4. Discussion

4.1 RADARSAT FINE BEAM

RADARSAT fine beam data, thanks to their ground resolution of 6.25 m, provide excellent images of all aquaculture and fisheries structures considered in this study and, therefore, allow for their inventory and monitoring with great accuracy. As indicated in Table 4, fish pens were detected and easily mapped only with RADARSAT data. Similarly, fish traps were visible only on the RADARSAT image, but their mapping was not immediate due to the inherent characteristics of the traps themselves.

Having considered these evident advantages, some other aspects of RADARSAT data should be evaluated: a RADARSAT fine beam frame covers only 50 x 50 km at a cost of US$ 3 000 if the image has been already acquired and is available (archive data). Satellite programming cost is US$ 100 but goes up to US$ 500 if an acquisition date is booked in advance. For further information see http://www.rsi.ca/.

4.2 ERS SAR

ERS SAR data in their GEC format have a ground resolution of 12.5 m and cover a 100 x 100 km area. Fishponds and fish cages were easily mapped through ERS SAR data during this study with accuracy comparable to that of RADARSAT. An ERS SAR frame costs US$ 1 400 for both archived and programmed data.

In the present study we had the possibility of having ERS SAR data both in ascending and descending orbit. As discussed, this is a distinct advantage as it greatly increases detection and, thus, accuracy in fishponds mapping. For mapping fishponds and fish cages we recommend using ERS SAR with data from ascending and descending orbits acquired with a limited time interval between dates of recording. For further information see http://earth.esa.int/helpandmail/help_order.html or http://www.eurimage.com.

4.3 FINAL CONSIDERATIONS AND RECOMMENDATIONS

Mapping and monitoring coastal aquaculture and fisheries structures is extremely important for governments as this generates baseline information (e.g. see Tables 5 and 6 and appendix) for decision-making for a proper development of aquaculture and fisheries, including regulatory laws, environmental protection and revenue collection. This can be achieved with good accuracy and at regular intervals by satellite remote sensing, which allows observation of vast areas, often of difficult accessibility, at a fraction of the cost of traditional surveys. In several cases the information obtained through satellite remote sensing is unique, as it cannot be generated by any other means.

This study, and the other conducted previously in Sri Lanka (Travaglia, Kapestky and Profeti, 1999) have demonstrated that satellite imaging radar (SAR) data are unique for mapping aquaculture structures for two reasons: (1) for their inherent all-weather capabilities that are very important because aquaculture activities occur mainly in tropical and subtropical areas that aften are cloud covered, and (2) essentially because the backscatter from the fisheries structure components allows for their easy identification and separation from other natural and man-made features.

Other satellite sensors, operating in the visible and near-mid infrared portion of the electromagnetic spectrum are of questionable use for this task, as frequent cloud cover over the areas of interest impedes their use and also because of the very high possibility

of misinterpretation of fishponds and other water-covered features, such as flooded rice paddies, marshes, etc.

The mapping accuracy obtained with SAR data is very high: 100 percent for fish pens and 95 percent for fishponds. It has been difficult to field check the mapping accuracy for fish cages, as they are floating and thus movable if need arises. However, their clear appearance on the SAR data, including information on their metallic/non metallic structure and the fact that they cannot be mistaken for any other object, permit a 90 percent estimated mapping accuracy.

Fish traps are detectable only on RADARSAT fine beam data, both offshore and inside river estuaries. Often their length can be measured. Being thin elongated structures almost completely under the water, their backscatter on SAR data should be maximum at low tide. Unfortunately, as indicated in section 2.1, tide information for the Lingayen Gulf was not available for the selection of the relevant data. Thus for fish traps it can be said that detectability on RADARSAT fine beam data is high and mapping accuracy can be estimated at 70 percent.

An extremely important aspect of aquaculture and fisheries structures mapping by satellite imaging radar (SAR) is that the resulting maps are geocoded and available in a Geographic Information System (GIS) as information layers. By adding other GIS layers such as land cover, urban development, tourist sites, areas subjected to conservation measures, potential/existing pollutants, water quality and other information layers of interest, the resulting database becomes a powerful tool for a proper management and development of the local resources, including environmental protection.

Another important aspect which should be considered is that the database facilitates identifying land cover changes which occurred during the development of the structures, mainly fishponds, and/or selection of the best places for their expansion, taking into account other potential and often conflicting uses of the area.

Although the hardware and software for remote sensing/GIS applications are available in almost all scientific institutions, the experience in handling SAR data is not common. Thus this report aims at the necessary technology transfer for an operational use of the approach indicated in other similar environments.

The present study complements two previous environmental and resources assessment for fisheries and aquaculture activities conducted in the Lingayen Gulf, namely the "Coastal Resources Management Profile" (McManus and Chua, 1990) and the "Socioeconomic Assessment" realized by BFAR in 2001. It could be used for fisheries and aquaculture development and management as well as for coastal area management of the Gulf.

Considering the low cost and precision of the methodology utilized for the aquaculture and fisheries structures mapping in the Lingayen Gulf, it should be expanded to cover all other areas of interest. The resulting database could constitute a powerful tool, essential for any decision-making concerning the management and development of these activities and could promote responsible fisheries by improving the sustainability of aquaculture and fisheries.

This would be easily accomplished by the creation of a GIS Unit in BFAR, including the necessary technology transfer, and by fostering, maybe with a FAO catalytic role at the beginning, close cooperation between BFAR and the existing local institutions having expertise in remote sensing and GIS, such as the National Mapping and Resource Information Authority (NAMRIA) and the Bureau of Soils and Water Management (BSWM).