↳4. DISCUSSION

4.1 Mapping seagrass meadow edges

Edges of seagrass meadows interpreted from acoustic methods (fan-beam technique) corresponded closely to boundaries interpreted from dive-based surveying. Low biomass (<5 g $DW.m^{-2}$) sites at Ellie Point were successfully interpreted as seagrass habitat from the acoustic method. But three low biomass sites at the edge of the Bessie Point meadow were interpreted from acoustic images as bare substrate. This mis-interpretation of the three seagrass sites may be due to one or a combination of factors:

1. the sites were too small in area to be detected by the sonar in the configuration used at Bessie Point;
2. the sites were too low in density to be detected by the sonar in the configuration used at Bessie Point (*Halodule pinifolia* has very narrow leaves and possibly reflect very little acoustic energy).
3. the resolution of the data at these sites was corrupted by factors such as errors in positioning data and data processing; causing data "smear" and increasing the difficulty of the interpretation of the fan beam data;
4. irregular bottom topography (sand rows and blow-outs) may have decreased the detection capability of the acoustic system and interpretation process.

A combination of these factors is the most likely cause for this result. Low biomass sites were identified at Ellie Point using the fan beam technique and transducer attached to a "towfish". Ellie Point data quality after processing was high and it is likely that the "towfish" dampens transducer motion (rolling and pitching) and hence increased the detection capability of the acoustic system and interpretation process.

Bathymetry, transducer instability, seagrass morphology and sediment type all influence fan-beam acoustic data, and information on all of these is used when interpreting fan-beam data to draw seagrass meadow boundaries. Successful application of acoustic techniques for mapping seagrass meadow boundaries in tropical Australia will require further advances in minimising the influence of bathymetry, transducer movement, seagrass morphologies, sediment type, etc. on acoustic data.

Low biomass *Halophila* and *Halodule* communities dominate many localities in northeastern Australia, (Lee Long *et al.* 1993), and are important habitat for dugongs and green sea turtles. Our trials indicate that acoustic surveying techniques may be appropriate for mapping low-biomass habitat in areas with flat bottom, but of limited use on undulating and deeply channelled banks. Large areas of Shoalwater Bay for example, support low-biomass seagrass habitat which is restricted to intertidal pools and drainage channels up to 1.5 m deep (Lee Long *et al.* 1997). Acoustic techniques would need to be modified to accommodate such variable bottom topography.

The efficiency of the fan beam system in distinguishing between seagrass and macro-algae habitat was not tested in this survey. Algae (eg., *Caulerpa, Halimeda, Dictyota, Udotea,* and *Padina*) and seagrass communities can appear similar in habitat structure and are not easily differentiated using most remote sensing methods. Acoustic survey techniques, as with other remote sensing techniques, require intensive ground-truthing in some areas to avoid misrepresenting algae as seagrasses.

4.2 Seagrass biomass

Seagrass biomass in Cairns Harbour could not be determined with any accuracy by the conical beam mapping technique in this survey. Although correlations with biomass >5 g DW. m^{-2} were detected at Bessie Point, the technique could not replicate the results using identical methods at the other survey areas. The lack of any significant correlation between acoustic data and seagrass biomass data is probably the result of a combination of many sources of error. Spatial errors in the data (smearing) can be caused by GPS position-fixing and the influence of surface chop on the orientation of the transducer. Irregular bottom topography and variation (patchiness at all scales) in seagrass species composition may also contribute to variability in the acoustic data.

Bessie Point acoustic images included large positioning errors because of large gaps in GPS data. Ellie Point images were correctly positioned, but shallow, rough waters caused large variation in the transducer angle and hence large errors in signal strength received from the target environment.

A large area of high-density seagrass habitat in shallow water was included for study, but became inaccessible to the acoustic survey vessel, and seagrass habitat greater than 20 g DW. m^{-2} was not included in the analyses. Seagrass density has been successfully mapped using acoustic methods in temperate (Offshore Scientific P/L, 1994) and tropical (Anon. 1995) marine areas. Temperate species of grasses (*Posidonia spp, Amphibolis spp,* and *Zostera marina*) and wide-bladed tropical seagrasses are generally large in structure and height, and acoustic signals reflected from densely vegetated habitat can be easily distinguished against background changes in sediment, bottom topography, etc.

With little statistically significant correlations to describe seagrass biomass from acoustic data, the minimum above-ground biomass detectable by the acoustic method could not be determined. The capacity of remote sensing information to discern low biomass habitat from bare substrate is important in mapping tropical seagrasses (section 4.1). In northern Australia large areas of low-biomass habitat dominated by the tropical seagrass species *Halophila ovalis, Halodule uninervis* (thin) and *Halodule pinifolia* are important food resources for dugong, a species declared as vulnerable. Information on these habitat types is important for conservation management of dugong in northern Australia. Acoustic and other remote sensing methods will continue to require technical improvements and extensive ground truthing (by diving or grab samples) to become reliable tools for mapping low-biomass seagrass habitats.

