1. INTRODUCTION

Background and Rationale

The natural environment provides the basic conditions without which humanity could not survive. Biological diversity is the key to the ability of the biosphere to continue providing us with these ecological goods and services and thus is our species life assurance policy. Biodiversity is one of the most important factors in human subsistence. People from all over the world use and consume natural resources as food, clothing, housing equipment and medicines. Diversity is often expressed in terms of the wide variety of plants, animals and microorganisms. So far, about 1.75 million species have been identified, most of which are small creatures such as insects and microorganisms (http://www.biodiv.org).

The Convention on Biological Diversity (CBD) was set out to maintain and conserve ecological process and ecosystems for biodiversity conservation and the sustainable use based on the equitable benefit-sharing principle. Therefore, the Global Taxonomic Initiative (GTI) and Convention on Biological Diversity (CBD) were established. GTI aims to make taxonomic information, at all levels of biodiversity (genetic, species and ecosystem) and for all organisms, available in order to implement the three goals of the CBD: 1) the conservation of biological biodiversity, 2) the sustainable use of its components and 3) the fair and equitable sharing of the benefits arising from the use of genetic resources (http://bch-cbd.naturalsciences.be/ belgium/cooperation/projects/gticontent.htm).

Thailand signed the CBD on 12 June 1992. The government then started to pay considerably more attention to biodiversity research (Hatacharern and

Cunningham, 2004). However, there is very little research regarding taxonomy in Thailand on any level of biodiversity (http://brt.biotec.or.th/Executive 2004.htm; http://brt.biotec.or.th/years.html).

Seaweed Biodiversity

Seaweeds, or macroalgae are an ecologically and economically important component of marine ecosystems worldwide. They are primary producers, shelter, nursery grounds and food sources for marine organisms. In addition, they are used around the world as foods and fertilizers, and for the extraction of valuable commercial products, such as industrial gums and chemicals (agars, carageenans and alginates). Recent research has pointed to new opportunities, particularly in the field of medicine, associated with bioactive properties of molecules extracted from seaweeds. Because of its importance, seaweed biodiversity studies and seaweed database have been carried out and are being established.

AlgaeBase was set up in 1996, initially as an attempt to list all of the marine algae reported from Ireland and Britain. Later, the list was extended to the Northeastern Alantic and the Mediteranean. At the same time, lists of marine algae from all over the world were added in an attempt to make the list as comprehensive as possible. Currently, AlgaeBase probably contains information on more than eighty-five per cent of currently accepted names of marine macroalgae worldwide. The data included mainly concern taxonomy, nomenclature and distribution and, predictably, are most complete for the North Atlantic and Mediteranean (Nic Dhonncha and Guiry, 2002). In addition, there are a few other databases and collections of seaweed around the world eg. Smithsonian, USA; Hawaii, USA; Townsville, Australia;

Hokkaido, Japan and Manila, The Philippines. However, very little has been known about seaweed biodiversity in Thailand. Only a few research have been carried out on seaweed study in recent years and the number of seaweed study in Thailand has sharply declined (Powtongsook, 2000).

Here, we would like to investigate:

1) Number of seaweed species at Sirinat Marine National Park to provide more information of seaweed biodiversity in Thailand.

2) What physical factors influence diversity, distribution and abundance of seaweeds?

3) Are there any variations in morphology and reproduction of some common seaweed among sites and seasons?

Review of Literature

Seaweed Biodiversity in Thailand

The very first report of marine algal flora in Thailand was published in 1866 in "Die Preussische Expedition nach Ost-Asien" (Martens, 1866), followed by "Flora of Koh Chang" (Schmidt, 1900-1916) and "List des algues du siboga" (Weber van Bosse, 1913-1928). Later, there were a few studies of marine algae reported in Thailand (Egerod, 1971, 1974, 1975; Velasquez and Lewmanomont, 1975; Lewmanomont, 1976, 1978; Abbott, 1988; Lewmanomont and Ogawa, 1995; Lewmanomont *et al.*, 1995; Aungtonya and Liao, 2002; Lewmanomont and Chirapart, 2004). Recently, there have been a series of taxonomical studies on red algae such as *Gracilaria* in Thailand (Lewmanomont, 1994, 1995; Lewmanomont and Chirapart, 2004). Recent studies show that 333 species of marine algae were found in Thailand (Lewmanomont *et al.*, 1995) and 180 algal records, collected from the Andaman Sea area off the coast of Thailand, are deposited in the Reference Collection of the Phuket Marine Biological Center (Aungtonya and Liao, 2002).

