Mapping Laborie Bay, Saint Lucia

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This report is a product of a research project aimed at testing and developing tools, methods and approaches critical to the sustainable development of coastal communities in the Caribbean and other parts of the world. The project, called *People and the Sea: a Study of Coastal Livelihoods in Laborie, St. Lucia*, is implemented by the Caribbean Natural Resources Institute (CANARI) in collaboration with the Laborie Development Planning Committee (LDPC), the Department of Fisheries in the Government of St. Lucia, and a number of governmental and community organisations. *People and the Sea* is funded by the United Kingdom Department for International Development (DFID) under its Natural Resources Systems Programme, and receives technical assistance from the Institute of Development Studies at the University of Sussex in the UK.

The primary focus of this initiative is on testing and developing specific tools and methods in participatory planning, institutional design and sustainable use. *People and the Sea* therefore tests, develops, refines and documents methods that aim at increasing effective participation of stakeholders in all stages of planning and management. It also explores and documents technologies and management tools which can enhance the social and economic benefits derived from the sustainable use of coastal resources, and particularly from the reef fishery, sea urchin harvesting, seaweed cultivation and heritage tourism. At the same time, the project will help to evaluate the impact of participation on the sustainability of resource use and on the livelihoods of people, by identifying and monitoring concrete linkages between institutional and technological change on the one hand, and the well-being of both the people and the reefs on the other. At the end of the project, results will be analysed, documented and disseminated for the benefit of resource managers and policy makers within and outside the Caribbean region.

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Background

Mapping is a valuable tool for the effective management of natural resources, providing visual representations of the types and extent of resources and their patterns of use. The mapped information can be analysed in detail, for example to monitor changes over time, using an appropriate Geographic Information System (GIS).There is a wide assortment of tools and methods available for mapping reefs and other marine and coastal features and the field has developed rapidly in recent years. This reflects the benefits of improved remote sensing data and Global Positioning System (GPS) tools, and the development of affordable cartographic and GIS hardware and software. However, the cost and complexity of some of these tools can be very high and the choice of techniques must be carefully balanced against the purpose of any mapping exercise.

In the Eastern Caribbean there are a few examples of detailed marine habitat mapping, such as for the British Virgin Islands, the United States Virgin Islands, and Anguilla. These examples represent an approach based largely on remote sensing, including satellite imagery, to provide small-scale maps of substrate and habitat types. Simpler tools and approaches may be more appropriate for relatively small study areas requiring larger scale maps. In addition, when mapping is being undertaken as part of a participatory process then precise delineation of substrate types may not be the most appropriate end product. People in coastal communities will have a wealth of information that can be incorporated in maps, such as local names for different physical features and places used for specific activities as well as anecdotal and historical information. Mapping such information will mean focusing on features that are meaningful to, and used by, resource users as well as working at much larger scales than are typically used for habitat mapping. This is particularly true in the coastal areas of high volcanic islands where recognisable shallow water features such as reefs are only found close to shore.

One activity of the *People and the Sea* project was the description of the type and distribution of habitats and other features in the study area. The study site includes three bays along 3.0km of coastline, Laborie Bay itself, Sapphire to the west and Titwou to the east. Reefs are found in all three, and extend to approximately 1.5km offshore in the first two. The Laborie watershed covers approximately 100ha, with drainage limited to a number of small seasonal streams and man-made drains running through the village.

As with most islands in the Eastern Caribbean, Saint Lucia’s reefs have not yet been mapped in any detail and it was soon evident that there was little published information on the reefs in Laborie Bay. Given that mapping can be a very costly exercise there was a need to make the best use of any existing material, and to build on that using cost-effective methods and equipment. The would involve firstly the collection of existing information of any type and complementing it with data gathered through field surveys and from the Laborie community, and secondly the use of the geographic information in experiments in participatory approaches to resource management and information dissemination.

Cartography resources

The assessment began with the identification of whatever published information was available in Saint Lucia on marine and coastal habitats, and identified the following.

