PARTICIPATORY GIS FOR BIOSPHERE RESERVE DESIGNATION, TURNEFFE ATOLL, BELIZE: LESSONS LEARNED

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Participatory GIS for Biosphere Reserve Zone Designation, Turneffe Atoll, Belize: Lessons Learned

Introduction

This paper discusses the development of a public participation geographic information system (PGIS) to contribute to the designation of a biosphere reserve for Turneffe Atoll, Belize.

Public participation is the engagement of a group or group of stakeholders with an interest in a particular project. A public participation endeavor is one that incorporates their interests, perspectives and concerns with the hope that the final outcome be one that is supported by the stakeholders. The amount of participation can range from providing feedback to actual participation in the creation and/or management of a project.

A geographic information system is a database that stores geographic and attribute data in layers and allows the user to view various layers simultaneously. This allows for flexible, multi-scenario data analysis. Further, it can be continually updated as new data is collected.

Turneffe Atoll is an extremely rich ecosystem consisting of extensive mangrove forests, coral reefs and abundant wildlife, some endemic to the Atoll. Turneffe currently has few resource protections. The Atoll is a popular location with both commercial and recreational fishers as well as recreational divers. As Turneffe Atoll's attributes become increasingly well-known, it is imperative that a comprehensive resource management plan be put into place to both protect and sustain its biota.

Participatory GIS for Biosphere Reserve Zone Designation, Turneffe Atoll, Belize: Lessons Learned

A biosphere reserve designation effort is currently underway for the Atoll in an effort to remedy this lack of a full-scale system of resource protection. More than just a protected area, however, a biosphere reserve aims to integrate scientific study, resource use and enjoyment with protection, to ultimately achieve a balanced and sustainable resource management plan.

The development of a PGIS for Turneffe is an effort to capture, in one location, the existing resource data about the atoll with the knowledge of the stakeholders of the atoll. By informing the stakeholders about the biosphere effort for Turneffe, and collecting important data from them, the project intended to create a participatory database while trying to help further consensus for the protection effort. The maps from this project will serve as an aid in the biosphere reserve designation process.

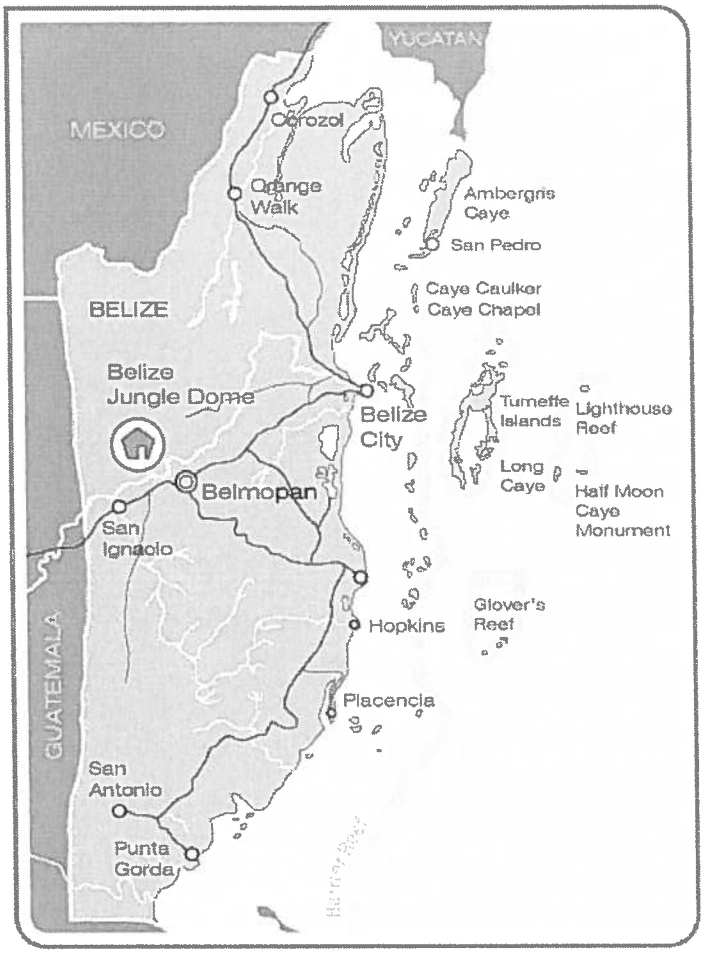
Conducting research for a master's thesis is a big undertaking and time commitment. The work can be even more challenging when the site of the research is in a developing country, such as Belize, with the potential for language and cultural differences as well as other possibly unanticipated hurdles. The two years I have spent working on my project have taught me, through trial and error, what I should have been anticipating prior to beginning my work.

Now nearing the completion of my work, I can look at the issues I faced and see how I could have minimized these from the outset through better awareness and preparation. My work in Belize has taught me that there needs to be a good understanding of the time-frame involved in any project; that it is essential to have contacts in the country in question that can facilitate relationship-building; and that there be a clear understanding of one's role in and goals for the project at hand.

Study Area and Background:

Turneffe Atoll is located 25 miles east of Belize City and is the largest of the three Belizean Atolls (Holguin 2006, Gischler and Hudson 1998) (Map 1). It is composed of a group of cayes (some greater than 5000 acres) surrounded by a coral reef. The reefs of Turneffe are part of the larger Mesoamerican Reef system, the second largest reef in the world, and the largest in the Atlantic Ocean

Turneffe Atoll measures approximately 30 miles long and 10 miles wide. The cayes are composed of dense mangrove forest representing over 10% of the total mangrove cover in Belize (McField 2005), which together with the coral and seagrass, provides substantial spawning grounds for fish.



Map 1. Belize and Atolls. Source: www.greendragonbelize.com/images/map_belize.gif

Turneffe is home to threatened, endangered and endemic species such as the American saltwater crocodile (*Crocodylus acutus*), the Antillean manatee (*Trichecus manatus*), the Nassau grouper (*Epinephelus striatus)* as well as the Belize Atoll gecko (*Phyllodactylus insularis*) and the white-spotted toadfish (*Sanopus astrifer*), the latter two believed to be endemic to the three atolls of Belize (McField 2005). The Atoll is a nesting site for both sea birds and a number of sea turtle species.

Turneffe is a significant recreational and commercial fishing site. In addition to commercial fish species, both conch and lobster are commercially harvested here. The Atoll is also a popular destination for bonefishing and scuba diving (Turneffe Island Development Guidelines www.turneffe.com/pdf/TIDG-FINAL.pdf). Currently, there is no significant conservation management system in place, although it has been identified by both the country of Belize and the Nature Conservancy as an area that should be of high priority for conservation in the Caribbean (McField 2005).

There are three diving/recreational fishing lodges on the Atoll, with more slated for development (**check to see if this has changed**). In addition, dive boats bring divers and tourists into the waters around Turneffe from neighboring areas, such as Belize City and San Pedro (Turneffe Island Development Guidelines nd). A runway was built on the Atoll in 2006(**confirm date**), signaling its rapidly growing importance as a tourist destination. In addition to the diving lodges, the University of Belize has a research facility, the Institute of Marine Studies, on Calabash Caye, and the Oceanic Society, a non-governmental organization (NGO), runs a research and ecotourism facility on Blackbird Caye.

History

Recognizing the economic and biological importance of the coastal zone, and the need for sustainable development, the Government of Belize established a Coastal Zone Management Unit in 1990, later becoming the Coastal Zone Management Project. Sustainable development refers to the careful development of an area such that it is able to provide for both the current needs of the inhabitants of the area, while also ensuring its long-term health and productivity. The Coastal Zone management bill, drafted in 1998, called for the establishment of the Coastal Zone Management Authority and Institute (CZMAI) in the same year, designed to oversee the management of the coastal zone (Gardiner and Harborne 2000).

The 1990 *Guidelines for Developing a Coastal Zone Management Plan for Belize* called for the systematic compilation of data on the coastal areas, with specific reference to GIS creation, which would enable "spatial and temporal updating" (Price *et al.* 1990, pg. 9). Early resource mapping comparing sensitive environmental areas with those of high resource use provided an overview of areas of "resource use conflict" (Price *et al.* 1990). The Atolls of Belize were identified as areas of significant resource use conflict, and as such, in need of resource management efforts.

The Coastal Zone Management Authority and Institute produced a Coastal Zone Management Strategy in 2001 which called for the creation of Coastal Advisory Committees to be established for all of the coastal areas of Belize. As a result, the Turneffe Islands Coastal Advisory Committee (TICAC) was formed to act as representative of the stakeholders of the Atoll and to bring to CZMAI's attention biological, social, economic and other significant issues. In addition, TICAC is charged with developing means of improving the above conditions on the Atoll. In 2001, a draft Island Management Plan was ordered drawn up for the Atoll. The draft Management Plan, recognizing the significant biological and economic importance of Turneffe, proscribed the designation of the Atoll as either a World Heritage Site, a Biosphere

Reserve or a Ramsar Convention Site in order to provide protection for the unique ecosystem and to establish a system of sustainable development for Turneffe. TICAC determined (**check on this**) that a Biosphere Reserve, a United Nations designation, would be the best fit for Turneffe, and in July of 2001, the organization began discussion and exploration of the Biosphere Reserve application process.

In 2003, the Oceanic Society, a TICAC member, retained Professor Ellen Hines from San Francisco State University and myself to create a public participation GIS for the Atoll. Along with the GIS creation, I was to collect resource data and work with local stakeholders to produce maps of the resources and structures of the Atoll to be included with the biosphere reserve application for Turneffe. The final GIS maps were to be reviewed by TICAC, which would designate the necessary Biosphere Reserve zones. I was to digitize this final zone map and provide it for inclusion in the Biosphere Reserve application to be submitted to the National Biosphere Reserve committee.

As mentioned previously, the country of Belize recognized the increasing pressures on the coastal zone and the need to proactively provide for this region's sustainable development in order that it continue to provide critical ecological and economic functions. Specifically, TICAC recognized that any sustainable development program for Turneffe needed to integrate environmental concerns with the economic needs of those who depend on the Atoll, and that the effort needed to include input from the Atoll's stakeholders. As such, the PGIS project for Turneffe was intended to be part of an integrated coastal zone management (ICZM) approach for the sustainable development of the Atoll.

Literature Review

Integrated Coastal Zone Management

Current thinking about the sustainable development of coastal zones holds that for long term success, humans must be an integral part of the conservation process (Jameson *et al.* 2002). Integrated Coastal Zone Management (ICZM) is a management approach that works to achieve sustainable development and conservation that is integrated across a range of scales and management approaches (Dutton and Saenger 1994). In looking at how to sustainably develop and manage a coastal area, ICZM takes into consideration cultural and historical uses of the area as well as any conflicting perspectives that might be present (Davos 1998). ICZM does not prescribe specific types of models or solutions for achieving these ends, rather an integrated coastal management approach attempts to create a conservation program tailored to the cultural, political, historical and ecological environment of a given area. An ICZM program often results in the creation of a marine protected area (MPA), or marine reserve; a conservation strategy that allows for the type of management flexibility as described above (**ref**).

Successful integrated coastal management must provide for the integration of differing viewpoints and interests (Davos 1998). A fully integrated approach to coastal planning is not an easy prescription, however, as the differing viewpoints may be conflicting. Further, one stakeholder group, no matter how pivotal, cannot be treated individually, for a broad community effort is needed to ensure long term conservation success. There are often significant connections between user groups and stakeholders that have implications for coastal resource management (White and Vogt 2000).

As Farnsworth and Ellison (1997) succinctly point out, the effort must be both top-down and bottom-up to be successful. Non-integrated approaches, such as that described by Kirkman & Kirkman (2000), are illustrative of the problems that can occur. In their study of seagrass management in Southeast Asia and Australia, the authors conclude that marine reserves that were designated without the input and involvement of local fishers have failed to produce expected results. Restrictions on resource use to protect the long term viability of a marine/coastal area (or any natural area) must be supported by the locals. If local resource users feel that their needs and perspectives were considered in the decision making process and the policies set forth by the reserve, it is more likely that they will abide by the regulations (Jameson *et al.* 2002). In addition, resource users must realize some benefits right away if the conservation project is going to retain their support (White and Vogt 2000). Comparisons of baseline resource data with those of current data from a reserve can help illustrate the positive impacts of a reserve. It is important that the resource users of a conservation area be able to experience the benefits first-hand, however, to ensure their ongoing support of a project (White and Vogt 2000).

Once management guidelines and protections have been established, enforcement of and cooperation with the area's usage rules must be secured. The successful enforcement of an area's resource use restrictions is often related to the buy-in by local stakeholders. Enforcement of extraction and use laws receives more support when there is a solid understanding among the local users and stakeholders of the economic benefits of protection and effective long-term resource management (White and Vogt 2000).

Apo Island, Phillipines, discussed by White & Vogt (2000), is a testament to the positive outcome that can be achieved with community involvement. The Apo Island Marine Reserve effort enjoyed both strong institutional and community support and involvement (Jameson *et al.* 2002). Silliman University, located in the Phillipines, helped establish a community-based marine management system in Apo to be overseen by the local fishing community. The creation of a series of marine reserves and sanctuaries provides protection for the reefs and fish of the island. Areas within the sanctuary are designated as no-take fishing zones and are strictly enforced by the community; the reserves allow for fish extraction but under specified guidelines designed to protect fish yields and the health of the coral (White & Vogt 2000).

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One of the central reasons for its success is the support of the local resource users, in this case, fishers. Since the Apo Island reserve system was established in 1985, fishers have seen fish yields both increase and stabilize, depending on the species. As a result of the protections provided to the coral reefs of Apo Island, (10% of the total coral area), the fishers benefited from increased fish yields, SCUBA diving and tourism (Alcala 1998). Further, the protected areas, increasing yields and resulting improved marine health in the area has resulted in increased revenue captured from the wave of tourists, environmentalists, divers and scientists interested in exploring the revitalized marine environment (White & Vogt 2000). The benefits realized by the community of Apo Island have provided an incentive to maintain and abide by the marine reserve system. Monitoring of the fishing regulations is done by locals, with only mostly token support from area police (White & Vogt 2000).

In the case of Balayan Bay, Phillipines, which is comprised of the municipalities of Mabini and Tingloy, alternative methods of capturing tourist income, particularly among ex-fishers, has led to improved financial conditions which have paved the way for a more solid foundation of support for reef conservation (White and Vogt 2000). An increase in tourism, development, and the use of destructive fishing methods was causing significant damage to the fragile coral ecosystem of Balayan Bay. Concerned interests banded together to form a community-based conservation effort comprised of various community groups, resort owners, fishers, the Phillipine Tourism Authority, and interests from the Municipality of Mabini in charge of regulating the coastal area in question (White & Vogt 2000). The group worked to educate all users about pollution and sustainable means of fishing and diving the reefs. The conservation effort ultimately established a marine reserve and three sanctuaries with enforcement provided by resort owners and fishers (White & Vogt 2000).

The Balayan Bay area presented some challenges that were not encountered in Apo Island, namely the presence of a significant non-resident group of users of different backgrounds making communication among stakeholders more challenging (White & Vogt 2000). Bitterness on the part of some local fishers over having to work with tourism interests presented an additional hurdle in the management process. Conversely, however, some former fishers now operate simple motorized boats to transport divers, enabling them to capture revenue from tourism, elevating their annual income (White & Vogt 2000). Despite improvements in the management and conservation of the Balayan Bay coast and water, according to White & Vogt (2000), work still needs to be done in many areas before more significant conservation objectives can be reached.

As mentioned in the example above, the lack of a permanent local resident community can require a more complex coastal management arrangement, as it has implications for both communication among stakeholders as well as resource management objectives (White and Vogt 2000). If fishers, for example, are ethnically diverse and reside in other localities it can be challenging to coordinate the dissemination of information to this stakeholder group. Further, differing interests among stakeholders, such as fishers and tourism operations, can present obstacles to coordinated management efforts thus requiring a very open exchange among user groups.

In order to maintain local cooperation and support, Luttinger (1997) recommends implementing a long term education program for the stakeholders. Such an effort would serve to reiterate and demonstrate the benefits of conservation and sustainable development practices. Further, she recommends that stakeholders be continually apprised of the progress or current state of the marine reserve to again maintain dialogue and open communication with the community.

