MARINE AND COASTAL MANAGEMENT

Dealing With the Past

Mapping and cleaning up 40 years of cast-offs at McMurdo Station

By C. K. Bretz, P.J. Iampietro, R.G. Kuitek

The United States established its first year-round research base in Antarctica in 1956 to provide logistical and operational support for polar science activities as part of the International Geophysical Year (IGY, 1957-58). Over the years, the Naval Air Facility McMurdo (renamed McMurdo Station in 1961) has grown from a few dozen prefabricated buildings that supported up to 100 men to the present infrastructure which supports a human population ranging from 200 over-winterers to a capacity of 1200 during summer seasons.

Three decades of year-round station occupation has generated significant amounts of domestic and operational waste products. Now, virtually all waste produced at McMurdo Station is removed from Antarctica for proper recycling or disposal. Formerly, however, the majority of station waste (domestic, construction, transport vehicles, structural debris) was either incinerated, placed in open pit landfills or set out on the annual sea ice of Winter Quarters Bay (WQB) with the hopes that it would float away during spring break up.

At the end of the IGY, stewardship of the U.S. Antarctic Program (USAP) fell to the National Science Foundation. Based on a series of Safety, Environmental, and Health (SEH) initiatives implemented in 1987, followed by an investigation by an NSF appointed Safety Review Panel-and the adoption of the Protocol on Environmental Protection to the Antarctic Treaty in1991 by the International Treaty Parties-the NSF stepped up its commitment to address environmental concerns by pursuing an intensive evaluation and restoration of both terrestrial and marine pollution in the vicinity of McMurdo Station. Removing the debris of past Antarctic activities, improving personnel health and safety, and minimizing the environmental impact of current research and operational activities were at the top of the list.

Project Background

Following their remarkable success in the terrestrial environment, the National Science Foundation has made a serious pledge to address marine pollution issues at McMurdo Station. Numerous diver observations, plus a Remotely Operated Underwater Vehicle (ROV) survey in 1990, and our preliminary side scan sonar survey in 1991, had already revealed large amounts of debris, including vehicles, cargo containers, fuel hose, airplanes, and many intact waste drums in the shallow (<30 m) near-shore habitats. Unfortunately, this debris occurs within a region of the marine habitat frequently used by research divers. Many of the seminal papers that form the basis for our understanding of Antarctic benthic ecology and community structure have come from work in shallow water habitats near McMurdo Station. Thus, while research and interest in the polar marine environment has continued to increase, the results and safety of these operations could be compromised by the presence of debris hazards and possible contamination.

Before any remediation or cleanup of this situation could begin, the NSF needed an accurate assessment of the distribution, nature and condition of the debris littering the seafloor at McMurdo Station. This need led to funding for the project to map and produce a visual and descriptive inventory of the marine debris. The goal was to collect, archive and create a multimedia GIS to display spatially explicit information on the types, sizes, and condition of this debris; information that would help assess potential risks to the environment or safety hazards during cleanup efforts. Of primary interest was the number of liquid waste containers (55 gallon barrels) still intact on the sea floor. Also important was the inclusion of new as well as existing information on sea floor sediments and near-shore water circulation patterns, because any direct mediation efforts such as debris removal could result in the disruption and transport of contaminated sediments to pristine areas. Finally, because this frigid and frequently ice covered environment is inaccessible to all but a few, the product needed to function as a virtual site visit, enabling the user to visually inspect most of the major debris items within the spatial context of a GIS.

Field Mapping and Data Acquisition

Harsh environmental conditions and seasonal sea ice cover create a challenging setting for marine surveys in polar habitats. Mapping nearshore marine habitats in Antarctica was a formidable task requiring creative, innovative methods for acquiring geospatial data.