Acoustic and other remote-sensing techniques can potentially improve the spatial and abundance resolution of habitat surveys, but reliable measures and maps of seagrass abundance will require further technical developments to minimise spatial and measurement errors. Sources of error in conical beam mapping of seagrass biomass include: vessel positioning error, vertical and horizontal movement of the transducer (influenced by wind and surface chop), seagrass species (variations in plant morphology affecting backscatter strength), seagrass patchiness, sediment type, bathymetry and positioning error in differential GPS fixes (approximately 1 - 5 m). The influence of surface chop and seabed undulations are also exacerbated in shallow water (<2 m), but they can be reduced by using a towfish sonar transducer instead of mounting the transducer onto a vessel which is rocking and pitching. The use of a static or stable transducer at single points to collect acoustic data would also greatly reduce these errors. Finally, acoustic reflectors could be used to verify/quantify any positioning errors.

The difference in acoustic signal strength from one seagrass community (eg., *Zostera* at Ellie Point) to another (eg., *Halodule pinifolia* at Bessie Point), irrespective of biomass, illustrates an effect of seagrass plant morphologies on acoustic survey data. Fibrous and wide-blade seagrasses may result in a stronger acoustic response than delicate and narrow-bladed leaves. Seagrass patchiness is also a source of error in acoustic surveying as it is in any sampling technique.

The influence of sediment type on acoustic measures of seagrass biomass has not been determined, and may have an effect when seagrass biomass is very low.

4.3 Other seagrass mapping information

Detailed information on seagrasses, such as general seagrass health, epiphyte cover, canopy height, dugong feeding trails, fruiting and flowering, and fine scale changes in community structure, are not recorded in an acoustic survey and still require observation and sampling by divers or video. Once this type of information is obtained for a monitoring locality, sampling by divers can be stratified and minimised in future monitoring events.

4.4 Sediment mapping

Grain size distribution is an important influence on distributions of infauna species in the tropics (Jones 1984; Chevillon and de-Forges 1988; Dall *et al.* 1990; Long and Poiner 1994), but ecological significance has also been attached to simple parameters, such as the proportion of mud, in marine sediments. For example, some penaeid prawn species show preference to sediments consisting of more than 25% mud (Somers 1987, 1994).

Percent mud was significantly correlated (inversely) with acoustic data and is probably one of the most useful parameters for calibrating against acoustic data when mapping sediments for marine ecology purposes. Conical beam surveying techniques appear to be very efficient at identifying changes in percent mud, but even better at predicting percent coarse sand. Increasing percentage of coarse sand (and decreasing proportion of muds) corresponded with higher decibel readings.

Coastal and marine sediments are usually mapped by collecting grab samples of sediment, but limitations in sample storage and laboratory processing time render this method very expensive. Acoustic techniques which are adequately calibrated against single parameters of sediment type can economically provide sediment maps at higher than normal resolution. The limitation is that acoustic backscatter signal represents an average of the acoustic reflectivity of the target area. This value is also calibrated to a single parameter of sediment type such as "mean grain size" or percent mud and cannot describe the distribution of sediment grain size. A single value cannot reflect important information on the range and variance of sediment grain size in sediments, ie., it cannot distinguish a well-sorted from a well-mixed grain size distribution. Sediment grain size composition data overlayed with acoustic data for sites at Bessie Point (Figure 10) visually illustrates some similarities between acoustic measurements and actual sediment grain size composition, but also confirms that acoustic data is usually clumped about a mean value irrespective of whether grain size distribution is clumped (eg., well sorted) or spread (eg., well mixed sediments).

The most robust technique for sediment mapping appears to be the vertical incidence (90°, multiple reflection) technique, which correlated better than the backscatter (45° incidence) technique to parameters of sediment type. Acoustic signals correlated to sediment type much more strongly than to seagrass biomass. Sediments may often be less patchy than vegetated habitat, but to ensure reliable calibration of acoustic data, ground-truth or calibration samples still need to be collected as close as possible to the acoustic survey track.

4.5 Efficiencies of survey methods

Acoustic surveying (fan beam and conical beam) can obtain data at high spatial resolution over 500-600 ha per day (60 ha per hour, based on a 10 hour day) with 4 days of analyses and reporting per field day (completed by 2 acoustic personnel, and excluding ground-truth divers). The extent of ground truthing is determined by the scale of the survey and frequency of changes in habitat type. Dive-based surveys obtain data at a much lower resolution to that from acoustic methods, but are able to cover large areas quickly (eg., for medium- to broad-scale surveys). Using the Shoalwater Bay April 1996 survey (Lee Long *et al.* 1997) as a guide, two vessels with 7 dive personnel can cover up to 11 km of coastline (approximately 2,100 ha of seabed) per day. For each field day, approximately 6 person-days are needed for analysis and writing of the report. When acoustic technology is further refined for tropical environments, the technology can be made more accessible and cost effective for seagrass survey teams via technology transfer, equipment hire, etc..

