IDENTIFICATION AND CLASSIFICATION OF LAKE BOTTOM SURFACE AND AQUATIC VEGETATION IN LAUT TAWAR LAKE, ACEH

Zulkarnaen Fahmi[1] and Husnah[2]
[1]Research Institute for Fisheries Enhancement and Conservation, Purwakarta
[2]Research Centre for Fisheries Management and Conservation, Jakarta
Received; November 13-2014 Received in revised from June 17-2015; Accepted June 19-2015
e-mail: fahmi.p4ksi@gmail.com

ABSTRACT

Identification and classification of benthic habitats in Lake of Laut Tawar, Aceh by using hydro acoustic method can provide data and information on types of substrate and aquatic vegetation in a short time and wide spatial coverage, as done in the present work. Data acoustic collection was performed in 2013 using quantitative echosounder with split beam frequency of 120 kHz, and through a visual observation. The later is destined to look at the bottom types and macrophytes that lie on the line transect of acoustic survey. Analysis of data is to extract the value of bottom volume backscattering for each transect of 0.5-1 km. Classification of the bottom type was done based on the value of Sv using geospatial models. Results show the interval value of Sv for soft bottom ranged between -24.00 dB and -32.00 dB, the type of hard bottom (e.g. rocks, rocky sand substrate) ranged between -14.00 dB and -22.00 dB, whereas the Sv value of macrophyte ranged between-45.00 dB and -54.00 dB. The percent covers were about 42.90%, 44.71% and 12.93% for hard bottom type, soft bottom and macrophytes, respectively. The types of aquatic vegetation commonly found in the lake were two genera belonging Hydrocharitaceaea and Gramineae. The current work is still lack of information on the classification of organisms into genera scales. Therefore, more signal verification and algorithms verification would be needed in order to estimate macrophytes biomass by comparing with other visual observation.

KEYWORDS*:* Bottom surface, Laut Tawar Lake, macrophytes, hydro acoustic methods

INTRODUCTION

Benthic habitat plays an important role as life for various aquatic organisms that are associated with the aquatic environment. Benthic habitat affects directly the growth and metabolism of living things that are in the water column (Bemba, 2011). Identification and classification on the type of benthic habitat can be done by several methods, one of which conducted by a visual technique method such as a diving technique. A trained and knowledgeable field of workers still the major factors of SCUBA diving and snorkeling techniques available as the most reliable method of benthic data collection. However, this method will not be effective and efficient when the waters are in high turbidity (e.g rivers, swamps, estuaries) and cover a wide range of spatial scales. Therefore, mapping of the bottom waters using hydro acoustic technology can provide the solutions for habitat mapping issues (Michaels, 2007; Anderson *et al*., 2008).

Several studies on benthic habitat classification using hydro acoustic method in Indonesia have been conducted with seabed echo integration techniques to measure the surface backscattering strength (SS) value and *ring surface scattering* numerical modeling using a quantitative echo sounder (QES) in off shore of southern Java (Manik *et al*., 2006).

Acoustic benthic habitat classification system can distinguish the type of seabed properties such sediment acoustic properties (e.g sound speed, acoustic impedance, and attenuation), a number of geotechnical properties such as grain size, density and porosity also proved efficient and precise distinction of echo signals coming from vegetation-covered and bare bottoms (Allo, 2011; Hamilton, 2001; Kruss *et al*., 2008; Lambert *et al*., 2002; Richardson *et al*., 2002). Based on the potential acoustic technology and signal processing techniques, the current work is aimed to identify and classify macrophytes and bottom substrates using quantitative echosounder in Lake of Laut Tawar, Aceh, in wide variety of depths and ranges.

