CHAPTER 1

INTRODUCTION

Seaweeds are a diverse group of marine macro-algae. They are usually attached to a solid substrate and are referred to as benthic in habit. They are diverse in size, morphology and color and fall naturally into several divisions or phyla based on biochemical and cellular features. Seaweeds may be small filaments (1 mm), encrusting or upright calcified blades, broad foliose blades or large complex organisms called kelp (> 25 m long). They may survive and even thrive in stressful environments such as at the edges of reefs, in crashing waves, in the dim subtidal zone (220 m. deep) and in the intertidal zone. The intertidal zone, especially in the tropics has many stressful aspects which impinge on organisms and challenge their survival. High light intensities, high temperatures and desiccation (Campbell *et al*., 1998) are especially important. Therefore the intertidal zone is an interesting habitat in which to study the populations of seaweed that can survive and distribute their populations abundantly.

The genus *Padina*, a brown alga in the Phylum Heterokontophyta, Class Phaeophyceae and Order Dictyotales (Lee, 1999), has a worldwide distribution in tropical and subtropical climate zones. *Padina boryana* Thivy is one of the most common species along the coasts of Thailand. This species was recognized as part of the record for Thailand in 1984 by Lewmanomont (1984). *P. boryana* can form extensive communities in intertidal and subtidal zones. It attaches to hard substrate and may periodically be partially or wholly buried in sand. The characteristic fan-shaped thalli, which grow from an apical cell row meristem, have periodic reproductive sori containing a homogeneously dense arc of reproductive cells. *Padina*, like all other genera in the order Dictyotales, shows an alternation of isomorphic generations type of life history with three possible vegetatively-identical thallus types: a sporophyte and two gametophytes (male and female). There are many species of *Padina* in Thailand. Nine have been described and recorded by Maneerat (1974); Pengseng (1992) and Lewmanomont and Ogawa (1995). They are *P. australis* Hauck, *P. durvillaei* Bory de Saint-Vincent, *P. boryana* Thivy (synonym *P. tenuis* Bory), *P. commersonii* Bory de Saint-Vincent), *P. tetrastromatica* Hauck, *P. pavonica* Linnaeus (synonym *P. pavonia*), *P. gymnospora* (Kutzing), *P. distromatica* Hauck, *P. minor* Yamada, and *P. japonica* Yamada

In the intertidal zone, many biological and physical factors affect the growth of seaweeds. Nutrient concentration (Schaffelke, 1999; Ichiki *et al*., 2000; Kuffner and Paul, 2001; Szmant, 2002; Lapointe *et al*., 2004; Palomo *et al*., 2004; Roberson and Coyer, 2004), light intensity (Hansen, 1977; De Ruyter Van Steveninck and Breeman, 1987; Flores-Moya *et al*., 1996; Ateweberhan, 2006; Plouguerné *et al.*, 2006), wave action (Payri, 1984; De Ruyter Van Steveninck and Breeman, 1987; Prathep *et al*., 2006), temperature (Creed *et al*., 1998; Hwang *et al.*, 2004), substrate type (Quartino *et al*., 2001; Diez *et al.*, 2003) and herbivory (Lewis *et al*., 1987; Steneck and Dethier, 1994; Van Alstyne *et al*., 2001) are all important. These factors are known to influence distribution (Campbell *et al*., 1998) and are known to be limiting factors for growth, reproduction, dispersal and settlement (Graham, 2002).

Padina spp. are dominant along the intertidal rocky shores of Phuket Province (Prathep, 2005; Thongroy *et al*., 2007) and also in the shallow subtidal zone in

Talibong, Trang (Prathep and Tantiprapas, 2006) and in Samui, Surat Thani (Mayakun and Prathep, 2005). In Phuket, it is especially easily observed at Sirinart National Park and Tang Khen Bay. Many factors contribute to the survival, growth and development of *P. boryana*, however, the patterns of the physical and biological factors that regulate the populations have not been studied. In other words, the specific parameters which allow *P. boryana* to survive the stressful conditions of the tropical intertidal zone are not fully understood. The purpose of this study is to investigate the patterns of the complex processes of recruitment, growth and reproduction of *P. boryana*. Since it grows rapidly and forms reproductive cells throughout the year (Prathep, 2005), *P. boryana* is a good model subject to study year round in order to establish its reproductive potential and understand how it is fulfilled. The hypothesis of this study is that characteristic patterns of growth, reproduction and recruitment determine the population structure of *P. boryana* in the natural habitats. The differences and similarities of the two sites help establish the true basis of the controls on this species.