The original plan was to use an acoustic seafloor mapping system (digital depth sounder and sidescan sonar) from aboard one of the U.S. Coast Guard (USCG) icebreaker ASB launches during the open water season to map the nearshore habitat types, bathymetry and debris. This map was to be used to direct SCUBA video surveys of all debris targets identified on the sidescan sonographs. However, two anomalous years of shorefast sea ice forced abandonment of the sidescan sonar survey plans which required the use of a boat. Instead, during those field seasons holes were drilled through the sea ice to acquire bathymetry and acoustic classification data. Following this, a heavily equipped ROV for mapping the study area with video and acoustics was deployed. Although the ROV permitted us to visually map virtually all the debris located within the study area at very high resolution, the processing time required to analyze the many hours of video footage acquired was significant.

To aid this mapping endeavor, program participants established a real-time differential GPS survey at McMurdo. Although local geodetic control is generally non-existent in Antarctica because most of the continent is covered with moving ice, McMurdo Station is built on exposed rock and has relatively stable benchmarks nearby. A permanent NASA ICG GPS Station (MCM4) now exists. At McMurdo's high latitude, satellite elevations were frequently just above the horizon, however visibility was not problematic during the surveys on the unobstructed sea ice.

Bathymetry

Bathymetric data was digitally recorded using an Innerspace 448 digital echo sounder, coupled with a Trimble Navigation 4000 RL real-time differential GPS system that provided +/- 2m x, y precision. A sounding line was used to calibrate the Innerspace sounder at the beginning of each survey. Hypack¨ Hydrographic software by Coastal Oceanographics was used for data acquisition and survey navigation along preplanned track lines. During two field seasons, the survey system was hauled in man sledges across the sea ice along preplanned survey lines while drilling equipment entry holes at 50m intervals through 2.5m sea ice. While covering the majority of the planned survey area, some regions were not sampled in this manner due to unsafe ice or open water conditions that prevented access. Data gaps in the bathymetry were filled during the ROV surveys in the third field season. Depth values were not corrected for tidal variation because tidal excursion did not exceed 1m at McMurdo during our field surveys (NOAA, National Ocean Service), confirmed by measuring tidal excursion of the sea ice at a fixed location with a depth sounder placed on the sea ice.

Acoustic Seafloor Classification

Bottom-sediment type and morphology were surveyed with a RoxAnn¨ (Marine Microsystems Ltd.) acoustic seabed classification system. RoxAnn¨ is a parallel-processor that extracts data on the roughness and hardness of bottom reflections from the depth sounder echoes. This device was an integral component of the bathymetric system described above. RoxAnn, in conjunction with the Hypack¨ hydrographic survey software, makes use of the 1st and 2nd acoustic returns from the Innerspace 448 depth sounder and classifies the substrate at each bathymetric sounding position as one of up to 16 user-defined types. Each classification type was ground-truthed either via diver observations or during ROV video analysis. Output from the Hypack-RoxAnn analysis was further processed with TNTmips¨ GIS software to create a point by point seafloor classification of each bathymetric sounding position, and a range classification, in which sounding positions were grouped into areas of like classifications.

ROV Video and Acoustic Seafloor Surveys

A Super Phantom¨ S2 ROV (Deep Ocean Engineering), provided by the NOAA National Underwater Research Program (NURP) was successfully used to acquire continuous, georeferenced video data of the seafloor debris fields. The ROV was deployed from a heated hut centered over a 1.3m diameter hole drilled through the sea ice. Entry holes evenly spaced across the survey area provided 100% coverage of the most highly impacted marine habitats out to 60m depth. The ROV was instrumented for standard color and wide angle low light black and white video recording to Hi-8 cassettes. Ambient and onboard lighting was used as needed for target and seafloor illumination. Parallel laser beams separated by a set distance were placed in the ROV video camera field of view for later measurement of debris object and patch dimensions from the recorded video images.

The ROV was also fitted with a pressure transducer for recording water depth along with the transducer from the Innerspace echo sounder/RoxAnn system. This arrangement enabled the acquisition of continuous bathymetry and seafloor classification data along all of the ROV survey lines. ROV survey guidance was accomplished with underwater acoustic tracking (Track Point II¨, ORB International) linked by the PC-based Hypack¨ hydrographic survey software to the Trimble DGPS system described above. This integrated navigation system permitted precise (+/-5m) ROV positioning along preplanned survey lines.