MATERIALS AND METHODS
Acoustic Survey

A field survey was conducted in July 2013 in Lake of Laut Tawar, Aceh with logistical support from Research Institute for Inland Fisheries, Palembang. The short time available for the field survey is restricted to investigate the macrophytes around of lake,

Corresponding author:
Research Institute for Fisheries Enhancement and Conservation, Purwakarta
Jl. Cilalawi, No.1, Jatiluhur, Purwakarta-Jawa Barat

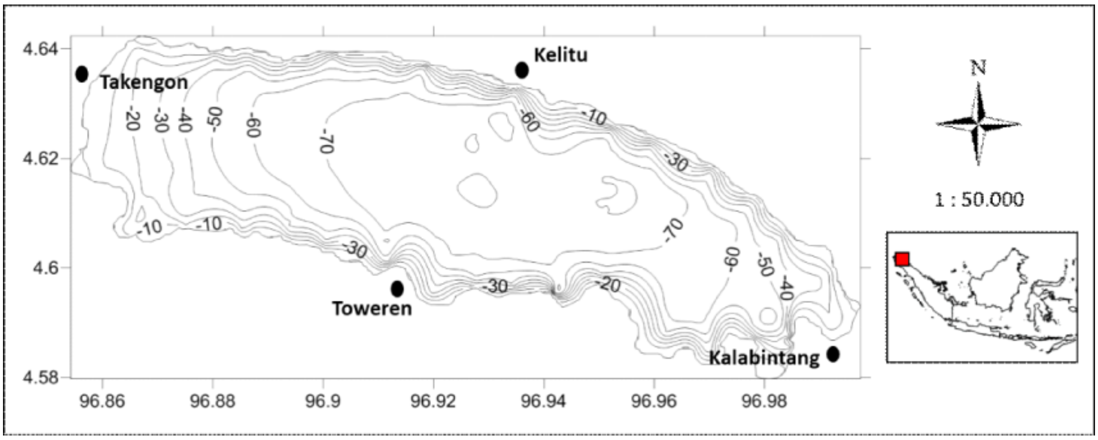


Figure 1. Research Map Location in Lake of Laut Tawar, Aceh.

whereas the main point of interest was the euphotic zone and along of shore line (Figure 1).

The primary tool for this study isa SIMRAD EY60 split beam echosounder. It operate at 120 kHz, with a narrow 3-dB beam width of 7.0°, looking downward system, temporary hull mounted installed in fishing boat side, with pulse duration operated at 0.128 ms.

Acoustic Survey Design

Transects were taken with adaptive circular grid transect parallel to the coastline and placed every 1 km. During 3 days of survey time along the shore, the entire part of the lake was covered. Seventy-seven acoustical transect at 1 km intervals coming out with 65.3 nm in length were recorded in 57.42 km^2 study area (Figure 2), which corresponded to ± 90% of Lake Laut Tawar's total area. In most areas, the boat speed was ranged between 4 and 5 knots yielder of echogram per 1,000 m of surveyed distance. After correction for sound speed in water and transducer immersion, the echoes were recorded with minimum signal amplification on echogram. A GPS antenna was installed over the transducer and the signal NMEA is sent to the EK-60 software, which managed all split-beam data acquisition. In addition to displaying useful information (e.g. course deviation and speed), the navigation computer provided position data at one second interval fix mark on echogram.

Visual Observation

A field survey with snorkeling was carried out at 5 sampling station to record plant vegetation cover (Figure 2). Sampling stations were precisely located in the lake with a positioning at along acoustic survey line. Identification of aquatic plants and other bottom substrates was noted following a numerical code system ranging from 1 to 3 where 1 = hard bottom, 2 = soft bottom and 3= macrophytes. Each individual echogram was examined along with snorkeling

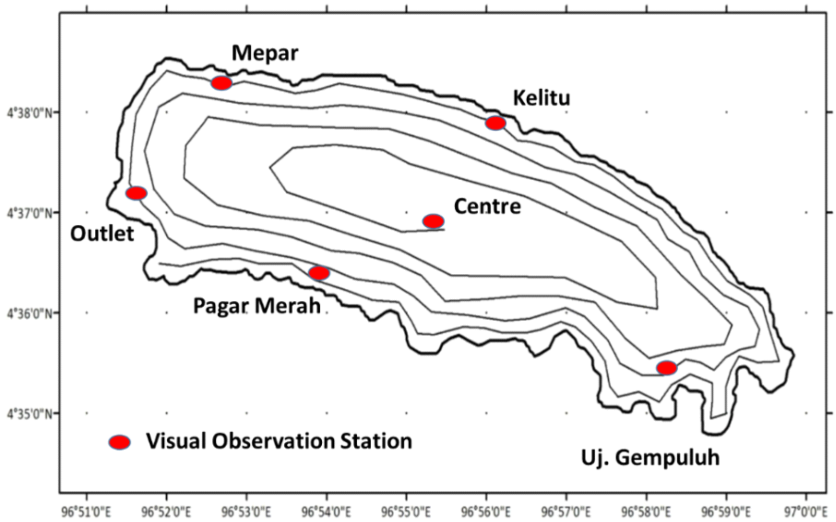


Figure 2. Acoustic survey transect design.

observation to visually describe vegetation cover. The average vegetation cover was estimated as the average value in entire echogram for each transect file.

