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Reproductive Dynamics of the Seagrass *Thalassia hemprichii* (Ehrenberg) Ascherson in Iligan Bay

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ABSTRACT

A study on the reproductive dynamics of the dugong grass, *Thalassia hemprichii* (Ehrenberg) Ascherson was carried out on the seagrass meadows of Tubajon, Laguindingan and Poblacion, Naawan, Misamis Oriental, and Danlugan, Lopez Jaena, Misamis Occidental from February to May, 2005. Age reconstruction technique through the analysis of leaf scars along the vertical rhizomes indicated that the flowering frequency of *T. hemprichii* is once every two years. The first flowering occurs between 1.5 to 2 years based on the presence of flower scars on vertical rhizomes. The average leaf plastochrone interval (LPI) on the shoots of *T. hemprichii* across sites was 6.4 days. The estimated biomass allocated to flowering ranged from 0.5 to 0.72 g DW m^{-2}. Spatial differences in the morphology of flowers and fruits of *T. hemprichii* were observed across stations in the three study sites. The average number of fruits during peak reproductive season ranged from 5.5 to 6.2 m^{-2}, with an average number of 2.0 to 2.6 seeds $fruit^{-1}$. These results indicate that the sexual reproduction of *T. hemprichii* is active and its capacity to provide new recruits from seedlings is relatively high.

Key words: Age reconstruction, flowering frequency, leaf plastochrone interval, recruits.

INTRODUCTION

Seagrasses are submerged marine angiosperms found mostly in all coastal waters of the world except in the Antarctic (Den Hartog, 1970). About 60 species of seagrasses have been recorded worldwide (Kuo and McComb, 1989; Den Hartog, 1970), 16 species of which are reported to occur in the Philippines. Seagrass beds are recognized world-wide for their economic and ecological importance. They help reduce current and wave energy, filter suspended sediments from water, and stabilize bottom sediments (Fonseca and Cahalan, 1992; Fonseca, *et al.* 1982) and serve as primary producers, habitats, shelters and food for fishes and marine invertebrates, many of which are economically important. Seagrass ecosystems in the ASEAN region, however, are threatened by both natural and human-induced disturbances and their physical loss is at ever increasing rates (Short, *et al.*, 1988; Short and Wyllie-Echeverria, 1996; Rollon, 1998). Along Philippine coasts seagrass losses are largely due to destructive fishing methods and increasing pollution and siltation (Fortes, 1990).

Seagrasses have been studied quite extensively in several bio-geographical regions, particularly in temperate zones (Den Hartog, 1970; Hemminga and Duarte, 2000). Reproductive dynamics of seagrasses in tropical areas have been rarely investigated, particularly on the aspects of (1) the reproductive capacity, (2) fruit and seed production potential, (3) age at first maturity and (4) flowering frequency. These important aspects of seagrass dynamics have been studied by earlier researchers in the Caribbean region (Tomasko and Lapointe, 1991; Gallegos, *et al.*, 1993; Tussenbroek, 1996) and Spanish Mediteranian (Marba, *et al.*, 1994). Related studies in the tropics were conducted in Kenya (Duarte *et al.*, 1996), Indonesia (Erftmeijer, 1993) Bolinao, Pangasinan, Philippines (Vermaat, *et al.*, 1995; Duarte, *et al*., 1994) and Negros in Central Philippines (Biyo, *et al*., 2001). The present study aims to elucidate the reproductive dynamics of the dugong grass, *Thalassia hemprichii,* in selected sites of Iligan Bay in terms of flowering intensity, flowering frequency, fruit and shoot morphology, and age at first maturity. These are vital information that would be useful in developing management strategies for conservation of seagrass resources in the country.

MATERIALS AND METHODS

The study was conducted from February to May 2005 in the seagrass meadows of the coastal municipalities of Laguindingan and Naawan, Misamis Oriental and Lopez Jaena, Misamis Occidental (Fig. 1). The areal extent of the seagrass meadows in every station was determined using a Global Positioning System (GPS). Three stations in every site were established to represent the shallow, exposed areas during low tide (S_1); submerged seagrass beds with depth of 30 cm (S_2); and the deeper parts with depths greater than 60 cm (S_3).

