USE OF SIDE-SCAN SONAR IN UNDERWATER STUDIES

Unravelling the Mysteries of Venice

The Venice Lagoon has been inhabited for over 1,300 years and the art and architecture of its city has been the subject of countless books and academic studies. Yet, despite this continuous scrutiny, virtually nothing has been known about the world beneath the surface of the lagoon. For centuries the hydraulic processes that fill and empty the 640sq km of the lagoon daily and the landscape of the seabed have been ignored or taken for granted.

The threat created by rising sea levels has finally concentrated minds on finding a way of protecting the cityâ€™s treasures. Plans are being laid for constructing storm gates across the entrance to the lagoon but this has raised questions about their impact upon its prolific eco-system. In a project under the direction of Pro-fessor Carl Amos, the Southampton Oceanography Centre (SOC) is one of the few non-Italian research institutes funded by CORILA (Consortium for Co-ordination of Research Activities concerning the Venice Lagoon System) to gather data that will help make possible sound decisions. Using digital side-scan sonar, the Centre has made a surprising discovery of submerged beaches that have a crucial role to play in preservation of the lagoonâ€™s wetlands. The SOC team is now continuing in its work to resolve a number of unanswered questions on the source and evolution of these beaches.

Mapping the Lagoon

The most fundamental task needed as a basis for all of the studies was to create accurate maps of the Venice Lagoon. These have never existed in the public domain, so the team used a Model 1640 scanning sonar from Marine Electronics Ltd to undertake a detailed hydrographic survey of the northern lagoon. The results were achieved by using the unit in side-scan mode in conjunction with the 1640â€™s profiling sonar. Both provided a high-resolution colour display with multiple display modes, in transportable PC format. The standard Model 1640 was operated at 500kHz, with 2.5Â° horizontal-beam width and 20Â° vertical-beam width. The profiling unit was operated at 700kHz, with 2.5Â° conical beam to obtain precise range and bearing information over the scanned area. The team subsequently collected over 512 line-km of bathymetric data and digital side-scan, and almost immediately discovered unexpected seabed features that have been shown to play an important role in the lagoonâ€™s complex evolution. Until this project, the behaviour of sediment had represented the biggest gap in scientific knowledge of the lagoon. Because it had not previously been known whether the lagoon was importing or exporting sand, this collection of data attained high priority for the Venetians. It was acquired from key areas and is now being used to permit the creation of accurate computer models.

Methane Escape

Another question arises from the presence of methane gas that escapes in significant quantities from the lagoon bed. In the past, local fishermen were said to land on local beaches, drive a pipe into the sand and cook their lunch over a flame fuelled by the escaping gas. The SOC team is now working to map these locations so that their potential impact on construction projects may be determined. The final objective is to establish the carrying capacity of the lagoon. This is a measure of its ability to sustain a certain level of organic production. Because the lagoon is flushed every 24 hours with oxygenated seawater and nutrients, the carrying capacity is high. The question is how this will be affected by the construction of a storm barrier. This is strongly influenced by the movement of large sheets of algae that move through the inlets close to the seabed. The Marine Electronics Sediment Imaging Sonar (Model 1640) will be used to quantify this movement in association with Venetian scientists.

Vital Flushing

Ten millions tourists a year visit the two main islands occupied by the City of Venice and the daily tidal flushing of its canals is vital to the cityâ€™s wellbeing. Because Venice has no sewage system it is dependent upon the action of the sea to remove whatever sewage is not retained in septic tanks. Failure of this mechanism would consequently eliminate the tourist industry as effectively as flooding. It was recognised over thirty years ago that the greatest danger would arise from loss of the tidal flats that bordered the inner parts of the Venice Lagoon. Three areas off Mestre were reclaimed for industrial development to be serviced by the artificial Malamocco Canal that bisects the Venice Lagoon. This was done without consideration of the impact upon Venice. In addition, large tracts of tidal flat in the western and northern lagoon were allocated for fish farming, so that by the year 1968 more than 50% of the natural lagoon had been destroyed. In total, over 160sq km of the lagoon has been reclaimed, thereby reducing the marshes by 75%.