Data Analysis

EK-60 software recorded backscattered signals from split-beam echosounder. These were corrected for TVG (Time Varying Gain) and converted into ASCII format before further processing. Each echo signal contains information from several bottom returns, due to type of benthic habitats. The first step of the discrimination procedure was to divide all echoes into bare-bottoms areas and areas with macrophytes. It was then possible for compute presence/absence of macrophytes from the backscattering strength. Volume backscatter (Sv) value was calculated from the represent part of echoes about ± 0.3 meters up from the bottom line respectively (MacLennan *et al*., 2005).

Two sets of parameters for each file were calculated based on split-beam data. The first one contained *bottom volume backscattering coefficient* (*Sv*) and the second one contained *surface backscattering coefficient* (*Ss*) (Manik *et al*., 2006).

$$Sv = \frac{Ss\Phi}{\Psi(\frac{c\tau}{2})} \quad \text{..(1)}$$

where, Ö = *instantaneous equivalent beam angle for surface scattering*
Ø = *equivalent beam angle for volume scattering*
c = *sound speed* (m/s)
ô = *pulse length*

On the *peak bottom echo*, integration value Ø H” Ö therefore equation (1) becomes:

$$Ss = \frac{c\tau}{2} Sv \quad \text{.. (2)}$$

SS [dB] = 10*log *Ss* .... (3)

More advanced classification techniques were then used to find bottom water properties significant for habitat discrimination using geo-statistic analysis (Overholtz *et al.,* 2006). All parameters were normalized and put into a classification system based on fuzzy cluster analysis. So far, statistical parameters mostly used for split-beam echosounder echo classification were, for each ping, mean value, maximum, minimum, skewness, standard deviation and variance, calculated and normalized. This set of features was divided into 3 classes during fuzzy-logic cluster analysis. Each data point belongs to a cluster to some degree specified by a membership grade; after many iterations, the optimal centers of the clusters are obtained and the data set is classified for the assigned number of classes.

RESULTS AND DISCUSSION

Results

Identification of Bottom Substrate

Based on the visual observation by snorkeling in the study site, it was found several types of substrates such as: sand, rocky sand, muddy sand, and several aquatic vegetations such as: *Brachiaria mutica, Polygonum sp, Oryza sativa, Murdannia sp., Rhynchospora corymbosa, Colocasia esculenta, Hydrilla verticillata, Eichhornia crassipes, Pistia stratiotes,* and *Ipomoea aquatic* (Table 1).

Among the ground truth data collection done by snorkeling, they are mostly found the macrophytes form such asthe emergent type that was the most predominant (six species), followed by fully submerged type (one species), and rooted with floating leave (one species). *Hydrilla verticillata* (fully submerged) and *Eichhornia crassipes* (fully floating) had the highest percent covered and included in the high dense criteria (Dewiyanti, 2012).

Table 1. The major vegetation types were found in the bottom waters of Lake Laut Tawar

No	Position		Major Macrophytes (Genera)	Station
	Latitude	Longitude		
1	4°37.762’ N	96°56.815’ E	*Gramineae*	Kelitu
2	4°35.267’ N	96°58.432’ E	*Hydrocharitaceae*	Ujung Gempuluh
3	4°36.000’ N	96°54.307’ E	*Gramineae;Hydrocharitaceae*	Pagar Merah
4	4°38.425’ N	96°52.715’ E	*Gramineae*	Mepar
5	4°37.108’ N	96°51.347’ E	*Hydrocharitaceae*	Outlet
6	4°36.955’ N	96°55.150’ E	-	Centre of Lake

Acoustic Data From Split-beam Echosounder

Acoustic data from field survey stored in the echogram contain position information, depth profile, the number of echo detection and acoustic signal properties from each detected target that reflect the signal from water column body and bottom waters (Figure 3).