Acoustic surveying may not detect very low seagrass biomass habitat, but high biomass habitat may be mapped at higher spatial resolution than from dive surveying. Areas of low biomass can only be reliably mapped using divers. A combination of acoustic and dive survey methods in large scale surveys may help to improve the spatial resolution of mapping high density meadows, and ensure that low biomass habitat is mapped and variations in seagrass habitat type are detected.

Variation in seagrass species, patchiness of the meadow, sediments and bottom topography all influence acoustic backscatter signals. Acoustic data needs to be ground-truthed during each survey event and the intensity of ground-truthing of acoustic data depends on the scale at which these influencing factors vary over the survey area. Initial surveys of new areas will require frequent ground-truth sampling. Once the spatial pattern of these influencing factors is known, the level of ground-truth sampling in subsequent monitoring surveys can be moderated.

The acoustic techniques trialed here show potential advantages against dive-based surveys. With further improvements, and with ground-truth sampling, acoustic survey techniques can provide high-resolution maps of tropical seagrass habitat boundaries. They potentially reduce the need for large numbers of dives in turbid, sub-tidal waters where other remote sensing methods are limited and where dangerous marine animals and other safety risks can occur. Advantages of these acoustic techniques may be greatest in fine-scale mapping and monitoring of small areas of high density habitat, where acoustic techniques can be intensively ground-truthed and the influence of seagrass species, sediment type and bottom topography on acoustic signals can be economically measured.

Improvements in acoustic techniques are recommended. Integrating real-time dGPS (position and time) data into the acoustic recording system and ensuring reliable data capture from satellites should reduce data redundancy and errors in positioning of acoustic data points. Acoustic reflectors or markers in known positions can also provide spatial reference points within the acoustic survey data. Techniques which stabilise the transducer (eg., use of a

towfish or fixed-point platforms) will help to reduce errors in signal strength and position of data points. For current acoustic survey techniques the minimum acceptable water depth is approximately 0.7m, and for fixed transducers the maximum acceptable surface chop is approximately 0.8m wave height.

5. CONCLUSIONS AND RECOMMENDATIONS

There is an increasing need to find remote sensing techniques which will help minimise time spent by divers in waters, where a) survey costs are high, b) spatial resolution of mapping requires improvement and c) dangerous marine animals and other potential safety risks occur. Our preliminary trials show that acoustic techniques can be applied to mapping seagrass meadow boundaries, but not for determining seagrass biomass in tropical northern Australia.

Boundaries of seagrass meadows were successfully mapped using a fan beam system, combined with ground-truth information. Obvious changes in the backscatter when checked with seagrass ground-truth data can help identify seagrass habitat boundaries, however patchy cover of low-density seagrass habitat cannot be mapped with confidence.

Meadow boundaries drawn from fan beam data can be continuous and at a much higher resolution than is normally possible from dive-based surveys alone. In turbid, sub-tidal waters where the aid of aerial photography is not possible, the accuracy of meadow boundaries drawn from dive surveys are usually dependant on the distance between survey sites.

Acoustic survey methods and techniques require further development before they can be used to reliably map seagrass biomass distribution in tropical seagrasses. We recommend that modifications be made to reduce transducer instability, ensure the use of real-time dGPS systems and reliable satellite data capture, and measure the effects of seagrass species, sediment type and bottom topography on acoustic signal strength.

Remote sensing techniques can only be applicable to monitoring seagrass biomass if they can measure changes which are statistically defensible and which are considered ecologically important. Present conical beam transponder/transducer hardware and signal processing software appear able to measure fine-resolution differences in acoustic signal response, however this acoustic-signal resolution for measuring seagrass biomass is masked by the large errors caused by transducer instability, environment patchiness, sediment type and bottom topography. Refinement of the conical beam technique is also required to discern low-biomass seagrass habitat from bare substrate.

Acoustic techniques can provide sediment mapping information at spatial resolutions better than normally available from traditional sediment mapping methods. Acoustic data shows strong statistical relationships with some parameters of sediment composition, but cannot be used to describe details of sediment grain-size composition (eg., grain size range, variance and distribution). Acoustic data can be used in some situations as a proxy for percent mud - a useful sediment parameter in marine ecology studies. Acoustic data also correlated to a weighted average of sediment grain size, but valuable ecological information on grain-size composition is missed when this parameter is used alone.

Acoustic signals provide a relative measure of changes in benthic habitat parameters. Absolute data on these habitat parameters must be obtained from ground truth sampling and be used to calibrate the conical and fan beam acoustic data. Ground-truthing is necessary for every survey event to interpret graphs and images created with the acoustic technique. The

frequency and intensity of ground-truth sampling required to interpret acoustic images and plots will depend on the spatial scales at which influencing parameters change.

Advantages of the acoustic techniques for habitat mapping could be greatest in monitoring small areas where the variation in seagrass species, sediment type and bottom topography are known and ground truth sampling can be minimised. For large scale mapping, a combination of acoustic and dive survey methods, might help improve spatial resolution of mapping high density habitat and ensure low biomass and variations in habitat type are still detected.

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