Review of literature

The characteristics of the genus *Padina*

Classification of *Padina* following Lee (1999).

Kingdom Protista

Division (Phylum) Heterokontophyta

Class Phaeophyceae

Order Dictyotales

Family Dictyotaceae

Genus *Padina* Adanson

Species *Padina boryana* Thivy

Padina is an unusual example of a brown alga in that it is calcified. Calcification in seaweeds is more common in green and red algae (Kraft *et al.*, 2004). *Padina boryana* thalli are erect, flattened, fan-shaped and parenchymatous (Figure 1). They attach by a rhizoidal holdfast. In submerged plants, the “fan” is often curved into a funnel shape and is composed of tufts of many overlapping lobes. Concentric lines, formed by hairs or hair scars, mark the frond. Reproductive sori of sporangia or oogonia appear as aggregations of minute dark spots also in concentric rows on the lower surface. Antheridia are colorless and low relief. The upper surface is always encrusted with calcareous substance. In *P. boryana*, plants are a greenish brown color. The blades are 2 cells thick throughout the thallus. The reproductive structures, sporangia, oogonia and antheridia, appear in alternate bands between the lines of hairs (Maneerat, 1974;

Geraldino, 2004). In the absence of reproductive structures it is not possible to determine the species of a *Padina* specimen.

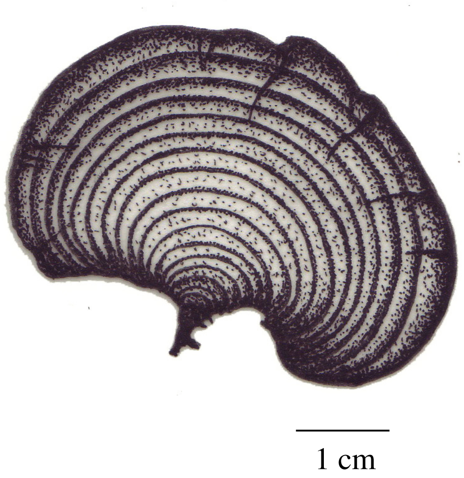

Figure 1. The whole thallus of *Padina boryana* Thivy

Diversity of *Padina* in Thailand

Many investigations of algae in Thailand have emphasized their diversity by describing the species (Maneerat, 1974; Pengseng, 1992; Lewmanomont and Ogawa, 1995). From these reports, nine species of *Padina* have been recorded from Thailand as mentioned above. Identification of *Padina* species has been problematical because of synonyms, that is, one species has been given many names by different authors who have collected them from different places. Also, some species do not have sufficiently detailed descriptions (Wynne and De Clerck, 1999).

Growth and reproduction of *Padina* species

Padina fronds have an infurled apical cell row. Both upright fronds and a prostrate stage called the *Dictyerpa* stage are produced. It is therefore vegetatively dimorphic. *Padina* species have variable growth patterns and reproduction also varies during the annual cycle.

The life history of any organism is its basic strategy for survival of the population in nature. Diverse types of life history or strategy are expressed amongst the algae. *Padina* has an alternation of isomorphic generations type of life history (Figure 2) involving a diploid sporophyte (a spore-producing phase) and haploid gametophytes (gamete-producing phases), characteristic of all members of the Dictyotales. The life cycle is of the isomorphic diplohaplontic type.

The sporophyte produces large haploid aplanospores (tetraspores) by meiosis from tetrasporangia which develop from epidermal cells and are clumped together in sori. The naked tetraspores are released by gelatinization of the apex of the sporangium, and soon after liberation, secrete a cellulose wall and develop into identical-looking monoecious or dioecious gametophytes (Lee, 1999) (Figure 2). *P. boryana* is dioecious (Maneerat, 1974; Geraldino, 2004).

