

**GIS in the Virgin Islands National Park
& the Coral Reef National Monument
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Abstract:

The Virgin Islands National Park (VINP) was established in 1956. It was comprised of most of the tropical, Western Atlantic terrestrial, coastal and marine ecosystems creating a diverse and unique island. Because of this, it was designated a Biosphere Reserve in 1976.

Throughout The Virgin Islands National Park's history it has been a site for the collection of invaluable data. GIS is now used in most data collection projects. It is now possible to return to sites with greater accuracy or to determine where to monitor based on the analysis of existing layers. GIS can be used to develop the random locations needed for statistical analysis. Using historic maps dating back to 1780, historic plantation sites can be located and recorded. The graphical representation of data improves our ability to visualize, track and present data.

With the benefit of years of experience combined with the use of modern technology, the Virgin Islands National Park will continue to be pioneers in marine and terrestrial research.

History

In 1956 Laurance Rockefeller gave 5,000 acres to the National Park, establishing the Virgin Islands National Park. Over the years additional acreage was added and now almost two thirds of St. John is National Park.

John (Jack) E. Randall was one of the pioneer researchers setting the trend of cutting edge research in the Virgin Islands National Park. He led the team selected to map the 58 miles of shoreline from November 1958 to June 1961. Randall with his wife and students made over 250 collections around St. John as part of a survey for the marine park.

The park was established as a Biosphere Reserve in 1976, by the United Nations Educational, Scientific and Cultural Organization, through its Man and the Biosphere program. The Virgin Islands Biosphere Reserve Center was not dedicated until 1987 though data had been collected for many years prior to this. The Virgin Islands Resource Management Cooperative (VIRMC) was formed in 1982. Members included: Virgin Islands National Park, the Department of Planning and Natural Resources of the U.S. Virgin Islands (Division of Fish and Wildlife and the Division of Natural Resources), University of the Virgin Islands, Eastern Caribbean Natural Area Management Program, U.S. Geological Survey, U.S. Fish and Wildlife Service, Southern Forest Experiment Station, University of Puerto Rico, Caribbean Fishery Management Council, the Ministry

of Natural Resources and Labor of the British Virgin Islands and the British Virgin Islands National Park Trust. During the period from December, 1983 through October, 1984 field work to establish baseline data and maps was conducted. First, maps were prepared from aerial photographs of the shorelines and bays within the Virgin Islands National Park. Reports were then prepared: "Trends in Recreational Boating in the British Virgin Islands, A Preliminary Assessment of Impact from Human Activities on Anchorages and Development of a Monitoring Program for Safe Anchorages," "Geographic Range and Research Plan for Monitoring White Band Disease," "Assessments of Fish and Shellfish stocks Produced in the Virgin Islands Biosphere Reserve Area," are just a few of the reports.

In 1996 a six year plan was developed to initiate Long-Term Ecological Monitoring. This was developed as a cooperative effort between the National Park Service and United States Geologic Survey – Biological Resource Division (U.S.G.S.-BRD) staff. The cooperation was charged with developing 6 monitoring protocols: 1) Coral Reefs, 2) Fisheries, 3) Seagrass, 4) Water Quality, 5) Temperature and 6) Beach Profiles.

The U.S. Coral Reef Task force (USCRTF) was established by President Clinton in June 1998 through Executive Order # 13089 to lead U.S. efforts, to preserve and protect coral reef ecosystems. From this the Virgin Islands Coral Reef National Monument was created thereby increasing the St. John Virgin Islands National Park submerged resources by 12,708 acres.

Introduction

I knew when I tackled this topic it was going to be extensive. I did not realize how extensive until I started researching our history. GIS has in some way been part of all research done in the VINP as everything done here has a spatial component. With maps dating back to 1780, aerial photos dating 1947 and benthic habitat maps from the 1950s (Fig. 1.), the Park has a long history of GIS products. Modern technology and software enables researchers to apply GIS mapping and analysis to most projects. The original park was about 5,000 acres with submerged lands being added in 1962. The current acreage under National Park Service management totals over 14,695. With the addition of the 12,700 acres of submerged lands in the monument we need all the technological help we can get.

Over the years there have been many protocols developed in Virgin Islands National Park by USGS Scientists and Park researchers. The Friends of the National Park provide much of the funding for the cultural research that takes place in the park.

