The population dynamics of *Enhalus acoroides* in the coastal waters of Waai Village, Central Maluku District, Indonesia

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Abstract. The coastal waters of Waai village contain seagrass ecosystems. Visually, these waters substrate consist of sandy, muddy, rocky and dead coral reefs substrates, allowing them to be overgrown by different types of seagrass. This research aimed to obtain information about the population dynamics of *Enhalus acoroides* covering age (cohorts), rhizome growth rate, mortality rate, the recruitment rate and the physical-chemical conditions of the coastal waters of Waai village. The results of this research showed that the population of *E. acoroides* in the sampling period I consisted of 7 cohorts, whereas in the sampling period II and III, each consisted of 8 cohorts. The estimation of the growth rate was 0.01 mm year^{-1} with a maximum length of 28.773 mm and the asimptot length 31.97 mm. The estimation of the mortality rate of *E. acoroides* ranged from from 0.04-0.06 year^{-1} with a mean of 0.05 year^{-1}. The highest recruitment rate was of 1,087.81 stands year^{-1} and occurred in August with a frequency of 30.05%, while the lowest recruitment rate was of 44.16 stands year^{-1} which occurred in January with a frequency of 1.22%. Seagrass growth in the coastal waters of Waai Village is facilitated by the environmental conditions, with the following values: maximum percentage of very coarse sand grains (30.70%); average temperature of 28.30^{0}C; average salinity value of 28.67‰; average dissolved oxygen value of 5.71 ppm; average nitrate content value of 0.94 ppm and average phosphate content value of 0.53 ppm.
Key Words: seagrass, recruitment, asimptot, sand grains, environmental conditions.

Introduction. Seagrass bed is one of the ecosystems located in coastal areas or shallow marine waters where the entire body is able to adapt to life in the sea (Nontji 2005). The seagrass community exists between the lowest tidal boundaries and a depth where the sunlight still can reach the bottom. Economically, seagrass can be used as food, animal feed, paper raw material, craft materials, fertilizer and medicine materials. Ecologically, seagrasses protect waters from erosion and play an important role in shallow sea waters, as components of fish and primary producers' habitats (Fachrul 2007).

Research studies on population and growth structure have been widely conducted on animals, but not sufficiently on plants. Research on population structure and growth in animals has been carried out by several researchers, while for plants information is rarely found. Research has been carried out on the population structure and growth in *Cymodocea nodosa* by Duarte & San-Jensen (1991), Azkab & Kiswara (1994), and Cunha & Duarte (2005). Also, Hulopi et al (2006) conducted a study on the population structure of *Cymodocea rotundata* seagrass species on different substrates in the waters of Suli Ambon Island. Further research was conducted on the population structure of *C. rotundata* seagrass species in Suli waters by Tupan & Uneputty (2008). For plants, the measurements can be performed by measuring the length of leaves, the length of rhizomes, the number of leaves and the number of flowers and roots. This study focused on the increase in length of rhizome, which provides information on the seagrass growth, also predicting the age group, recruitment rate and mortality rate of the seagrass.

Waai Village is one of the coastal waters with a dense community of seagrasses that directly or indirectly contributes to the local community For instance, *Enhalus acoroides* is a type of seagrass with a high productivity, which provides, besides economic value, a habitat for various species of fish, crustaceans and mollusks, a natural barrier to the coastal erosion and a mechanism for nutrients cycling (Dahuri 2003; Castro & Huber 2005). The uncontrolled exploitation of the coastal area by removing sand and stone and by disposing solid and liquid waste can damage the coastal ecosystems including seagrass. If the quality of the environment degrades, the productivity of the seagrass ecosystem will also decrease, including all animal associated populations (Rijal et al 2014). This irrational exploitation is often caused by the lack of biological information on the seagrass ecosystem, such as growth, age, recruitment and mortality. Therefore, information is very important to be given to the community in order to preserve nature, including the seagrass ecosystem.

Material and Method. The research was conducted in the coastal waters of Waai Village in Central Maluku district from April to December 2017, comprising several stages described below.

Sampling of seagrass plants. The sampling of the seagrass plants used the quadratic linear transect method. The transect line was drawn perpendicular to the shoreline seaward. This was done when the sea water subsided by referring to the tidal. The distance between transects was 20 m. Along the transects, there were installed iron squares with the size of 1 x 1 m with the distance between squares 10 m. In each of the squares, *E. acoroides* samples of seagrass were collected.