Signal Properties of Bottom Substrate

Energy curve from insonified bottom properties may be classified in three groups: water column, bottom water (1st bottom), and echo from bottom water signal (2nd bottom). Figure 4 shows the echo envelope curve from sample echogram profile in Lake of Laut Tawar, which is on further analysis for identification and classification the type of benthic habitat.

The identification and classification of each type of aquatic vegetation and bottom type based on the value of Sv and SS can recognize the types of substrate as sand, silt and mud with Sv value ranging between -24.00 dB to -32.00 dB, whereas rocks, and rocky sand reflected peak echo signals with Sv value ranging between -14.00 dB to -22.00 dB. The macrophytes had value of Sv ranging between -45.00 dB to -54.00 dB. Gramineae is distinguished between Gramineae, Hydrocharitaceae, and the mixture of Gramineae and Hydrocharitaceaea (Figure 5).

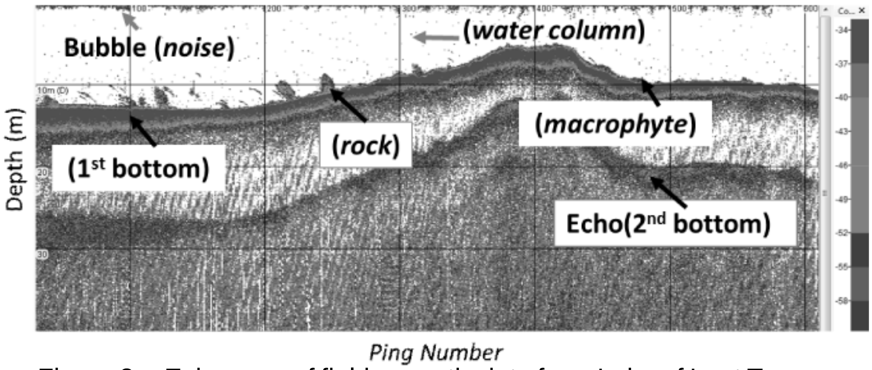


Figure 3. Echogram of field acoustic data from Lake of Laut Tawar.

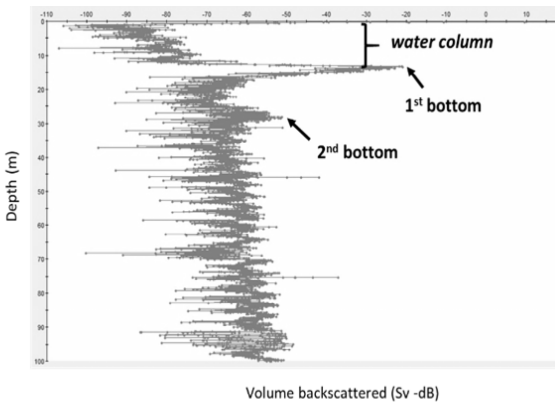


Figure 4. Echo envelope of bottom substrate in Lake of Laut Tawar.

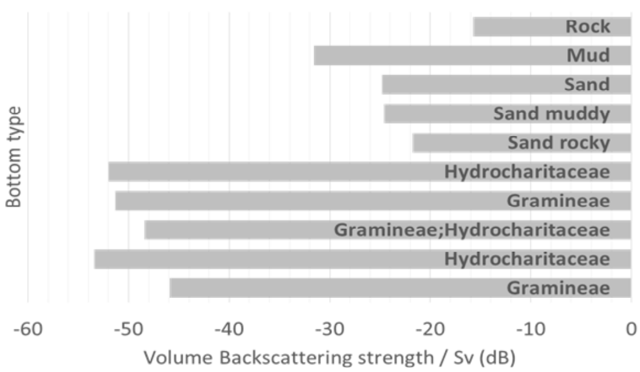


Figure 5. Bottom type and macrophytes classification in Lake of Laut Tawar.

