STATISTICAL PROPERTIES OF BACKSCATTER FROM SEAGRASS COLLECTED FROM A SIDESCAN SONAR SURVEY

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Abstract: *As part of a sidescan sonar survey of a shallow water estuary, backscatter collected from seagrass was compared with uncovered areas to investigate the possibility of potential improvements to seafloor mapping. A high-frequency (250/550 kHz) EdgeTech 4200 sidescan sonar system was used in a survey of parts of the Swan-Canning estuary in Perth, Western Australia. Backscatter data were corrected for transmission loss and insonification area to derive the backscatter strength. The statistical distribution of backscatter intensity data collected from seagrass and sand were compared with Rayleigh and non-Rayleigh models. The K-distribution was found to be the best-fit model for variations of backscatter from both sand and seagrass. After processing, which includes averaging, the data no longer fit the moments of a K - distribution, but can be modelled by a gamma distribution., This is consistent with previously observed results and theoretical interpretation. However, in some instances, a log-normal distribution model fits the experimental data better than the gamma distribution.*

Keywords: *High-frequency backscatter, intensity statistics, seagrass, sidescan sonar*

1. INTRODUCTION

This study investigated the statistics of acoustic backscatter collected over seagrass and bare sediment, which was constituted primarily of sand, using an EdgeTech 4200 MP sidescan sonar (SSS) system operating at 250 and 550 kHz. For a Gaussian scattering process, the distribution of instantaneous backscatter amplitudes (envelopes) is Rayleigh and, subsequently, the backscatter intensities are exponentially distributed. However, it has been demonstrated both theoretically [1] and experimentally [2] that, under certain conditions, the statistics of acoustic backscatter from the seafloor can be essentially non-Gaussian, when fluctuations of the backscatter envelope are not Rayleigh distributed. Recent studies have noted a non-Rayleigh character of backscatter statistics at high acoustic frequencies and suggested different models. One such model is the *K*-distribution, which has been shown to fit the distribution of backscatter fluctuations for certain types of the seafloor [2, 3]. The theoretical basis for the *K*-distribution approximating variations of the backscatter amplitude and intensity has been considered in [1] and [4] respectively. In this study, the distributions of backscatter fluctuations observed over seagrass and sand at 250 kHz and 550 kHz are compared with the exponential and *K*-distribution models to investigate the validity of these models at high frequencies.

The SSS data were collected as part of a habitat mapping project [5], which involved creating backscatter mosaics. For producing backscatter mosaics, backscatter data are gridded, which usually involves averaging the raw data within the grid cell and provides an improvement of the signal-to-noise ratio. Fluctuations of the average backscatter intensity were demonstrated theoretically in [4] to tend to be gamma distributed. This has also been found experimentally in the case with averaged backscatter intensity collected with a multibeam sonar system [6]. The SSS dataset used for this study provided a useful insight into the effect of averaging on backscatter intensity statistics, which has implications for habitat mapping.

2. METHODS

The tow-fish of the EdgeTech SSS was fixed mounted to the vessel to improve the navigation accuracy of backscatter measurements. Backscatter data were collected to a maximum range of 75 m either side of the tow-fish over sand and seagrass covered areas in the Swan River in Perth, Western Australia. The depth of the seafloor over the SSS transect was varying within 4-6 m.

Backscatter data were recorded in EdgeTech's native format (.JSF). A program written in Matlab was used to read this into the Matlab environment and correct backscatter for transmission loss and insonification area (assuming a flat bottom). An additional routine was developed to produce the backscatter mosaics.

Backscatter intensity data used in the statistical analysis were resampled at a 5-time lower rate to exclude correlated samples received from the same insonification area on the seafloor. When calculating the probability false alarm PFA = 1 - CDF (cumulative distribution function), the intensity backscatter data were normalised by the mean value.