Dwindling Tidal Flats

The bed of the Venice Lagoon is the substrate upon which bio-diversity depends. The food chain is founded upon primary production taking
place on the dwindling tidal flats.

The marshes (barene) and mudflats (palude) provide essential habitats for feeding fish, invertebrates and the plants that govern the wellbeing of the lagoon. These habitats are under threat of being lost entirely from the lagoon, with 1sq km disappearing every year.
In the past industrial and domestic pollutants have been freely discharged into the lagoon and the tidal flats sequester pollutants that become released into the water column as erosion occurs. Carl Amos predicts that the tidal flats will disappear within forty years, resulting in deteriorating water quality and productivity. This will be made worse when tidal flushing decreases in efficiency as the water volume of the lagoon increases through erosion.

Gains and Losses

In the northern lagoon, however, the tidal flats are growing, with Palude della Centrega steadily increasing in size while the southern and central parts are scoured and deepened. Recent estimates of the sediment budget of the lagoon suggest that there is a net loss of material to the open sea via the Chioggia, Malamocco and Lido entrances. According to Carl Amos, this does not explain the accumulations of sediment in the north, nor does it offer any clues as to the factors influencing this growth. The input of sediment to the region is small and confined to a seasonal discharge from the River Sile. The budget of materials is, therefore, governed by throughput in the main tidal channels feeding the northern flats. Furthermore, the trapping efficiency of the tidal flats must be high, or else like their southern counterparts they would erode. Trapping efficiency depends upon the type of estuarine circulation. It was realised that without an understanding of the mechanisms involved it would be impossible to undertake any structural changes without endangering the entire lagoon, its ecosystem and the livelihoods of the ten thousand people who live in communities on the lagoon, depending upon its fish resources.
To gain a better understanding of the mechanisms involved in estuarine circulation, a detailed bathymetric survey was carried out at the confluence of the Burano and Treporti canals. This was known to be a region of active scouring and on survey completion it was discovered that an active scour to 18m depth was taking place at most triple junctions of the canal system. Re-suspension was evident on ADCP profiles at tidal fronts evident on early ebbing tides. These develop at the confluence of ebbing tidal masses moving at different velocities and as the bottom of the scours are a mixture of sand and gravel they become a source of sand to the canal system.

Sonar Finds Beaches

Using the Marine Electronics side-scan sonar, however, yielded the most important discovery of the survey: the existence of submerged beaches of fine sand surrounding the Palude della Centrega. These beaches were seen to reduce wave action and to protect the marshes from wave erosion due to the presence of Cymadocea beds on the outer submerged beach. The SOC team observed that the wake of ships was strongly reduced by the presence of this beach, especially over the Cymadocea beds. The team subsequently carried out a detailed survey of the morphology of the beaches, as well as grain size of the material. The team also measured wave reduction and sand re-suspension over them and concluded that this morpho-dynamic feature provided natural protection of the mudflats against wave erosion. In addition, the team noted that remedial works to protect the mudflats from erosion near Scanello had involved removal of the submerged beach, with the result that the potential for erosion had been increased rather than removed.

The Final Options

This final observation has served to highlight the risks inherent in tampering with the natural mechanisms of the Venice Lagoon. It has also demonstrated the need to continue with the studies and gather data until a point is reached at which it becomes possible to confidently predict the consequences of any changes to its structure. The threat of flooding to the city of Venice is, however, very real, and the options available for its protection are limited. The construction of storm gates is an obvious solution favoured by many, but there are alternatives. These include rebuilding the crumbling foundations of the city with granite or concrete to ensure its stability and then accepting that floods will occur so that the residents can adapt their lifestyles accordingly. Alternatively, it has been calculated that the construction of a 30-cm lip around the cityâ€™s waterfronts would protect against the next fifty years of sea-level change. However, whichever option is eventually chosen, the studies are revealing that the consequences of inappropriate change could be fatal to the wellbeing of the lagoon. If the lagoon dies, the city of Venice will become virtually uninhabitable and will be destroyed as effectively as by a flood. At least we now know that unskilled tinkering with the balance of the lagoon would be as reckless as setting an untrained restorer to work on a priceless Canaletto.

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