Political support is also an essential component to the success of an integrated coastal management endeavor, as its absence can spell ruin to a marine conservation effort. In 1974 a coral reserve was established in Sumilon Island, Cebu, Philippines, the first in the country. Although it served as an important starting point for the creation of other community supported coral reef conservation efforts, it did not succeed as a result of local political vagaries. Specifically, a local mayor in the area was able to bring about the demise of the first coral reef sanctuary in the Phillipines despite support for it from the local fishing community. As White and Vogt (2000) point out, this highlights the importance of political buy-in in even a localized resource management project.

Persistent management issues in the aforementioned Balayan Bay area led to the coordination of a "multi-sector and multi-donor" approach to local reef conservation (White and Vogt 2000). In turn, a local coastal development group was formed and put in charge of overseeing the reef management in hopes of providing a more solid "institutional and planning base" to the marine reserve (White and Vogt 2000 **page#**). In fact, lessons from marine reserves around the Philippines have demonstrated that no coastal conservation effort can be successful in the long term unless there is multi-sectoral support.

In addition to soliciting opinions, concerns and other input from stakeholders, it is also wise to gather local knowledge about the area and its resources (Johannes 1981). Resource users can be an invaluable source of data as those with long term experience with a resource can provide information, the existence of which outside experts may not be aware. Scientists recognize the need for more data on marine processes and the interplay of humans and resources in order that reserve planning be done effectively (Roff and Evans, 2002; Ray 1999, Johannes 2000). Taking the time to collect data from locals and learn about their relationship with resources can provide valuable insight into the needs and the functioning of a given locale.

Biosphere Reserves

A biosphere reserve is a type of protected area that ultimately aims to sync resource conservation with sustainable development. The biosphere reserve model is predicated on the idea that human livelihood is improved by the health of the surrounding natural resources, locally but also globally (Price 2002).

In 1970, The United Nations Educational, Scientific and Cultural Organization (UNESCO) launched the Man and the Biosphere program (MAB). The mandate of the MAB was to both obtain data on the major biomes of the world and learn about how humans alter the biosphere and the impacts of these alterations on human beings. The MAB defined 13 different project areas, one of these being Biosphere Reserves, a network of conservation areas designed to protect biodiversity while incorporating humans and their socioeconomic activities in the process.

Involvement in the MAB program is voluntary; each country that does partake forms its own national MAB committee. Individual biosphere reserve applications must first be approved by the respective nation's MAB committee, which in turn submits it to the international MAB headquarters, located in Paris. It is here that the application is finally approved or denied.

Biosphere Reserve Structure

Biosphere reserves meld conservation with sustainable development, research and education (citation). Unlike ICZM, a biosphere reserve is a specific conservation model with a proscribed structure. In 1984, UNESCO devised a Biosphere Reserve Action Plan that clearly articulated four main goals of the program (Kuhn 2000):

- the development of sustainable land uses;
- the protection of natural and genetic resources;
- environmental research and monitoring:
- environmental education, public relations and communication.

In addition to the above goals, biosphere reserves must also fulfill three primary roles: a conservation role; a logistical role, under which fall the research and monitoring activities; and a development role, the activities of which seek, create and refine sustainable methods of resource use (Batisse 1989).

Zoning

To achieve the aforementioned goals and fulfill the mandated functions of conservation, sustainable development, research and education, biosphere reserves are divided into three zones or rings: a core, a buffer zone and a transition, or multiple-use zone. The original model was presented as concentric circles, one within the other (Figure X). In reality, the zones need not be nested; they can be situated to reflect the individual geography of an area.

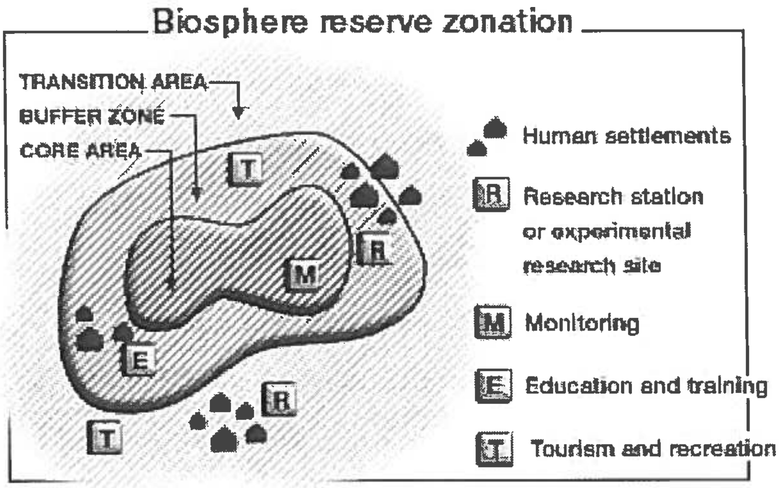


Figure 1. Biosphere Reserve Zones. Source: www.unesco.org/mab/images_2005/zonation.jpg

The core is managed for the least amount of disturbance. This area is intended to protect the most sensitive biota and acts somewhat like a control against which any change in the same resource or setting within the outside zones can be measured. To maintain the highest level of protection for the resources in the core zones only monitoring, non-destructive research and other location-approved minimally-invasive activities (UNESCO 1996) are permitted. The vast majority of lands (80%) under biosphere reserve designation fall in core areas (Gregg and McGean 1985).

A buffer zone rings the core and it is here that research, education and demonstration of new development or sustainable land use methods can be applied. This is the zone in which scientists investigate how to improve or devise new ways of using the land for production. Additional activities permitted in buffer zones include ecotourism, environmental education, as well as other similar activities compatible with the objective of the buffer zone and approved for the location in question (UNESCO nd.). The aim is to help make the above land-use activities sustainable and compatible with the environment.

The third ring, or zone, is the transition, or multiple-use area. It is here that human settlements will be found and the zone in which lessons, knowledge and techniques gained from studies in the buffer zone can be applied. It is this zone that integrates conservation practices with sustainable development and where stakeholders can participate in the active use and conservation of the land or sea (Gregg 1999). This is the physical manifestation of one of the central biosphere reserve tenets: conservation efforts will be much more successful if the local population is integrated into the process and can experience the benefits of sustainable practices. The transition zone also emphasizes and establishes a symbiosis between the stakeholders and authorities. Batisse (1996, pg. 30) identifies this zone as playing the role of "…living laboratories for the resolution of land-use conflicts." The biosphere reserve model strives to achieve a high level of environmental protection while also addressing and incorporating the needs and concerns of the local human population.

The biosphere reserve program encourages local participation at all phases of a biosphere reserve's creation and management. The initial discussion and planning phases are designed to be open to the public and the participation and input of local citizens and other stakeholders is encouraged through public meetings and similar forums. Involving the citizenry and soliciting their input also enables program directors to inform the local population about the aims and goals of the program and the envisioned benefits a biosphere reserve designation would confer, not only to the environment, but also to those living within its vicinity.

This approach aims to cultivate an even greater sense of stewardship towards the land or sea. By impressing upon stakeholders that the ethic behind biosphere reserves is to actually integrate development and resource use with conservation, the hope is that the local population will be encouraged to support the conservation efforts and agree to integrate less invasive, sustainable resource-use measures into their means of livelihood.

A Networked System Fostering Cooperative Management

The biosphere reserve program promotes regional as well as global networking to facilitate knowledge and data exchange at the varied scales. Although different biosphere reserves are not linked to one another in any formal capacity, they are part of a larger system that allows for science and conservation to take place on a global level (Batisse 1997). Specifically, a biosphere reserve becomes part of a world network. The network serves as a conduit through which lessons learned from individual biosphere reserves can be shared with one another. In this way, conservation, science and sustainable development can evolve in a regional and global manner as opposed to through a piecemeal, parochial approach. As a result, conservation and management decisions can ideally be made with access to the greatest amount of data that has been gleaned through the similar experiences of other biosphere reserves. Further, like the philosophy of ICZM, the biosphere reserve program also aims to facilitate greater cooperative management among stakeholders, government entities, scientists, and managers (Kenchington 1990). By creating a forum in which parties at both a local, regional and a global level can communicate and exchange information, the program serves as a nexus of conservation efforts thereby helping to foster a large-scale integrative approach.

Biosphere Reserves: Meeting Requirements for Successful Conservation

In addition to stakeholder integration, there are several other components believed to be necessary for lasting conservation endeavors. These include forging a network of protected areas (Ray 1999); ensuring that conservation decisions consider protecting representative areas and not just specific species (Roff and Evans 2002) and that stakeholders be continually apprised and informed of the state of the project to help ensure the long term viability of the protected area (Luttinger 1997). All of these aspects are considered integral to the mandate of biosphere reserves. As mentioned above, the biosphere reserve program is intended to be a network over which data and management lessons, among other knowledge, can be shared. Further, a biosphere reserve is designed to protect not just small islands of habitat or sensitive areas, but an entire biogeographical region that encompasses a range of ecological systems (Gregg 1999). Specifically, the mandate of biosphere reserves is "...to conserve representative examples of the world's ecosystems" (Gregg and McGean 1985). Finally, as is exemplified by the biosphere reserve mandate that stakeholders be an integral component of the planning and development process, as well as the stated biosphere reserve program goal of education and communication, it is clear that a biosphere reserve model addresses the criteria believed by the conservation community to be necessary for the long term protection and sustainability of an area.

Integration and Public Participation GIS

Integrating local users into decision-making processes is often facilitated by the use of geographic information systems (GIS). GIS is a common tool in geographic and spatial analysis. Once primarily the purview of managers and GIS developers, GIS is being used more frequently by local stakeholders to empower themselves and participate directly in spatial decision-making traditionally conducted by GIS professionals (Fox *et al.* 2005). Public participation GIS is intended to extend the use of GIS to communities that would not otherwise have access to the technology and therefore be at a disadvantage in engaging in dialogue and debates that result from its use (Kwaku Kyem 2001). As such, PGIS is used to handle historical knowledge and other non-traditional forms of information. By incorporating input and knowledge from local stakeholders through means such as interviews and participatory mapping efforts, PGIS aims to incorporate local perspectives and concerns, thereby helping to ensure a final product that is reflective of their knowledge and needs. In this way, it is expected that communities that use PGIS are more readily able to ensure that their input and knowledge is incorporated directly into the maps and databases, giving locals more ability to shape planning and development outcomes (Abbott *et al.* 1998).

Today PGIS is being used on a global scale. Its uses range from development projects, natural resource management and conservation work, to mapping efforts in developing countries and neighborhood improvement endeavors including environmental justice movements in the developed world (Craig *et al.* 2002; Elwood and Ghose 2004). Non-governmental organizations working in developing countries are particularly well known for using PGIS in efforts to improve natural resource access and equity to local communities (Harris and Weiner 1998; Kwaku Kyem 2001).

One example of this includes a participatory mapping project in an area along the Ampicyacu River in Peru, led by the Joint Research Project on Economic Strategies for Indigenous Amazonians (Harris and Weiner 1998). GIS, participatory mapping, satellite imagery and a number of other methods were used to situate the indigenous natural resource use within an historical and political context. The data and resulting maps provided crucial indigenous input into the resource management planning and environmental monitoring of the area (Harris and Weiner 1998).

Criticism and Weaknesses of PGIS

Critics of GIS point out that they are the product of a relatively small handful of developers in the western world (Obermeyer 1995). As such, the GIS paradigm is that of the GIS "technocrats," as Obermeyer (1995) labels the developers, and more generally, a Eurocentric perspective. Scientific thinking of the western world holds that knowledge must be objective, and GIS is built to reflect this. However, many non-western cultures, and even minority groups of developed countries know the world in more subjective ways. In Kwaku Kyem's 2004 opinion, GIS is very adept at analyzing objective spatial data, but it cannot effectively handle an analysis of qualitative data, common among traditional communities. Although PGIS is intended to help empower local communities by enhancing their ability to capture spatial data, even in the subjective realm, GIS' continued inability to represent subjective knowledge forms, often intangible, can preclude its ability to meaningfully confer power to local communities (Kwaku Kyem 2004).

In addition to the difficulties of GIS in representing non-traditional forms of data, the cost of the technology and its technical aspects can make it prohibitive for local communities to use without the intervention of outside experts (Kwaku Kyem 2004).This reliance on outside entities can also lead the community to weaken its resolve for its goals and integrate those of the outside actors. In addition, it can create a situation whereby the GIS project becomes open to cooptation by these external enterprises (Kwaku Kyem 2004, Abbot *et al.* 1998).

For example, in response to a national governmental program to reform the practice of forest management in Ghana in the early 1990s, Kwaku Kyem (2004) designed and started a PGIS project in three southern Ghanaian rural communities. After implementing and overseeing the project at each of the three sites for 18 months, Kwaku Kyem turned over the projects to forestry officials helping with the projects and the local PGIS groups. Revisiting the sites in July 2001, he found that in spite of some positive results, the PGIS organizations had largely dissolved. The PGIS organizations had no long-term, stable source of funding, and as such, had to turn to the forestry department for financial support. At two of the sites the PGIS organizations dissolved quite quickly. At both of these locations, the PGIS organizations had little money to sustain the operations and the local forestry department officials demonstrated paltry support for the projects, resulting in the organizations' demise. At the third location, in return for funding the state forestry department required the PGIS organization to adopt the departments' goals which were out of step with those of the PGIS organization. Adherence to its positions meant the loss of badly needed funding. In all three cases, Kwaku Kyem (2004) concluded that the absence of an ongoing source of funding and dependence on an outside agency with dissimilar goals ultimately hastened the demise of the PGIS organizations.

Potential Solutions

A prescription for this problem can be found in the development of a GIS that is more accessible, both in terms of cost and ability, to a non-expert user (Abbot *et al.* 1998). Abott *et al.* (1998) suggest that one way to increase local participation in a PGIS effort is by way of participatory resource mapping (PRM), such as through the use of sketch maps. By drawing their own maps, community members directly contribute their knowledge to the project as opposed to just attending public forums where their input may or may not be integrated into a map by an outside expert. Participatory mapping is a means for directly integrating stakeholders into the mapping process. However, its use has shown, at least in some circumstances, that it does not totally eradicate the power structure that may be inherent in a PGIS effort. The McCall & Minang (2005) study of a forest project in Cameroon illustrates that although there was a large amount of community participation in sketch mapping and even GPS use, GIS and content decisions were still dominated by outside experts. The challenge of fully integrating stakeholders into the PGIS process seems to remain imperfect. McCall and Minang (2005) did find, however, that the PGIS effort in Cameroon was successful in providing opportunities and forums for communication among stakeholders.

Other Considerations

Creation of a GIS using local knowledge can make information that was once just the purview of the community, more public. Ironically, this can result in a loss of control over the data when the GIS creation was likely intended to empower, not disenfranchise the local community (Abbot *et al.* 1998). The database can provide information about the location of important resources, increasing attention by outside parties, or even result in increased monetary burdens such as the levying of taxes (Abbot *et al.* 1998).

The creation of a GIS database also raises the questions of data ownership, and whose knowledge and experience is being used and recorded (Abbot *et al.* 1998; Kwaku Kyem 2004; Fox *et al.* 2005; McCall and Minang 2005). Who contributes to the knowledge that is incorporated into the database? Power structures within the community must be addressed in order to understand whose interests within the community it might be designed to serve. In addition, it is necessary to consider where the GIS will reside and who will have control over its information and management (Abbot *et al.* 1998). Will the only copy remain in the community, or will the entire database reside with an outside agency, for example? The answers to these questions have important implications for how much benefit the community as a whole ultimately receives from being part of a GIS project.

The idea of public participation itself must be critically examined. It is not enough just to identify a project as one of public participation; the questions of who is the public in the situation, and what does one mean by participation in that circumstance, must be addressed at the beginning of a project (Schlossberg and Shuford 2005). These variables need to be defined to maximize chances of achieving the intended result. Schlossberg and Shuford (2005) outline a number of different scales (or "ladders") of public involvement as devised by a range of authors. The different scales generally represent little public participation at one end and a large degree of public involvement at the other.

One example of this is the "ladder" devised by Arnstein (1969), that categorizes a very minimal amount of participation solicited only for the benefit of those in power, as "manipulation," and full participation and oversight as "citizen control," with a variety of measures of control falling on the rungs in between (Schlossberg and Shuford 2005).