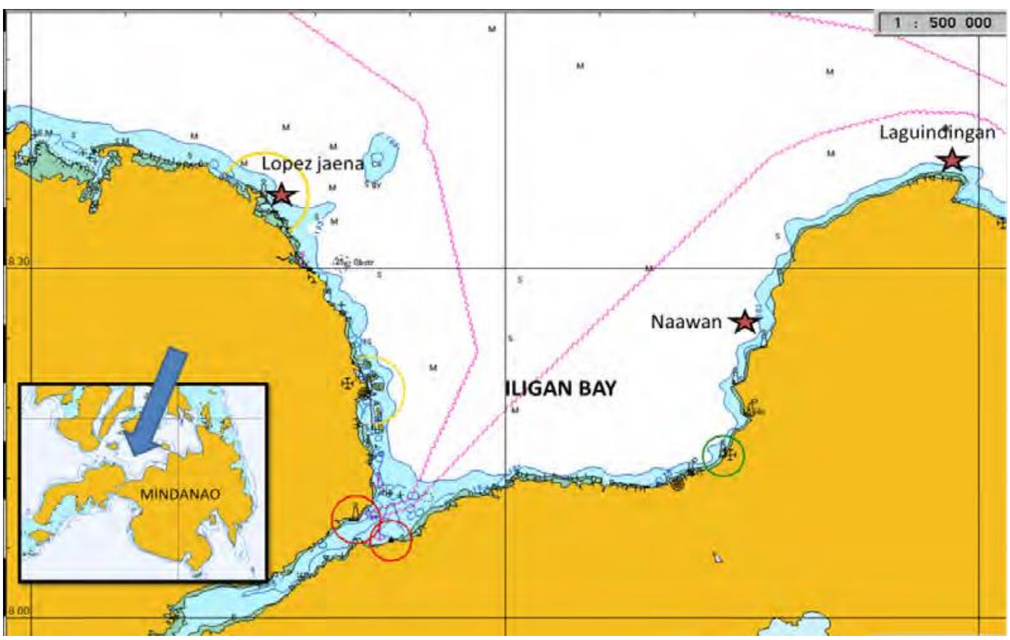

Figure 1. Map of Iligan bay showing the location of the three study sites.

Flowering shoot density

Sampling to determine shoot density of flowering *T. hemprichii* was conducted during the peak reproductive period (based on monthly observations made from 2003 to 2005) on February 2005 in all sites while collection of mature fruits was done in May 2005. Sampling was done by throwing quadrats (0.5 x 0.5m) randomly 20 times in the seagrass meadow in every station during low tide. The shoot density of the *T. hemprichii* was estimated by counting the number of standing shoots within the 0.25 m^2 quadrat. All shoots of *T. hemprichii* bearing flowers and fruits found inside the quadrat were collected, placed in plastic bags with appropriate labels, and brought to the MSU at Naawan research laboratory for morphological analysis and biomass estimation.

Shoot morphology and flower biomass

In the laboratory, all harvested male and female flowering shoot samples were cleaned carefully by removing the sediments and other debris. After washing in tap water, samples were wrapped with aluminum foil, labeled, placed in an aluminum tray and oven-dried for 48 h at 50-60^0C. Desiccation process after oven-drying followed within two to three days to get the constant weight expressed as in g DW m^{-2}. Morphological attributes (i.e., age, shoot height, stem height, leaf width, number of leaves, flower peduncle height, number of flower scars) of the flower-bearing shoots were determined and compared across stations and study sites.

The flowers, oven-dried to constant weight (DW), were held in a porcelain crucible and placed in a muffle furnace (Barnstead Thermolyne) set at 555^oC for combustion for about five hours, afterwards, the remaining material in the crucible was weighed in a Sauter analytical balance. The ash free dry weight (AFDW) of each sample was then obtained by subtracting the weight of remaining material from the DW of the sample (Kendrick and Lavery, 2001).

