Correlation of substrate fraction percentage with acoustic backscattering strength from single beam echosounder detection

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Abstract. The dependence of acoustic backscattering strength on substrate fraction percentage is examined using SIMRAD EK15 single beam echosounder with frequency of 200 acoustic kHz and 10 substrate grab samples on the Yos Sudarso bay waters, Jayapura city, Indonesia. The data analysis using software Echoview 4.0 with threshold E1 -50 dB to 0 dB and threshold E2 -70 dB to 0 dB, yet to certain the percentage of substrate fraction using sieve shaker. The result of classified analysis falls into four type namely sandy mud, mud, fine-sand and rough-sand. The rough-sand acoustic backscattering strength is higher than fine-sand and mud backscattering strength. A positive correlation between substrate fraction percentage and acoustic backscattering was observed. The higher the percentage of big faction, the acoustic backscattering strength is higher. Otherwise, the higher the percentage of small fraction, the acoustic backscattering strength is lower. Correlation coefficient of percentage fraction to E1 such as rough-sand r=0.81, fine-sand r=0.47 and mud r=0.99, yet to E2 is rough-sand r=0.77, fine-sand r=0.41, and mud r=0.92.

Key Words: E1 and E2, grain size, seabed type, SIMRAD EK15, 200 kHz frequency.

Introduction. The hydroacoustic technology utilizes the searching of underwater medium with a strong voice to detect, observe and count the parameters in terms of physical and biological aspects. The acoustic system of seabed substrate classification can approximate the substrate type by geotechnics away from the target site which is utilized in every side of marine geology, civil engineering, military, science and fishery sector (Lambert et al 2002; Richardson et al 2002). The instrument that is used in the hydroacoustic survey is a single beam echosounder. The classification of seabed using single beam echosounder had been practiced for a long time to distinguish the seabed types and classify them based on different acoustic reflection. The single beam echosounders advantages includes relatively low acquisition costs, ready availability and wide use, calibration (on-axis) for scientific users, efficiency of data processing because of low data volumes and standard procedures, it is relative ease of understanding and handle it, water-column backscatter availability and readily processing and use of multiple frequencies during a single survey (Anderson et al 2008).

The characteristic of seabed is to reflect and re-dissipate the wavy sound such as the surface of seabed. The impact is more complex because of the seabed characteristic which is loaded with various elements from strong stones to fine substrate and also due to the different layers composition (Urick 1983). The utilization of the hydroacoustic technology is suitable in mapping and classifying the seabed based on various physic parameters such as the level of roughness and hardness of the seabed and based on the measurement of sediment grain and seabed relief. The various physical conditions of the seabed will influence the acoustic signal reflection such as the physical characteristics of the seabed relief which influence the process of signal acoustic backscattering (Thorne et al 1988; Demer et al 2009). The differences of the seabed characteristics are described by the level of roughness and hardness of the seabed such as stone, sand, mud and blend (Penrose et al 2005).

The hydroacoustic research represents a significant improvement in many fields. The prediction and classification of the seabed characteristic is usually the first echo (Hamilton 2014) or first (E1) and second echoes (E2) measured with single beam echosounders (Anderson et al 2008). The acoustic backscattering from the first echo refers to the roughness feature of the seabed, while second echo is commonly referring to the hardness signature of the seabed (Penrose et al 2005; Anderson et al 2007)

The purpose of this research is to analyze the seabed acoustic backscattering (E1 and E2) characteristic from single beam echosounder detection and to perform correlation analysis of substrate fraction percentage with acoustic backscattering strength.

Material and Method

Acoustic data and substrate sampling. This research was conducted in April 2017 in Yos Sudarso bay waters, Jayapura, Papua, Indonesia (Figure 1). The instrument for this research was SIMRAD EK15 single beam echosounder with 200 kHz frequency. The recording of the acoustic data was done stationery from the stopped ship in 10 stations (5 station of sand group and 5 stations of mud group) with different substrate fraction with the record from 5 to 10 minutes. In addition, the recording of acoustic data included oceanographic parameter measurements such as temperature, salinity, and pH which were used for the calibration of the results of the acoustic recording. The samples of substrate were harvested under a transducer using sediment grabs.