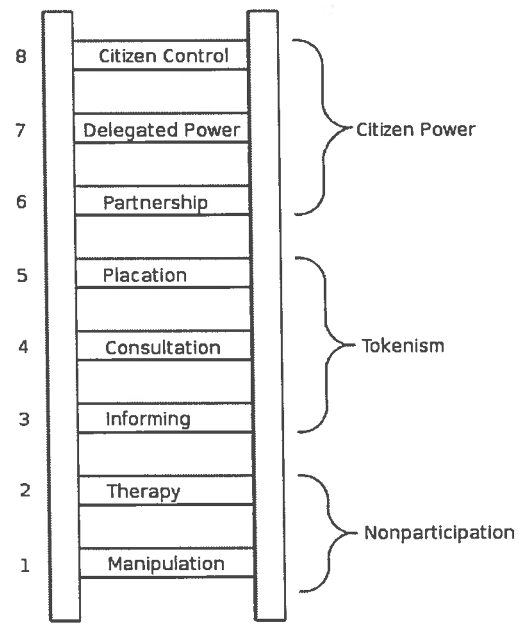


Figure 2. Eight rungs on the ladder of citizen participation

It is also necessary to identify who the public is for a given project. Often projects proceed without a contained answer to this question, with often negative consequences (Schlossberg and Shuford 2005). The entity "public" is often equated with "stakeholder," but this too, is able to be broadly defined and as such leaves the answer ambiguous. Schlossberg and Shuford (2005) enumerate three categories of participants: those most affected by a decision; those with relevant knowledge relating to a given project or decision; and those who can wield influence over the project. The public could therefore be one or a combination of these categories, with implications for who should be included in the project design. Given the different ways that public and participation can be defined, PGIS takes on a much more complex character- one that is able to represent a broad array of designs and outcomes (Schlossberg and Schuford 2005).

Summary

ICZM and biosphere reserves, coupled with the use of PGIS, are two ways to sustainably manage and conserve sensitive coastal regions and islands. Biosphere reserves achieve these ends through a specific model and design providing for various levels of protection and use, each one becoming part of a larger global network through which information and data can be exchanged. By contrast, ICZM is a more flexible planning tool; there is no specific blueprint or management design. Public participation in both is critically important for the project and process to be successful. PGIS is one way to engage the public in the planning and development process and a means for capturing and sharing local knowledge, experiences and concerns. PGIS is therefore a significant means for contributing to the long term success of a sustainably managed coastal conservation area such as that of Turneffe Atoll.

My project was designed to integrate public participation and the principles of ICZM into the biosphere reserve effort for Turneffe Atoll. In the following section, I will outline the means by which I worked to achieve this end.

Methods:

This research set out to create a Participatory Geographic Information System (PGIS) for the Turneffe Atoll region. The creation of a PGIS for Turneffe Atoll was intended to bring together into one database disparate data about the atoll so that it can be spatially analyzed in its entirety. Given the ability to look at specific data in relation to all the other data recorded about the Atoll, resource managers could then obtain information critical to the successful resource management of the atoll. Further, the PGIS would provide a means for the integration of stakeholders into the conservation process through the collection of data from the stakeholders themselves. In this regard, the project focused on obtaining data from the largest stakeholder group on the Atoll, commercial fishers. These data are included in the PGIS, providing an important perspective on the resources from those who have a long-term familiarity both with the resources of the Atoll and the Atoll itself. The maps generated from the PGIS are to provide assistance to Turneffe Islands Coastal Advisory Committee (TICAC) in deciding the location of the biosphere reserve zones on the Atoll. This map will be included in the final application for Biosphere Reserve status.

At the time this project commenced, researchers had already generated and recorded a significant amount of data about the natural resources and structures (such as fishing huts and dive lodges) of the Atoll. Other data were in the process of being collected by researchers. Through data mining efforts, I collected and compiled all of the data known to be in existence or in the process of being recorded. Specifically, I collected geographically-referenced natural resource data about the Atoll as well as data on the location of human-made structures on Turneffe. I obtained the majority of the data through discussions with individuals familiar with the Atoll. From these discussions I learned what data were known to exist and their location, as well as about what data were currently being compiled. Stakeholder data were obtained through a group interview with a commercial fisher group and one-on-one, key informant interviews.

I initially focused my data mining efforts on obtaining existing natural resource data for Turneffe. I compiled a list of all possible data and their sources. This list was the result of discussions with Birgit Winning, Director of the Oceanic Society. Additionally, through reviewing scientific reports about the Atoll, I was able to put together a list of the biota known to exist on the Atoll and whether or not the particular biota had been studied. I made two visits to Belize, one in July of 2003 and the second in March of 2004, in order to meet with individuals involved in the biosphere reserve effort and to learn more about what data may exist for Turneffe and where the data were located. Data were ultimately obtained via email, on disc or from original scientific reports. While half of the data were already in digital or GIS layer format, such as the habitat, land use and vegetation layers (Appendices I – III) half had to be converted to digital form for use in the GIS.

Specifically, I sought out bottlenose dolphin (*Tursiops truncatus*), American crocodile (*Crocodylus acutus*), bonefish (*Albula vulpes*), Antillean manatee (*Trichechus manatus manatus*), coral, bird, vegetation, lobster and other commercial fish data as well as data about what areas of the Atoll were currently developed. I obtained a digital base map of Turneffe Atoll as well as GIS layers of habitat, vegetation and land use from Ian Gillett of CZMAI in Belize City.

Data Collection

I signed a Memorandum of Agreement with both CZMAI and the Belize Fishers' Cooperative Association (BFCA) which specified the parameters of my research and stated that both organizations would receive a copy of the final database and acknowledgement in my thesis.

In order to collect fisheries data while also including stakeholders in the process, I interviewed fishers who work the waters around the Atoll. Obtaining data from this group about fish and other sea resources like lobster and conch was essential both because of the significant experiential knowledge the fishers have of these resources, and because of the importance of including such a large stakeholder group in the biosphere reserve conservation process underway for the Atoll. While it is necessary fishers' input be included in the biosphere reserve development process, they also have a vested interest in the outcome of the conservation designation of the area. Collecting primary data from the fishers provided an opportunity to both discuss the biosphere reserve process and incorporate their knowledge into the GIS. As part of the GIS for Turneffe Atoll, these data were to be a significant part of the planning and management process.

The stakeholder data were collected through in-person interviews with the fishers at the National Fishers Cooperative meeting held in Belize City during March 2004. BFCA helped to facilitate the interviews by working with the National Cooperative to set up a meeting time and to ensure that time was allotted for the biosphere reserve presentation, the interview questionnaire and the one-on-one map interviews.

Prior to the cooperative meeting I met with Moustafa Toure, and Vincent Gillett of BFCA and Melanie McField from World Wildlife Fund (WWF) Belize. Both Toure and McField represent their organizations on the TICAC board, and Gillette was the head of BFCA at the time. Both BFCA and WWF have been working to assist in the long-term sustainability of Turneffe. During this meeting, we went over my interview questions and they provided advice on the questionnaire as well as how to orchestrate the interview.

This was valuable advice, given their experience with these forums. Based on their recommendations, I revised my approach, dividing my interview process into two parts as described below.

At the meeting, I conducted a group interview with the fishers where each attendee received a two-page packet with a series of open and closed-ended interview questions (Appendix IV). I projected the interview questionnaire on a large screen and went over each one verbally to ensure each question was clear to the attendees. I provided an opportunity for questions after each interview question was shown. I was available to answer individual questions regarding the questionnaire while the fishers completed them. Once this part was complete, I conducted a random sampling of one-on-one interviews with fishers in an open question format. I introduced the second part of the interview process to the fishers after the questionnaires were completed. Participation in this interview section was voluntary; anyone willing to participate was asked to convene in a designated area of the meeting room during the meeting's recess. This interview section included questions about fish locations and asked the participants to draw those locations on a map of the Atoll (Appendix V). My goal was to interview seven to ten participants. Due to time constraints and the loss of interest by participants due to a meeting recess, only one interview was conducted in full.

I was due to return home to the United States later that day so was unable to schedule subsequent meetings with the fishers to obtain more data. Budget constraints did not permit me future travel to Belize. However, a fellow graduate student, Suzanne Poloner-Holguin, was scheduled to visit Turneffe Atoll to conduct manatee research in July of

2004. She agreed to conduct a key informant interview with an employee of the Oceanic Society Field Station on Turneffe Atoll and a fisherman with 30 years of experience fishing the waters around Turneffe. Through Holguin, I obtained a completed questionnaire and map with fish locations from him. Winning also conducted a key informant interview on my behalf with the manager of the Oceanic Society Field Station during her visit to the Atoll in May 2004. He is a long-time fisherman of the Atoll and is a rich source of knowledge about the fish of the area. He also marked a map of the Atoll indicating the locations of lobster traps, fish tailnets and beach seines.

Map Creation and Data

To create the map layers for the GIS, digital data sets were projected and saved as individual shapefiles. Non-digital, geo-referenced data were put into digital format using Microsoft Excel and saved as .dbf files. If there were no geographic coordinates included with the data, I did not include them in the GIS layers I created.

The coral reef data (Appendix VI) were collected by Sheila Walsh as points per transect at different sites along the Atoll and classified as either fore reef or back reef. There were various species of coral and benthic cover observed and recorded at each site, but given that it was point data, I displayed it in terms of species richness (variety), using graduated circles to represent the number of species of coral present at each site.

Seagrass cover and density (Appendix VII) data were collected as part of the Turneffe Habitat layer provided to me by CZMAI. I created the seagrass map layer from the habitat layer by selecting to only display the benthic categories that contained seagrass in the attribute table.

The Kaplan Survey fish data (Appendix VIII) are a result of a study conducted by Melanie McField of World Wildlife Federation, Mito Paz and Thom Grimshaw of Greenreef Environmental Institute on larval transport linkages in the Caribbean. The study reported the fish species observed and the maximum number of that species present at each location during dives conducted in Belize in 2003. The point data were collected by the scientists at dive sites on the Northern and Central barrier reef of Belize as well at nine different sites on Turneffe Atoll during 2003. The number of individuals was recorded for each species at one particular location. Like the coral map, the Kaplan Survey map layer I created displays, by way of graduated symbols, the number of species found at a given location, or species richness.

A series of threat assessment maps (Appendices IX-XII) were produced during a workshop held in Belize City on September 23, 2004 by Wildlife Conservation Society. The workshop was attended by representatives from Belize government agencies, CZMAI, Oceanic Society, Turneffe tourist interests and non-governmental agencies. The purpose of the workshop was to identify and map the most significant threats to the Atoll's biodiversity, in order that management efforts be focused on these specific threats. The results were published in the Belize Coastal Threat Atlas by the World Resources Institute. Workshop participants created four hand-drawn maps on large format white paper depicting each of the four geographic impacts believed to be the most significant hazards to the resources of the Atoll. These are overdevelopment, mangrove clearing, overfishing and dredging. I made each threat assessment map into a shapefile through the use of on-screen digitizing.

Comment [C1]: It actually says Draft 2005 o internet- have to confirm if there is a final

Once the data were in digital format, I displayed them on the background map of Turneffe Atoll at a scale of 1:275,000. The completed draft digital layers were submitted in .pdf (Adobe 7.0) format to Birgit Winning, who took them to Belize in June of 2004 to present them to TICAC members for review.

The layers in Table 1 have been submitted to TICAC so that the committee can review the geographic extent of the natural resources and structures of the Atoll. The layers will aid TICAC in deciding where to situate the various biosphere reserve zones.

Data Layer	Source
Manatees	Ellen Hines and Suzanne Holguin
Dolphin	Barbara Bilgre
C. acutus nests	Steven Platt
C. acutus sitings	Steven Platt
C. acutus spotlight surveys	Steven Platt
Fresh Water	Suzanne Holguin observation
Juvenile Permit	Aaron Adams
Kaplan Fish Data	Kaplan Report
Coral	Sheila Walsh
Vegetation	Ian Gillette, CZMAI
Habitat	Ian Gillette, CZMAI
Land Use	Ian Gillette, CZMAI
Seagrass	habitat map obtained from Ian Gillette, above
Commercial Fish Data	Key informant interview conducted by Suzanne Holguin
Dredging	Threat Assessment Workshop map
Mangrove Clearing	Threat Assessment Workshop map
Fishing Threats	Threat Assessment Workshop map
Overdevelopment	Threat Assessment Workshop map

Table 1. Map Layers in GIS created for Turneff Atoll, Belize.

Once all of the possible map layers were created, I produced a draft zone map for the Atoll, a departure from the original intent of my project (Appendix XIII). The draft zone map was originally to be produced by TICAC once I provided them with the resource maps and GIS for the Atoll. The draft zone map was based on my knowledge of the requirements of the three biosphere reserve zones and my initial analysis of the map layers for the Atoll. The draft zones were delineated by way of on-screen digitizing. Once the draft zone map was complete, I provided copies in .pdf (Adobe 7.0) format to Birgit Winning who took the maps to Belize City during her visit in the spring of 2005. Birgit provided a copy of the map for initial review and comments during each of her individual meetings with TICAC members Melanie McField, Craig Hayes of Turneffe Flats Lodge and Eden Garcia of the University of Belize (UB). During the same period, I emailed a copy of the draft zone map to Steven Platt, the researcher who studied the American crocodile (*C. acutus)* on Turneffe and who provided the crocodile data to me. Given his familiarity with the Atoll and knowledge of the locations on Turneffe preferred by *C. acutus,* I wanted to solicit his initial comments on the zones. Due to concerns over this draft zone map by Craig Hayes, a member of TICAC, the map was rescinded and is not part of the GIS. These concerns included apprehension about a single person (myself) outlining the zones without the input of other stakeholders, even in a draft form, especially considering that I did not have first-hand knowledge of the Atoll. Further, he feared the draft map could be mistaken for a final draft, if it circulated without the appropriate information.

Comment [MSOffice2]: Confirm these detail with Birgit

Further research was needed to address the concerns of the stakeholders regarding the initial zone map. This research was not possible under the time and budget constraints of this project. As a result, only the digital data layers were provided to TICAC.

Once TICAC agrees upon the zone locations, a digital zone layer will be created. This zone layer will be included in the Biosphere Reserve application put forward by the University of Belize on behalf of Turneffe Atoll.

Comment [e3]: Be clear who the players are…why the UB and not the TICAC?

Comment [MSOffice4]: I have contacted Bir[…] to get this info

Results and Discussion

The scope and nature of this project differs from that of the original intent. This project initially focused on the creation of the map layers so TICAC could use them to designate the conservation zones required for the biosphere reserve application, and it was to be a public participation endeavor. The following paragraphs discuss observations from the map layers I obtained and/or created for the PGIS.

I obtained several map layers from Ian Gillette at CZMAI: the map of the Atoll, fringing reef, land use, habitat and vegetation. I have used a map of the Atoll digitized by Sadie Waddington and Dori Dick as the base map of the Atoll as it contains more detail and is more spatially accurate, as the background map for the rest of the data layers.

From the vegetation layer (Figure 3) one can get a sense for the thick vegetation that covers the majority of the cayes with the exception of two large areas of savanna on the eastern side of the Atoll. Mangroves appear to be the dominant plant form throughout the Atoll.

Vegetation of Turneffe Atoll

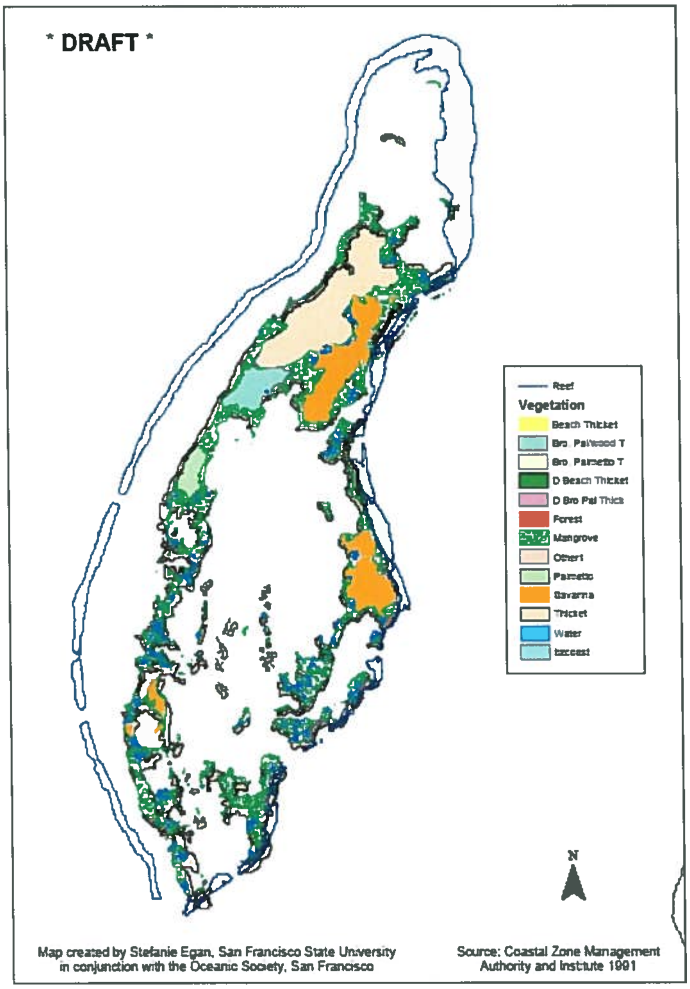


Figure 3. Vegetation, Turneffe Atoll

The habitat layer (Figure 4) shows that a majority of the Atoll is shallow lagoon and unclassified habitat. The classification system for the fringing reef will be useful in overlays with regard to future detailed animal presence and abundance layers, possibly providing a correlation between reef density and species data.