In addition, there were a few Master theses on seaweed biodiversity as follows:

Jindapon (1976) studied the taxonomy of marine algae on the coast of Trang Province. Five divisions, 53 genera were found along the coastal line. They were: 15 genera of Chlorophyta, 2 genera of Chrysophyta, 4 genera of Cyanophyta, 6 genera of Phaeophyta, 23 genera of Rhodophyta and 3 genera were not identified.

Pirompakdee (1976) studied the taxonomy of marine algae on the coast of Trad Province. Six divisions, 54 genera were found at the study site. They were: 12 genera of Chlorophyta, 2 genera of Chrysophyta, 1 genus of Pyrrophyta, 10 genera of Phaeophyta, 22 genera of Rhodophyta, 7 genera of Cyanophyta and 4 genera were not identified.

Sakuntab (1976) studied distribution, ecology, morphology and taxonomy of the marine macroalgae on the coast of Phuket Island. The study covered a period of time from March 1, 1975 until February 23, 1976. There were 3 divisions, 46 genera distributed on coast of Phuket. The genera were: 13 genera of Chlorophyta, 6 genera of Phaeophyta and 22 genera of Rhodophyta

Mesang (1987) studied the taxonomy, zonation and distribution of macroscopic marine algae at Ko Samui, Suratthani Province. Sample were monthly collected from December 1985 to November 1986 by belt transect method. There were 12 genera of marine algae: 2 genera of Chlorophyta, 4 genera of Phaeophyta and

6 genera of Rhodophyta. Most genera were in the intertidal zone. Only 2 genera, *Sargassum* and *Turbinaria,* were in subtidal.

Supowkit (1988) studied the distribution of red algae on the Eastern Coast of the Gulf of Thailand. The study was made during September 1987 to August 1988. Forty- two species of red algae were collected and identified. The most abundant species were *Centroceras clavulatum, C. minutum, Ceramium byssodeum* and *Gracilaria* spp.

Sangchan (1989) investigated the distribution, morphology, taxonomy and habitat of useful marine benthic algae on Nakhornsithummarat coastal line. The study covered a period of time from January 1987 until December 1987. There were 3 divisions, 13 genera, 19 species found that Nakhornsithummarat coastal line. The species were: 4 genera, 5 species of Chlorophyta, 5 genera, 7 species of Phaeophyta and 4 genera, 7 species Rhodophyta.

Pengseng (1992) studied species composition of the benthic marine algae at Ao Phe, Rayong Province. It was investigated by monthly collection for 12 months from April 1991 to March 1992. Forty- five genera, and 67 species were found growing on rock, gravels, dead corals, shells, sand and other seaweeds. Among these, 34 genera and 47 species were found in this study and 43 genera and 62 species were previously reported. They were: 3 genera, 3 species of Cyanophyta, 11 genera, 13 species of Chlorophyta, 7 genera, 13 species of Phaeophyta, 13 genera and 18 species of Rhodophyta. The greatest abundance was observed during April to September 1991. The most common genera were *Enteromorpha, Neomeris, Padina, Sargassum, Hypnea* and *Acanthophora.*

Effects of Physical Factors on Seaweeds

The major environmental factors affecting intertidal organisms including seaweeds are wave motion, nutrient availability, light, temperature and salinity (Lobban and Harrison, 1994; Nybakken, 2001). These physical factors are known to affect diversity, abundance, distribution and variation in morphology of marine algae (Kilar and McLachlan, 1986a, 1986b; Cecere *et al.,* 2000; Cecere and Perrone, 2002) and various marine organisms (Levinton, 2001; Boaventura *et al.*, 2002).

Wave motion affects macroalgae in three ways: 1) The velocity and acceleration of the fluid impose forces on plants. In areas of rapid water motion, these forces are substantial and may even break the plant or dislodge the holdfast. 2) Metabolism requires that inorganic nutrients and CO_2 be taken up from the water surrounding the plant and that wastes be expelled into the water. If the water is not moving, nutrients may become saturated, the rate of diffusion sets a limit to the rate at which metabolic processes may occur. This limit is increased substantially if the water is moving relative to the plant. 3) Many species of macroalgae depend on water movement to transport gametes and to disperse spores and propagules. The movement of water not only affects how far and in what direction spores will disperse, but may also determine which areas are hydrodynamically suitable for settlement (Littler and Littler, 1985). Wave exposure has been shown to play a significant role in seaweed community composition, specifically in relation to diversity and species richness. (Dí ez *et al.,* 2003).