Morphology and biomass of fruits and seeds

In the laboratory, the morphology of *T. hemprichii* shoots where the fruits were attached was characterized by measuring the shoot height, stem height, leaf width, number of leaves, number of flower scars, number of fruits and presence of new flowers. The age of each shoot was estimated by counting the number of leaf scars then multiplying this by the leaf plastochrone interval (LPI).

The fruits *T. hemprichii* were washed and cleaned by removing the sediments and other attached particles then all the seeds and pericarp of the fruits were weighed using a digital weighing scale. The length and width of seeds were measured to the nearest mm using a vernier caliper. Fruit morphology parameters (i.e., fruit width, fruit height, stylar beak length, fruit peduncle height, number of seeds) were carefully measured and recorded to establish comparative differences across stations. All the seeds of each capsule or pericarp were separated then their sizes (i.e. height and width) were measured using a vernier caliper. Wet weight of each seed was taken using a digital weighing scale and then oven-dried for at least 48 h at 50-60^oC to constant weight.

Leaf plastochrone interval (LPI) determination

Leaf plastochrone interval is the period of time needed to produce two successive leaves. The LPI of *T. hemprichii* was determined by leaf marking technique described in Uy (2001) continuously from August 5 to September 10, 2004. A total of 20 shoots occurring at different depths in the three study sites were marked by tying a colored ribbon around the stem of each shoot. The end of the youngest leaf of each marked shoot was clipped so that the new leaves formed during the observation period could be identified. The marked shoots were collected after 1-2 weeks, and the number of new leaves produced during the marking period was determined. Leaf plastochrone interval (LPI) was determined using the following equation (Duarte, *et al.*, 1994; Vermaat, *et al.*, 1995):

Shoot age reconstruction

Ten shoots of *T. hemprichii* with long vertical rhizomes were collected from each site The growth history of each rhizome was reconstructed from the scars left by abscised leaves and flowers on the long-lived rhizome or the seasonal signal imprinted in the flowering and size of their modules. Age reconstruction of all the shoots was determined with the aid of a dissecting microscope and a magnifying lens. Shoot age was estimated based on the number of standing leaves plus the number of leaf scars on the shoots. The inverse of the number of internodes in a cycle (number of leaves yr^{-1}) corresponds to the annual average leaf plastochrone interval and was used to convert LPI values into absolute time units (days)

Determination of age at sexual maturity and flowering frequency

The age at sexual maturity of *T. hemprichii* shoot, or its age at the first time of flowering, was determined from the shoot samples used in age reconstruction and from shoots bearing flowers which were collected from sampled quadrats in the study sites. The age of a shoot at flowering is determined from the number of leaf scars from the peduncle scar up to the insertion of the shoot on the horizontal rhizome (Duarte, et al., 1997). With known LPI values converted into the number of days, age at sexual maturity was determined by counting the nodes from the insertion of the vertical stem into the horizontal rhizome up to the first flower scar. The succeeding number of flower scars or remnants of flower peduncles on the stem was also counted to determine the past flowering events initiated on the shoot. The age at flowering of *T. hemprichii* is easy to determine as this seagrass has differentiated vertical stems and horizontal rhizomes (Duarte, et al., 1994). Shoot age minus age at the time of flowering equals the time elapsed since flowering.

Physico-chemical parameters

Some environmental factors were considered in this study since they influence and largely contribute to the health of the seagrass community. Environmental parameters such as water temperature, salinity, and water depth during lowest tide were measured *in situ* while soil and water samples were collected and brought to the laboratory for nutrient analysis. Soil nutrient analyses included determination of organic matter content using calorimetric method, total nitrogen content using modified Kjeldahl wet digestion method, and soil phosphorus using the modified Truog method (Chang, 1966). Analysis of water nutrients included nitrite (NO_2-N) and nitrate (NO3-N) using Cadmium method and phosphate analysis using the stannous chloride method (Jackson, 1958). Sediment grain sizes ranging from 1.7 mm to 75 *u*m were also analyzed using the ASTM standard sieve method (Jackson, 1958).

Data management and analysis

Data on flower and fruit production, flowering frequency, and seed production potential of the dugong grass *T. hemprichii* in the study sites were subjected to an analysis of variance (ANOVA) available in the SPSS statistics package (ver. 7.0). Significant results were further subjected to Tukey's Honest Significant Difference (HSD) test to determine the source of variation at 5% level of significance.

