feeding for a Sustainable Ruminant Farming
19 May 2006

96. Prof. Dr. Mahiran Basri
Green Organic Chemistry: Enzyme at Work
14 July 2006

97. Prof. Dr. Malik Hj. Abu Hassan
Towards Large Scale Unconstrained Optimization
20 April 2007

98. Prof. Dr. Khalid Abdul Rahim
Trade and Sustainable Development: Lessons from Malaysia's Experience
22 Jun 2007

99. Prof. Dr. Mad Nasir Shamsudin
Econometric Modelling for Agricultural Policy Analysis and Forecasting: Between Theory and Reality
13 July 2007

100. Prof. Dr. Zainal Abidin Mohamed
Managing Change - The Fads and The Realities: A Look at Process Reengineering, Knowledge Management and Blue Ocean Strategy
9 November 2007

101. Prof. Ir. Dr. Mohamed Daud
Expert Systems for Environmental Impacts and Ecotourism Assessments
23 November 2007

102. Prof. Dr. Saleha Abdul Aziz
Pathogens and Residues; How Safe is Our Meat?
30 November 2007

103. Prof. Dr. Jayum A. Jawan
Hubungan Sesama Manusia
7 Disember 2007

104. Prof. Dr. Zakariah Abdul Rashid
Planning for Equal Income Distribution in Malaysia: A General Equilibrium Approach
28 December 2007

105. Prof. Datin Paduka Dr. Khatijah Yusoff
Newcastle Disease virus: A Journey from Poultry to Cancer
11 January 2008

106. Prof. Dr. Dzulkefly Kuang Abdullah
Palm Oil: Still the Best Choice
1 February 2008

107. Prof. Dr. Elias Saion
Probing the Microscopic Worlds by Lonizing Radiation
22 February 2008

108. Prof. Dr. Mohd Ali Hassan
Waste-to-Wealth Through Biotechnology: For Profit, People and Planet
28 March 2008

109. Prof. Dr. Mohd Maarof H. A. Moksin
Metrology at Nanoscale: Thermal Wave Probe Made It Simple
11 April 2008

110. Prof. Dr. Dzolkhifli Omar
The Future of Pesticides Technology in Agriculture: Maximum Target Kill with Minimum Collateral Damage
25 April 2008

111. Prof. Dr. Mohd. Yazid Abd. Manap
Probiotics: Your Friendly Gut Bacteria
9 May 2008

112. Prof. Dr. Hamami Sahri
Sustainable Supply of Wood and Fibre: Does Malaysia have Enough?
23 May 2008

113. Prof. Dato' Dr. Makhdzir Mardan
Connecting the Bee Dots
20 June 2008

114. Prof. Dr. Maimunah Ismail
Gender & Career: Realities and Challenges
25 July 2008

115. Prof. Dr. Nor Aripin Shamaan
Biochemistry of Xenobiotics: Towards a Healthy Lifestyle and Safe Environment
1 August 2008

116. Prof. Dr. Mohd Yunus Abdullah
Penjagaan Kesihatan Primer di Malaysia: Cabaran Prospek dan Implikasi dalam Latihan dan Penyelidikan Perubatan serta Sains Kesihatan di Universiti Putra Malaysia
8 Ogos 2008

117. Prof. Dr. Musa Abu Hassan
Memanfaatkan Teknologi Maklumat & Komunikasi ICT untuk Semua
15 Ogos 2008

118. Prof. Dr. Md. Salleh Hj. Hassan
Role of Media in Development: Strategies, Issues & Challenges
22 August 2008

119. Prof. Dr. Jariah Masud
Gender in Everyday Life
10 October 2008

120 Prof. Dr. Mohd Shahwahid Haji Othman
Mainstreaming Environment: Incorporating Economic Valuation and Market-Based Instruments in Decision Making
24 October 2008

121. Prof. Dr. Son Radu
Big Questions Small Worlds: Following Diverse Vistas
31 Oktober 2008

122. Prof. Dr. Russly Abdul Rahman
Responding to Changing Lifestyles: Engineering the Convenience Foods
28 November 2008

123. Prof. Dr. Mustafa Kamal Mohd Shariff
Aesthetics in the Environment an Exploration of Environmental: Perception Through Landscape Preference
9 January 2009

124. Prof. Dr. Abu Daud Silong
Leadership Theories, Research & Practices: Farming Future Leadership Thinking
16 January 2009