Nutrients are a limiting factor for seaweeds (Lobban and Harrison, 1994). Nitrogen and phosphorus are the most important and are often the limiting factor in the growth of seaweeds and phytoplankton. After nitrogen (nitrate and ammonium forms) is taken up, it is usually used to synthesize amino acids and proteins for growth. Phosphorus plays key roles in the formation of many biomolecules, such as nucleic acids, proteins, and phospholipids (the latter are important components of membranes). However, its most important role is in energy transfer through ATP and other high-energy compounds in photosynthesis and respiration and in "priming" molecules for metabolic pathways. Experimental study on nutrients by Karez *et al*. (2004) showed that the composition of the ephemeral assemblage changed with nutrient richness. Therefore, nutrients can play an important role in the biodiversity, abundance and distribution of seaweeds.

Light and temperature are important abiotic factors affecting plants. The primary importance of light to seaweeds is in providing the energy for photosynthesis (Lobban and Harrison, 1994). Also, light controls the formation of tetrasporangia in the tetrasporophytes of some seaweeds (Guiry, 1992), among its many other physiological effects. Temperature is a singularly important factor governing the life processes and the distribution of organisms. Marine organisms are extremely susceptible to desiccation due to exposure to high temperatures (Nybakken, 2001). This especially affects intertidal organisms, which have evolved mechanisms to counteract the effects of desiccation. Often there will be temperatures at which growth is optimal, although these may vary with different life cycle stages. Therefore, water temperature influences growth (Kubler Dudgeon, 1996), abundance and distribution of some seaweeds (Gordon Guist *et al.*, 1982; Peckol, 1983; North *et al.,* 1986; Guiry, 1992; Kubler and Dudgeon, 1996; Scrosati, 2001).

The most important effects of salinity are the osmotic consequences of the movement of water molecules along water-potential gradients and the flow of ions along electrochemical gradients. It has been shown that salinity changes may control distribution of the seaweed *Macrocystis* (North *et al.,* 1986).

Acanthophora* and *Chondrophycus

Preliminary study showed that *Acanthophora spicifera* and *Chondrophycas tronoi*, which have a wide distribution in both tropical and subtropical habitats, occurs primarily in the tidal and subtidal zones, are also dominant at Sirinat Marine National Park, Phuket. *A. spicifera* is an economic species. They are used for abalone feeding, which increases abalone growth and survival rate (personal communication). *C. tronoi* contains rich secondary compounds and very common on this shore (Prathep, 2005). In addition, there are some other interesting characters of both species. Fragmentation is a significant mode asexual reproduction of *A. spicifera*. It increases their distribution on the shore. Its branching pattern and number of branches vary with the amount of wave exposure (Kilar and McLachlan, 1986a). In addition, Gupta *et al.* (1991) discovered antimicrobial activity in *A. spicifera*.

Saito (see Saito and Womersley, 1974) divided the Japanese species of *Laurencia* Lamouroux into two subgenera: *Laurencia* and *Chondrophycus*. 1) *Laurencia* has secondary pit-connections between the epidermal cells and parallel arrangement of tetrasporangia, while *Chondrophycus* lacks such secondary pit-connections between epidermal cells and has a right-angle (cruciate) arrangement of tetrasporangia. 2) *Chondrophycus tronoi* was known as *Laurencia tronoi* Ganzon-Fortes (1982) subgenus *Chondrophycus*, *Laurencia* subgenus *Chondrophycus* was recently raised to generic status as *Chondrophycus* (Tokida *et* Saito) Garbary *et* Harper (see Nam, 1999). Previous studies have focused on secondary metabolites of

Laurencia spp.; the chemical compounds produced by this species (Masuda *et al.,* 1997; Masuda *et al.*, 2002; Takahashi *et al.*, 1998).

Both *Acanthophora* and *Chondrophycus* are invasive marine algae in Hawaii. These two species have been studied extensively at the University of Hawaii (ALIEN-HOME.htm; http://www.botany.hawaii.edu/invasive). Therefore, it also would be interesting to study branching pattern and reproductive cycle of both species here in Thailand since they are potential economic species and common on the shore.

Hypotheses

1. Differences in physical factors seasonally cause differences in diversity, abundance and distribution of macroalgae.

2. Differences in wave action cause differences in morphology of *Acanthophora spicifera* and *Chondrophycus tronoi*.

Objectives

The purposes of this study are to:

1) Assess the biodiversity of macroalgae at Sirinat Marine National Park, Phuket.

2) Study the effects of physical factors (wave motion, nutrient concentrations: NO_3^-, PO_4^{3-}, salinity, temperature, light) on diversity, abundance and distribution of macroalgae.

3) Compare morphology of *Acanthophora spicifera* and *Chondrophycus tronoi* at different degree of wave exposure sites.