- Reproductions of various historical maps with little or no detail of marine features. A number of these have been produced commercially and are readily available in shops catering to visitors, particularly at marinas and chandleries.
- Original hand-painted maps from the mid 18th Century indicating soundings, reefs and anchorages. These were located in the collections of the Saint Lucia National Archives where they were made available for scanning. Relevant sections were scanned directly into a notebook computer using a desk top scanner.
- Topographic maps at 1:2,500, 1:10,000, 1:25,000 and 1:50,000, the most recent compiled in 1995 from a 1992 aerial survey. These were readily available in the Lands and Surveys Department of the Ministry of Planning. Hard copies measured up to 0.7m X 1.0m and were scanned on a drum scanner and saved to CD.
- Navigational charts showing general reef distribution but at a very coarse level of detail, intended only to identify the seaward boundary of reefs as potential navigational hazards and mainly based on 19th Century surveys. Charts are included in various cruising guides to the region as well as from software packages, such as Chart Navigator, produced for the yachting community.
- Airphotos made for land cartography but including marine features to a distance of approximately 1.25 km from shore, from series made in 1941, 1966, 1977 and 1992, were also made available by the Survey and Mapping Department and scanned directly into a notebook computer using a desk top scanner.

Relevant information is also available in a number of technical publications on marine habitats, particularly those focusing on the status and distribution of reefs, and many of these are available free from Internet sources. Many astronaut photographs taken from the Space Shuttle clearly show shallow reefs to a depth of 15m and are now freely available via the Internet from the NASA-Johnson Space Centre. Some key resources of this type are listed in the bibliography.

Tools

An appropriate GIS application was needed to use the available maps and airphotos, and to generate new maps to include information that would be gathered during the project. The following criteria were used in selecting a GIS application for the project:

- Ability to exchange spatial data with GIS applications already in use in the country.
- Ability to use both raster and vector formats[1].
- Ability to calibrate (georeference) raster images.
- Affordability at startup, without costly annual maintenance and upgrade fees.

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[1] An example of a raster image is a scanned map in which each pixel is described, but which does not contain information that describes objects. Common file formats are *.BMP, *.JPG and *.TIF. An example of a vector image is an object drawn in Map Maker or other GIS. A vector file contains information that describes the position and magnitude of objects. File types include *.DRA used by Map Maker, *.DXF used in CAD applications, and *.SHP used by Arc View.

ü Ability to import and use GPS data.
ü Ability to convert among raster file formats.
ü Availability of these features in one program without the need for costly add-on modules or third-party software.

Based on these requirements, Map Maker Pro, developed by Map Maker Ltd in the UK was a suitable choice. Of particular importance was its compatibility with all commonly used GIS packages and that it was designed specifically for resource management studies.

Data gathering

Historical maps

Early maps of Saint Lucia, produced in the 17th and 18th Centuries, did not identify Laborie Bay but showed a small island at the eastern end of it, and the small beach at Sapphire identified as Anse a Charles (Figure 1). The bay was also identified as an anchorage for ships.

Figure 1. Extract of a map from 1758

More detailed description and cartography of the area were published in 1784, with subsequent versions of maps, by Jean Francois Lefort de Latour, Surveyor to the King of France. Figure 2 shows part of the original oil painting which depicted the whole of Saint Lucia. Laborie was located in the *Quartier de l'Islet à Caret*, indicating the importance of the extensive sandy beach as a turtle nesting site. Laborie was thus one of dozens of places in the region named after turtles, providing an historical proxy of ecosystem change and of the past abundance and subsequent decline of these and other species (Jackson *et al*. 2001). At that time the small island in Laborie Bay, named l'Islet à Carret (Figures 2 to 4), was also noted for turtle nesting and as a roosting site for seabirds. This was possibly a sand bank and even when it was described in 1787 it was already being washed away by the sea (Jesse 1986). The units of measurement are not indicated on the maps of Lefort de Latour but the unit used for the depth soundings was most likely the French fathom, or toise, equivalent to 1.949m.