Volume backscattering values (Sv) from data analysis were quantified from echogram to calculate surface backscattering value (SS) using equation Sv and SS linkage (Manik *et al*., 2006). In Kelitu Station, Sv and SS value were -45.89 ± 3.31 dB and -56.05 ± 3.31 dB respectively. The habitat was dominated by *Gramineae* with the percent cover of 34.90%. Macrophyte type was found in Ujung Gempuluh station dominated by *Hydrocharitaceae* with the Sv value -53.44 ± 2.66 dB and SS -63.60 ± 2.66 dB and percent cover 11.6%. Mixed *Gramineae* and *Hydrocharitaceae* were found in Pagar Merah station, result Sv value -48.42 ± 1.32 dB and SS value -58.58 ± 1.32 dB respectively (Table 2).

Table 2. Acoustic bottom backscattering strength from each sample macrophyte and bottom substrate in Lake of Laut Tawar

Bottom and Macrophytes Type	***Acoustic Bottom backscattering strength* (dB)**				***Station***
	Sv		**SS**		
	Mean	**STD**	***Mean***	**STD**	
Gramineae	-45.89	± 3.31	-56.05	± 3.31	Kelitu
Hydrocharitaceae	-53.44	± 2.66	-63.60	± 2.66	Ujung Gempuluh
Gramineae;Hydrocharitaceae	-48.42	± 1.32	-58.58	± 1.32	Pagar Merah
Gramineae	-51.30	± 1.97	-61.46	± 1.97	Mepar
Hydrocharitaceae	-51.98	± 2.35	-62.14	± 2.35	Outlet
Sand rocky	-21.73	± 7.13	-31.89	± 7.13	
Sand muddy	-24.63	± 5.42	-34.79	± 5.42	
Sand	-24.77	± 4.83	-34.93	± 4.83	
Mud	-31.57	± 3.22	-41.73	± 3.22	
Rock	-15.75	± 5.92	-25.91	± 5.92	

From the analysis of acoustic, the bottom waters of Lake of Laut Tawar were classified into three major groups, hard bottom (i.e. rock, gravel, sandy rock); soft bottom (i.e. sand, sand mud and mud) and macrophytes that attached on bottom substrate distinguished by merge vegetation, submerge vegetation and floating vegetation types.

Geospatial modelling for benthic habitat discrimination classified bottom type based on the volume backscattering strength (Sv), showing percent of coverage hard bottom type 2,495 hectares, equivalent to the percent cover of 42.90%. Percent of coverage for soft bottom type was 2,569 hectare, corresponding to the percent cover of 44.17%, while macrophytes type spread widely dominant in euphotic zone covering about 752.2 hectares, equivalent to the percent cover of 12.93% (Figure 6).

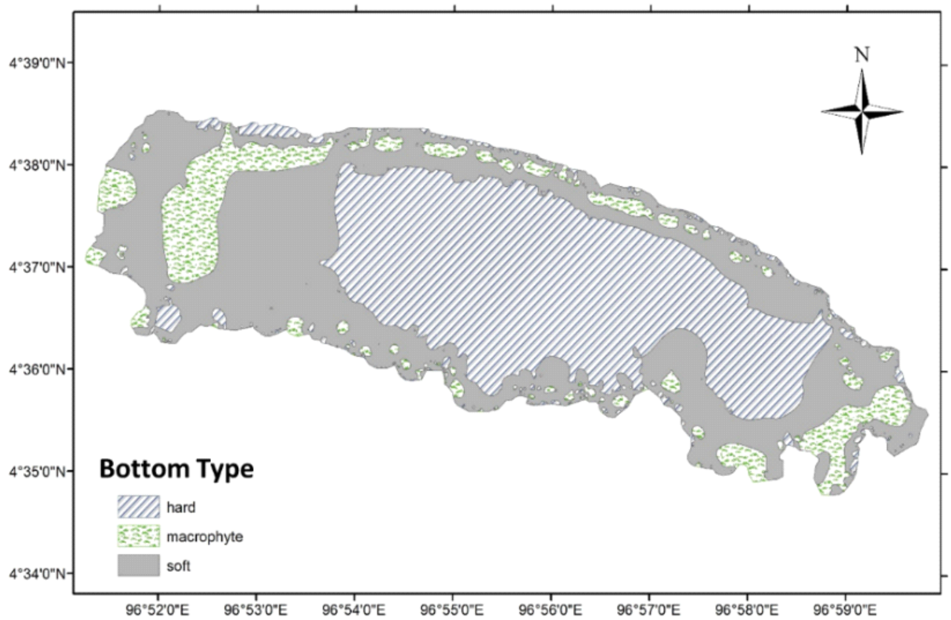
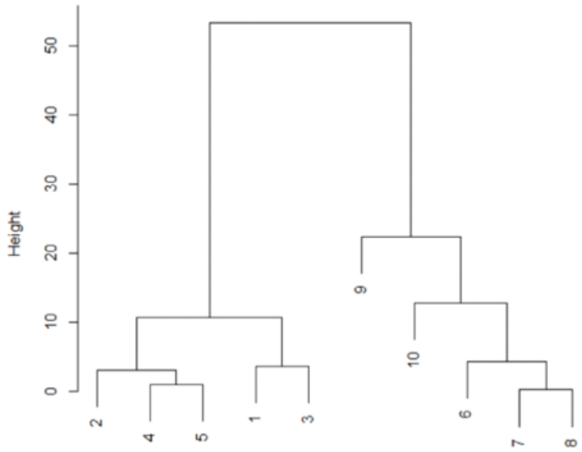


