

Figure 5: Above, interactions of a radar beam with a fish cage. Below, appearance of small cages (left) and large cages (right) in a RADARSAT-1 image.

Finally, the appearance of the structures in the SAR imagery is also greatly influenced by the spatial resolution of the sensor. Fisheries structures are generally made out of thin components and cover limited extensions; thus, the highest the spatial resolution the higher the possibility of detecting them. In particular, the smaller fish pens may not be evident in ERS SAR images, and fish traps are generally too thin to be detected; they appear only in the higher-resolution RADARSAT image.

Results

The results obtained by the visual interpretation of the SAR images and the comparison with the data obtained from the topographic maps of 1977 are reported in this paragraph. Results refer to the area under study, that is the area covered by the satellite frames, and to the period of acquisition of the satellite data.

Fishponds

Fishponds occupy the largest surface of all the structures occurring in the area. It is interesting to compare the surface occupied by fishponds in the year 2002 (excluding the class fishponds/uncertain) with their area coverage mapped in the 1977 cartography. The cartography showed three types of fishponds: active, empty, and active containing nipa . Fishponds are routinely emptied for maintenance purposes, and nipa trees are cultivated inside active fishponds; thus, in order to perform a correct comparison, the cumulative surface covered by these three classes in the cartography of 1977 has been calculated. The results are shown in Table 2: the cumulative area occupied by fishponds has increased. It must be noted that this does not correspond to a simple expansion of the fishponds existing in 1977. Some of the ponds mapped in 1977 were converted to other uses (e.g. commercial lots). Fishponds appear in SAR images as shown in Figure 2.

Table 2: Length of the fish traps detected in the study area

Class Description	N. of elements	Cumulative length (km)	Average length (km)	Min length (km)	Max length (km)	Std deviation
Traps in the open sea	378	50.104	0.133	0.018	0.642	0.093
Traps inside rivers	84	7.886	0.094	0.024	0.036	0.061

Fish pens

Fish pens were detected only on RADARSAT-1 data, as explained in the preceding paragraph. The pens are located in the estuaries of the major rivers. In many cases, they are adjacent to fishponds. The 1977 cartography does not include fish pens, thus a comparison with the actual position and location is not possible. Figure 6 shows the typical appearance of fish pens on SAR images.

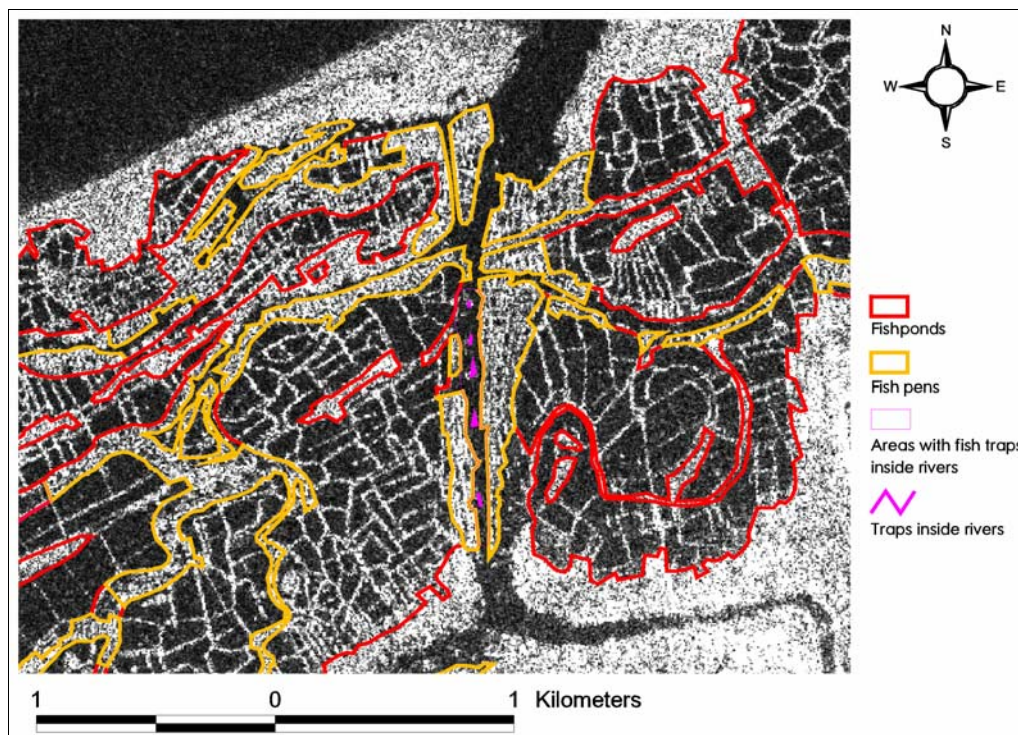


Figure 6: Interpreted RADARSAT-1 SAR image.

Fish cages

Fish cages were detected both on the RADARSAT-1 image of 4 February 2001 and in the two ERS-2 images of 2002. They are more evident in the first ERS-2 image (2 December 2002), as in the second one (23 December 2002) the roughness of the sea surface and the low tide decreased the contrast between cages and the surrounding surfaces.