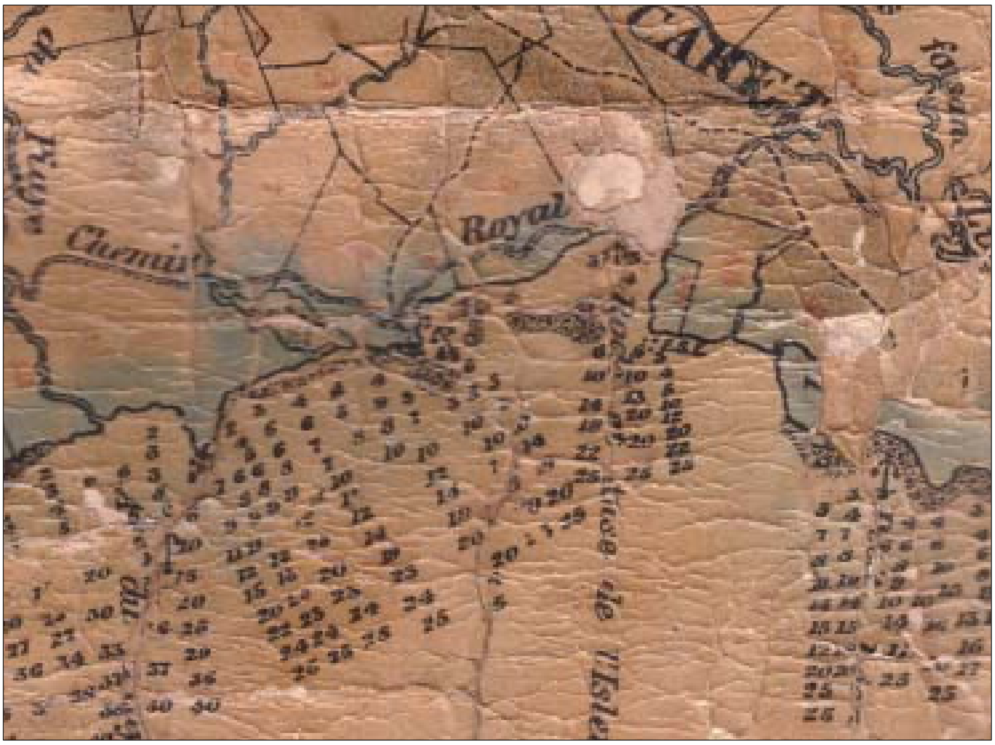

Fig. 2 . Extract of an original 1787 map by Lefort de Latour

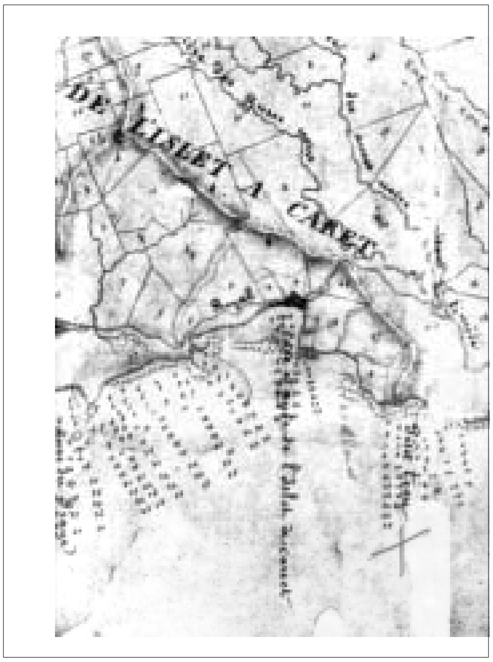

Fig. 3 Extract of one of the copies of the original map of Lefort de Latour

Fig. 4. Detail of Fig. 3 showing depth soundings and the location of the island in Laborie Bay in the 1780s

Topographic maps

Topographic maps prepared in 1995 at 1:2500 scale were obtained from the Survey and Mapping Department in hard copy, scanned on a drum scanner and calibrated (georeferenced) in Map Maker. A mosaic was compiled of the three map files that covered the study area and an extract from the mosaic is shown in Figure 5. These calibrated maps provided the basis for calibrating airphotos and for verifying the accuracy of GPS coordinates.

Airphotos

Contact prints of monochrome airphotos were available from surveys conducted in 1941, 1966 and 1977, and from 1992 in normal colour. While these were produced for land cartography there is some marine coverage where flight paths crossed embayments, such as Laborie. Relevant prints were scanned and calibrated. The colour airphotos from 1992 provided the initial information on the general distribution of different marine habitats, including sand, seagrass, reef and mangrove areas.