RESULTS AND DISCUSSION

The mean shoot density of *T. hemprichii* ranged from 251.5 to 860.7 shoots m^{-2} with the highest value obtained in the deep station of Laguindingan (Table 1). Estimates of shoot densities of *T. hemprichii* in this study are comparable to those reported by Arriesgado (2000) in Laguindingan station (453 shoots m^{-2}) and by Azkab (1989) in Indonesia (485 $\pm$191 m^{-2}). These results imply that shoot densities of *T. hemprichii* in the three areas of Iligan Bay can be reliably used to estimate their standing crop.

Table 1. Comparison of average shoot density (shoot m^{-2}) in all stations.

Study Site	Station	February, 2005		May, 2005	
	Depth (cm)	Mean	S.E.	Mean	S.E.
Laguindingan	Exposed (0)	287.89	83.42	482.37	43.12
	30	317.74	80.6	523.38	63.36
	60	631.36	90.18	860.66	19.88
Naawan	Exposed (0)	667.56	54	344.31	26.09
	30	–	–	–	–
	–	–	–	–	–
Lopez Jaena	Exposed (0)	671.41	42.85	634.52	43.58
	30	290.55	13.81	263.78	18.57
	60	251.47	11.93	280.08	11.99

Flower biomass production and flowering frequency

Annual flower biomass production of *T. hemprichii* in the three sites ranged from 0.52 to 0.86 g DW m^{-2} (Table 1), with the lowest biomass obtained at Laguindingan and the highest in Lopez Jaena. The maximum biomass of *T. hemprichii* was obtained in Lopez Jaena (0.50 g AFDW m^{-2}), while the minimum was in Laguindingan (0.33 g AFDW m^{-2}). Low flower biomass production of *T. hemprichii* in all areas indicates that its sexual reproduction is a negligible component in carbon allocation involving less than 10% of the annual production for most species (Ramage and Schiel, 1998; Olesen, 1999).

Table 2. Annual average flower biomass (±SE) and Ash free dry weight (AFDW) of *Thalassia hemprichii* in the three study sites.

Study Site	BIOMASS ($g\ DW\ m^{-2}y^{-2}$)	AFDW ($g\ m^{-2}y^{-2}$)
Laguindingan	0.52± .05	0.33 ± 0.02
Naawan	0.59	0.48
Lopez Jaena	0.86 ± 0.03	0.50 ± 0.13

About half of the ten long shoot samples of *T. hemprichii* examined in Laguindingan and Naawan and 60% of the shoots examined in Lopez Jaena had flowered once. Some shoots from Lopez Jaena had produced flowers twice with an average flowering interval of 362 days. The mean flowering frequency of *T. hemprichii* (0.465 flowers $shoot^{-1}yr^{-1}$) in Iligan Bay is higher (Table 3) compared to that observed by Duarte, *et al*. (1997) in Silaqui Island in Bolinao, Pangasinan (0.125 flowers $shoot^{-1}yr^{-1}$), and is comparable to flowering events commonly reported for the other seagrass species (Hemminga and Duarte, 2000), including congeneric species in the Caribbean and Mediterranian Seas where an average of 9.6% of the shoots flowered every year (Gallegos, *et al*., 1992). These low flowering frequencies imply that most of the shoots would die without ever producing a flower, since the median life expectancy of *T. hemprichii* shoot is only 230 days (Vermaat, et al., 1995) shorter than the average time needed for a shoot to produce a flower. The 9 months to 1 year maturation period of *T. hemprichii* to be able to flower is also in agreement with the observations on the other seagrass species (Gallegos et al., 1992).

Table 3. Flowering frequency of *Thalassia hemprichii* in all study sites.