Fish cages may be of several shapes (square, rectangular, circular) and of various materials. Those made up mainly of metal have a brighter appearance on SAR images. In fact, in addition to the factors already described, the intensity of the SAR backscattered signal is proportional to the dielectric constant of the scattering surface; metals have high dielectric constants and generate a stronger return signal. Figure 7 shows the appearance on RADARSAT-1 SAR and ERS-2 data of small metallic and non-metallic fish cages. Figure 8 shows the appearance of large cages on RADARSAT-1 SAR data. Data on fish cages in 1977 are not available, thus a comparison with the actual area coverage and location is not possible.

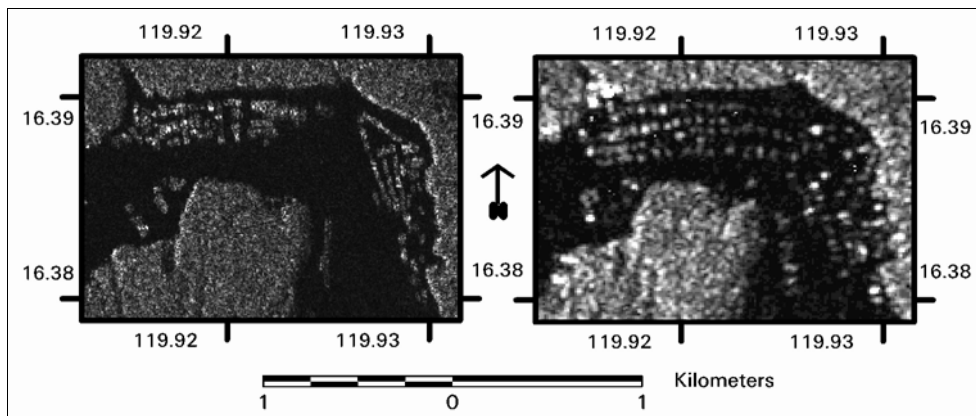


Figure 7: Appearance on RADARSAT-1 (left) and ERS-2 (right) images of small metallic and non-metallic fish cages. Metallic cages appear as brighter spots.

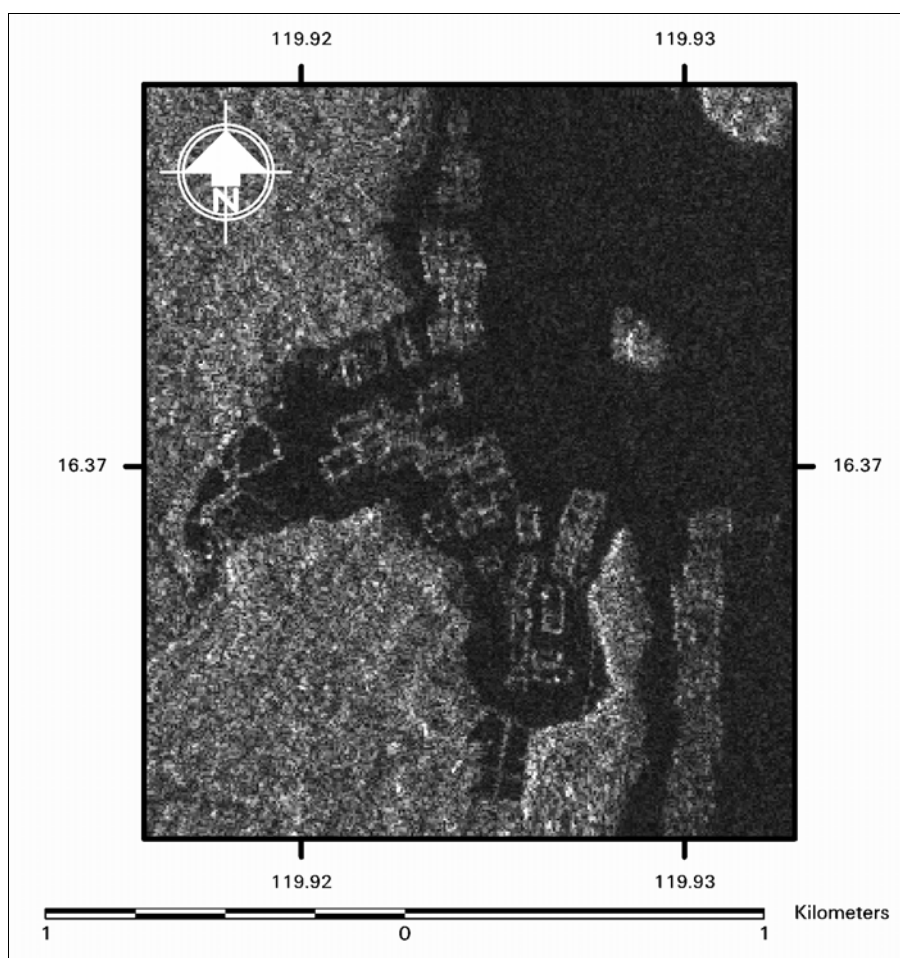


Figure 8: Appearance of large fish cages on RADARSAT-1 SAR data.

Fish traps

Fish traps were separated into two categories: offshore traps and traps inside major rivers. The areas occupied by fish traps were contoured only approximately to estimate their extension. Traps were detected only on RADARSAT-1 data of 2001. In many cases only the central structure of the traps is visible in the images; on the other hand, because of their dimensions the uncertainty on the identification of traps is higher than that of the other structures. Figure 9 and Figure 10 show respectively the typical appearance of offshore traps and traps inside major rivers on RADARSAT-1 SAR images. Traps were not mapped in the cartography of 1977, thus a comparison with the past situation is not possible.