Sediment sampling and sea water. The sediment sampling in the research area was done randomly along the transects and collected in a plastic bag that had been labeled in accordance to the observation transect. After that, the sample was analyzed for the sediment grain size. In addition, the aquatic physical-chemical parameters at the research area were also measured. The salinity was measured by using a hand refractometer, the temperature was measured by using a thermometer, and the dissolved oxygen was measured by using DO meter of Hanna brand. The seawater samples were taken by dipping a dark colored glass bottle near the sediment, in order to determine the nitrate and phosphate content of the waters

Identification of seagrass plants. The seagrass species found were identified based on the study of Kuo & Hartog (2001). The substrates still attached to the stand of seagrass were cleaned and then there were counted: the number of stands, the number of internode, the number of leaves, the number of flowers (if any), the number of dead roots were counted and the length of rhizomes between stands.

Sediment and sea water samples. In the laboratory, the sediment samples which had been dried were weighed by using a digital scale and then they were sieved by using *an* automatic sieve shaker. Subsequently, the sieve samples were weighed again according to the retained grain size, based on the Wentworth scale (Hutabarat & Evans 1985). The analysis of the sediment grain size was carried out at the Aquatic Resource Management Laboratory of Fishery Faculty of Pattimura Ambon University.

Rhizome frequency distribution. The length data for the *E. acoroides'* rhizomes were collected during the sampling, and then organized into a frequency distribution table. The estimates of the frequency distribution referred to the formula proposed by Riduwan (2005):

$$C = \frac{(xn - xi)}{k}$$

Where:
C-value of class interval;
X_n-longest rhizome;
X_i-shortest rhizome;
k-number of classes.

To obtain the number of classes (k), the Sturges rule was used (Riduwan 2005):

$$k = 1 + 3.322 \log n$$

Where:
n-total number of rhizomes measured.

The table of length frequency is used to estimate the average value ($\overline{X}$) and the sample standard deviation (SD) with the equation proposed by Connel & Miller (2006) as follows:

$$X = \frac{\left(\sum fiXi\right)}{n}$$

$$SD = \sqrt{\frac{\sum fi\left(Xi - \overline{X}\right)^2}{n-1}}$$

Where:
$\overline{X}$ -average of samples;
f_i - the frequency of the-i class;
X_i-the middle of the-i class;
n-total number of samples;
SD-standard deviation of sample.

To determine the *E. acoroides* population structure by age groups (cohorts) based on the rhizomes length, the Bhattacharya (1967) method was used. According to this method, an algorithm was developed as a software program by Sparre & Venema (1992), under the name FISAT.

Rhizome growth rate. To determine the rhizome growth of *E. acoroides* seagrass was analyzed through a Von Bertalanffy growth model (Khouw 2008) fed with the distribution data of the length frequency of rhizomes, which were then analyzed using the FISAT II software program (version 1.2.2).

$$St = S_\infty \left[1 - e^{-k(t-to)}\right]$$

Where:
St-length of rhizome at time t;
S_∞-length of asymptotic rhizomes (infinite);
K-growth rate;
to-age when the size of the rhizome is equal to zero;
t-age at the time of growth bending.

The maximum length of the rhizome was calculated using the following formula (Khouw 2008):

The maximum length = 0.9 x length of asymptotic rhizomes

Recruitment rate of rhizome. The recruitment rate of stands was estimated based on Cunha & Duarte (2005) as follows:

$$Rgross = \ln \sum_{t=0}^{\infty} Nt - \sum_{t=1}^{\infty} Nt$$

$\sum_{t=0}^{\infty} Nt$ = Number of initial stands

$\sum_{t=1}^{\infty} Nt$ = The number of stands at time t

The calculation of the recruitment rate was performed based on the distribution of rhizome length frequency by using the "Converted Length Catch Curve" function available in the FISAT II software program (version 1.2.2).

Mortality rate of rhizome. The mortality rate was calculated based on the exponential decrease of the number of dead stands and provided estimates of the characteristic mortality rate (Cunha & Duarte 2005):

$$N_t = N_0\, e^{-Mt}$$

Where:
N_0-number of initial stands;
N_t-the number of stands at time t;
e-exponential;
M-constant mortality;
t-time.