Study site	No. of shoot samples	LPI (days)	Shoot age (days)	Mean no. of flower scars $shoot^{-1}$	Flowering frequency $shoot^{-1}$ yr^{-1}
Laguindingan	10	6.4	318	0.5	0.6
Naawan	10	6.4	566	0.5	0.3
Lopez Jaena	10	6.4	570	0.7	0.5

The male and female (Fig. 2) shoot ratios of *T. hemprichii* were 1:1, 2.1:1 and 2.4:1 in Laguindingan, Naawan, and Lopez Jaena, respectively. Higher frequency of male flowers suggests a higher flowering potential in *T. hemprichii* in Iligan Bay due to a higher probability of fertilization. Average shoot age of flower-bearing *T. hemprichii* ranged from 352 to 542 days, where the youngest shoot was found at 60 cm deep in Laguindingan, while the oldest shoot was in the exposed area of Lopez Jaena (Table 4).

Figure 2. Female (A) and male (B) flowering shoots of *Thalassia hemprichii.*

Table 4. Mean shoot morphology of flower bearing *Thalassia hemprichii.* Values with different superscripts in a column (across stations) in each site are significantly different (Tukey's P <0.05).

Study Sites	Station Depth/ (cm)	Age (days)	Shoot Height (mm)	Stem Height (mm)	Leaf Width (mm)	No. of Leaves	Male and Female Ratio
Laguindingan	Exposed (0)	475^{b}	127^{b}	42.6^{b}	7.0	6.2^{a}	1:2.6
	30	437^{b}	100.8^{a}	29.3^{a}	7.0	6.7^{b}	1:0.0
	60	352^{a}	105.5^{a}	28^{a}	7.2	7.1^{b}	1:1.7
	P value	0.002	0.001	0.001	0.509	0.001	
Naawan	Exposed (0)	405	95	34.1	4.8	3.9	1:0.5
Lopez Jaena	Exposed (0)	542^{b}	129.8^{a}	48^{a}	7.3^{a}	6.7	1:0.4
	30	431^{a}	153.8^{b}	42.8^{a}	8.6^{b}	6.8	1:0.5
	60	474^{ab}	170^{c}	58.3^{b}	9.3^{c}	6.7	1:0.3
	P value	0.001	0.001	0.001	0.001	0.390	

Shoot morphology

Shoot and stem heights of flower bearing *T. hemprichii* in Laguindingan and Lopez Jaena stations exhibit wide variations or "plasticity" (Table 4), with taller plants found in exposed areas of Laguindingan while occurring in deeper stations in Lopez Jaena. No significant difference in leaf width of the seagrass is observed in Laguindingan while leaf width in Lopez Jaena is significantly wider in the deep stations. The number of leaves on the shoots of *T. hemprichii* is significantly higher in the deeper stations in Laguindingan but do not vary significantly among stations in Lopez Jaena.

Fruit and seed production

The average fruit production of *T. hemprichii* in Laguindingan is higher than in Lopez Jaena (Fig. 3). No comparison was made for Naawan stations due to limited samples although a number of plots exhibit high density of fruiting shoots (Fig. 4). Across sites the average fruit production values per square meter per year are 6.2 $\pm$0.46, 7.0, and 5.5 $\pm$0.66 m^{-2} yr^{-1} while seed production of 16.5 $\pm$3.30, 13.8 and 13.3$\pm$0.31 m^{-2} yr^{-1} are estimated in Laguindingan, Naawan and Lopez Jaena, respectively.