There are more than 60 marine research sites in the near shore waters alone. Terrestrial research sites and studies cover the island from one end to the other. Studies range from water quality, water temperature, coral disease, seagrass counts, bird counts, turtle nesting, invasive species, mangrove restoration, archeological research and marine and terrestrial inventory and monitoring. These are just a few of our projects. In addition to the work performed by National Park Service and USGS staff, visiting scientists, professors, and researchers conduct other studies. St. John may be a small island, and the park located here may not compare in acreage to parks such as the Grand Canyon, but from our volcanic mountain peaks to our near shore bays and deep waters, there are many tropical ecosystems that create this unique island making this an ideal tropical research area.

GIS Projects & Layers

This paper will explain several protocols and techniques currently used in the Virgin Islands National Park and Monument.

Inventory, mapping and monitoring make up a large part of the work performed in the Park. With more than 20,000 submerged acres and 7,000 terrestrial acres, inventory and monitoring has become a huge task. To date documented species include: 140 birds, 302 fish, 7 amphibians, 22 mammals and 740 plants. In addition there are about 50 corals species and numerous gorgonians, and sponges. Some of our marine projects include coral video monitoring, coral disease monitoring, elkhorn coral monitoring, fish counts, sea turtle nest success, ship groundings, transplant success, anchoring and cultural resource surveys and buoy management. Our terrestrial projects include: wildlife surveys, hepatofaunal inventories, stream flow, soil moisture, historic and prehistoric site preservation, erosion studies, forest inventories. threatened & endangered species inventories and mangrove restoration. Once in awhile law enforcement requests our help and recently our GIS system was used to track down a kidnapper from cell phone coordinates. Our most common GIS base layers include park and monument boundaries, aerial photos, historic aerial photos, vegetation and marine habitat layers, benthic, elevation, bathymetry, roads and trails layers. Our benthic habitat layer was developed by NOAA and can be downloaded, along with the aerial photo it was created from at <http://ccma.nos.noaa.gov/products/biogeography/benthic/htm/data.htm>. Our Vegetation Habitat shape file was developed by the Conservation Data Center, University of the Virgin Islands. There site is <http://cdc.uvi.edu/>.

Marine Research

We have over 60 marine research sites in the park and monument waters: 16 water quality sites, 6 water temperature sites, 5 video sites, 13 elkhorn coral sites, 18 seagrass sites, numerous disease and coral settlement sites. This does not include visiting scientist projects, coral transplant sites, underwater cultural sites or the many ship groundings that take place within the Park and Monument waters.

GIS Protocols

There have been several research protocols developed in house for specific needs. In some instances terrestrial type data collection and GPS coordinates can be used, usually only in very shallow water. For deep water other methods had to be developed.

Video and Aqua-Map Monitoring

Coral reefs have been referred to as the rain forests of the sea. They are extremely diverse, productive and economically important habitats. They protect shorelines, provide fisheries and fish nurseries. Scientists are continually trying to determine the health or status of coral reefs.

In 1997 USGS scientists requested that a methodology or protocol be developed so that data collected would be considered statistically rigorous. In terrestrial projects it is possible to use a GPS to repeatedly return to a site or many sites allowing researchers to have the replication and repeatability needed for a statistically rigorous sampling project. This can be difficult in certain types of studies but was near impossible in the marine environment. It was difficult as there were no GPS units available that could be used under water. Some units are water resistant and record on the surface but they definitely do not work when submerged. I accidentally took one with me on a shipwreck dive to 70 ft, it survived the pressure but of course it could not receive a signal.

Historically, coral data was recorded on site, on data sheets then entered into a database or spread sheet after returning to the office. This left a lot of room for individual biases and interpretation. Photos were not usually part of data collection process because, until recently underwater housings for cameras were extremely expensive. A method to reduce biases which could be repeated and would create a permanent record was needed. It was important that whatever was developed have little or no impact on the reef system being monitored. Digital video was selected as the recording media. This would provide a permanent digital record of each transect and surrounding area. Desert Star Underwater navigation system was selected as the navigation system. This system allows divers to navigate to a specific site with sub-meter accuracy. This was a non-invasive approach which eliminated the need to attach any hardware to the substrate and corals or mark the corals in anyway.

Site Selection

Several sites were selected, some in high impact areas (lots of dive activity and shore line development) and some in low impact areas (little dive activity or development) all in known coral reefs habitats.

Process

Site selection is done in the office using aerial photographs. Once a site has been selected the divers go on a reconnaissance dive and map the perimeter of the selected site. Using the diver station it is then downloaded to the computer using the software that comes with the Aqua Map system. The area is calculated in square meters and then a virtual grid is created within the polygon. Each cell in the grid is assigned a separate XY coordinate to represent all possible sample sites. This grid is randomized and then a sub-sample is randomly selected by the software (Fig. 2). The points are then uploaded to the diver station. Using the diver station (Fig.3) and three base stations which are attached to a pins installed in the substrate surrounding the reef, the diver can then navigate to an exact location and begin to survey, inventory or video the area.