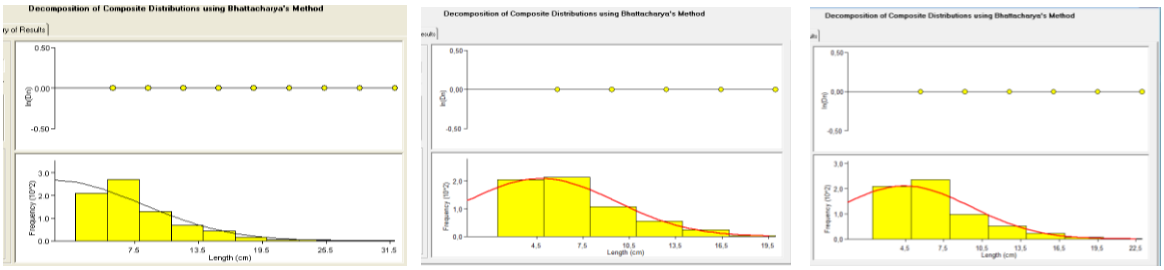
The calculation of the mortality rate was analyzed based on distribution of rhizome length frequency by using the "Converted Length Catch Curve" function available in the FISAT II software program (version 1.2.2).

The effect of nutrient on rhizome growth. In order to find the rhizome growth of seagrass and its relation with nutrient element, namely phosphate and nitrate, the Microsoft Excel multiple linear regression statistical analysis was used, with the general equation:

$$\hat{Y} = a + b_1x_1 + b_2x_2$$

Where:
$\hat{Y}$-the average length of rhizomes;
a-constants ;
b_1, b_2-regression coefficient ;
x_1-nitrate;
x_2-phosphate.

Results. Population structure analysis determined cohorts (sub-populations), using frequency and middle class length data obtained from the rhizome measurement of *E. acoroides.* The FISAT II program shaped the age group distributions for the three sampling periods were (Figure 1).



Sampling Period 1 | Sampling Period 2 | Sampling Period 3

Figure 1. Normal curve length frequency distribution of rhizome of *Enhalus acoroides* FISAT II program results.

The clearer peaks of the normal distribution correspond to the young seagrass, whereas for the aged plants peaks are not clear. In addition to shaping the normal curve which describes the age groups, the Bhattacharya method, in FISAT program, can also show the average value, standard deviation and number of stands of each age group (Table 1).

Table 1
Estimates of the Total Age Groups of *Enhalus acoroides* seagrass results from FISAT II program

Sampling	*Number of cohorts*	*Average length (mm)*	*Standard deviation*	*Population*	*Separation index*
I	1	0.14	8.36	1,863	n.a.
II	1	4.76	4.86	847	n.a.
III	1	4.45	5.19	910	n.a.

n.a.-not available.

The estimation results of the mortality rate based on the frequency distributions of the rhizomes length using the "Length-Converted Catch Curve" analysis on FISAT II program showed that the mortality rate of *E. acoroides* sea grass in coastal waters of Waai village ranged from 0.04 year^{-1} up to 0.06 year^{-1} with the average of 0.05 year^{-1} (Figure 2).

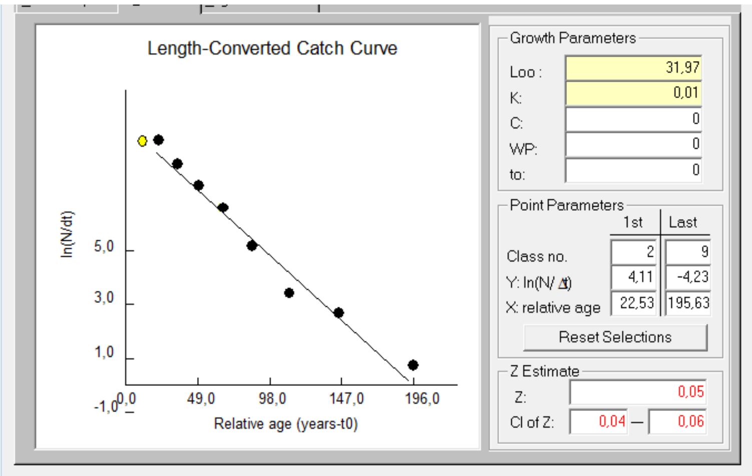


Figure 2. Estimated mortality rate curve of *Enhalus acoroides* seagrass in the coastal water of Waai Village.