125. Prof. Dr. Azni Idris
Waste Management, What is the Choice: Land Disposal or Biofuel?
23 January 2009

126. Prof. Dr. Jamilah Bakar
Freshwater Fish: The Overlooked Alternative
30 January 2009

127. Prof. Dr. Mohd. Zobir Hussein
The Chemistry of Nanomaterial and Nanobiomaterial
6 February 2009

128. Prof. Ir. Dr. Lee Teang Shui
Engineering Agricultural: Water Resources
20 February 2009

129. Prof. Dr. Ghizan Saleh
Crop Breeding: Exploiting Genes for Food and Feed
6 March 2009

130. Prof. Dr. Muzafar Shah Habibullah
Money Demand
27 March 2009

131. Prof. Dr. Karen Anne Crouse
In Search of Small Active Molecules
3 April 2009

132. Prof. Dr. Turiman Suandi
Volunteerism: Expanding the Frontiers of Youth Development
17 April 2009

133. Prof. Dr. Arbakariya Ariff
Industrializing Biotechnology: Roles of Fermentation and Bioprocess Technology
8 Mei 2009

134. Prof. Ir. Dr. Desa Ahmad
Mechanics of Tillage Implements
12 Jun 2009

135. Prof. Dr. W. Mahmood Mat Yunus
Photothermal and Photoacoustic: From Basic Research to Industrial Applications
10 Julai 2009

136. Prof. Dr. Taufiq Yap Yun Hin
Catalysis for a Sustainable World
7 August 2009

137 Prof. Dr. Raja Noor Zaliha Raja Abd. Rahman
Microbial Enzymes: From Earth to Space
9 Oktober 2009

138 Prof. Ir. Dr. Barkawi Sahari
Materials, Energy and CNGDI Vehicle Engineering
6 November 2009

139. Prof. Dr. Zulkifli Idrus
Poultry Welfare in Modern Agriculture: Opportunity or Threat?
13 November 2009

140. Prof. Dr. Mohamed Hanafi Musa
Managing Phosphorus: Under Acid Soils Environment
8 January 2010

141. Prof. Dr. Abdul Manan Mat Jais
Haruan Channa striatus a Drug Discovery in an Agro-Industry Setting
12 March 2010

142. Prof. Dr. Bujang bin Kim Huat
Problematic Soils: In Search for Solution
19 March 2010

143. Prof. Dr. Samsinar Md Sidin
Family Purchase Decision Making: Current Issues & Future Challenges
16 April 2010

144. Prof. Dr. Mohd Adzir Mahdi
Lightspeed: Catch Me If You Can
4 June 2010

145. Prof. Dr. Raha Hj. Abdul Rahim
Designer Genes: Fashioning Mission Purposed Microbes
18 June 2010

146. Prof. Dr. Hj. Hamidon Hj. Basri
A Stroke of Hope, A New Beginning
2 July 2010

147. Prof. Dr. Hj. Kamaruzaman Jusoff
Going Hyperspectral: The "Unseen" Captured?
16 July 2010

148. Prof. Dr. Mohd Sapuan Salit
Concurrent Engineering for Composites
30 July 2010

149. Prof. Dr. Shattri Mansor
Google the Earth: What's Next?
15 October 2010

150. Prof. Dr. Mohd Basyaruddin Abdul Rahman
Haute Couture: Molecules & Biocatalysts
29 October 2010

151. Prof. Dr. Mohd. Hair Bejo
Poultry Vaccines: An Innovation for Food Safety and Security
12 November 2010

152. Prof. Dr. Umi Kalsom Yusuf
Fern of Malaysian Rain Forest
3 December 2010

153. Prof. Dr. Ab. Rahim Bakar
Preparing Malaysian Youths for The World of Work: Roles of Technical and Vocational Education and Training (TVET)
14 January 2011

154. Prof. Dr. Seow Heng Fong
Are there "Magic Bullets" for Cancer Therapy?
11 February 2011

155. Prof. Dr. Mohd Azmi Mohd Lila
Biopharmaceuticals: Protection, Cure and the Real Winner
18 February 2011

156. Prof. Dr. Siti Shapor Siraj
Genetic Manipulation in Farmed Fish: Enhancing Aquaculture Production
25 March 2011

157. Prof. Dr. Ahmad Ismail
Coastal Biodiversity and Pollution: A Continuous Conflict
22 April 2011

158. Prof. Ir. Dr. Norman Mariun
Energy Crisis 2050? Global Scenario and Way Forward for Malaysia
10 June 2011

159. Prof. Dr. Mohd Razi Ismail
Managing Plant Under Stress: A Challenge for Food Security
15 July 2011

160. Prof. Dr. Patimah Ismail
Does Genetic Polymorphisms Affect Health?
23 September 2011

161. Prof. Dr. Sidek Ab. Aziz
Wonders of Glass: Synthesis, Elasticity and Application
7 October 2011

162. Prof. Dr. Azizah Osman
Fruits: Nutritious, Colourful, Yet Fragile Gifts of Nature
14 October 2011

163. Prof. Dr. Mohd. Fauzi Ramlan
Climate Change: Crop Performance and Potential
11 November 2011

164. Prof. Dr. Adem Kiliçman
Mathematical Modeling with Generalized Function
25 November 2011

165. Prof. Dr. Fauziah Othman
My Small World: In Biomedical Research
23 December 2011