Sporangia, oogonia and antheridia are formed in concentric rows of sori on the blade surface. Tetrasporangial sori appear to the naked eyes as dark spots forming dark rows on the upper blade. Fertile female gametophytes and sporophytes are difficult to distinguish from each other in surface view because sporangial and oogonial sori are rather similar in size and color**.** They can be distinguished by the cell size and the morphology of the sori (Figure 3-4). In *P. boryana* as in *Dictyopteris undalata*, sporangia at maturity are usually bigger in diameter than oogonia (Tanaka, 1998). Mature oogonia are more spherical or slightly ovoid and ca. 78 x 50 µm. diameter (Garreta *et al.*, 2007). Moreover, the fertile female gametophyte shows a light band on the upper surface of the blade and the oogonia are packed into wave-like sori. Antheridial sori are distinguished macroscopically from tetrasporangial and female sori by their whitish color and may be confused with sterile thalli. Sporophytes, female and male gametophytes appear similar and cannot be distinguished from each other when they are sterile. Sexual maturity in male gametophytes is more difficult to determine because antheridia and the small motile sperm are much less conspicuous than oogonia and eggs. However, antheridia are always seen prior to the release of eggs by females.

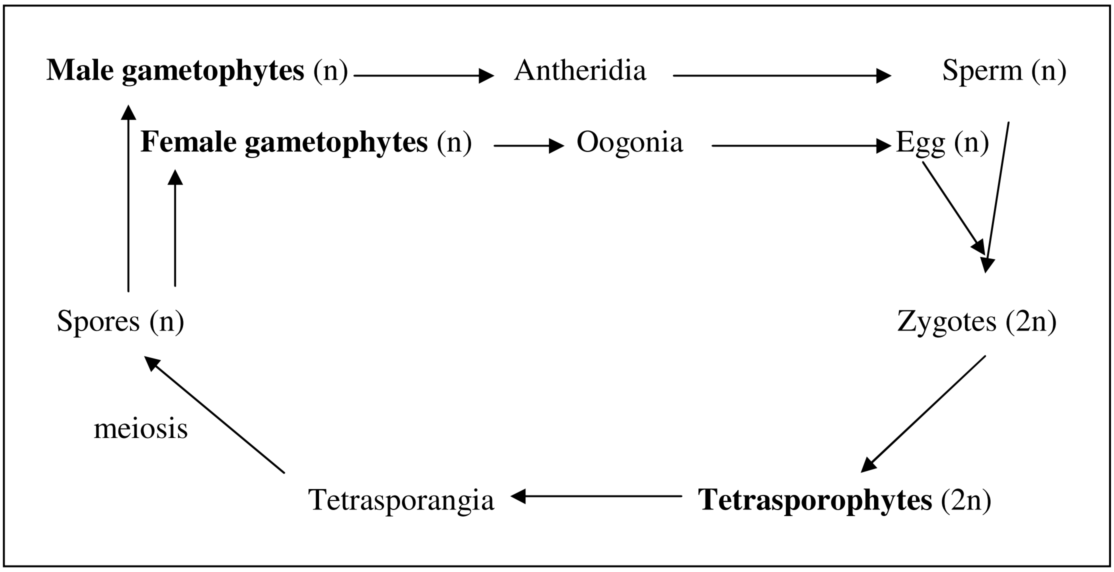

Figure 2. Diagram of the life cycle of *Padina boryana* Thivy (modified from Lee, 1999).

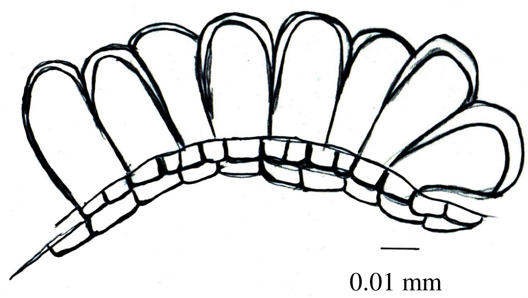

Figure 3. The longitudinal cross-section of *Padina boryana* (X400) showing the oogonia packed on the blade.