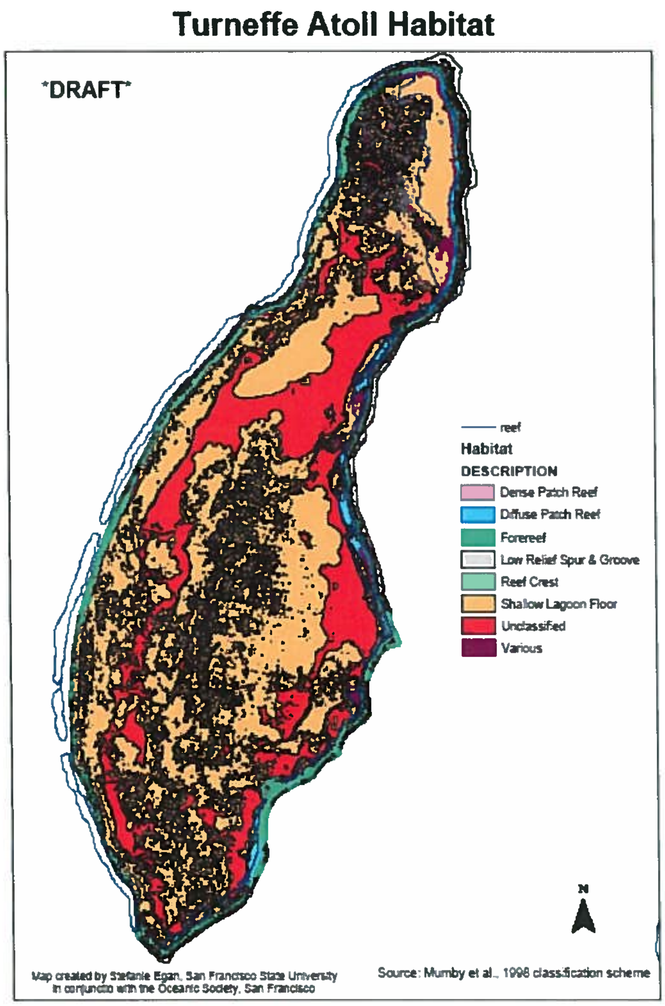


Figure 4. Habitat Types, Turneffe Atoll

The Land Use layer (Figure 5) primarily shows the locations of human-made structures, such as fisher camps and tourist lodges. The fisher camps are fairly evenly distributed throughout the Atoll, whereas the tourism and educational facilities are concentrated on the southern half of the east coast of the Atoll.

Land Use Types of Turneffe Atoll

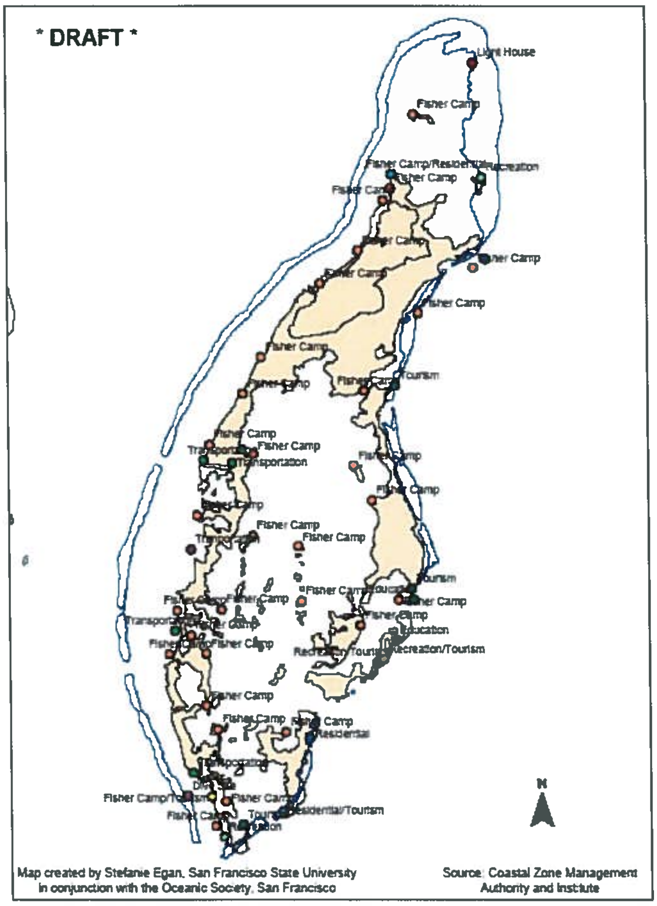


Figure 5. Land Use Types, Turneffe Atoll

The dolphin 1989-1990 data layer (Figure 6) shows that the majority of dolphin sitings occurred in the southern third to half of the Atoll. The data from 1993-1994 (Figure 7) also displays a concentration of sitings in the lower one half to third of the Atoll, but there are more sitings in the norther half of the Atoll than recorded in 1989-1990. In both maps it appears that it was most common for dolphins to be groups of between one and eight individuals. There are no larger groups (greater than 10 individuals) observed in the upper third of the Atoll.

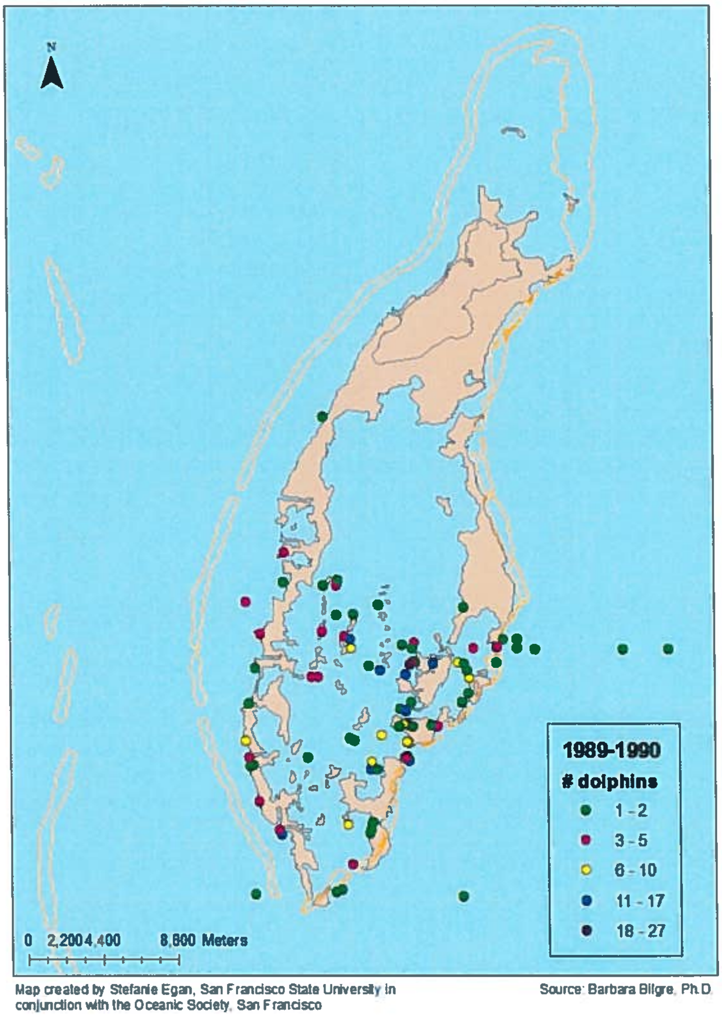


Figure 6. Dolphin Sitings, Turneffe Atoll, 1989-1990

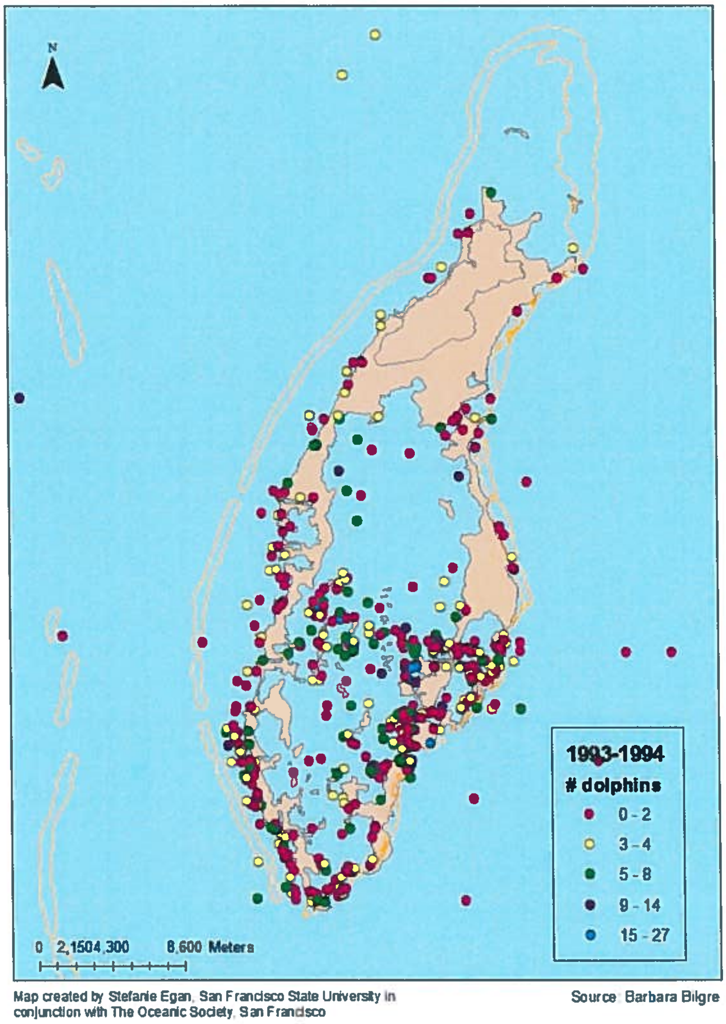
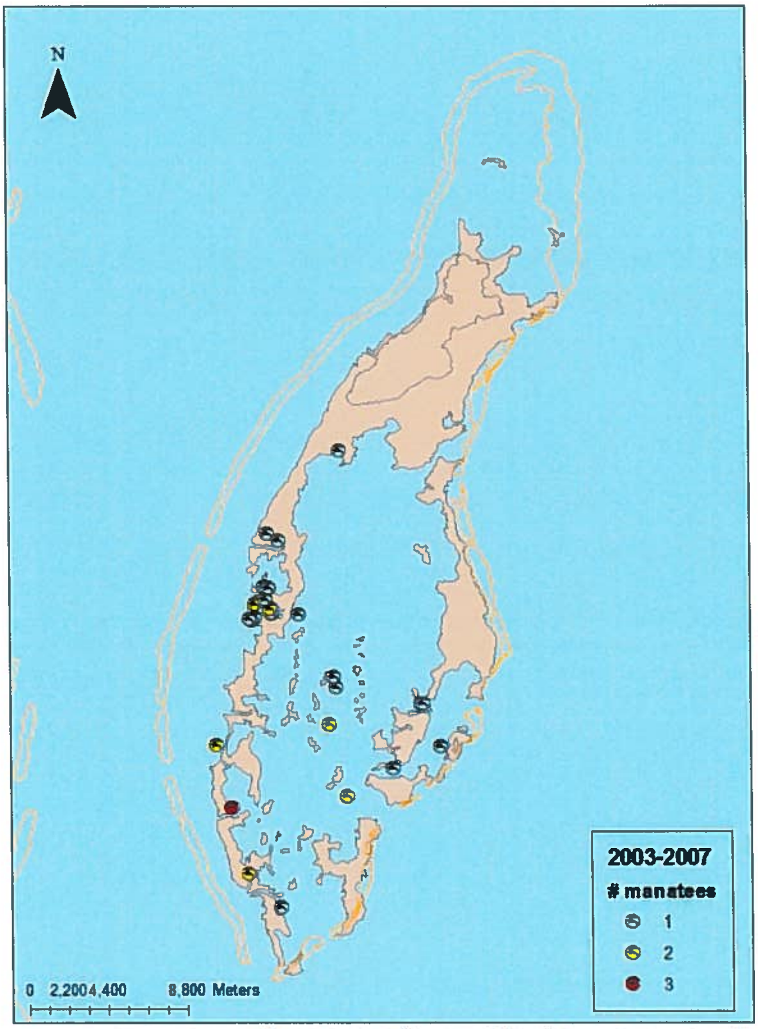


Figure 7. Dolphin Sitings 1993-1994

From analyzing the manatee data layer (Figure 8), it appears the majority of sitings occur in and around Douglas Lagoon and Tarpon Creek on the western side of the Atoll. When analyzed in conjunction with the vegetation map, one can see that the manatees were observed in areas where mangroves and dense seagrass are present. The manatees were observed in small groups of up to three animals.



Map created by Stefanie Egan, San Francisco State University in conjunction with The Oceanic Society, San Francisco

Source: Ellen Hines, Ph.D. and Suzanne Holguin, San Francisco State University

Figure 8. Manatee Sitings 2003-2007, Turneffe Atoll

Comment [C5]: I will be redoing this map to include a Legend!!!

Juvenile permit (Figure 9) were observed in four distinct locations around the Atoll, ranging the full length of the Atoll north to south. Two of the sites have high concentration of juvenile permit: Calabash Caye and Deadman's Caye.