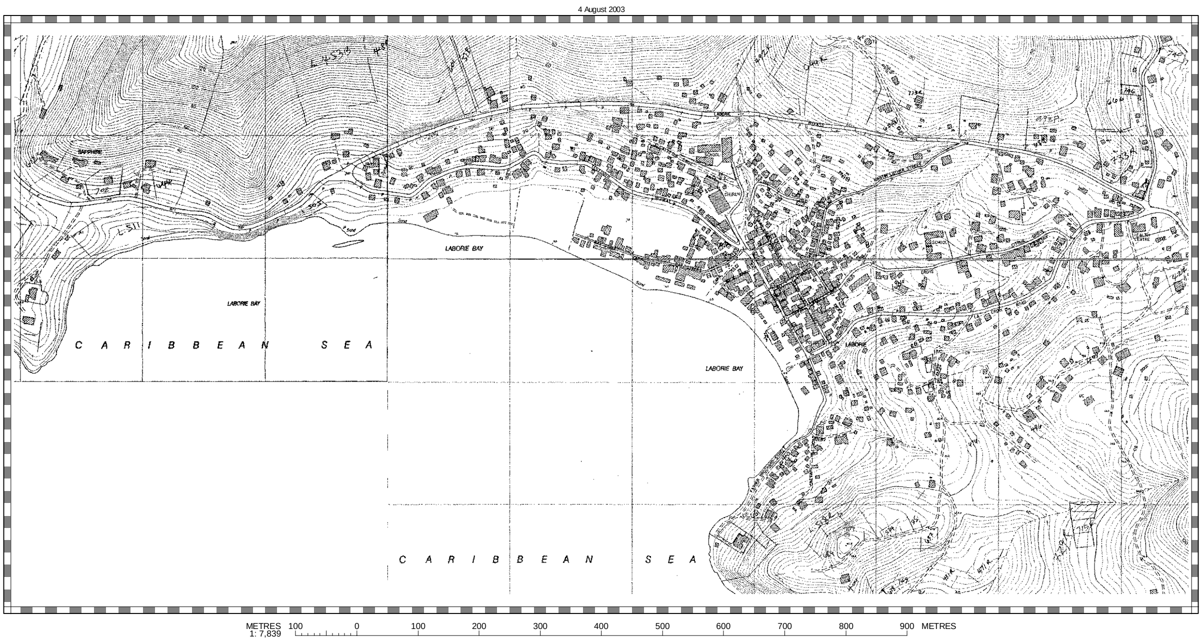

Figure 5. Extract from a mosaic of three 1:2500 topographic maps.

Some rectification of airphotos was necessary for terrestrial features to account the distortion induced by the hilly topography. This was done using the rubber sheeting facility in Map Maker, which manipulates the raster image to match identifiable features in a vector layer drawn from the topographic maps. Calibration using features on flatter coastal areas gave a more precise match with the topographic maps and no rectification was necessary.

Nautical charts

A widely used chart of the bay is shown in Figure 6 below. This gives only a very general indication of reef distribution as navigational hazard. It does, however, emphasise the distance to which shallow reef extend offshore, which is uncommon in many of the volcanic islands of the region where bathymetry commonly drops sharply close to shore.