Digital video was selected as the recording media as it would provide a permanent record of that moment in time but with more flexibility. By using video, not only does the

diver record the transect, individual corals and the surrounding area can also be captured to provide a better understanding of what is taking place within that coral reef system. This will be invaluable in later years should other researchers want to review the videos for other studies.

Once back in the office the video is captured to unique adjacent images and stored to a hard drive and a DVD. These images are then uploaded to Adobe Photoshop (Fig.4). Excel, Adobe Photoshop and a WinBatch script named Lola.wbt are used to generate random points which are then pasted onto each image. The images are then analyzed and the species under each point or dot are entered in to MS Access database (Fig 5). By recording the exact location of the base stations with a GPS unit, the sites and each point can be back calculated to create an ArcView shape file and map of the area for graphic and presentation purposes (Fig.6.).

The protocol for both the Video Monitoring, and Monitoring using Aqua Map, was developed by William J. Miller, Inventory & Monitoring South Florida & Caribbean Network and Caroline Rogers US Geological Survey St. John, USVI. They can be downloaded from http://www1.nature.nps.gov/im/units/sfcn/coral_reef_mon.htm.

***Acropora palmata* (Elkhorn Coral)**

Acropora palmata is being considered for listing as threatened, under the Endangered Species list. Once, a main reef building coral in the Caribbean much of it has been destroyed by hurricanes and disease. Though it does still recruit in some areas, either through sexual or asexual reproduction, disease and storm damage limit its recovery. In 2002 scientists wanted to submit the species to the endangered or threatened list but they needed to know if it was really in decline or possibly recovering. At that time there was no monitoring or inventory protocol available. A monitoring protocol was needed that would allow researchers to inventory, measure and photograph individual colonies. Two protocols were needed because this species can grow very close together forming a densely populated intertwining reef or they can be very sparse, spread over a larger area. For high density study areas a random point extension in ArcView was used to generate points which were then uploaded to a GPS unit. The researcher then swims to the GPS point and tags measures and photographs the closest colony within a meter. In low density areas the researchers tag and photograph each colony. The data collected includes size, presents of disease and or predation, and any other damage.

Both habitats are usually located in high wave areas which required a simple approach with light buoyant equipment. The equipment includes a digital camera with underwater housing, and GPS unit in water proof bag attached to a kick board. The kick board keeps the GPS unit buoyant and helped to keep track of the GPS unit so that it did not float away. A plastic clipboard with water proof paper and pencil are needed to record the field data. (Fig. 7).

Thirteen sites were select on St. John using aerial photography to locate potential sites (fig.8). Once sites were selected field personnel conducted reconnaissance to determine if there where elkhorn present, and if so what type of protocol should be applied to that reef system. The colonies are then revisited monthly. A tremendous understanding of the rapid changes which occur in relatively short periods of time. In less than 5 months one healthy colony was completely destroyed by disease (fig.9).

The purpose of these studies is to gain a better understanding of the ecology, life cycle and spatial distribute of what was once the major reef building coral in the Caribbean (Fig.10). In the 1970s much of *A. palmata* was destroyed by white band disease and hurricanes. Many, once huge stands of coral where reduced to rubble (fig 11). These ongoing studies conducted in the Virgin Island National Park waters give scientists a better understanding of the ecology and lifecycle of this species. Now researchers are looking at genotypic diversity within local populations of *A. palmata* corals. Preliminary studies have also shown that asexual reproduction is common in the western Caribbean islands while in the eastern Caribbean reproduction occurs sexually (Baums). Samples from our research sites have recently been sent to determine genotype. This will provide valuable understanding to the genetic spatial distribute within and between sample populations.

National Park Mooring System:

The Virgin Islands National Park installed a boat mooring system in an effort to prevent anchor and chain scouring of the ocean floor. It was hoped that the mooring system would allow recovery of areas where benthic communities had been obliterated or severely damaged and also prevent future damage. The benthic monitoring system was initiated in 2000 to inventory and monitor recovery.

Overnight moorings, dive moorings, fishing moorings and day moorings were installed in areas of the park where high boat activity could damage the fragile reef or grass systems. In 2005 a hurricane anchoring system was installed to protect the fragile mangrove lagoons from boaters securing their boats during hurricanes. In addition to the damage done by storms, for many years the mangroves suffered further damage do to the lines and chains attached to secure boats during storms. Now there is a chain system attached to the ocean floor for boaters to secure their boats, reducing the stresses on the fragile mangroves. Park staff also maintains the many regulation buoys and restricted area buoys.