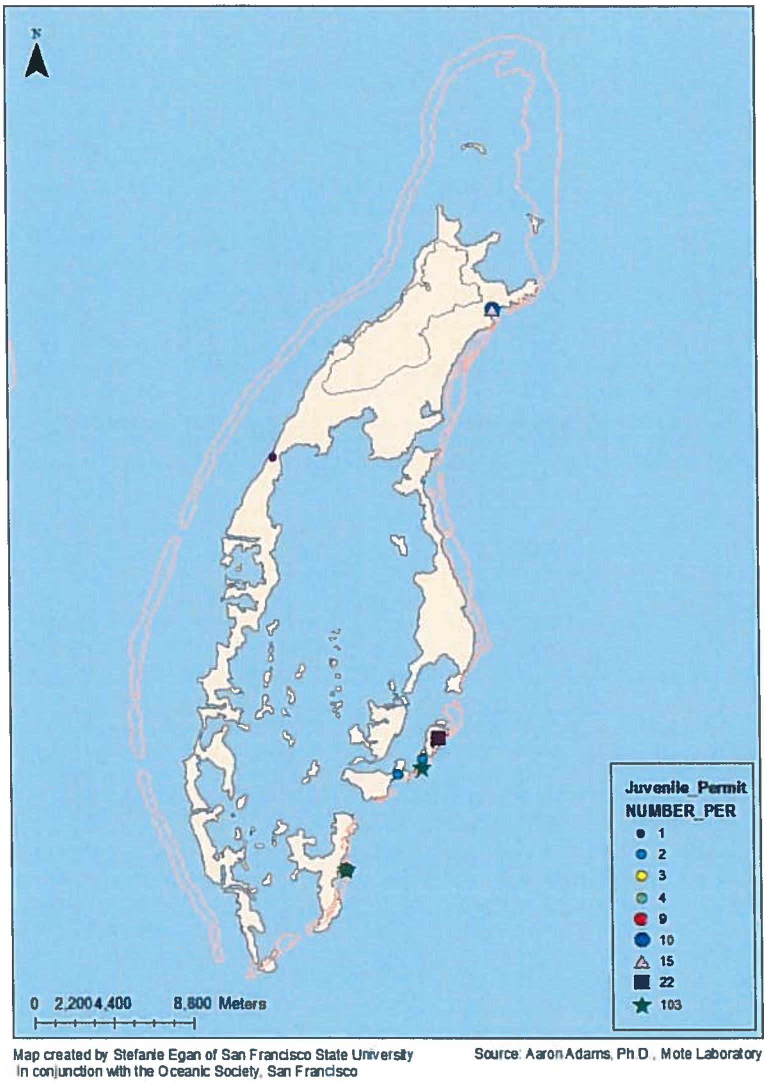


Figure 9. Juvenile Permit Richness & Distribution, Turneffe Atoll

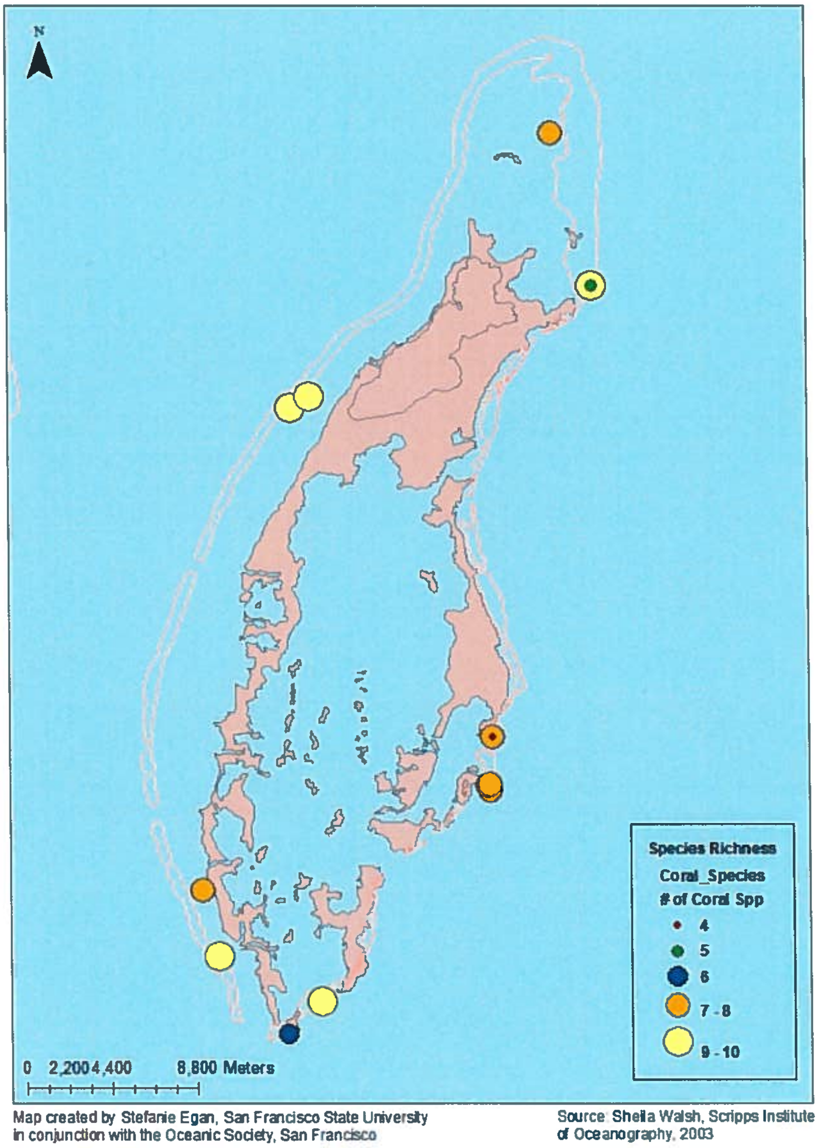


Figure 10. Coral Richness, Turneffe Atoll

The map of coral variety, (Figure 10) indicates the richness of coral species around the Atoll. There were between seven and ten types of coral present at the majority of sample sites. As mentioned previously, the data was collected as point data which did not permit that it be mapped with more spatial specificity, but it does give a sense of the variety of coral species in the area. This is one of the contributing factors to the ecological importance of the Atoll and surrounding waters.

The Kaplan Survey Data (Figure 11) of fish species was collected as point data. As such, the map legend provides most of the key information, such as species and number of individuals. The Elbow of the Atoll was richest with 25 species observed. Conch, an important commercial species, was found at three locations all in the northeast portion of the Atoll.

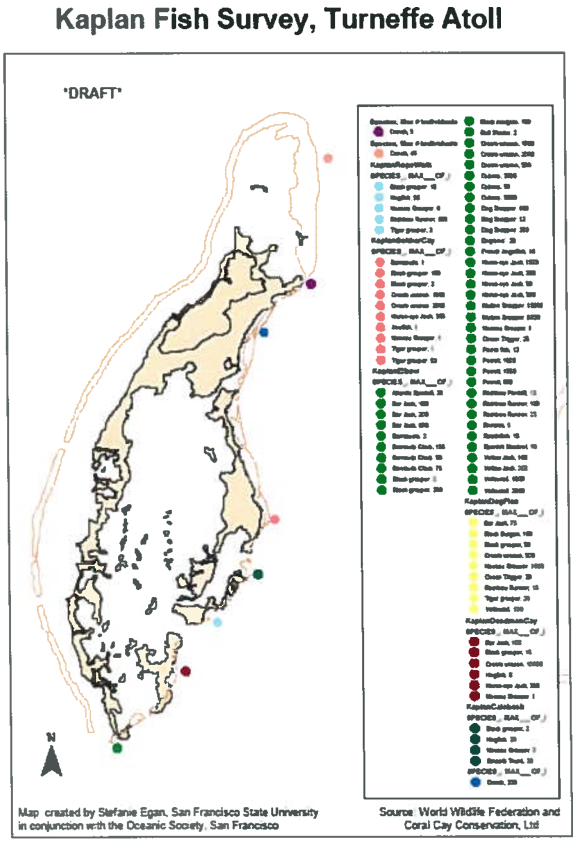
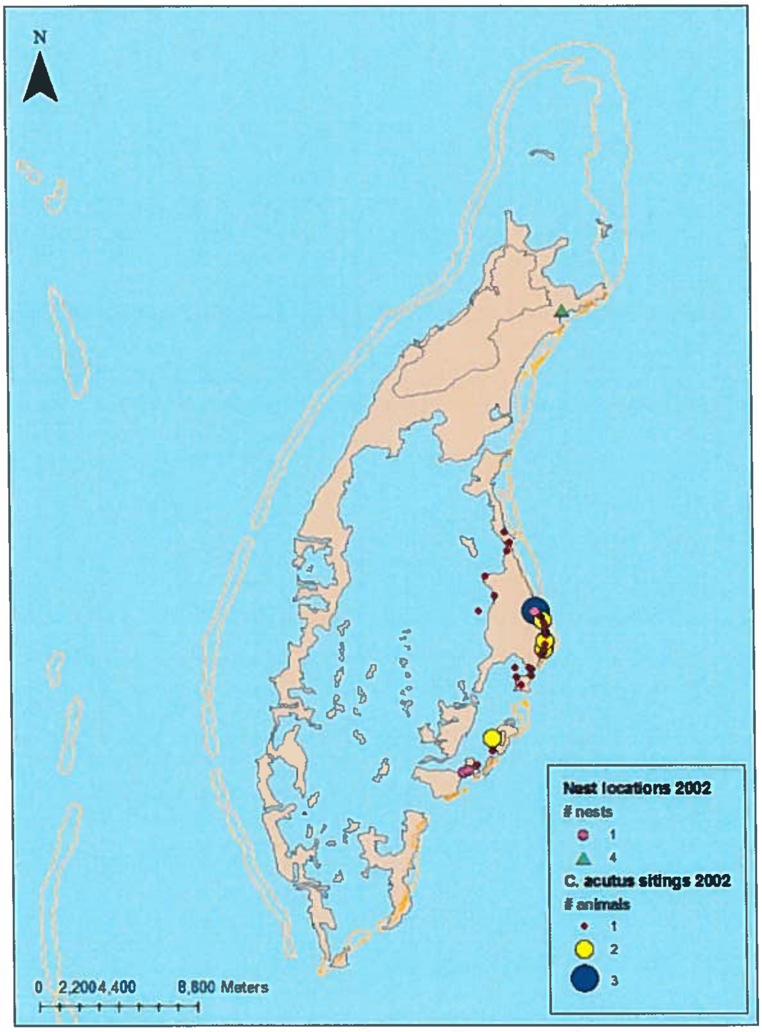


Figure 11. Kaplan Fish Survey

I created two maps for the American crocodile (*C. acutus*), a map that displays nest locations observed during a 2002 survey (Figure 12), and a spotlight survey transect map (Figure 13). One can see that there is a high concentration of *C. acutus* along the eastern edge of Blackbird Caye. From looking at the Fishing map (Figure 18) one notes that the outer (far eastern) edge of the coral reef in this location is identified as a fish spawning aggregation site.



Map created by Stefanie Egan, San Francisco State University in conjunction with the Oceanic Society, San Francisco

Source: Steven Platt, Ph.D. 2002 Crocodile Survey completed for the Oceanic Society

Figure 12. C. acutus sitings and nest locations, 2002

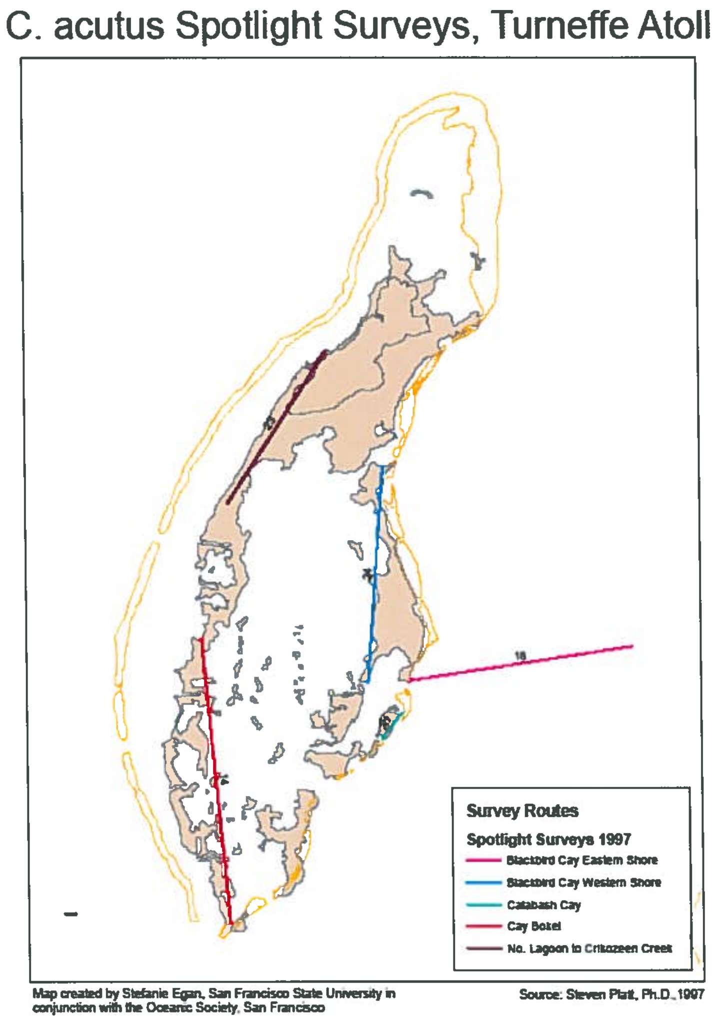


Figure 13. C. acutus Spotlight Survey

The fishing map produced by the Threat Assessment Workshop (Figure 14), outlines the areas of the Atoll where different types of fishing take place. Given how much of the Atoll is fished commercially, one can see how important it is to obtain the support of the commercial fishers for sustainable fishing practices.

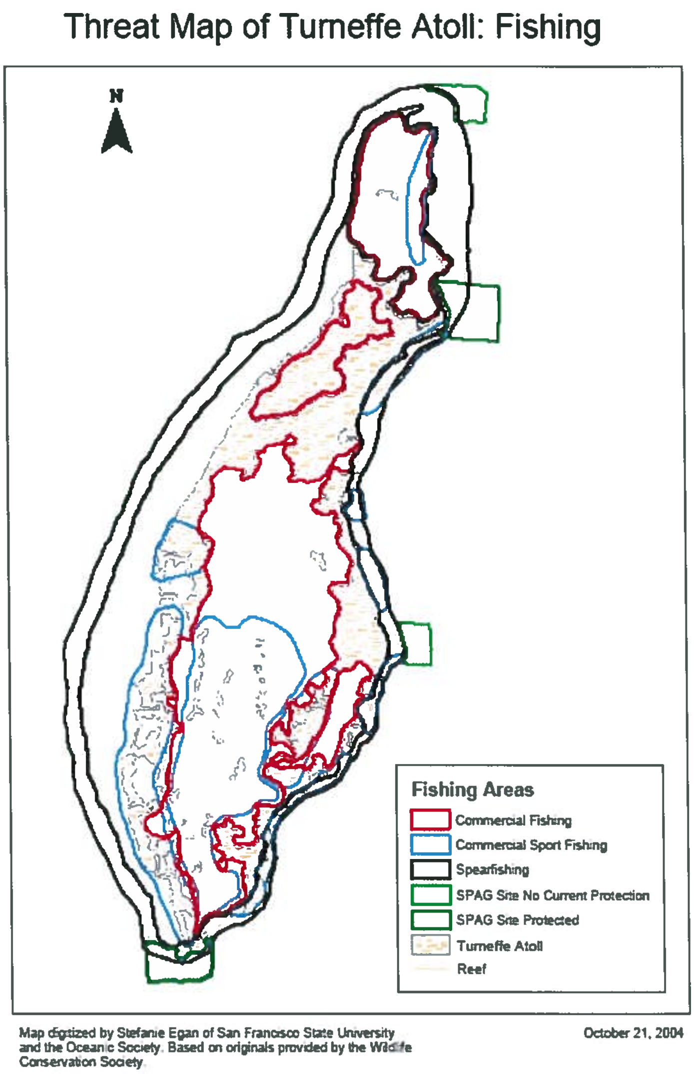


Figure 14. Fishing Types and Locations, Turneffe Atoll

Two of the other maps produced during the Threat Assessment Workshop, Overdevelopment (Figure 15) and Mangrove Clearing (Figure 16), when compared to each other, highlight the overlapping areas at high risk of degradation. Specifically, one can see that the mangrove areas of highest value are also the areas most likely to be cleared as they are most desireable for development for lodges and other settlements.