3. RESULTS

The mean backscatter strength from sand and seagrass at 250 kHz and 550 kHz is shown in Fig 1 as a function of slant range to the bottom. A noticeable increase in backscatter strength with slant range at the higher frequency is likely due to inadequate correction for the insonification area at small grazing angles made for a flat-bottom model. At the lower frequency, the effective width of the transmitted pulse is nearly 3 times longer, so that errors in the insonification area estimates due to the actual bottom slope are not as critical as those at the higher frequency.

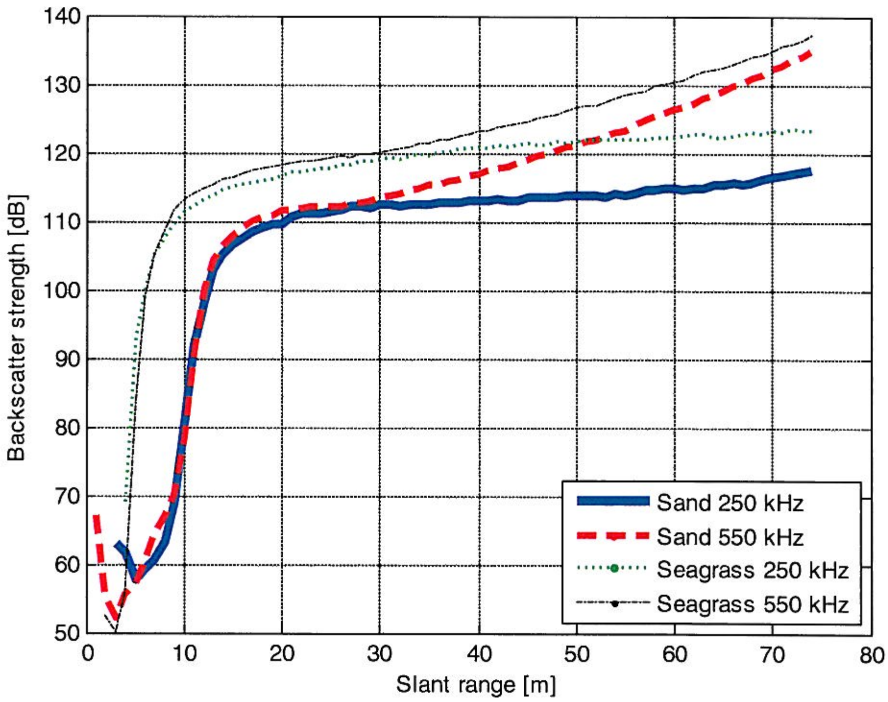

Fig. 1: Backscatter strength versus slant range for sand and seagrass at 250 and 550 kHz. The backscatter strength is shown in dB relative to an arbitrary but constant value, which is not corrected for unknown total gain of the sonar receive system.

The coefficient of variation (CV) of the backscatter intensity versus incidence angle from sand and seagrass is shown in Fig 2. For an exponential distribution of fluctuations the CV equals unity. The CV for both sand and seagrass at both frequencies remains close to unity between 45 to 75°, which is characteristic for a Rayleigh-like process. As incidence angle increases beyond 75° the CV becomes greater than unity, which indicates a deviation from a Rayleigh-like process. This deviation in CV is greatest in the 550-kHz backscatter data. Reasons for this change could relate to changes in the insonification area. The insonification area versus incidence angle is shown in Fig 3 for the two different seabeds. At large incidence angles (small grazing angles), the transverse width of the insonification area is as small as approximately 3 cm at 550 kHz and small variations in the seafloor slope could lead to considerable fluctuations of the insonification area, which might result in much larger fluctuations of the backscatter intensity.