The results of the frequency estimation of the rhizome recruitment of *E. acoroides* seagrass in coastal waters of Waai village for one year based on the frequency distributions of the length of rhizomes using the "Length-Converted Catch Curve" analysis on FISAT II program are presented in Table 2.

Table 2
The estimation of the relative recruitment rate of *Enhalus acoroides* seagrass in the coastal waters of Waai Village

Recruitment pattern	
Relative time	*Percent recruitment*
Month 1	1.22
Month 2	1.74
Month 3	4.25
Month 4	4.14
Month 5	6.35
Month 6	14.33
Month 7	10.35
Month 8	30.05
Month 9	13.24
Month 10	9.49
Month 11	4.85
Month 12	0.00

According to Cunha & Duarte (2005), flowers are associated with the internode, in that, the longer the internode, the longer the seagrass is within the substrate. Thus, the flowering rate will increase, if the vertical speed of rhizome also increases. In this research, the highest sediment percentage with very coarse grain size was 30.705 % (Figure 3).

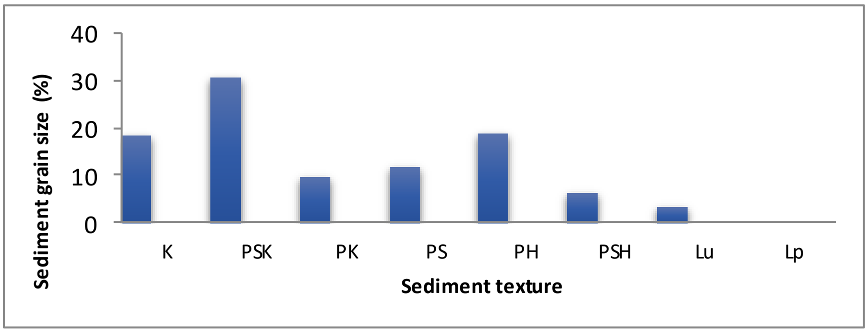


Figure 3. Percentage of sediment grain size on the coastal waters of Waai Village based on the Wentworth scale: K-gravel; PSK-very coarse sand; PK-coarse sand; PS-fine sand; PSH-very fine sand; Lu-silt; Lp-clay.

The analysis of the phosphate and nitrate content in the water column against the *E. acoroides* rhizome growth length, using multiple linear regressions, determined the regression equation (Telussa 2008):

$$Y = 7.289 - 0.187X_1 - 0.003\ X_2.$$

This condition shows that the nitrate (X_1) and phosphate (X_2) contents of the water are negatively correlated to the rhizome length growth (Y) of *E. acoroides* from the coastal waters of Waai village, which is confirmed by the low value (0.052) of the determination coefficient (R^2). Consequently, the contribution of the nitrate and phosphate nutrient contents to the rhizome length growth of *E. acoroides* is only of 5.2%.

Discussion. Sparre & Venema (1992) observe that the Bhattacharya method breaks the normal length-frequency distribution. The normal curve generated illustrates the age groups distribution in the studied population. Thus, it can be said that the population of *E. acoroides* that lives in the coastal waters of Waai Village in Central Maluku consists of only one age group, fact attributed to the ability of *E. acoroides* to reproduce both generatively and vegetatively. According to Dahuri (2003), seagrass can perform its pollination and generative cycle under water, having flowers and fruits which then develop into seeds. The plant blooms once a year in a relatively short period of time.

All the seed-producing flowers are the result of a single flowering of the same year and their growth is almost uniform, so that by the end of the year the length of rhizome is within a certain length range, but the distribution is normal (English et al 1997). The peak of the normal distribution can be differentiated from the peak of the length distribution for seagrass rhizomes, explained by the blooming or the seedlings in the previous year (Sahetapy 2004). According to Sparre & Venema (1992), the separation of two adjacent age groups is accurate if the separation index is more than two.