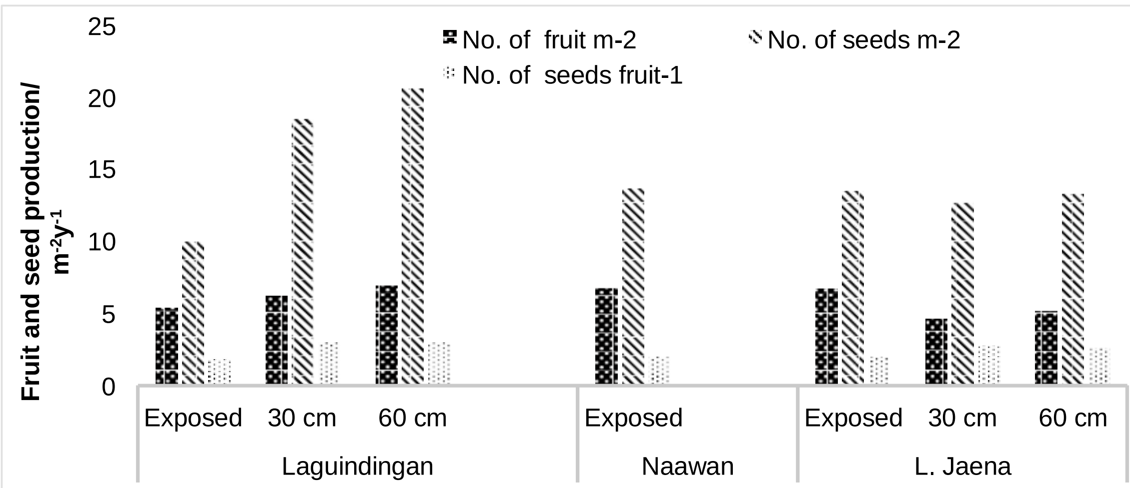

Figure 3. Comparison of fruit and seed density (m^{-2}) and number of seeds per fruit in *Thalassia hemprichii* across study sites in Iligan Bay

Figure 4. A. Sample from a plot with high density of fruit-bearing shoots of *T. hemprichii* collected in Naawan. **B.** *T. hemprichii* Seeds removed from the fruit capsule.

Table 5 shows the variability in fruit morphology across stations in each site (ANOVA; P<0.05). Fruit sizes of *T. hemprichii* tend to be bigger at moderate depths (30 cm) in Laguindingan, while the bigger fruit sizes in Lopez Jaena are generally found in deeper (60 cm) seagrass meadows. In both sites shoots in shallow, exposed seagrass beds have smaller fruits. Likewise, the number of seeds per fruit is generally lower in the exposed than in deeper areas of the seagrass ecosystem.

Table 5. Reproductive morphology of *T. hemprichii* in Iligan Bay. Values with the same superscript in a column among stations across sites are similar (ANOVA P < 0.05).

Study Site	Depth/ Station (cm)	Fruit Width (mm)	Fruit Height (mm)	Stylar beak Length (mm)	Fruit Peduncle Length (mm)	No. of Seeds $Fruit^{-1}$
Laguindingan	Exposed	13.8^{b}	13.2^{b}	3.1^{b}	18.7	1.9^{a}
	30	23.4^{c}	20.1^{c}	2.2^{a}	22.6	3.0^{b}
	60	11.2^{a}	10.8^{a}	2.6^{ab}	18.7	2.9^{b}
	P values	< 0.001	< 0.01	< 0.05	< 0.05	< 0.01
Naawan	Exposed	12.9	12.1	2.8	16.4	2.0
Lopez Jaena	Exposed	14.3^{a}	13.9^{a}	3.5^{b}	17.4^{a}	2.0^{a}
	30	18.0^{b}	16.5^{b}	2.7^{a}	30.1^{b}	2.8^{b}
	60	18.1^{b}	15.7^{b}	3.2^{b}	32.8^{b}	2.6^{ab}
	P values	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

The mean fruit production (seeds plus pericarp) values of the *T. hemprichii* in the three study areas are presented in Table 6. The mean weight of the seeds, when combined with the mean weight of the pericarp, is equal to the total fruit biomass of *T. hemprichii.* Fruit biomass is similar across the three study sites in Iligan Bay (Table 6), however, estimates of annual production by area are higher in the extensive seagrass ecosystems of Laguindingan and Lopez Jaena than in the narrow reef flat of Naawan.

Table 6. Comparison of individual fruit and areal biomass of *T. hemprichii* in Iligan Bay.