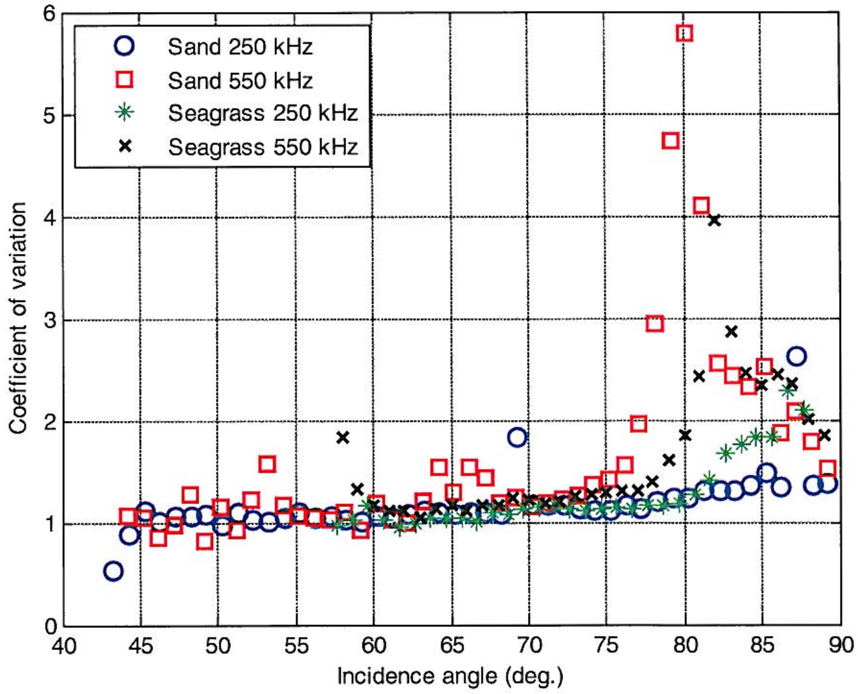

Fig. 2: Coefficient of variation versus incidence angle for sand and seagrass at 250 and 550 kHz.

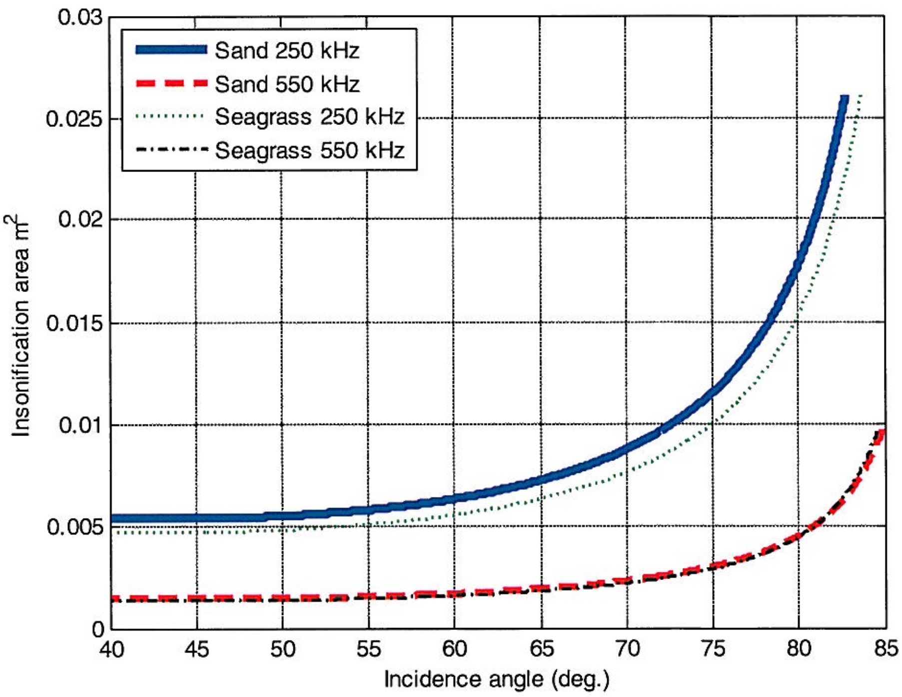

Fig. 3: Insonification area (m^2) versus incidence angle (deg.).