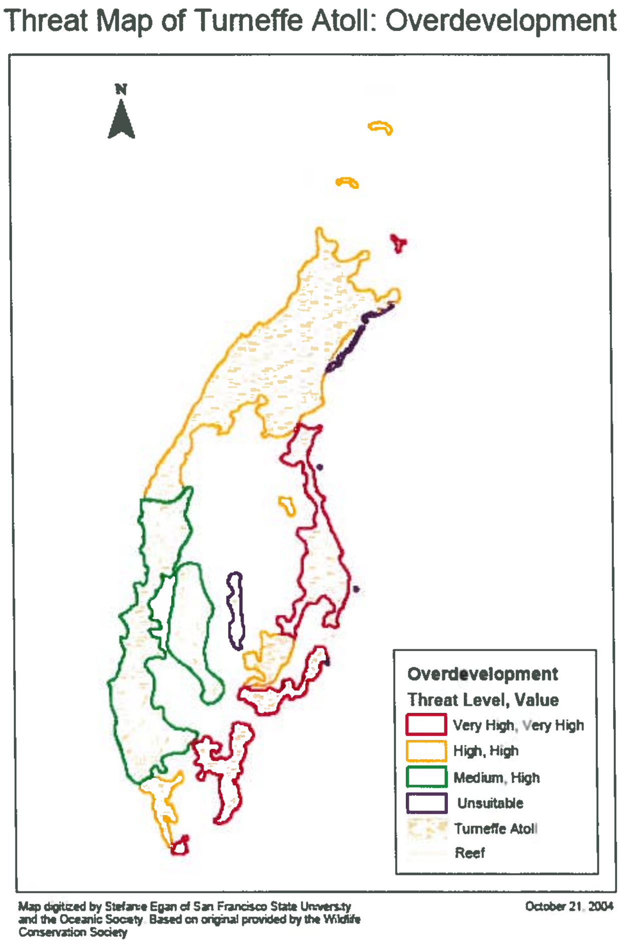


Figure 15. Overdevelopment Risk, Turneffe Atoll

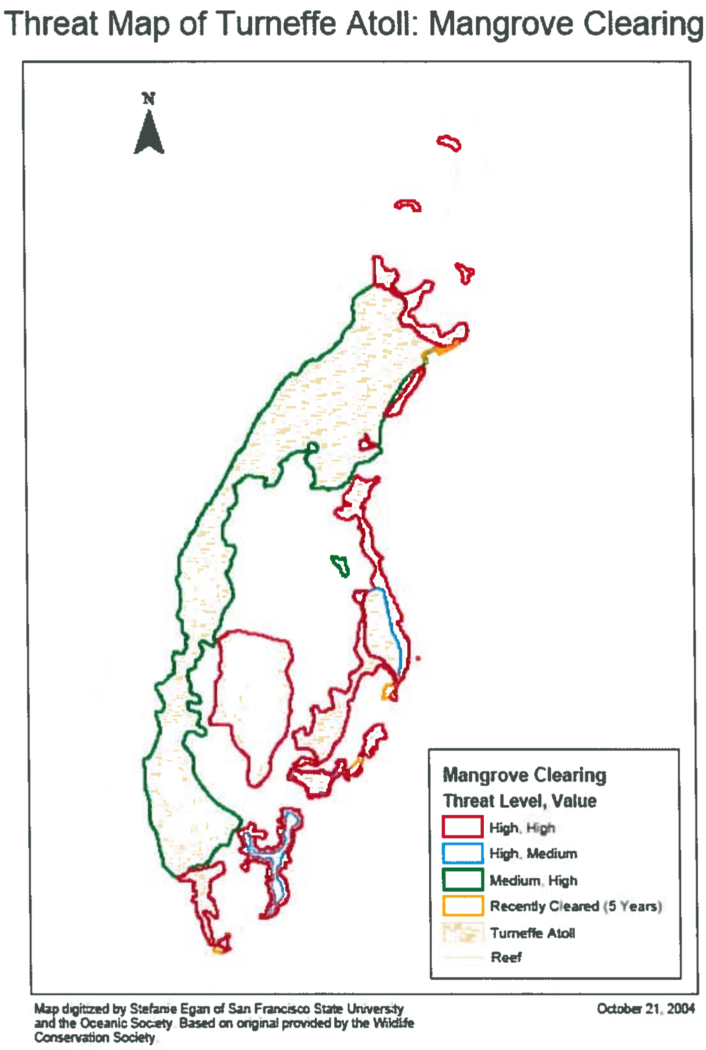


Figure 16. Mangrove Clearing Risk, Turneffe Atoll

The dredging map (Figure 17) shows that the areas that would be most affected by dredging activities (most often carried out for development purposes) are those that occur on the Northern-most tip of the Atoll and down along the eastern reef to the southern-most tip (Elbow).

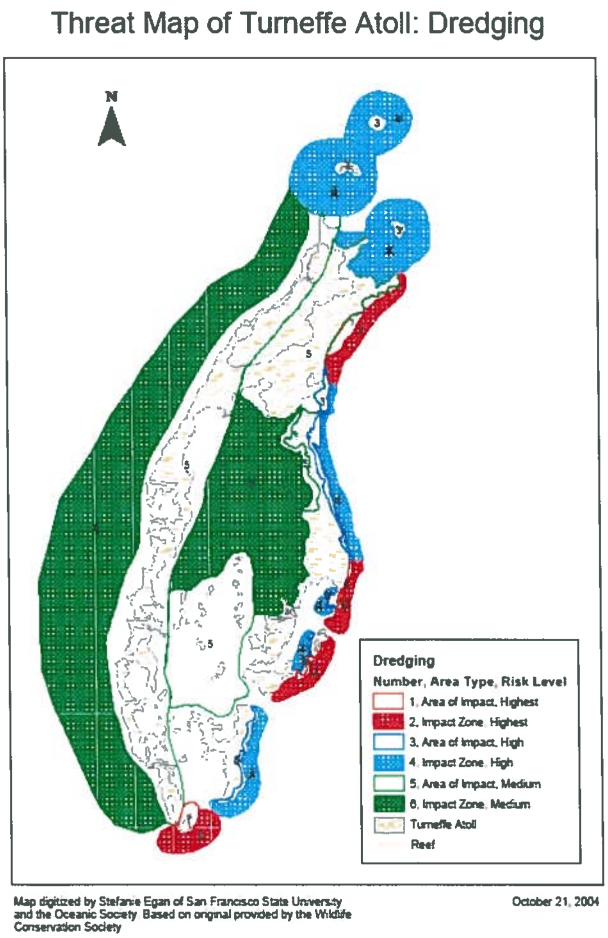


Figure 17. Dredging Risk, Turneffe Atoll

The commercial fish layer (Figure 18) was produced from a map on which a long-time fisher of Turneffe indicated the typical locations of the various commercial fish species typically fished on and around the Atoll. From this map one can see that Snapper have the most widespread presence around the Atoll among the fish species included on the map.

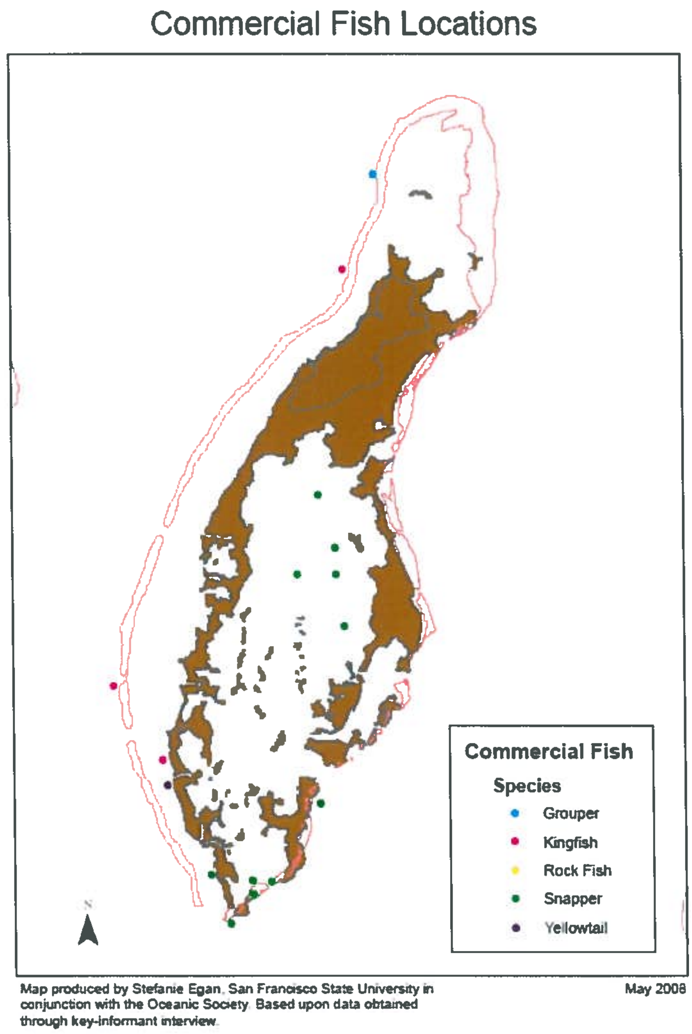


Figure 18. Commercial Fish Locations, Turneffe Atoll

Lobster map from interview at coop meeting: (Figure 19) to come

Draft Zone Map Creation

Participatory GIS for Biosphere Reserve Zone Designation, Turneffe Atoll, Belize: Lessons Learned

In 2004, following my two visits to Belize, a decision was made to deviate from the original scope of the project whereby I would create a draft biosphere reserve zone map that would be submitted to TICAC for discussion (Figure 20). It was intended that this map be used only as a starting point for discussion of the zone placements. By reviewing all of the layers I had at my disposal, and incorporating biosphere reserve guidelines for zone designation from my research, I digitized preliminary zones. There was a large amount of misgiving on my part given that I had little on-the-ground knowledge of the resources, conflicts and stakeholder concerns. However, I knew that this was to be used only as a starting point for discussion among TICAC members, none of my recommendations certainly needed to be heeded or kept.

I designated the core zones as the areas currently identified as Spawning Aggregation (SPAG) sites. Currently two of these sites have legal protection and two do not. Given the high level of importance of SPAG sites to fish recruitment, it seemed that these would certainly need to be areas that are off-limits to any fishing or other activity. To protect these SPAG or core zones, the areas immediately surrounding these sites need to be designated as buffer zones, in which only approved, non-destructive activities can take place. I extended the buffer zones to include: areas of manatee sitings, any areas in which crocodile nests had been observed, and areas of sensitive vegetation such as the mangrove areas at highest risk of clearing. I did not specify the transition zones on the map, as I consider the remaining areas of the Atoll not designated as core or buffer zones to be transition zones. Given that transition zones typically surround or are adjacent to buffer zones, and are areas where sustainable development takes place, this seemed to represent the rest of the Atoll.

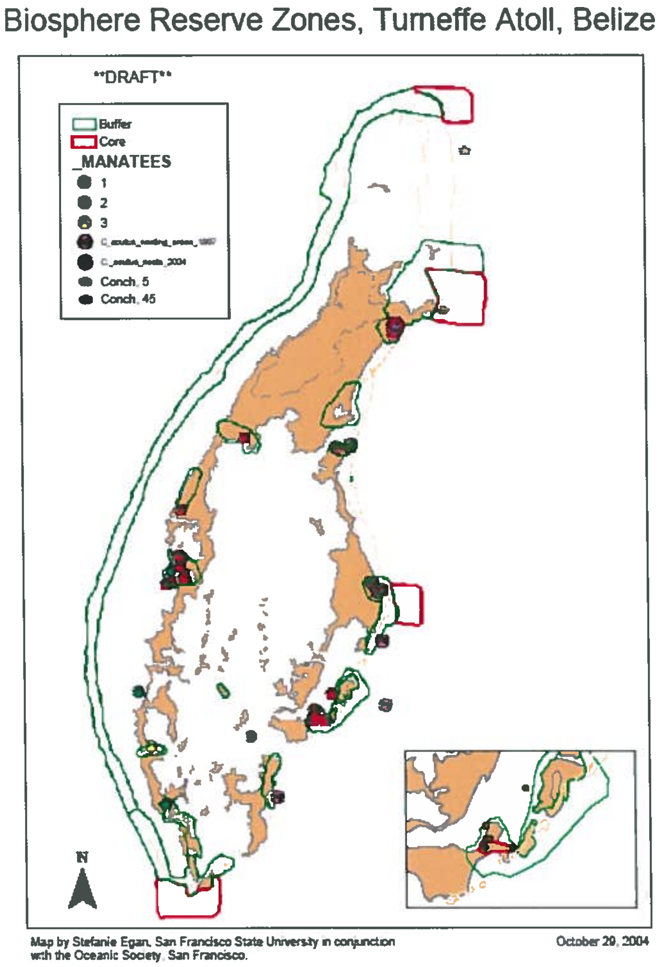


Figure 20. Draft Biosphere Reserve Zone Map

The draft zone map was circulated by Birgit Winning as a .pdf to various TICAC members with whom she was scheduled to meet on her trip to Belize City in **(date).** It was never seen by the committee in its entirety, so it was not used as a jumping off point for zone designation discussion as originally intended. Further, it was seen in conjunction with the other maps, before the draft maps were considered approved and ready for inclusion in the GIS by TICAC members. Although I did receive helpful feedback on the draft zone map from two individuals, this exercise seemed to shift focus away from having it be a discussion point, to my approach to designating the zones. Most disturbingly, it raised the ire of the one TICAC member who saw my attempts to create a draft zone map as a gross overstepping of my bounds, and a threat to the very collaborative process that is necessary for the zone designation, should the map ever get misinterpreted as a final copy. This resulted in a public relations problem and required me to defend my skills and intent with regard to the project.

Data mining and GIS layer Results

Data collection efforts returned 11 data sets: dolphin, manatee, juvenile permit, threats to the Atoll (mangrove clearing, overfishing, overdevelopment, dredging), seagrass, fresh water, coral, lobster, commercial fish, crocodile nest locations, and crocodile transect data, all of which needed to be projected and saved as shapefiles. Three existing GIS layers were obtained on compact disc from the Coastal Zone Management and Authority: habitat, vegetation and land use, as well as a base map for the Atoll. In total, there are currently fourteen data layers that comprise the GIS database for the Atoll.

The data compilation provided a comprehensive view of the resources and other physical and biological characteristics of the Atoll, but it also highlighted gaps in the data; that is, the process provided a window into what data were missing and what aspects of the Atoll still needed to be studied by the scientific community. This data gap provides a guideline for what data need to be collected to have a more fully representative geographic and biological understanding of the natural resources of the Atoll. Some data that need to be collected and mapped in the future include: bird species presence/abundance and nesting location data, bat abundance, bathymetry, dive site locations, and mooring sites used for dive boats and other vessels. Further, the following data sets will benefit from additional data to make them more complete: commercial fish catch data and location, more extensive geographic information on the location of bonefish, updated geographic data on land use/developed areas of the Atoll, and more extensive spatial data on coral type and locations.

Comment [MSOffice6]: i.e more than point

Interview Results

The group interview with the National Cooperative of commercial fishers in March 2004 resulted in 46 completed questionnaires from about 70 attendees. The questionnaire answers provided qualitative data about the fishers' background and knowledge of and feelings about the biosphere reserve effort (Appendix 3). Results (Table 2) indicate that the majority of fishers (36) support others financially which highlights the importance of fish availability, as any depression in catch numbers would mean less income for the fishers. It was assumed that this was their primary means of income, but to be absolutely certain I should have included that question on the interview sheet. The majority of fishers (36) indicated that they have noticed a change in catch availability, but when asked the reason for this, most of them (28) did not respond. Of those who did respond, the greatest consensus (12) was that this was due to overfishing. One hypothesis of mine as to why most did not offer a reason for the change in catch availability is that they are concerned that an answer of overfishing could lead to the implementation of restrictions they believe would hurt fish availability, not help improve it. A couple of fishers (2)

Comment [MSOffice7]: The table is quite l so am trying to figure out if I can include it in th body or in appendix.

responded that reserves were the reason for the change in catch availability. It is not clear from this whether this means that they feel that the catch numbers are declining and that reserves are responsible for that, or whether they feel that catch numbers are increasing as a result of reserves. This indicates a problem with my questionnaire, that had I had an opportunity to re-administer it, I would have fixed. The questionnaire should have asked in what way they believed the catch availability was changing, up or down, and then why. Given that a significant number indicated a negative reason (overfishing), I have to surmise that the others who wrote in reserves, also believed that catch availability was declining and therefore believe that reserves have a negative impact on fish numbers.

Based on interview results, I believe an effort needs to be made to provide data to the fishers from successful reserves to demonstrate the consistent improvements in fish numbers that have resulted from marine reserves. For the conservation effort on Turneffe to be successful, it is necessary that baseline data about fish catch be presented to the fishers, and that they be continually apprised of changes in this data as the reserves are put into place and data becomes available. Enforcement would need to be effective and consistent, as this would be the only way to accurately gauge the effectiveness of the reserve and give the reserves a chance at success. Once the benefits begin to be realized, hopefully compliance with reserve guidelines will become more voluntary and enforcement of reserve regulations would be adopted by the fishers.

In addition to this one group interview with the National Cooperative, two additional interviews were conducted with key informants - long-time fishers of Turneffe. The individual interviews provided limited geographic data on commercial fish and lobster trap locations. One interviewee marked a map to show the general locations in which the various significant commercial fish species are found and fished. The map obtained from the second interviewee was not specific enough to enable a GIS layer to be produced.

Project Hurdles

Limitations

As the work proceeded it became apparent that the goal of creating a timely and fully public participatory GIS was more difficult to achieve. The following relays hurdles I encountered while working on the project and identifies reasons why these two goals were not fully met.