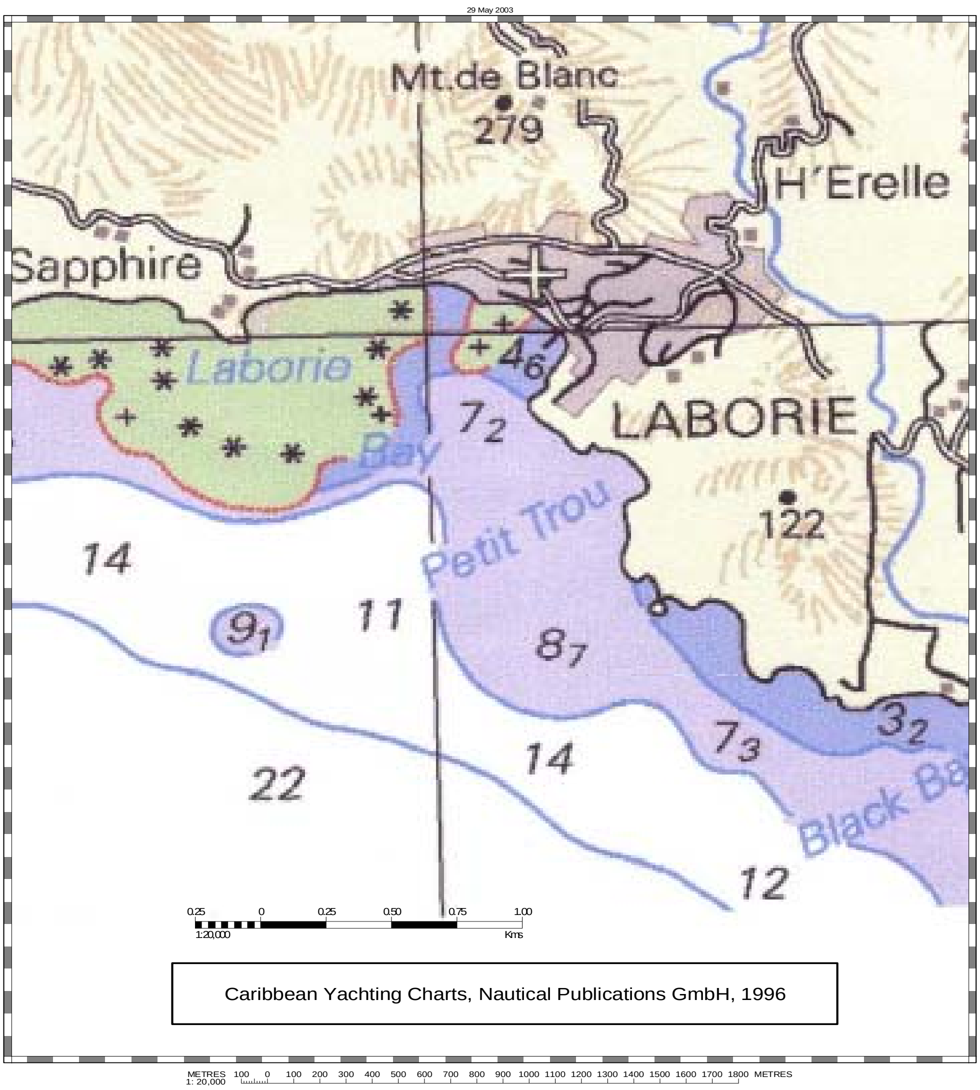

Figure 6. Extract of a current nautical chart of Laborie Bay showing reefs in green, with 5m, 10m and 20m isobaths, based on 19th Century British Admiralty surveys.

Popular knowledge

While some reefs could be clearly delineated from the airphotos, more detailed definition required ground truthing and gathering information from fishers and divers. This began with boat trips with people familiar with the area. To prepare for these, copies of the scanned airphotos were printed, mounted on card and covered with clear plastic sheet. As the boat captain navigated around the Bay features in the airphotos were annotated using permanent marker on the plastic overlay, to include place names (Fig. 7) and notes on any locations of particular importance for fishing or other activities. GPS waypoints were saved at key locations to improve the accuracy of mapping and to provide a means of returning to places of interest for further surveying and description of habitats. The information was used to compile thematic maps, using the topographic maps as a base, but in the ongoing process of information exchange the airphotos were found to be a more effective tool than line-drawn representations of the Bay. People who were not familiar with interpreting either line-drawn maps or aerial views would very easily orient themselves to features in the airphotos despite never previously having had access to such a perspective of their environment.

Once the main reefs had been identified, a large painting depicting a vertical view of the Bay was prepared on a 4ft X 8ft sheet of plywood. The reefs identified in the field trips were clearly shown and labelled with their local names. As with the airphotos, people readily oriented themselves to the features in the painting and were able to provide and locate additional details. This painting was used in planning activities and in public meetings as a centre for discussion, which allowed people to continue to contribute information related to specific locations. Later it became possible to borrow an LCD projector and this was used with the project computer at evening meetings in the village marketplace. This was an effective means of presenting various types of information, including maps, text and tables of data from surveys, but was particularly effective when projecting colour airphotos of the Bay. Projecting the airphotos in Map Maker allowed graphic annotations to be displayed as thematic layers but equally important it was a dynamic tool that allowed new information to be added and displayed during the meetings. It is worth noting that the use of a laptop computer and projector appeared to be quite appropriate for public meetings in the village marketplace.