Figure 6. Bottom classification map related to backscattering value in Lake of Laut Tawar.

Discussion

Cluster analysis on benthic habitat type in Lake of Laut Tawar conducted with complete linkage cluster method and using euclidean distance measure give two major groups of macrophytes and other bottom substrates. Genera Gramineae in Kelitu station that has similarity wih mixture genera Gramineae and Hydrocharitaceae was found in Pagar Merah. Genera Hydrocharitaceae in Ujung Gempuluh and Outlet has similarity with genera Gramineae in Mepar station. Average of percent coverage for macrophytes in Kelitu station and Pagar Merah were 33.8% and 34.9%, in Ujung Gempuluh and Outlet were 48% and 75%. Large scale field survey for macrophytes identification has lack of information to distinguish precisely between macrophytes in genera scales, but efficiently classify in percent cover of macrophytes (Figure 7).



Code	Remarks
1	Gramineae (Kelitu)
2	Hydrocharitaceae (Ujung Gempuluh)
3	Gramineae; Hydrocharitaceae (Pagar Merah)
4	Gramineae (Mepar)
5	Hydrocharitaceae (Outlet)
6	Sand rocky
7	Sand muddy
8	Sand
9	Mud
10	Rock

Cluster Method = Complete; Distance= euclidian

Figure 7. Dendrogram plot of benthic habitat in Lake of Laut Tawar.

The presence of aquatic plants affects directly the growth and metabolism of aquatic fauna. Related aquatic plants are the primary producer of the food chain in a body of water. Macrophytes might contribute significantly the increase of dissolved oxygen concentration in the water and give benefits in increasing the productivity of an aquaculture activity through its ability to supply oxygen (Rose *et al.,* 2008). Van *et al*. (1976) stated that *H. verticillata* is able to perform photosynthesis process in short light intensity condition. This causes the *H. verticillata* can photosynthesize earlier in the morning, so that *H. verticillata* can perform a photosynthesis earlier than other plants. *H. verticillata* photosynthesis process productivity will increase proportional to degree of light penetration in the water. Nevertheless, increasing temperature causes the thermal effect, which lead to increase respiration activity. These factors cause the oxygen consumption of *H. verticillata* higher than most other macrophytes.

Four macrophytes species are categorized as primary oxygen producers as follow: *C. demersum, H. verticillata, L. minor, E. crassipes* and *S. molesta*. Both *C. demersum* and *H. verticillata* are classified as fully immersed macrophytes (Rose *et al*., 2008).Therefore, oxygen concentration released in the water from photosynthesis process was higher than other macrophytes type such as floating types and emergent types.

Oxygen consumption rate of *Hydrilla verticillata* (submerge type) was 1.43 mg/L, while the production of oxygen released in the water was only 0.25 mg/L. *Eichornia crassipes* needs the oxygen consumption for respiration about 0.13 mg/L. The rate of oxygen consumption of *E. crassipes* less is than *Salvinia molesta*, which is influenced by the morphology of *E. crassipes*. The bloated petiolus form in *E. crassipes*, filled with the air, thus may help free floating as well as a factor to support the respiration mechanism (Mawar *et al*., 2008).