The PFA of normalised backscatter intensity collected from sand and seagrass at 250 and 550 kHz between 60 and 70° is shown in Fig. 4. Most of the data in Fig. 4 can be reasonably well approximated by the exponential model with the data only deviating at the tail. The deviation from the exponential model is more significant for backscatter collected at 550 kHz. The K - distribution provides a better approximation for the tail of the data, although it is not perfect. For backscatter collected at greater incidence angles of 80 - 90° (Fig. 5), the approximation by exponential model is noticeably worse than that at smaller angles.. In this angular domain, the K - distribution also provides a better approximation for the tail of the data than the exponential model.

The effect of averaging backscatter intensity on its distribution is shown in Fig. 6, where the PFA of backscatter intensity averaged over 50 samples collected over sand and seagrass at 250 and 550 kHz at 60 to 70° (left panels) and 80 to 90° (right panels) is compared with the exponential, gamma, log-normal and K – distribution models.

It was found that the more data samples were averaged over, the more the resulting distributions moved away from the exponential model. The averaged backscatter intensity collected between 60 and 70° was, in general, found to be approximated best by either the gamma or log-normal distributions. For larger angles of 80 - 90°, the best approximation models for backscatter fluctuations can be either the log-normal or K - distributions. While there is a theoretical premise for the gamma and K - distributions to fit the averaged intensity, no such reasons for the log-normal model are evident. However, the log-normal distribution has been found experimentally to fit a variety of backscatter data [6-9]. Trevorrow [9] observed a variation of backscatter distributions between the log-normal and Rayleigh distribution models, whereas Stanic and Kennedy [8] observed high-frequency shallow-water backscatter variations obeying the Gaussian distribution model at large grazing angles and the log-normal distribution at small grazing angles. Chotiros *et al.* [7] showed that high-frequency seafloor backscattering could depart from a Rayleigh distribution depending on the beamwidth. The wide-beam seafloor backscattering followed the Rayleigh distribution whereas the narrow-beam seafloor backscattering obeyed the log-normal distribution. Gavrilov and Parnum [6] found the gamma and log-normal distributions to approximate well the average backscatter intensity collected with multibeam sonar over a variety of seafloor habitats.

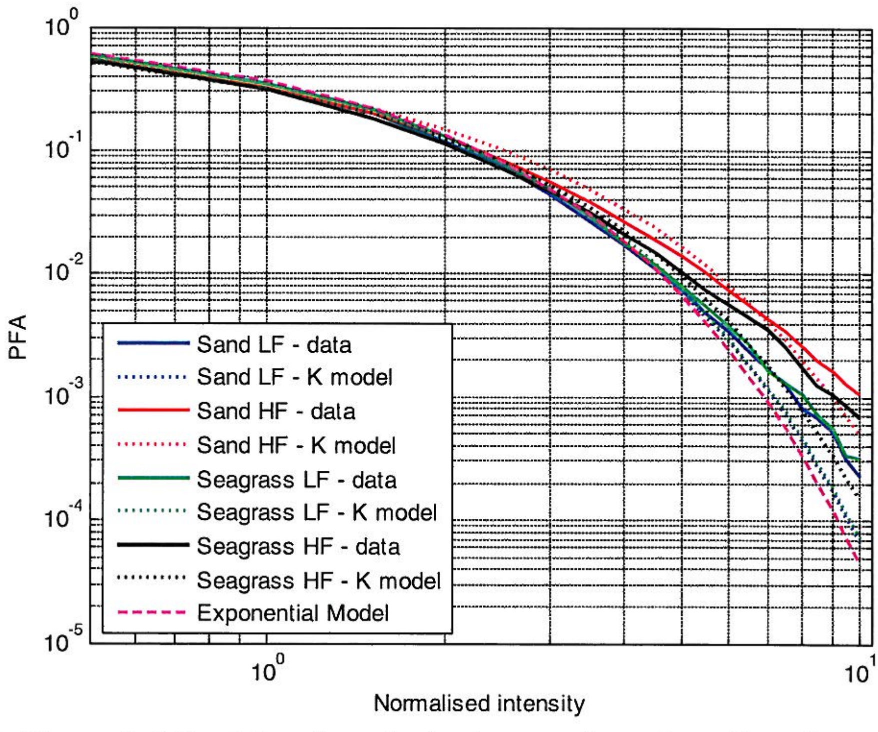

Fig. 4: The probability false alarm for backscatter intensity collected over sand and seagrass at 250 and 550 kHz for incidence angles between 60° to 70°.