Field surveys

Interpretation of some of the features identified in the airphotos was aided by photographs taken at lower altitude from a helicopter. In cases of uncertainty reef locations were confirmed by swimming around their boundaries while storing routes or waypoints in a GPS. To map the variation of reef community composition benthic surveys were conducted using the Reef Check protocol (Reef Check Foundation 2003) which had been selected by the Global Coral Reef Monitoring Network (GCRMN) as the community-level reef assessment tool. The protocol quantifies relative cover of different substrate types including live coral and macroalgae as indicators of reef condition.

Most field surveys were conducted with a kayak, aided by GPS, a hand-held depth sounder and underwater camera equipment. The kayak was a convenient platform either for two people with snorkelling gear or for one person with SCUBA gear. GPS waypoints were used to locate specific reef and seagrass sites for repeated visits, such as the monitoring of sea urchin populations.

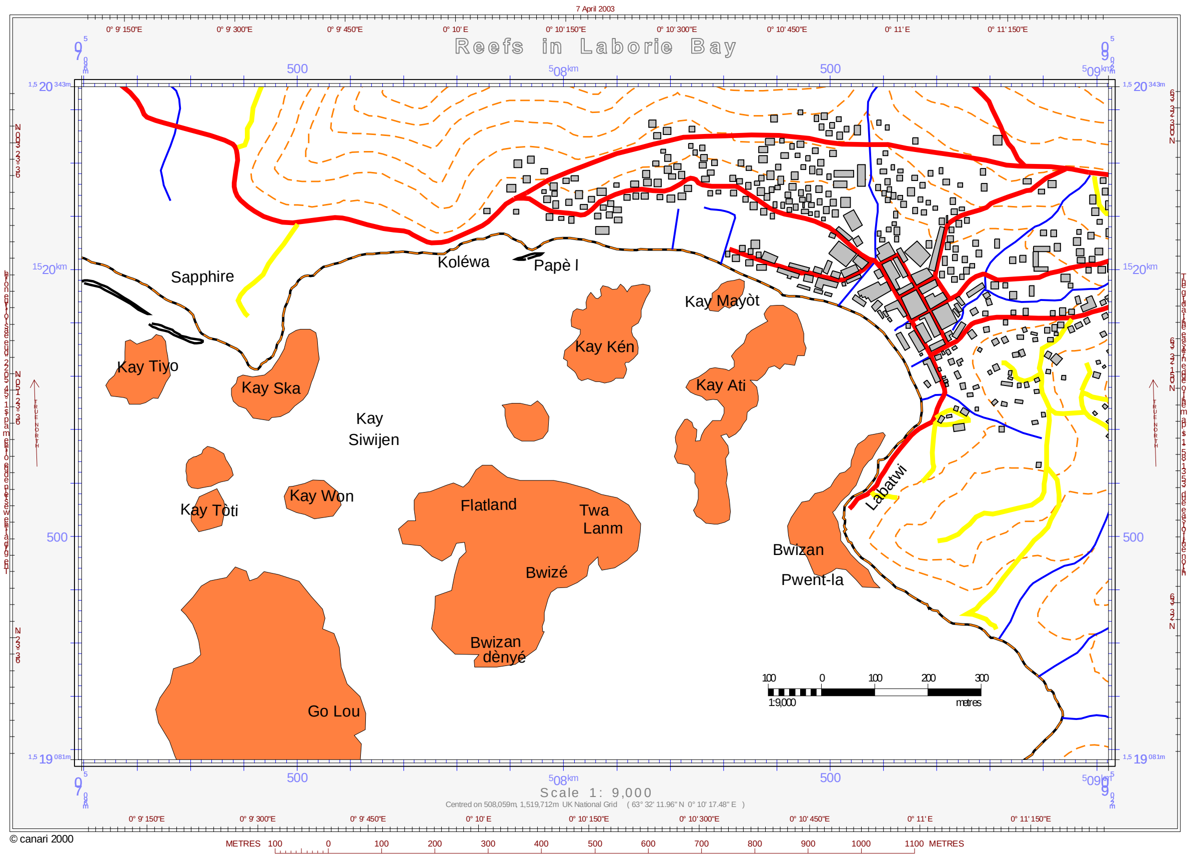

Figure 7. Distribution of reefs in the study area.

The availability of airphotos also allowed the mapping of the development of the village since 1941, shown in Figure 8, and in Figure 5 based on the 1992 aerial survey.