Time Frame

The lack of understanding on my part, and perhaps on the part of TICAC as well, of the full scope and time frame of this project was a central stumbling point. I did not press for or draw up a formal timeline at the outset of my work. As I have learned through my involvement with this project, a biosphere reserve designation is a very time consuming and iterative process. It would have been extremely helpful for both the outcome of my project and for my contribution to the biosphere reserve project to have a better understanding of how long this may take. A discussion of the timeline with my advisor and Birgit Winning could have brought to light that it may have been too broad of a scope for a master's student, or that the project needed to be more bounded in its goals in order to meet my time frame. Further, it would have been helpful to decide at the outset of my work how I would handle a time overrun and to set forth an agreed upon plan should it go beyond the projected timeline.

I did not spend long enough in Belize City or on the Atoll to fully understand the concerns about and challenges of the biosphere reserve project. To be able to grasp more comprehensively the politics at work in the designation process and to establish necessary and meaningful contacts and trust among the stakeholders I should have stayed for an extended period of time in the area, even several months, in which I split time between the Atoll and Belize City. My personal situation and budget constraints on both my part and that of the Oceanic Society did not permit me to make more than two trips or to spend an extended period of time in the country. The limited trips and their short duration did not allow for a full understanding of the situation at hand or a chance to establish important relationships, both of which could have benefited my work.

Public Participation

Recognizing the importance of stakeholder input, one of the long term objectives of the Draft Turneffe Islands Management Plan (TIMP) was to involve current Atoll stakeholders, (which the Draft TIMP defined broadly as MRC committees, fishers, tourist interests and conservation NGOs) in meetings and forums to learn of their concerns and opinions in order that these be incorporated in the sustainable management plan for the Atoll **(date)**. Given that one of the original goals of this project was to create a public participation GIS for the area, it was part and parcel of the planning objective identified by the TIMP.

Although this project was participatory, there was a limited amount of input obtained from the commercial fishers, the GIS was not actually worked on by this stakeholder group, and only one stakeholder group, the fishers, was consulted. To have made this a more fully participatory effort, results would have been presented to the Fisherman's

Coop, more Belizean commercial fisher coops would have been contacted, input from other stakeholder groups, such as recreational interests (dive lodges etc.) would have been obtained and more data would have been collected on the range and seasonal presence of each fish species.

Loss of Contacts

As discussed earlier in this work, data collection was an essential component of this project. I relied on established contacts in Belize who were knowledgeable about my work and the biosphere reserve effort to facilitate data collection as well as to gain access to user groups, such as the commercial fishers. Unfortunately two of these critical contacts were lost due to unforeseen developments. Ian Gillette, the GIS technician at CZMAI, who provided me with GIS layers for the Atoll and was a very valuable resource for existing digital data, became unavailable with the sudden dissolution of the CZMAI due to their loss of funding. Although I have heard that this agency has since reopened, it is unclear at this time whether Ian is again with the agency. Regardless, the timing of the dissolution of CZMAI and therefore the loss of Ian as a contact, resulted in the loss of an important resource for data.

In addition, Moustafa Tourre of the Belize Fisherman Cooperative Association, a commercial fishers representative on TICAC and one of the central figures in the biosphere reserve effort, lost his position as the fishers' liaison. Moustafa had been an advocate for me with the fishers, along with Vincent Gillette of BFCA, in terms of helping me set up time with the National Cooperative for the group interview, and acting as a source of information during my visits to Belize. Further, he was a champion of the biosphere reserve effort and of my work in Belize in terms of how it was to help the biosphere reserve effort, and he assisted me in gaining access to TICAC meetings and other contacts while on my visits.

Communication

I did not have direct contact with the biosphere reserve subcommittee or TICAC. Due to the infrequent nature of the TICAC meetings and to streamline communication, Birgit Winning of the Oceanic Society requested that she provide TICAC members with information about my work and on the other side, relay to me their feedback and concerns. In hindsight, it may have been more beneficial and time efficient had I been able to communicate directly with the committee as it convened, ideally through conference calls, if not in person at the meetings in Belize. One of the obstacles to this however, is that it does not appear that the biosphere reserve subcommittee ever formally met as a group, and its existence as a subcommittee is also uncertain. As such, it was necessary for Winning to present my work to each committee member as she encountered them one-on-one in Belize to discuss other agenda items.

Map Format

Upon request, I provided draft maps to Winning which she took with her to Belize and presented to individual TICAC members as she met them in order to solicit feedback and show them the current state of my work. In order for her to view the maps, I would provide them to her in a .pdf (Adobe 7.0) format that she could print out and take with her. Furthermore, most of the TICAC members do not have access to GIS; it would have been prohibitive for them to view the draft layers in digital format. The static nature of these draft maps did not allow for the dynamic nature of the GIS layers to be understood- in order that the hard copies of the maps could be easily read and understood, elements had to be excluded from the maps for display purposes. This unfortunately reduced the overall impact and message of the maps in their draft form.

Fishers Interviews

A central component to the public participation aspect of this project was the interviews that were to be conducted with the commercial fishers of Turneffe. I had planned to conduct one-on-one interviews in which I would ask a mix of open and closed-ended questions in order to obtain first-hand data about the location, seasonality and type of fish present throughout the Atoll. Given the individual nature of fishing, I had hoped to conduct the interviews at the various fisher cooperative meetings as this would provide a forum in which the fishers were all assembled.

Through the assistance of Vincent Gillette and Moustafa Toure of the Belize Fisherman's Cooperative Association (BFCA), I was able to gain access to the National Fisherman's Cooperative meeting in Belize City in March 2004. As mentioned previously, I met with Toure, Gillette and McField of the World Wildlife Fund prior to the cooperative meeting as Toure and McField were also to present at the meeting, and we wanted to be sure we understood the order and nature of each other's presentations. Given this group's experience with cooperative meetings, upon hearing of my plan for the interviews, they recommended that I do a group interview in lieu of one-on-one interviews given the time constraints they knew I would face at the meeting. Further, they proposed that the individual interviews in which I wanted to obtain specific fish data, be conducted during the scheduled break after my group interview and presentation. I was to ask willing participants to meet me in a specified corner of the room in order to answer the few fish data questions.

The cooperative meetings are conducted in English and as such, the questionnaire I handed to the fishers during the group interview was also in English. Despite my presentation and explanation of the questions during the time they were asked to fill out the questionnaire, it was apparent that the mix of multiple choice and open-ended questions was somewhat unclear to them and would have been easier for them to understand in Spanish. Several cooperative workers traveled the room to answer individual questions by the fishers and to translate as necessary. Even with this assistance, however, I noticed that many were talking to their neighbors and there seemed to be a sense that some questions had "correct" answers, as it appeared from the finished questionnaires that some fishers had copied answers from each other. As a result, it is difficult to assess the accuracy of some of the answers.

Once the questionnaires were close to being completed, I asked for volunteers to answer a few more questions in brief one-on-one interviews during the break. At this point, however, it had become difficult to get the fisher's attention due to the talking and the looming break. The fisher's were anxious to take advantage of the break in this all-day meeting and as such there were no willing volunteers. Ultimately, I was able to talk to only one fisher, albeit an individual who had fished the waters of Turneffe for almost three decades and who had valuable insight into fish locations. Given his age, failing eyesight and the relatively small size of my map, he had a difficult time identifying locations on the map of the Atoll without my assistance.

The fishers' cooperative meeting was only one day long and I was scheduled to depart Belize a few short hours after my presentation and interviews. I was therefore not able to rectify the shortcomings of my approach at a subsequent meeting. Given a combination of budget and time constraints coupled with the lack of willingness by BFCA to coordinate another meeting with a fisherman's cooperative, this remained my only significant interview opportunity with the fishers.

Current State of the Project

The GIS layers have been created for the existing geo-referenced data of the Atoll. The layers are available for review in GIS format by those who have the authority to designate the zones for the biosphere reserve. Once this is completed, a zone layer can be created by a GIS technician and provided for inclusion in the biosphere reserve application.

Future of the maps/GIS Database

A copy of the GIS database will reside with the University of Belize and a copy of the maps will be kept by the Oceanic Society. A Memorandum of Understanding (MOU) I signed with Coastal Zone Management and Authority specifies that a copy of the GIS also reside with CZMAI. Access to the database and permission to update it are items that still need to be discussed and decided upon.

It is anticipated that TICAC will convene at a future date to discuss and review the GIS maps and designate the biosphere reserve zones. Once the zones have been decided upon by the committee, a GIS technician will digitize them, creating a zone layer for the GIS database. This final zone map will be provided for inclusion in the biosphere reserve application for Turneffe Atoll.

Future data collection on the resources mentioned above, as well as on the development of the Atoll will provide a more complete understanding of the richness of the area and the locations that are particularly sensitive given the abundance of resources and development pressures. As more data become available, the GIS database can be easily updated providing managers with the ability to refine, if necessary, the zone locations and gain a better understanding of management needs of the area.

Conclusions and Recommendations

Given the sensitivity of the resources of the Atoll, its importance as a commercial fishing site and the increasing popularity of Turneffe among tourists, it is essential that the Atoll be protected in a comprehensive manner. The concurrent use of the Atoll as a location for commerce, scientific study and recreational activity makes the selection of a biosphere reserve an appropriate means of protection by blending sustainable use with conservation. Further, the emphasis that a biosphere reserve places on the integration of stakeholders in the conservation process is a logical component of any management effort for the area and necessary for successful conservation planning for Turneffe.

Despite the shortcomings discussed previously, this project enabled me to pull together into a single database natural resource data for the Atoll that had previously been in many disparate locations. The GIS database will permit these data to be analyzed in a multiplicity of ways, and continually be updated as new data becomes available. As a result, it will serve as a very important tool in the ongoing sustainable management of the Atoll.

The data collection highlighted what aspects, both natural and otherwise, of the Atoll still need to be documented or updated. This provides key information to the organizations involved in the management of Turneffe, allowing them to target future efforts on the acquisition of necessary and missing data. Further, data collection efforts provided a means for spreading the word about the biosphere reserve effort underway among stakeholders such as fishers, scientists and lodge operators. Informing stakeholders about the current conservation effort is a key step in including them in the process.

Generally speaking, there are times when PGIS projects, given the involvement of the public and the variability of working with a range of skill sets, potential language barriers and differing viewpoints for example, can end up producing different results than those originally envisioned (Bujang 2005). When coupled with the issue of working in a developing country, there is an increased risk that additional issues can arise, such as the loss of contacts, inadequate funding and time-frame over-runs. Directors of a PGIS project should consider these issues and other potential pitfalls at the outset and try to prepare as much as possible before-hand, having alternate plans in place but also being flexible enough to rework parts of the project to keep the overall objective as intact as possible.

Participatory GIS provided an opportunity for stakeholder groups, such as the commercial fishers, to participate directly in the conservation effort, by providing their first-hand, unique knowledge of the Atoll. A series of unanticipated events and incomplete understanding of certain political, cultural, and logistical issues has resulted in the creation of a GIS that is not as participatory as originally intended. Recalling the

McCall and Minang (2005) case study discussed earlier in this work, however, this project stands as another example of some of the difficulties inherent in fully integrating stakeholders into the PGIS process. Further, as White & Vogt (2000) discuss, when there is a lack of a permanent residential community, as in the case of commercial fishers of Turneffe Atoll, communication with stakeholders can be more challenging.

With that said, GIS is a dynamic product that can be continually updated to reflect current conditions on the Atoll. Given this flexibility, it can also be used to incorporate future input from the various stakeholders on the Atoll as it is obtained. As such, I would recommend that efforts are continued to get data from stakeholder groups – particularly as these groups may change and grow over time. In addition, I would recommend that an attempt is made to further engage stakeholders in the creation of the GIS layers and management of the system to more fully integrate them into the process and further ensure, or help increase their commitment to the protection and sustainable use of the area.

Draft/ Example only!
Formatting to come...

Appendices:

Appendix I. Habitat attribute data

Appendix II. Land use attribute data

Appendix III. Vegetation attribute data

Appendix IV. Interview questionnaire Part I

For each question, please circle the appropriate answer write in your answer in the space provided. Where indicated, it may be appropriate to circle all that apply.

1. What is your age?
   20-30 30-40 40-50 50-60 60+
2. What is the highest grade level you have completed?
3. How long have you been fishing?
   0-5 years 5-10 years 10-15 years 20+ years
4. Have you noticed any change in the catch numbers/ fish availability over the past 15 years?
   Yes No
5. If yes, what do you think may have caused these changes?
6. Are you familiar with the biosphere reserve concept?
   Yes No
7. Are you aware of the effort to designate Turneffe Atoll as a biosphere reserve?
   Yes No
8. How do you think this might affect you?
   I think it will help I don't think it will help I don't know
9. For which species (types) do you routinely fish?
10. Would you indicate on the map where these different fish are generally found?

11. Does the presence of the fish change with the season? If so, can you indicate on the map what season the fish are generally found (next to the name of the fish)?

Appendix V. Interview Questions Part II

The following questionnaire contains both multiple choice and open-ended questions. For the multiple choice questions, please circle one answer, except where indicated.

1. Do you believe this map accurately reflects the layout of Turneffe Atoll?
   Yes No

2. If not, what do you find to be inaccurate? (You may check more than one)
   names of waterways
   names of cayes
   location of cayes
   location of waterways
   other (please specify)

3. How would you change the map to make it more accurately portray your knowledge of the atoll? (You may make the changes directly on the map if you wish)

4. Name the species (types) of fish that you have routinely seen in the waters around Turneffe Atoll over the past year.

5. Do the various species (types) of fish around the atoll vary (change) according to the time of year?
   Yes No

6. If yes, do they vary seasonally (spring, summer, fall etc.) or month to month?
   Seasonally Month to Month

7. Can you describe the species' variation (change) over the indicated period of time? (increase in summer, decrease in fall etc)

8. Which of the species (types) of fish named above (Question 7) occur in each season, or in which month or months do they occur around the atoll? If possible, please write the name of the season or the month next to each fish listed in the previous questions.

Appendix : Interview Results

Fisher Meeting Results 3-12-04		
National Fisher Cooperative, Belize City		
Total Responses: 41 Total Fishermen present 70		
Age	**20-30**	**31-40**
	13	7
Education	**Some or finished Primary**	**some or finished highschool**
	10	5
Years Fishing	**1-5 Years**	**6-10 years**
	4	7
Other Fishers in Family?	**Yes**	**No**
	41	2
How Many Fishers in Family	**One**	**Two**
	6	11
Generations	**Ist Generation**	**2nd Generation**
	13	17
Financial Support for Others?	**Yes**	**No**
	36	3
For Whom?*	**Mother**	**Father**
	some of all combinations reported	
Change in catch availability?	**Yes**	**No**
	36	3**
Why?	**more/too many fishermen i.e overfishing**	**reserves?**
	12	2
Familiar with Biosphere Reserve concept?	**Yes**	**No**
	16	21
Know about effort to designate Turneffe?	**Yes**	**No**
	20	17
How do you think this might affect you?	**Help**	**Not Help**

	18	2
*unable to report results due to nature of how question set up- all the permutations available		
**these respondees have not been fishing for 15 years which may explain why they felt had to respond no		

Appendix VI. Coral reef attribute data

Appendix VII. Seagrass cover and density

Appendix VIII. Kaplan Survey Fish data

Appendix IX. Overdevelopment attribute data

Appendix X. Mangrove Clearing Attribute data

Appendix XI. Overfishing attribute data

Appendix XII. Dredging attribute data

Appendix XIII. Zone map attribute data

Appendix XIV Manatee attribute data

DATE	X_COORD	Y_COORD	METHOD	#_MANATEES
4/2/2004	406892	1927050	Aerial	1
4/2/2004	402759	1922389	Aerial	1
4/2/2004	402930	1918151	Aerial	2
4/2/2004	401626	1903287	Aerial	2
4/6/2004	400712	1907004	Boat	3
4/8/2004	402638	1918660	Boat	1
6/17/2002	411243	1909340	Boat	1
6/17/2002	411253	1908945	Boat	1
6/21/2002	411344	1908966	Boat	1
3/13/2003	403015	1917880	Aerial Su	1
3/13/2003	399863	1910525	Aerial Su	2
3/13/2003	407182	1907628	Aerial Su	2

3/13/2003	412411	1910420	Aerial Su	1
3/13/2003	402039	1918424	Aerial Su	2
3/13/2003	402963	1917861	Aerial Su	1
3/13/2003	402830	1919289	Aerial Su	2
7/12/2004	402088	1917624	Boat	1
7/13/2004	402660	1919391	Boat	1
7/14/2004	402617	1919347	Boat	1
7/14/2004	402564	1919370	Boat	1
7/27/2004	401843	1917514	Boat	1
7/29/2004	401716	1917548	Boat	1