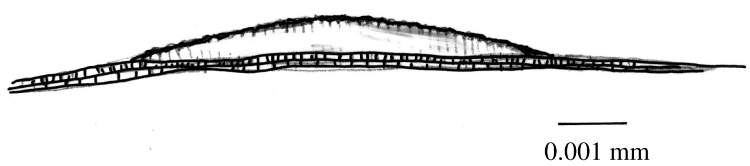

Figure 4. The longitudinal cross-section of *Padina boryana* (X100) showing the reproductive sori of antheridia.

Recruitment

Recruitment is of fundamental importance to population structure because it is the foundation upon which all subsequent interactions within the population take place. When recruitment fails, the new individuals do not have the opportunity to survive and that establishes the population structure. According to Woodin *et al*. (1995) there are two types of process that determine the recruitment success of organisms. First, the number of reproductive cells that reach a site and are retained is of primary importance and second, mortality during or after settlement.

Environmental factors

Many biological and physical factors influence *Padina* populations in nature. There is a paucity of relevant research reports on the subject. The Garreta *et al*. (2007) study of fertile gametophytes of *P. pavonica* revealed that the most important factor is the water temperature at the time of the early development of gametophytes. At higher temperatures, the gametophytes tend to be dioecious, while lower water temperatures apparently increase the ratio of monoecism.

The effects of salinity, pH and temperature on the spores and sporelings of *P. tetrastomatica* Hauck have all been studied (Subbaraju *et al*., 1982). The alga showed tolerance to salinities between 27 and 32‰. At salinities <17.9‰ and >32.1‰ no spores survived. Temperatures between 23-28 °C and pH 8.0-8.5 were shown to be optimal for growth. The results of these studies will be compared with the observations made during this project.

Benthic algae have several life-history stages that may respond differently to environmental pressures. Algal propagules (spores and zygotes in the case of *Padina*) are released into the water column and dispersed. After they settle and attach they become part of the microscopic benthic community. The impacts of herbivory and nutrients cannot be assumed to be uniform, but will vary depending on the species, the life history stage or demographic factors (Diaz-Pulido and McCook, 2003). For example, growth and density of *Sargassum fissifolium* was affected by herbivore grazing while *Lobophora variegata* does not show any signs of grazing damage (Diaz-Pulido and McCook, 2003) even though they are part of the same community. The growth form of *L. variegata* is similar to the early post recruitment stage of *Padina* sp. However, its small fan-shaped thallus is prostrate and part of the under story and grows at greater depths on coral substrate. Moreover, *Padina* accumulates calcium on the blade which is reported to resist herbivores (Hay, 1985). Some publications report that one of the major causes of increased macroalgal abundance is high nutrient levels in the seawater. Schaffelke (1999) reported that the net photosynthetic rate was also higher and indicated that the growth would be expected to be faster. Algal fecundity would be higher due to its positive correlation with size (Nordemar *et al*., 2007).

Hypothesis

The characteristic patterns of growth, reproduction and recruitment determine the population structure of *Padina boryana* Thivy in the natural habitats. Differences in these patterns would also explain variations at two different intertidal sites.

Objectives

1. To monitor the population structure of *P. boryana* in two locations in Phuket.
2. To study the relationship between growth and maturity and to describe the optimal growth and reproductive potentials.
3. To investigate the reproductive cycle and define the time of production of new individuals.
4. To investigate the potential recruitment on the hard substratum.
5. To determine the factors to which the differences in growth, reproduction and recruitment at the two study sites can be attributed.

Research Questions

An experiment was designed to address the following questions:

1. Do populations of *P. boryana* show the same population structure at two study sites?
2. Does growth of *P. boryana* relate to its reproduction?
3. When does *P. boryana* show the gametophyte and sporophyte life stages and when does it produce the reproductive cells?
4. How does it recruit on the hard substratum in nature?
5. What are the factors that can trigger the differences between two *Padina* populations at Koh Phuket?