Based on the frequency distribution of the length of rhizomes, determined with the "Length-Converted Catch Curve" FISAT II function, the estimated growth rate of the rhizomes of *E. acoroides* seagrass in the coastal waters of Waai village is of 0.01 mm year^{-1}, reaching a maximum rhizomes length of 28.773 mm, while the length of its asimptot is 31.97 mm. This indicates that the vegetative growth of *E. acoroides* by the rhizomes is more frequent, although slower. Tjitrosomo (2001) also confirmed that vegetative reproduction is more common in plant species having parts contained in the substrate, such as rhizomes.

According to Cunha & Duarte (2005) the low growth rate of seagrass population is due to the slow growth rate of the rhizome. When the rhizome is in the process of forming a new stand, the population is potentially more vulnerable, recording a higher mortality rate. Flowers are associated with the internode; the longer the seagrass in the substrate, the longer the internode. Thus, the flowering rate increases with the vertical speed of rhizoma.

Supriharyono (2009) stated that the seagrass living at the tropics generally grow in areas with water temperatures ranging between 20 and 30ºC, while the optimum temperature is 28-30ºC. The average temperature value measured in this research was optimal (28.3ºC). In general, the salinity required for the growth of seagrass ranges between 25 and 35‰ (Supriharyono 2009), while for the flowering phase it ranges between 28 and 32‰ (Supriharyono 2009). The average salinity value in this research was also optimal (28.67‰) for the growth up to the flowering.

The dissolved oxygen (DO) in this research ranged from 4.02 to 5.81 ppm, with an average value of 5.71 ppm, being favorable to the growth of *E. acoroides* seagrass. According to Effendie (2003), a dissolved oxygen level less than 4 mg L^{-1} has a bad effect on almost all aquatic organisms. The nitrate levels of the water ranged between 0.13-2.16 ppm, with an average value of 0.94 ppm while phosphate level ranged from 0.01 to 1.73 ppm, with an average value of 0.53 ppm.

According to Efriyeldi (1997), the sediments content record variations in particles, composition, size, source or origin. Larger and heavier materials will be deposited more rapidly in areas that are relatively close to the shore. Soft materials will be carried by currents and waves to the open seas. A substrate with very coarse grain size in the coastal waters of Waai village supports the growth of *E. acoroides* seagrass, the plant being able to adapt to various types of substrates, especially to a sandy substrate (Romimohtarto & Junawa 2007). The substrate plays a role in maintaining the stability of the sediment, protecting plants against the ocean currents and supplying nutrients (Dahuri 2003).

Sediments play a role in the availability of phosphorus in many aquatic regions. Coarse sediments have a low adsorption capacity of phosphorus, thus, the content of dissolved phosphorus is higher, stimulating the seagrass growth (Rijal et al 2014). The content of phosphorus, limiting the growth of seagrass in the tropics, is a function of the size of the sediment (Supriharyono 2009).

Conclusions. The population of *E. acoroides* that live in the coastal waters of Waa village in Central Maluku district consists of one age group. The estimation results showed that the rhizome growth rate of *E. acoroides* is 0.01 mm year^{-1}. The maximum length of the rhizome that can be achieved for one year is 28.773 mm, while the length of the asimptot is 31.97 mm. The estimated the mortality rate ranges from 0.04 year^{-1} up to 0.06 year^{-1}, with a mean of 0.05 year^{-1}. The highest recruitment rate reached 1,087.81 stands year^{-1} which occurred in August with the recruitment frequency of 30.05%, while the lowest recruitment rate is 44.16 stands year^{-1} which occurred in January with the recruitment frequency of 1.22%. Waai village coastal water conditions (temperature, salinity, dissolved oxygen, and nutrient substrate) are favorable to the growth of *E. acoroides* seagrass.

Acknowledgements. The authors would like to thank I. Ch. Tupan for his guidance to the authors, the lecturers in biology education programs who have assisted in the process of collecting data in the field; Aquaculture laboratory Ambon that helped in the analysis of the chemical content of the samples tested.

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Received: 31 July 2020. Accepted: 14 October 2020. Published online: 30 October 2020.
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How to cite this article:
Rijal M., Rosmawati, 2020 The population dynamics of *Enhalus acoroides* in the coastal waters of Waai Village, Central Maluku District, Indonesia. AACL Bioflux 13(5):3135-3143.