Study Site	Seeds (g DW m^2)	Pericarp (g DW m^{-2})	Fruit biomass (g DW m^{-2})	Area production (ton DW yr^{-1})
Laguindingan	1.56+0.29	1.14+0.16	2.70	2.40
Naawan	1.25	1.01	2.30	0.04
Lopez Jaena	1.46+0.06	0.90+0.02	2.40	2.16

Leaf plastochrone interval (LPI) of *T. hemprichii* did not vary across study areas with an average value of 6.4 days. The LPI values obtained from the three sites are comparable to the works of Arriesgado (2000) and Uy (2001) in Laguindingan. De Guzman *et al.*, (1994) obtained LPI value of 12 days for *T. hemprichii* in Initao Marine Park while Uy and de Guzman (1992) reported an LPI of 9.5 days in Panguil Bay (adjacent to Iligan Bay). Estimated LPI values in this study suggest that shoot growth of *T. hemprichii* in Iligan Bay is relatively faster that in other areas in the Philippines such as Bolinao, Pangasinan (Vermaat *et al.*, 1995) and Guimaras, Iloilo (Biyo, *et al.* 2001).

The vertical internode length of *T. hemprichii* in the three study areas showed annual cycles indicating seasonal changes in vertical growth (Fig. 5), however, no definitive pattern of growth and flowering is observed for Laguindingan and Naawan. A seasonal pattern in *T. hemprichii* in Lopez Jaena, on the other hand, is apparent with peak growth during the cold months of the year from November to January. Durations of LPIs can exhibit considerable spatial and temporal variability resulting from environmental influences (Durako and Moffler, 1987), and that interannual variability in LPI's is usually much smaller than seasonal variability (Duarte, et al. (1994). Leaf PI estimates for *T. hemprichii* in Iligan Bay can, therefore, be reliably used to reconstruct the life history of this species in order to assess population loss or gain in the area.

Age at sexual maturity

The average ages at sexual maturity of *T. hemprichii* are the same between Laguindingan and Lopez Jaena (Table 7) but slightly different from Naawan. Based on the average LPI value (6.4 d) in the present study, it would take one year for *T. hemprichii* shoots to flower in the first two sites, while it will take only 0.7 years (or 8.4 months) to mature in Naawan. The flowering intervals observed in the three sites (Table 7) indicates that if the life expectancy of *T. hemprichii* shoots would extend to two years, the shoots may flower three times.

Table 7. Age at sexual maturity of *Thalassia hemprichii* in Iligan Bay.

Study site	No. of Shoots with flower scars	Age (years)	Mean No. of Days Flowering interval
Laguindingan	148	1.00	262.90
Naawan	146	0.70	201.60
Lopez Jaena	248	1.00	268.40

Repeated field observations (in the years 2003, 2004, 2005, and 2006) have noted that *T. hemprichii* shoots start to flower in February and peak in the middle of March. Fruiting follows after two months and peaks around the middle of May. It is likely that flowering peaks in this period because the sea is calm, the temperature is stable, and sunlight is abundant - all favorable factors for reproductive activity in *T. hemprichii.* Due to the limited life span of *T. hemprichii*, flowering intervals are rarely observed on the shoots. Vermaat, *et al.* (1995) reported that the life expectancy of *T. hemprichii* is 230 days, shorter than the average time needed for a shoot to produce a flower. This observation implies that most shoots die without producing flowers. The evidence of a maturation period (0.7-1.0 year) necessary for the shoots of *T. hemprichii* to be able to flower is also in agreement with observations on other seagrass species (Gallegos, *et al.*, 1992).