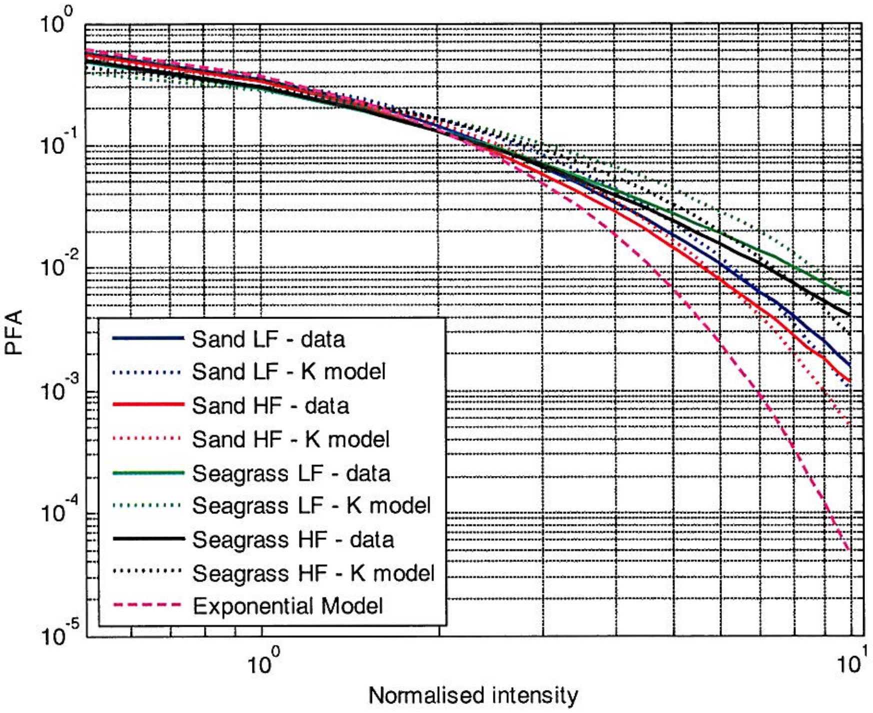

Fig. 5: The probability false alarm for backscatter intensity collected over sand and seagrass at 250 and 550 kHz for incidence angles between 80° to 90°.