CONCLUSION

Pre-processing and signal analysis in the current work distinguished echoes from areas with and without macrophytes resulted in preliminary map of benthic habitat Identification and classification of macrophytes were successfully conducted based on acoustical data and visual observation to estimate percent of coverage of macrophytes and other bottom substrates. It was estimated that the percesnt coverage of macrophytes in Lake of Laut Tawar ranged for 30 – 35 % which mainly spread at littotoral area. , However there was a further work required to collect more information to classify it into genera scales. Therefore, more signal verification and algorithms verification would be needed to estimate macrophytes biomass by comparing with other visual observation.

ACKNOWLEDGEMENT

We would like to thanks Research Institute for Inland Fisheries for logistic and financial support, Takengon Divers Team, RIIF staff for samples collecting, are all gratefull acknowledge.

REFERENCES

Allo, O.A.T. 2011. Kuantifikasi dan karakterisasi acoustic backscattering dasar perairan. *Tesis*. Bogor Agriculture University, Bogor. 77 pp.

Anderson, T.J., D.V. Holliday, R. Kloser, D.G. Reid & Y. Simard. 2008. Acoustic seabed classification: current practice and future directions. *ICES Journal of Marine Science.* 65: p. 1004-1011.

Bemba, J. 2011. Identifikasi dan klasifikasi life form karang menggunakan metode hidroakustik. *Tesis*. Bogor Agriculture University, Bogor. 84 pp.

Dewiyanti, I. 2012. Keragaman jenis dan persen penutupan tumbuhan air di ekosistem Danau Laut Tawar, Takengan, Provinsi Aceh. *Depik 1(2):125-130*.

Hamilton, L.J. 2001. Acoustic seabed classfication systems, Maritime Operations Division. *Defence Science and Technology Organisation - Technical Note-0401*. 66 pp.

Kruss, A., P. Blondel, J. Tegoswski, J. Wiktor & A. Tatarek. 2008. Estimation of macrophytes using single beam and multi beam echosounding for environmental monitoring of arctic fjords (Kongsfjord, West Svalbard Island). *The Journal of The Acoustical Survey of America*. 123: 3213 pp.

Lambert, D.N., M.T. Kalcic & R.W. Fass. 2002.Variability in the acoustic response of shallow-water marine sediments determined by normal-incident 30 kHz and 50 kHz sound. *Marine Geology*. 182: p. 179-208.

MacLennan, D.N & E.J. Simmonds. 2005. *Fisheries Acoustics: Theory and Practice*. *Second edition*. Oxford: Blackwell Science Ltd. 472 pp.

Manik, H.M., M. Furusawa & K. Amakasu. 2006. Measurement of sea bottom surface backscattering strength by quantitative echosounder. *Fisheries Science 2006.* 72 (3): p. 503-512. The Japanese Society of Fisheries Science. Tokyo. Japan.

Mawar, P., I. Munifatul & H. Sri. 2008. Produksi dan konsumsi oksigen terlarut oleh beberapa tumbuhan air. *Makalah Produksi dan Konsumsi Oksigen. Lab. Biologi Struktur Fungsi Tumbuhan*. Jur. Biologi FMIPA UNDIP (51): 47-55.

Overholtz, W. J., M. Jech, W.L. Michaels, L.D. Jacobsob & P.J. Sullivan. 2006. Empirical comparisons of survey designs in acoustic surveys of Gulf of Maine-Georges Bank Atlantic herring. *Journal of Northwest Atlantic Fisheries Science* 36: p. 55-63.

Richardson, M.D., K.B. Briggs, S.J. Bently, D.J. Walter & T.H. Orsi. 2002. The effects of biological and hydrodynamic processes on physical and acoustic properties of sediments off the Eel River, California. *Marine Geology*. 182: p. 121-139.

Rose, D., J. Jöris, J. Hackermüller, K. Reiche, Q. Li, & P. F. Stadler. 2008. Duplicated RNA genes in teleost fish genomes. *J Bioinform Comput Biol*, 6 (6): p. 1157-1175.

Van, T. K., W. T. Haller & G. Bowes.1976. Comparison of the photosynthetic characteristics of three submersed aquatic plants. *Plant Physiol*. 58: p. 761-768.