

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 7: 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 Figures 8 and 13.

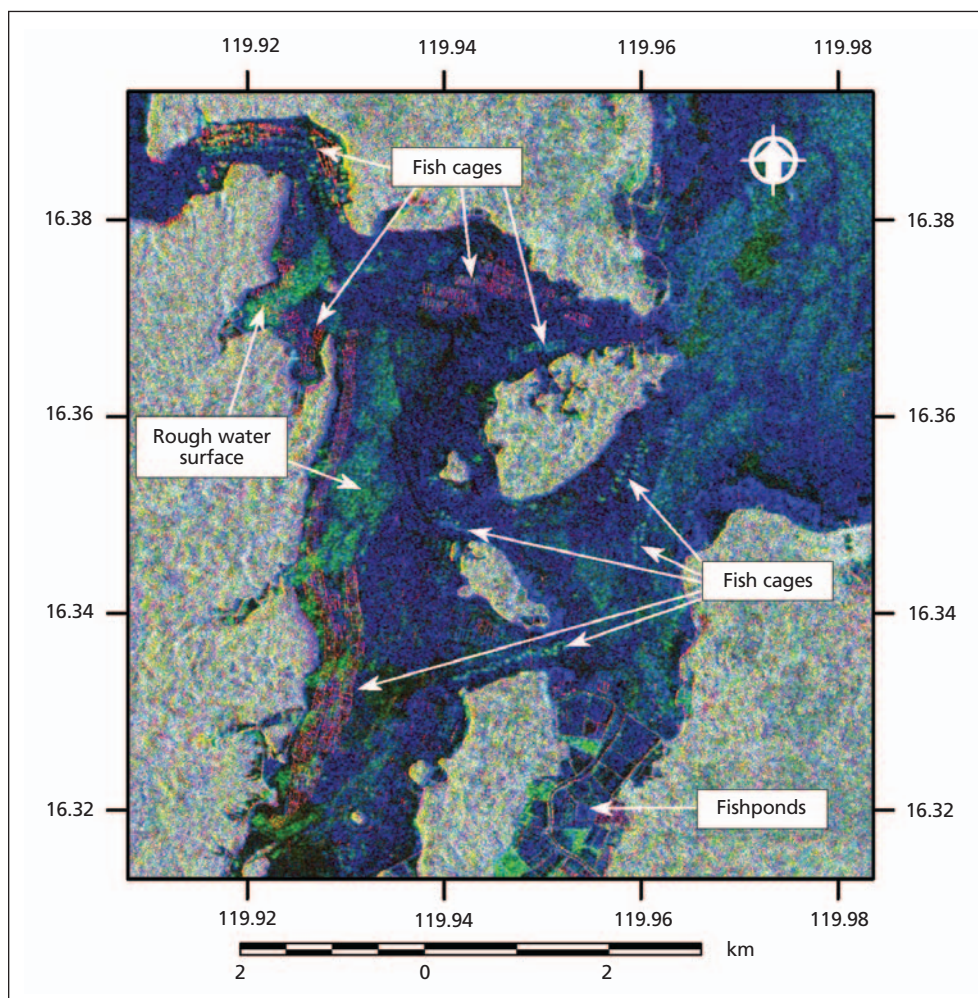
TABLE 7

**Comparison between the fishponds area coverage in 1977 and in 2002**

|                | Total Number of elements | Cumulative area<br>(km <sup>2</sup> ) |
|----------------|--------------------------|---------------------------------------|
| Fishponds 1977 | 640                      | 110.248                               |
| Fishponds 2002 | 677                      | 176.485                               |
| Difference     | + 37                     | + 66.233                              |

FIGURE 14

**Colour combination of the three SAR images used in the study. Red: RADARSAT-1, 4 February 2001; green: ERS-2, 2 December 2002; blue: ERS-2, 23 December 2002**  
(Note the different position of fish cages in 2001 and 2002)



### 3.2 FISH PENS

Fish pens were detected only on RADARSAT-1 data, as explained in the preceding chapter. 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 13 shows the typical appearance of fish pens on SAR images.

### 3.3 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 (Figure 14). Table 5 lists the number of elements (cages or groups of cages) found by visual interpretation of the RADARSAT-1 and ERS-2 images, and the corresponding total surface. The number of cages detected in the ERS-2 images of 2002 is greater than in the RADARSAT-1 image of 2001. However, the total surface of the cages in 2002 is smaller than in 2001. In fact, more small cages and less large cages were detected in the 2002 images with respect to the 2001 images.

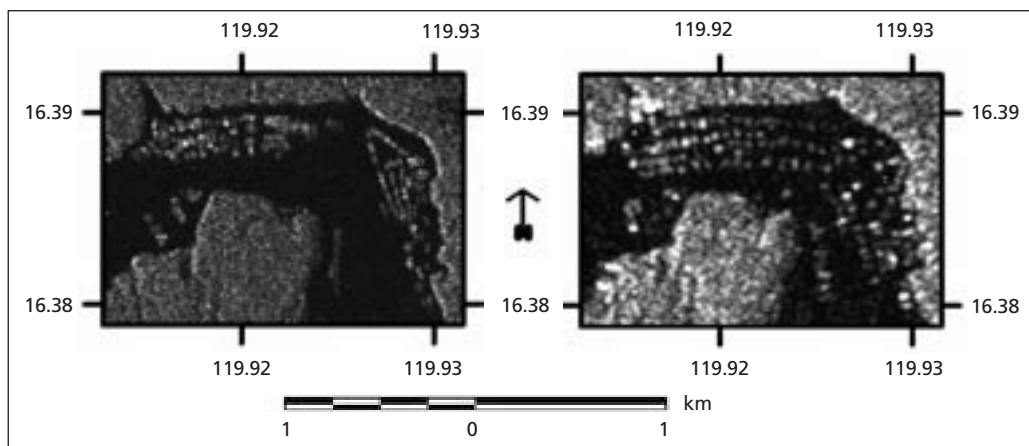
Fish cages may be of several shapes (square, rectangular, circular) and of various materials. Those made up mainly of metal have a brighter appearance on SAR images. In fact, in addition to the factors described in section 2.2, the intensity of the SAR backscattered signal is proportional to the dielectric constant of the scattering surface; metals have high dielectric constants and generate a stronger return signal.

Figure 15 shows the appearance on RADARSAT-1 SAR and ERS-2 data of small metallic and non-metallic fish cages. Figure 16 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 15

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



### 3.4 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.

Table 6 shows the statistics obtained from the polylines digitized from the detected traps. These data are not precise, as in many cases only the central structure of the traps is visible in the images; on the other hand, because of their dimensions (section 2.2) the uncertainty on the identification of traps is higher than that of the other structures. Figure 17 and 18 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.