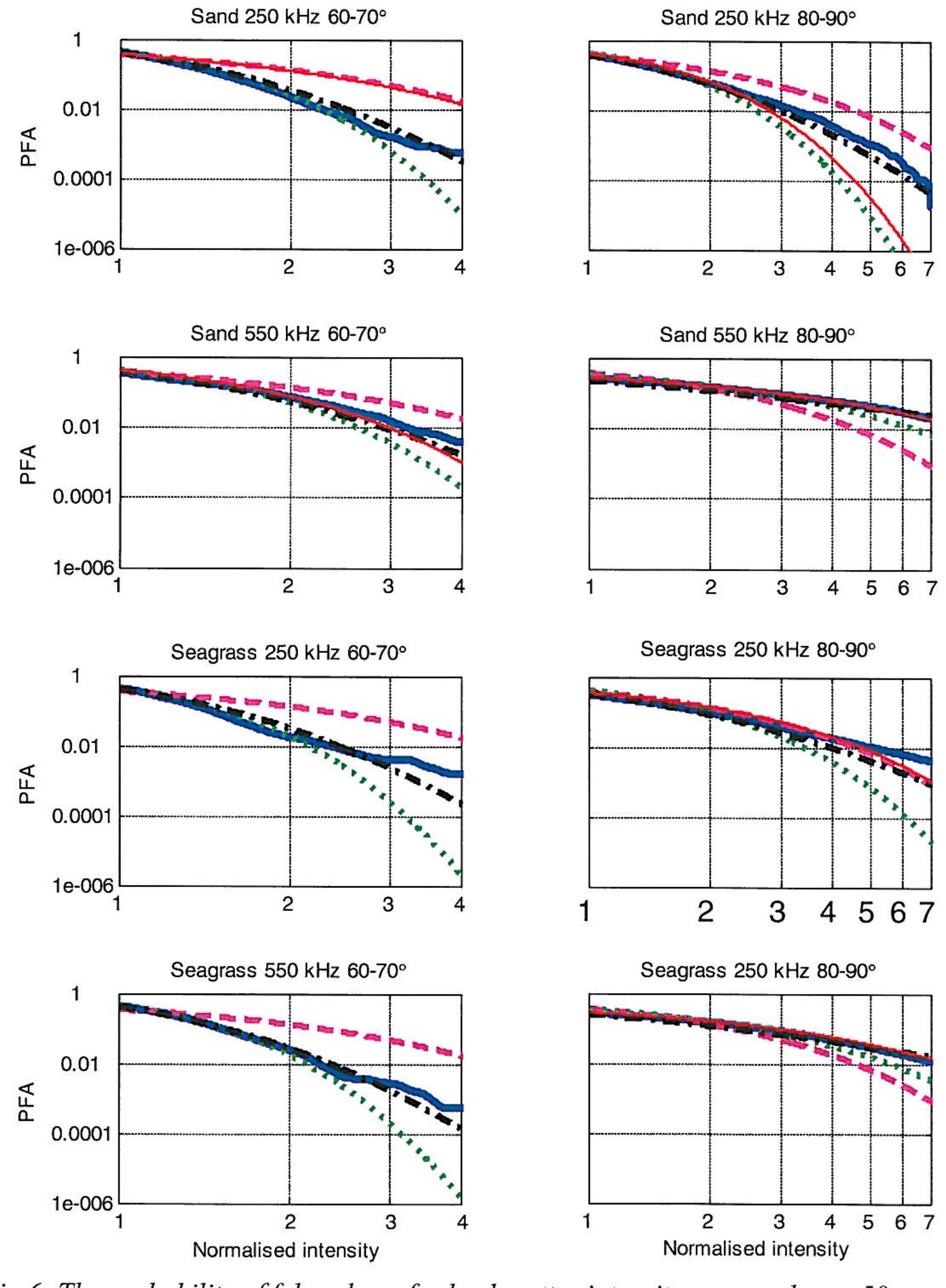

Fig 6: The probability of false alarm for backscatter intensity averaged over 50 samples collected over sand and seagrass at 250 and 550 kHz for incidence angles between 80° and 90°: data (-), exponential (--), gamma (...), log-normal (-.-.) and K (-) distributions. The K-distribution is not shown, where its parameters cannot be estimated based on the method of moments.

4. CONCLUSIONS

Fluctuations of backscatter intensity collected over sand and seagrass at 250 kHz and 550 kHz using a sidescan sonar were found to be reasonably well approximated by an exponential distribution, when the grazing angle of backscatter is not small. This means that backscatter fluctuations can be modelled as a Rayleigh-like process. For small grazing angles, when the insonification area becomes strongly dependent on the local slope of the seafloor, the distribution of backscatter fluctuations deviate noticeably from a Rayleigh model and can be approximated much better by the K – distribution. When backscatter intensity is averaged, the gamma distribution model provides a good approximation for the majority of incidence angles, except small grazing angles where the K - distribution and log-normal distribution are much more accurate models for backscatter fluctuations.

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