Debris objects were initially identified as they first appeared on the ROV video monitor screen during the survey. At that time each object or patch of objects was assigned a unique identifier and their UTM positions marked as a "target fix" in Hypack¨. A given debris target was cataloged as a single object or a patch of similar or dissimilar objects. An effort was made to use an arbitrary distance of 5m between objects as a cutoff for inclusion in an existing debris target or creation of a new one, although limitations imposed by visibility and performance of underwater acoustic positioning equipment compromised this effort at times. In addition, the density of debris objects in some areas necessitated the creation of debris "fields." Because the video tape and Hypack¨ data were synchronized and time-stamped, images of each target noted during the survey could be reliably retrieved at a later date for more detailed inspection, measurement and characterization. Debris target information recorded during ROV surveys included position (x, y, z), date, time, video tape number and descriptive comments. With few exceptions, all targets were re-visited at least once to assess positional precision, eliminate duplicate targets, allow further observation, and acquire additional footage of the debris. Video footage recorded during ROV surveys was then viewed in the laboratory for verification of initial debris target classifications made in real-time during the survey. Further classification and enumeration of within-target debris objects was also performed using all archived footage available for each target. During this process, video frame captures were made of most targets for an image library archive.

SCUBA Surveys

SCUBA and surface-supplied divers re-inspected many of the targets first identified with the ROV. This secondary inspection aided in confirming the classification of targets that were difficult to identify from the ROV video tapes due to visibility, viewing perspective or lighting conditions. Divers also aided in assessing the condition of the hundreds of barrels that litter the survey area. Finally, SCUBA was also used to ground-truth the substrate types for calibration of the RoxAnn¨ seafloor classification data.

The Database

A spatial database was created containing all positional, descriptive, and video link information associated with each debris target. Queries can be composed from 24 parameters within this database providing a versatile means to utilize the attribute (field) information. For instance, a remediation coordinator might compose a query to identify all locations where intact fifty-five gallon barrels were within depths accessible to SCUBA or surface-supply divers.

Data acquisition technique determined the procedures used for post-processing. ArcView¨ display software was used for viewing thematic layers processed by MicroImages TNTmips¨ software, as well as spatially referenced video and still imagery from the ROV and SCUBA surveys. Data was published on a CD-ROM and provided to NSF in an ArcView 3.0 format to ensure compatibility with the developing USAP GIS program.

Final Product

By using a complex and creative combination of GPS, GIS, ROV, seabed mapping, and video technologies we were able to provide the National Science Foundation with a complete multimedia GIS inventory of >1000 debris objects on the sea floor at McMurdo Station. The analytical capabilities available with this product will assist in the next phase-assessment and prioritization of marine debris objects for cleanup based on a set of weighted ranking criteria. This capability is critical because any marine debris removal program will have to consider trade-offs between the potential environmental impacts of leaving the debris in place versus the undesirable environmental consequences and safety concerns associated with remediation activities.

Current research focus centers on the application of 3D perspectives to further enhance the utility of virtual site visits for fisheries resource and environmental management in marine habitats. The expectation is that the application of multimedia GIS will provide an efficient means for McMurdo Station managers to make sound environmental decisions and evaluate site specific pros and cons for various debris cleanup scenarios.

About the Authors:

The authors are from the Institute of Earth Systems Science and Policy (ESSP) at California State University Monterey Bay (CSUMB). ESSP emphasizes the use of technology and multimedia applications to earth systems sciences and policy education. ***Carrie Bretz*** *and* ***Pat Iampietro*** *are staff researchers specializing in seafloor and hydrographic mapping and analysis.* ***Dr. Rikk Kvitek*** *is an associate professor for ESSP whose lab provides hands-on research experience for graduate and undergraduate students in applied technologies.*