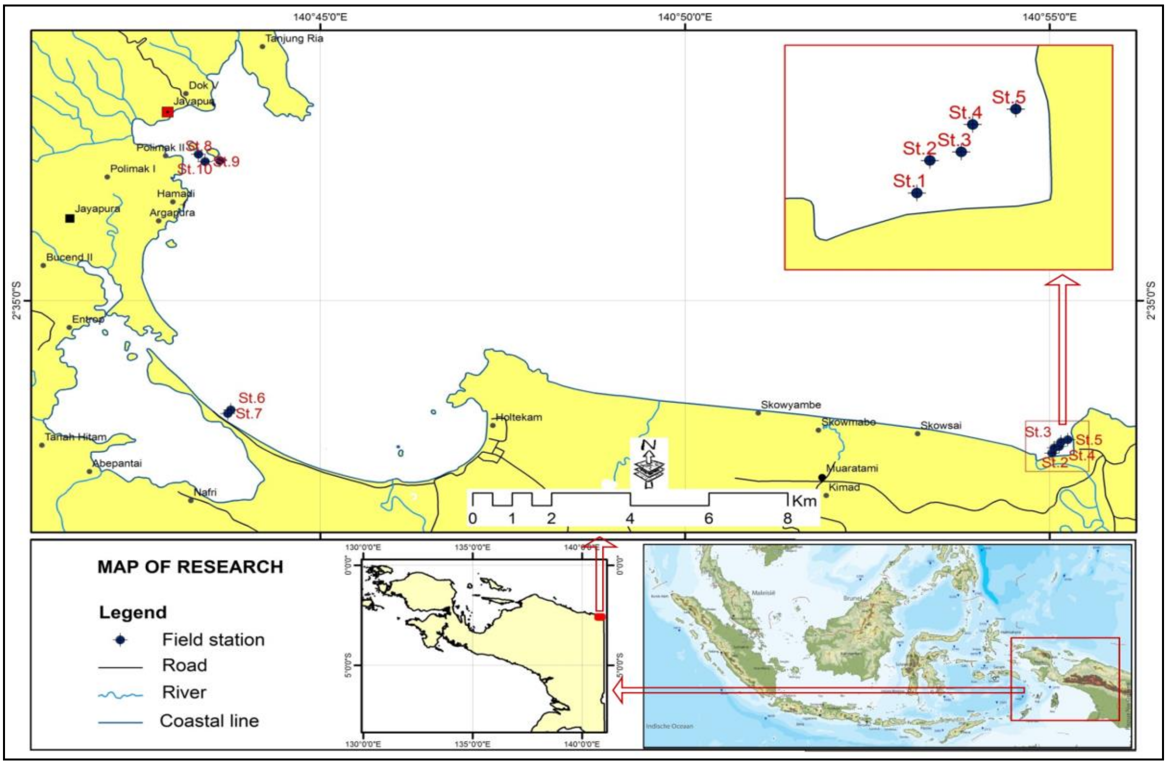

Figure 1. The location of acoustic data recording and substrate sampling at Yos Sudarso bay, Jayapura, Indonesia.

Data analysis. The analyses of the volume of the backscattering strength of seabed was extracted with Echoview 4.0 software. The data of seabed acoustic backscattering consisted of the first echo (E1) and the second echo (E2) data. The E1 using threshold of -50 to 0 dB, yet the E2 using threshold -70 dB to 0 dB (Pujiyati et al 2010; Hamuna et al 2017). The elementary sampling unit used the processing data to understand the value of seabed acoustic backscattering of 100 ping with the integration of E1 and E2 which is 0.2 meters according to the thickness of Van Veen grab penetration at the seabed. The analysis of the texture classification was performed Marine Science Laboratory (Cenderawasih University) using sieve shaker. The classification of the blend seabed substrates was performed based on particle composition using triangle sediment diagram (Krumbien & Sloss 1951).

The correlation analysis between substrate fraction percentage and acoustic backscattering (E1 and E2 values) was performed with regression analysis. The decibel (dB) value of E1 and E2 must be converted to linier value.

Results and Discussion

Substrate type and acoustic backscattering. The data's from the sample results at the 10 stations shows that there were four type of substrates namely sand mud substrate (station 1), mud substrate (station 2-5), fine sand substrate (station 6 and 7) and middle-rough sand substrate (station 8-10). Each type of substrate has a different grain measurement. Even though, there was same type of substrate in some stations, however the diameter of grain size was different. Generally, rough sand has roughness level higher than roughness of fine substrate of sand and mud. One of the factors is the high composition fraction for the grain of fine-sand and mud measurement (Table 1).