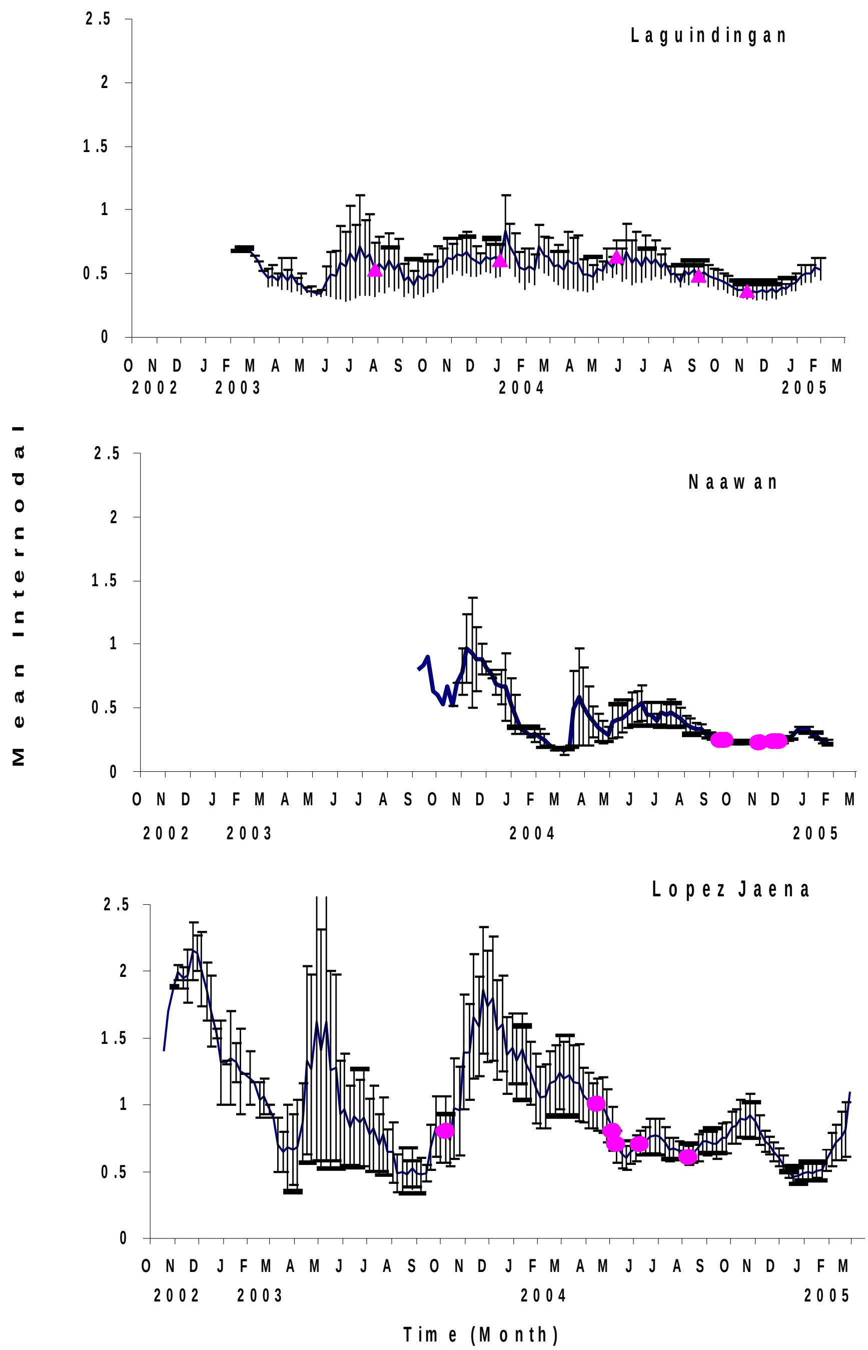

Figure 5. Seasonal variation in vertical internode length (mm) of *Thalassia hemprichii* shoots collected in the three stations in Iligan Bay. Error bars are standard errors of 10 samples.

MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

The study on the reproductive dynamics of the dugong grass, *Thalassia hemprichii* (Ehrenb.) Aschers. was carried out during peak flowering and fruiting period in the seagrass meadows of Laguindingan and Naawan of Misamis Oriental, and at Lopez Jaena, Misamis Occidental from February to September 2005. Results indicate that abundance and reproductive patterns, in terms of flowering and fruiting, in *T. hemprichii* plants exhibit spatial and geographical variabilities. These are important information in understanding the population dynamics of this seagrass and would be useful inputs to formulating an ecologically sound, and management program for the seagrass ecosystems of Iligan Bay.

Among the recommendations of this study are 1) designing and implementing site-specific conservation strategies, taking into consideration the uniqueness of each site; 2) launch a continuing Information, Education and Communication (IEC) campaign which builds on community and multistakeholder participation; and 3) carry out investigation of reproductive dynamics of *T. hemprichii* in equally important seagrass ecosystems to build up the database for this species. The methods used in this study are easy to replicate, e.g., morphological examination of reproductive features and age reconstruction in combination with the leaf marking technique. These tools can be useful in describing the reproductive dynamics of *T. hemprichii* in other sites or of other seagrass species.

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