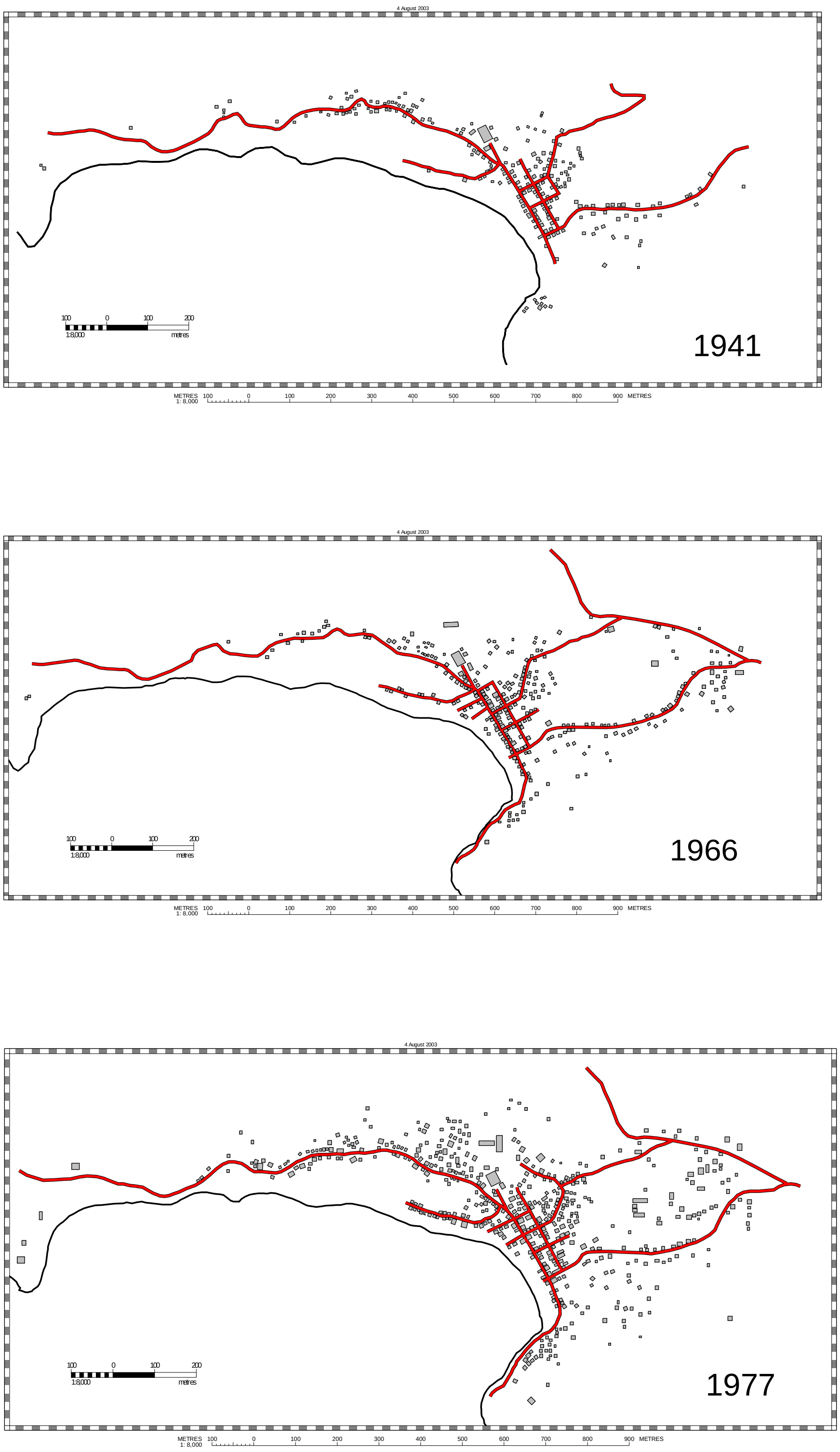

Figure 8. Development of Laborie village from 1941 to 1977

Discussion

Access to information on the history of ecosystems and habitats provides a useful basis for understanding past trends and possible directions for management. Maps are an important component of the historical record that can provide invaluable details on the development of settlements and the urbanisation of coastal areas, changes in vegetation cover on land, and coastal changes due to natural processes human impacts. Old maps may include place names and annotations that reflect past conditions and types of resources or activities that no longer exist, but which may help in the interpretation of current features and conditions. In some cases, collections of airphotos may be available and these are particularly useful when there is a time series over a number of decades. Older airphotos focus primarily on the land but shallow marine features may be included. More recent photographic coverage conducted for land surveys is likely to be in normal colour which greatly enhances the interpretation of marine features. While terrestrial mapping has evolved relatively rapidly, updating the historical record, in the case of coral reefs the only information available for many islands, such as nautical charts, may be based on data collected in the 19th Century. Reefs were often mapped relatively coarsely as navigational hazards, but the series of depth soundings on older charts provide a useful baseline for comparison with new surveys.

One advantage of the present project was the opportunity gather and redistribute information over an extended time period as this allowed for an iterative process that is not possible in a single rapid assessment (Doolittle 2003). This process also encouraged the gradual involvement of people who only began to participate, often very constructively, after a period of observing from the fringes of the public meetings. While much of the information gathered showed that people had a good understanding of aspects of the environment in which they lived and worked, there are some limitations to the way that such information can contribute to a participatory mapping exercise. For example, people's understanding may be limited to only those aspects that directly affect their livelihoods and different resource users will therefore have different interpretations of the same features and processes. An important part of information gathering, therefore, is the ability and opportunity to test and validate it. In addition to providing opportunities for people to contribute information, the mapping exercise was a useful tool for disseminating information, both at the popular level in community meetings and at the technical level in presentations to management agencies.

There is an extensive literature on the use and mis-use of GIS and its potential to disempower communities and to formalise information that may not warrant it. The *People and the Sea* project demonstrated the benefits of the technology when the information base is developed through the integration of scientific and popular knowledge. While the project used some of the analytical tools available in the GIS application, probably the greatest benefit of GIS was in the use of its cartographic tools as a means of gathering and redistributing information at community meetings. The ability to manage both raster and vector images allowed the use of airphotos, GPS data and thematic layers which could be projected and manipulated during public discussions.