Table 1

The composition of substrate fraction

Station	*Depth (m)*	*Substrate fraction (%)*			*Substrate type*
		Sand (0.25-5.00 mm)	*Sand (0.063-0.25 mm)*	*Mud (<0.063 mm)*	
1	5.3	3.56	24.81	71.62	Sandy mud
2	18.2	5.03	18.17	76.80	Mud
3	12.5	2.83	15.32	81.85	Mud
4	8.9	2.58	12.72	84.70	Mud
5	5.5	4.60	20.17	75.23	Mud
6	6.1	13.79	68.40	17.81	Fine-sand
7	4.5	18.18	66.86	14.96	Fine-sand
8	4.3	73.87	18.60	7.52	Rough-sand
9	4.6	72.58	22.53	4.88	Rough-sand
10	7.8	71.63	22.56	5.80	Rough-sand

Based on Table 2, the value of seabed acoustic backscattering is consisted of first echo (E1) and second echo (E2) values. The acoustic backscattering from the first echo referred to the roughness feature of the seabed, while second echo is commonly referred to the hardness signature of the seabed (Penrose et al 2005; Anderson et al 2007). E1 is correlated with the topography, grain size, and attenuation of the near surface portion of the seabed. Second echo results primarily from complex scattering caused by refraction from the sea surface and the substrate. Second echo varies when the sound wave penetrates the seabed surface and is reflected by a substrate layer of different density (Anderson et al 2007).

Table 2 shows that the acoustic backscattering of rough-sand has highest value than the acoustic backscattering of fine-sand or mud. The rough and fine seabed gives an influence to the intensity of the return reflection where the roughness seabed has bigger reflection rather than fine seabed (Siwabessy 2001; Hamilton 2001; Siwabessy et al 2006). The substrate of rough seabed (stone or coral) will produce high intensity reflection E1 or E2, otherwise the fine seabed (mud or clay) will produce low reflection. Generally, the result of this research get the value of sand E1 higher than mud E1 around 8-10 dB and the value E2 is higher, being around 8-15 dB. The result is same with the result of Manik (2012) which get the quarrel acoustic backscattering sand with mud and clay around 10 dB.

Table 2

Acoustic backscattering strength of seabed substrate type

Station	*Substrate type*	*SV*	
		E1 (dB)	*E2 (dB)*
1	Sandy-mud	-35.99	-54.12
2	Mud	-37.49	-61.72
3	Mud	-37.81	-62.85
4	Mud	-37.73	-62.16
5	Mud	-37.44	-55.62
6	Fine-sand	-28.12	-49.69
7	Fine-sand	-28.40	-49.17
8	Rough-sand	-27.36	-47.44
9	Rough-sand	-27.96	-48.56
10	Rough-sand	-28.02	-50.96

The volume of the backscattering strength (E1 value) of seabed in this research does not differ from acoustics backscattering values from which used different acoustic frequency (Manik et al 2006; Pujiyati 2008; Ningsih et al 2013; Hamuna et al 2015). The result of several researches obtained the acoustic backscattering of sand (-18.30 dB) and mud (-29.99 dB) using multi frequency (Manik et al 2006), sand (-20.00 dB) and mud (-35.91 dB) at 38 kHz frequency (Pujiyati 2008), mud (-30.87 dB) at 120 kHz frequency (Ningsih et al 2013) and acoustic backscattering of sand between -19.41 up -18.80 dB at 200 kHz frequency (Hamuna et al 2015). Besides, the condition of seabed, using different frequency will give different result of acoustic backscattering at the same seabed (Chakraborty et al 2007; Freitas et al 2008; Cutter & Demer 2014; Hamuna et al 2014). At high frequencies acoustic, the backscattering from the seabed can generally be attributed to two contributing factors. Part of the energy is scattered by the interface relief and by bottom roughness. The other part of the energy penetrates the sand and muddy sediment, were, is reflected back by the volume heterogeneities of seabed (Anderson 2006; Anderson et al 2007; Lurton 2002). The using frequency will be connected directly to the absorption. Absorption can have an effect on the acoustic reflection, where the use of high frequency will be higher absorbed (Jackson & Richardson 2007).

The relation of substrate fraction percentage and acoustic backscattering. Figures 2 and 3 illustrate the relation between substrate fraction percentage and backscattering of the seabed. Based on the regression analysis of each substrate and backscattering strength (E1 and E2), there is a strong correlation coefficient of rough sand fraction (r=0.81), fine sand (r=0.47), and mud (r=0.99) towards E1 value, and rough sand fraction (r=0.77), fine sand (r=0.41), and mud (r=0.92) towards E2 value. There is a positive correlation between acoustics backscattering strength and sediment grain size, in which the highest backscattering correlate with rough sediment (Collier & Brown 2005), E1 will be related with fraction diametric size of seabed substrate of 0.73 (Goff et al 2000). Some research findings confirmed these results, where E1 value will be related with fraction diametric size of seabed substrate of R=0.73 (Goff et al 2000). Some research shows high correlation, such us R=0.87 (Pujiyati et al 2010), between R=0.85 to 0.95 (Manik 2015) and R=0.95, R=0.79 for sand and silt substrates, respectively (Ningsih et al 2013).