Currently there are more than 400 floating objects maintained in the park and monument waters. GIS is essential in maintaining and managing the system. GPS points have been collected for each object and entered into a Geodatabase. Maps were created to inform the boating community where the different types of moorings where located (Fig. 12). All location and maintenance information has been entered into the Geodatabase. This system makes it quick and easy for staff to return to exact locations for any repairs that are needed. Many times the objects break free or are damaged during severe weather or from boaters hitting them. In some instances the ground tackle (chain) used to attach the floating objects to the sea floor is located in very deep waters. Therefore it is critical that exact locations are known so divers can quickly locate the ground tackle to reattach the floating object. Because of deep water and strenuous labor required to reinstall these objects dive time is limited. By having the exact location of ground tackle available the amount of time in locating the object is reduced, allowing divers to concentrate on the work needed (Fig. 13).

In less than five years we have already seen a tremendous change. Seagrass density has increased in several bays. We have just finished entering all data. Our next step will be to analyze the data to determine if there has been a significant increase in density of seagrass blades.

Turtle Nest Monitoring

Sea Turtles have been nesting in the Virgin Islands since probably before man ever set foot here. In the nineteenth century they were harvested for subsistence. Turtles have also been harvested for jewelry and ornament and medicinal purposes. By the 1920's the harvesting was so severe that carcasses were commonly found on the beaches. Nesting sites were greatly reduced as the population was depleted from over harvest and egg poaching. There are few early reports to provide any accurate population data for comparison.

Three species were known to nest on the three U. S. Virgin Islands, St. Croix, St. John and St. Thomas. By the mid 1950s the leatherback (*Demochelys coriacea*) population was so reduced that only two nesting sites were known. Green (*Chelonia mydas*) turtles nested on all three islands until the mid 1960's. At that time nests were no longer seen on St. John or St. Thomas. (Small 1982) They stopped nesting in St. Croix by the late 1970's. Over harvesting of turtles and eggs, and the destruction of nesting sites from development and sand mining, was sending all three turtle species down the road to extinction.

The depletion of turtle populations was so severe by 1972 that the USVI government made it illegal to harvest turtles from beaches. They did allow harvest from the water between October and April. It was not until the following year that the Federal Endangered Species Act declared it illegal to kill any Hawksbill or Leatherback turtles. The Green turtle was not included in the protection until 1978.

Turtles have distinct species specific nesting behaviors. Some species nest in the soft sand while others travel further up the beach to rocky brushy areas. They usually nest 4-7 times during a season but only every 2-3 years. They usually lay between 90-120 eggs which hatch in approximately 60 days. Hawksbill and Green turtles do not reach reproductive maturity for 25 to 50 years. Leatherbacks turtles reach reproductive age at about 15 years of age. It is thought that they return to the beach where they were hatched or as close to it as possible. With the development that has taken place on so many islands often the beaches where they hatched are no longer viable as nesting sites.

The Virgin Islands National Park started its turtle monitoring program in 1980. Surveys were conducted by walking the beaches during daylight hours looking for signs of nesting activities. Surveys are still conducted the same way. Park staff monitors several beaches and fill in a survey sheet and database. The nests are monitored for hatching or any predation. GPS points are now collected at all nest sites. They are then entered by downloading the GPS or entered manually into the Turtle Nest ArcGIS project. The Fire Incident Mapping tool was adapted to allow staff to enter coordinates using the latitude longitude point tool.

The St. John data has shown some signs of improvement. By 1978 there were no longer documented Hawksbill nests on St. John and now, there are between 16-40 nesting events each year.

Turtles have slowly returned to the Virgin Islands. Once again turtles are nesting on all three islands. St. Croix has the largest population of Leatherback turtles. St. John now has between 16 and 40, Hawksbill nesting events per season. They are a common site in most bays while snorkeling or diving. Hopefully with the lack of development allowed in the National Park they will reach sustainable numbers again.

Summary

In the years since the inception of the Virgin Islands National Park in 1956, much knowledge and understanding of tropical ecosystems has been gained from all the studies conducted here. Mapping has been a large part of many of the projects conducted over the years. A considerable amount of work has been conducted in an attempt to inventory the many different species that make this Park their home. Now with the use of GIS, conducting inventory and other studies or mapping can be done more efficiently.