The geographic information collected during the project was an essential part of the research and experimentation around which the project was designed. However, the use of this information resource extended beyond its research application. It was also an integral part of a real-life process of resource management that directly impacted people's livelihoods, such as the participatory planning of sea urchin harvests, the development of an action plan for the future development of seaweed cultivation and the decisions taken to investigate options to reduce pollution levels in the Bay. These experiences demonstrated the potential benefits to the community of transferring this project information management system to the Laborie community for its future use in resource management and development planning. Accordingly, all of the GIS components, includings maps, data, project documents and photographs have been installed on the project computer which has been given to community and housed in the offices of the Laborie Village Council. Following the closure of the *People and the Sea* project CANARI will provide training to two members of the community in managing the system, as part of a project aimed at further developing the GIS in support of Laborie's efforts to better manage its reef resources.

A note on the technology

The use of GPS technology was greatly enhanced when the degradation of the satellite signals (through Selective Availability) for public use was discontinued shortly before the start of the project. Position errors were reduced from around 100m to the 15m resolution of most hand-held GPS receivers without differential correction. Depending on satellite geometry, Estimated Position Error computed by the GPS was commonly between 3 and 4m. While precision was increased, accuracy presents a problem in the area and GPS data need some form of correction or post-processing. One option was to compare known coordinates and GPS coordinates for a number of locations and compute transform functions, such as the Molodensky transformation. Five factors could be calculated and used by Map Maker to improve accuracy, and while this was partly successful there are insufficient known sets of coordinates in the south of the island to make the best use of this option. Transform functions are most effective the closer the determination points are to the study site and functions determined from stations in the north of the island were found not to be helpful.

Instead a second method was tested. A set of 10 – 12 waypoints were gathered at obvious landmarks and downloaded onto a calibrated 1:2500 topographic map. The process was repeated at three different times to include temporal variations in signal quality. In each case it was evident that the displacement of the waypoints relative to the landmarks on the map was uniform in distance and direction. By moving the waypoint thematic layer as a whole by a calculated distance and direction all waypoints could be seen to match their corresponding landmarks with a mean error of around 5m. This approach was therefore used to correct the GPS data collected on the water.

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