Based on the correlation values found on this research, the higher percentage of rough substrate grain size (rough sand) was the higher acoustic backscattering (E1 and E2 values). Contrariwise, the higher percentage of small or soft substrate grain size (mud) has the lower acoustic backscattering (E1 and E2 values) accepted by transducer. This is proven that the difference of seabed substrate grain size will influence the intensity of acoustic backscattering. Some research findings confirmed these results (Goff et al 2000; Pujiyati et al 2010; Manik 2015), where the size of substrate grain highly influences the seabed acoustic backscattering; greater of the seabed grain size, higher is the roughness and hardness level of seabed (Pujiyati et al 2010; Manik 2015). Acoustic backscattering strength difference between rough and fine substrate inter alia the rough substrate (sand) would give high acoustic backscattering strength, caused by scattering of rough particles, high roughness level, low porosity, and high density and sound velocity (Greenlaw et al 2004; Manik et al 2006), otherwise, fine substrate (mud) would give low acoustic backscattering strength caused by low density and sound velocity (Jackson et al 1996; Jumars et al 1996).

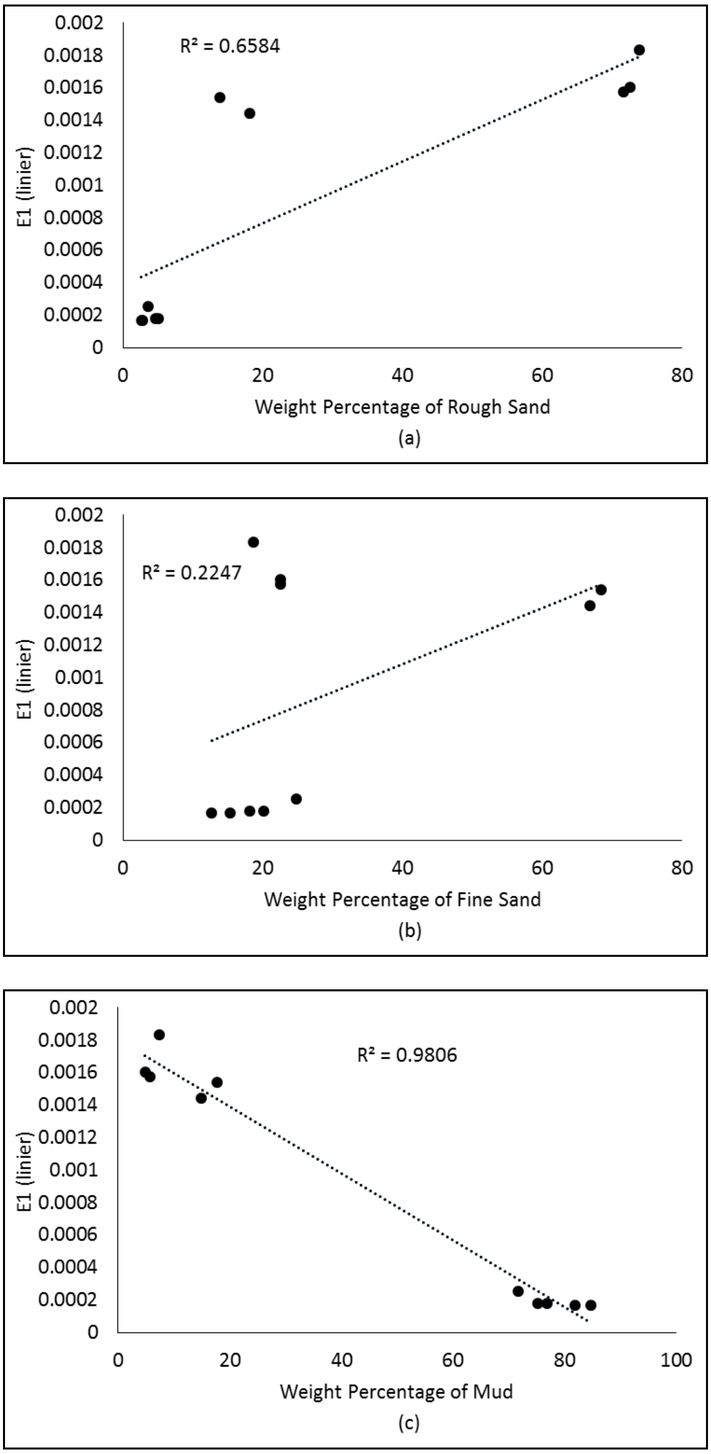

Figure 2. Graphic of the correlation between substrate fraction percentage with E1 value; (a) rough sand, (b) fine sand and (c) mud.

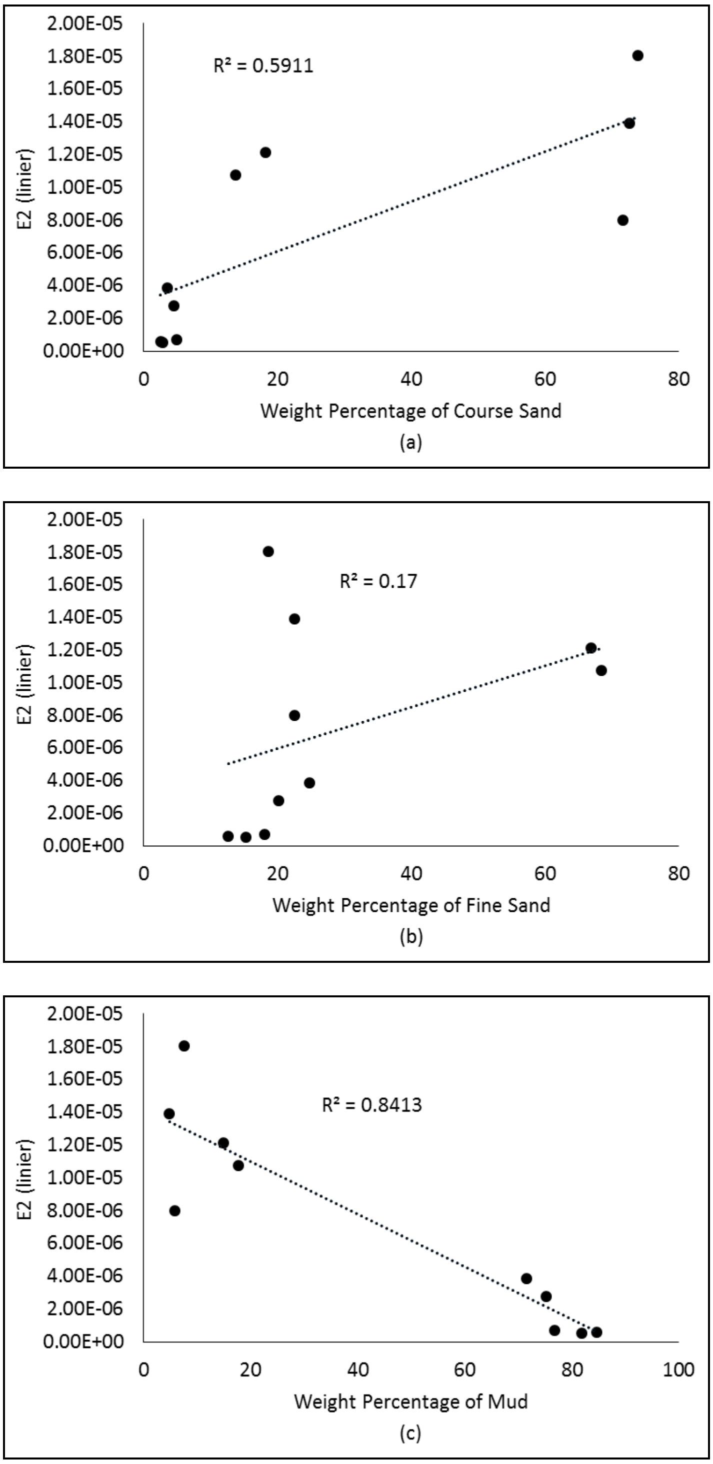

Figure 3. Graphic of the correlation between substrate fraction percentage with E2 value; (a) rough sand, (b) fine sand and (c) mud.

Conclusions. The result of this research shows that acoustic backscattering strength of rough sand substrate is higher than that of the fine sand and mud substrates. There is a positive correlation between substrate fractions percentage with acoustic backscattering strength. This percentage of fraction substrate highly influences the value of seabed acoustic backscattering. The higher the percentage of a big fraction, higher is the acoustic backscattering strength either of the first echo (E1) and the second echo (E2). Otherwise, the higher the percentage of a small fraction such as fine sand and mud, lower is the acoustic backscattering. The correlation coefficient between E1 value and rough sand fraction is r=0.81, with fine sand fraction r=0.47 and with mud fraction r=0.99. Correlation coefficient between E2 value and rough sand fraction r=0.77, with fine sand fraction r=0.41 and with mud fraction r=0.92.

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