Appendix XV. Commercial Fish Attribute Data

Id	Species	Time of Year
0	Rock Fish	NA
0	Grouper	December and January
0	Kingfish	Year Round with the Moon
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Snapper	March, April, May
0	Yellowtail	Year Round
0	Kingfish	Year Round with the Moon
0	Kingfish	Year Round with the Moon

Appendix XVI. Dolphin Attribute Data (double check this)

DATE_	TRIP__	SURVEY_	SURVEY_TYP	SIGHT__	GROUP_	ZONE_	OF_DOLPHI	CALVES	LOCATION
9/25/1989	18	1	P	1	1	5	1	0	Grand Bogue Char
9/27/1989	18	2	P	1	1	12	9	0	NW of Jones Hole
9/29/1989	18	3	P	1	1	5	2	0	Grand Bogue Char
9/29/1989	18	4	P	1	1	4	2	1	Long Bogue
9/29/1989	18	4	P	2	2	6	6	1	E of Cross Cay
10/11/1989	19	1	P	1	1	16	2	0	NW of Long Bogue

10/11/1989	19	1	P	2	2	9	2	1	SW of Jones Hole
10/11/1989	19	1	P	3	3	9	14	1	Spanish Man's Bight
10/11/1989	19	1	P	4	4	6	2	0	SE Central Lagoon
10/14/1989	19	3	P	1	1	17	4	1	E of Western Four C
10/15/1989	19	4	P	1	1	7	1	0	W. of Coco Tree Ca
10/19/1989	20	1	P	1	1	14	4	0	W. of Central Weste
10/20/1989	20	3	P	1	1	2	2	0	N. Central Harry Jor
10/20/1989	20	3	P	2	1	19	0	0	E. of NE Crayfish Ca
10/20/1989	20	4	P	1	1	19	11	1	SW of Fishing Bogu
10/22/1989	20	5	P	1	1	15	4	1	1/2 way b/w Shag C
10/22/1989	20	5	P	2	2	6	14	2	N. Southeast Bight
10/22/1989	20	6	P	1	1	17	7	1	1/2 way b/w S. Wes
10/23/1989	20	8	P	1	1	12	3	0	W. of Ambergris Cre
10/24/1989	20	9	P	1	1	4	12	1	W. Long Bogue
10/24/1989	20	10	P	1	1	5	2	0	Grand Bogue Chann
10/24/1989	20	10	P	2	2	14	3	0	NW Western Four C
11/2/1989	21	2	P	1	1	4	13	3	Long Bogue
11/2/1989	21	2	P	2	2	19	1	0	SE of Crayfish Caye
11/20/1989	22	1	P	1	1	19	16	3	SE of Crayfish Caye
11/20/1989	22	2	P	1	1	5	8	4	Grand Bogue Chan
11/21/1989	22	3	P	1	1	4	1	0	Long Bogue
11/21/1989	22	4	P	1	1	16	2	1	New Bight
11/21/1989	22	4	P	2	2	4	12	6	Long Bogue
11/22/1989	22	5	P	1	1	9	5	0	Grand Point
11/22/1989	22	6	P	1	1	6	8	3	NW of Southeast Bi
11/23/1989	22	7	P	1	1	5	12	4	Grand Bogue Chan
11/23/1989	22	8	P	1	1	5	12	4	Grand Bogue Chan
11/25/1989	22	9	P	1	1	12	1	0	W. of Little Jones H
11/25/1989	22	10	P	1	1	5	7	3	Grand Bogue Chan
11/26/1989	22	11	P	1	1	8	2	0	NE of Turneffe Islai
11/26/1989	22	11	P	2	2	7	2	1	NW of Ropewalk C
11/26/1989	22	11	P	3	3	7	2	1	SW of Ropewalk C
11/26/1989	22	11	P	4	4	7	6	2	NE Southern Lagoo
11/26/1989	22	12	P	1	1	5	10	2	Grand Bogue Char
11/30/1989	23	1	P	1	1	9	3	0	W. of Blue Creek
12/2/1989	23	4	P	1	1	12	1	0	SW of Grand Bogu
12/2/1989	23	4	P	2	2	4	4	1	Long Bogue
12/3/1989	23	5	P	1	1	4	6	2	Long Bogue
12/3/1989	23	5	P	2	2	15	3	1	1/2 way b/w Firewo
12/3/1989	23	6	P	1	1	19	4	0	W. of Fishing Bogu
12/5/1989	23	7	P	1	1	2	2	0	Harry Jones Cut
3/4/1990	24	3	P	1	1	12	3	0	SW of Tarpon Cree
3/6/1990	24	4	P	1	1	5	1	0	Grand Bogue Char
3/20/1990	26	4	P	1	1	19	2	0	W. of Blackbird Ca
3/23/1990	26	8	P	1	1	19	3	0	E. of South Crayfis
3/24/1990	26	9	P	1	1	4	1	0	Long Bogue
4/1/1990	27	5	P	1	1	6	10	3	SW of W. Entrance
4/6/1990	28	2	P	1	1	8	2	0	Big Cay Bokel Cha
4/8/1990	28	3	P	1	1	6	2	0	W. of Long Bogue
4/24/1990	30	6	P	1	1	19	1	0	N. of Fishing Bogu
5/2/1990	31	1	P	1	1	9	1	0	SW of Jones Hole
5/16/1990	32	1	P	1	1	18	12	0	W. of South Crayfi
5/17/1990	32	3	P	1	1	14	2	0	W. of Western Fou
5/18/1990	32	5	P	1	1	2	5	0	Harry Jones Cut
5/27/1990	33	4	P	1	1	6	1	0	W. of Long Bogue

6/7/1990	34	4	P	1	1	19	2	0	E. of Crayfish Cayes
6/17/1990	35	12	P	1	1	5	4	1	Grand Bogue Chann
7/1/1990	37	1	P	1	1	12	3	0	W. of Douglas Caye
7/5/1990	37	8	P	1	1	18	2	0	W. of North Crayfish
7/18/1990	38	1	P	1	1	6	2	0	SE Central Lagoon
8/16/1990	41	2	P	1	1	2	2	0	Harry Jones Cut
8/19/1990	41	6	P	1	1	4	1	0	Long Bogue
8/19/1990	41	7	P	1	1	2	3	0	S. of Soldier's Bight
9/8/1990	42	11	PB	1	1	19	1	0	E. of Crayfish Cayes
9/26/1990	43	1	P	1	1	1	2	0	E. of Blackbird Caye
9/27/1990	43	3	BP	1	1	1	2	0	E. of Blackbird Caye
9/27/1990	43	4	BP	1	1	4	2	0	NE Long Bogue
9/28/1990	43	5	BP	1	1	2	2	0	E. Entrance to Harry
9/29/1990	43	7	BP	1	1	20	8	0	S. Fishing Bogue
9/29/1990	43	8	BP	1	1	18	1	0	S. of Central Crayfis
10/15/1990	44	1	P	1	1	12	2	0	W. of Crooked Creel
10/18/1990	44	3	P	1	1	18	2	0	W. of Crayfish Caye
10/19/1990	44	6	P	1	1	2	2	1	S. of Soldier's Bight
10/23/1990	45	1	P	1	1	8	2	0	SE of Turneffe Islan
10/23/1990	45	2	P	1	1	14	2	0	W. of North Westerr
10/24/1990	45	4	P	1	1	15	2	0	SW of Cross Cay
10/25/1990	45	5	BP	1	1	1	1	0	NE of Blackbird Cay
10/27/1990	45	7	BP	1	1	17	17	2	SW Crayfish Cayes
10/28/1990	45	9	BP	1	1	9	4	0	SW of Jone's Hole
10/28/1990	45	10	BP	1	1	14	2	0	W. of North Westerr
10/29/1990	45	11	BP	1	1	7	3	1	W. of Cockney Poin
10/29/1990	45	12	BP	1	1	5	3	0	Grand Bogue Chan
11/5/1990	46	3	P	1	1	2	1	0	E. of Fishing Bogue
11/10/1990	47	2	BP	1	1	19	27	5	SE of Crayfish Cay
11/12/1990	47	6	BP	1	1	0	1	0	W. of Snake Point

Appendix XVII. Juvenile Permit Attribute Data

LAT	LON	SHORELINE_	SUBTIDAL_H	SAMPLE_TYP	SAMPLE__	NUMBER_PEI
17.41971	-87.89874	leeward beach	sand	net	2	[illegible]
17.27980	-87.81274	windward beach	th, sand	net	3	[illegible]
17.26177	-87.83436	windward beach	sand	net	3	[illegible]
17.26177	-87.83436	windward beach	sand	net	5	[illegible]
17.26513	-87.82175	windward beach	th	net	4	[illegible]
17.26940	-87.82122	windward beach	ha, th	net	3	[illegible]
17.21413	-87.86068	windward beach	th	net	4	[illegible]
17.49394	-87.78394	windward beach	th	net	3	
17.27980	-87.81274	windward beach	th, sand	net	2	
17.21413	-87.86068	windward beach	th	net	5	
17.49394	-87.78394	windward beach	th	net	4	1
17.49394	-87.78394	windward beach	th	net	2	1
17.27980	-87.81274	windward beach	th, sand	net	1	2
17.26513	-87.82175	windward beach	th	net	3	10
17.21413	-87.86068	windward beach	ha, th	net	3	10

Appendix XVIII. *C. acutus* Siting Attribute Data

ANIMAL	LOCATION	LATITUDE	LONGITUDE	DATE_	_ANIMALS_
C. acutus	Turneffe	17.3833	-87.8141	7/3/2002	1
C. acutus	Turneffe	17.3779	-87.8118	7/3/2002	1
C. acutus	Turneffe	17.3737	-87.8127	7/3/2002	1
C. acutus	Turneffe	17.3611	-87.8247	7/3/2002	1
C. acutus	Turneffe	17.3512	-87.8196	7/3/2002	1
C. acutus	Turneffe	17.3510	-87.8196	7/3/2002	1
C. acutus	Turneffe	17.3435	-87.8283	7/3/2002	1
C. acutus	Turneffe	17.2789	-87.8208	7/2/2002	2
C. acutus	Turneffe	17.2612	-87.8360	4/24/2002	1
C. acutus	Turneffe	17.2726	-87.8210	4/22/2002	1
C. acutus	Turneffe	17.2652	-87.8291	4/22/2002	1
C. acutus	Turneffe	17.3223	-87.7939	4/21/2002	1
C. acutus	Turneffe	17.3267	-87.7931	4/21/2002	1
C. acutus	Turneffe	17.3332	-87.7929	4/21/2002	1
C. acutus	Turneffe	17.3403	-87.7952	4/21/2002	1
C. acutus	Turneffe	17.3057	-87.8060	6/30/2002	1
C. acutus	Turneffe	17.3146	-87.8088	6/30/2002	1
C. acutus	Turneffe	17.3099	-87.8083	6/30/2002	1
C. acutus	Turneffe	17.3146	-87.8014	6/30/2002	1
C. acutus	Turneffe	17.3106	-87.8003	7/1/2002	1
C. acutus	Turneffe	17.3142	-87.8006	7/1/2002	1
C. acutus	Turneffe	17.3217	-87.7952	7/1/2002	1
C. acutus	Turneffe	17.3240	-87.7939	7/1/2002	2
C. acutus	Turneffe	17.3318	-87.7931	7/1/2002	1
C. acutus	Turneffe	17.3356	-87.7931	7/1/2002	1
C.	Turneffe	17.3386	-87.7946	7/1/2002	2

acutus					
C. acutus	Turneffe	17.3414	-87.7964	7/1/2002	1
C. acutus	Turneffe	17.3435	-87.7979	7/1/2002	1
C. acutus	Turneffe	17.3432	-87.7979	7/5/2002	3
C. acutus	Turneffe	17.3424	-87.7974	7/5/2002	1
C. acutus	Turneffe	17.3414	-87.7966	7/5/2002	1
C. acutus	Turneffe	17.3405	-87.7959	7/5/2002	1
C. acutus	Turneffe	17.3374	-87.7939	7/5/2002	1
C. acutus	Turneffe	17.3328	-87.7932	7/5/2002	1
C. acutus	Turneffe	17.3311	-87.7928	7/5/2002	1
C. acutus	Turneffe	17.3281	-87.7934	7/5/2002	2
C. acutus	Turneffe	17.3244	-87.7937	7/5/2002	1
C. acutus	Turneffe	17.3228	-87.7941	7/5/2002	1
C. acutus	Turneffe	17.3219	-87.7948	7/5/2002	1
C. acutus	Turneffe	17.3211	-87.7957	7/5/2002	1

Appendix XIX. *C. acutus* Spotlight Survey Attribute Data

AREA_NAME	DATE_SEEN	POINT_NUMB	LAT	LONG	NUMBE
Blackbird Cay (E. shore)	11/26/1996	1	17.3037	-87.8015	
	11/26/1996	2	17.3228	-87.6737	
	2/6/1997	1	17.3037	-87.8015	
	4/3/1997	2	17.3228	-87.6737	
Blackbird Cay (W. shore)	11/21/1996	1	17.4230	-87.8178	
	11/21/1996	2	17.3025	-87.8265	
	2/5/1997	1	17.4230	-87.8178	
	4/10/1997	2	17.3025	-87.8265	
Calabash Cay	11/28/1997	1	17.2852	-87.8075	
	11/28/1997	2	17.2710	-87.8190	
	2/4/1997	1	17.2852	-87.8075	
	4/11/1997	2	17.2710	-87.8190	
Calabash Cay (Lagoon)	2/28/1997	1	17.2852	-87.8075	
Cay Bokel	4/2/1997	1	17.1688	-87.9063	
	4/2/1997	2	17.3263	-87.9227	
Northern Lagoon	11/23/1996	1	17.4853	-87.8405	
	2/7/1997	1	17.4853	-87.8405	

No. Lagoon to Crikozeen Creek	11/24/1996	1	17.4872	-87.8502
	11/24/1996	2	17.4017	-87.9075
	2/27/1997	1	17.4872	-87.8502
	2/27/1997	2	17.4017	-87.9075
Northern Cay Interior Lagoon	8/21/1996	1	17.4912	-87.7835
	11/21/1996	1	17.4912	-87.7835
	7/10/1997	1	17.4912	-87.7835

Appendix XX. *C. acutus* Nest Location Attribute Data

DATE_	LOCATION	DESCRIPTIO	LATITUDE	LONGITUDE	_NESTS	COMMENTS
2002	Northern Ca	C. acutus nes	17.4960	-87.7837	4	2 additional nests were
2002	Blackbird Ca	C. acutus nes	17.3434	-87.7986	1	
2002	Calabash	C. acutus nes	17.2617	-87.8364	1	recently excavated
2002	Calabash	C. acutus nes	17.2632	-87.8340	1	probably constructed du
1997	Blackbird Ca	Beach Ridge	17.3095	-87.7930	0	
1997		Beach Ridge	17.3393	-87.7930	0	
1997		Beach Ridge	17.2718	-87.7908	0	
1997		Low Beach	17.4228	-87.8202	0	
1997	Northern Cay	Beach Ridge	17.4892	-87.7847	0	
1997	Deadman's Ca	Beach Ridge	17.2175	-87.8573	0	
2004	Blackbird Ca		17.3384	-87.7951	0	7 eggshells
2004	Blackbird Ca		17.3405	-87.7964	0	5 eggshells
2004	Blackbird Ca		17.3437	-87.7987	0	7 eggshells
2004	Blackbird Ca		17.4245	-87.8113	0	9 eggshells
2004	Blackbird Ca		17.4242	-87.8113	0	5 eggshells
2004	Blackbird Ca		17.4242	-87.8118	0	10 eggshells
2004	Blackbird Ca		17.4242	-87.8118	0	14 eggshells, 2 unhatc
2004	Calabash Cay		17.2628	-87.8352	0	2 eggshells, 1 unhatch
2004	Calabash Cay		17.2627	-87.8278	0	6 eggshells
2004	Northern Cay		17.4938	-87.7852	0	6 eggshells, 1 unhatch
2004	Northern Cay		17.4943	-87.7850	0	7 eggshells
2004	Northern Cay		17.4943	-87.7850	0	3 eggshells

2004	Northern Cay		17.4943	-87.7850	0	5 eggshells, 1 unhatched
2004	Northern Cay		17.4945	-87.7849	0	10 eggshells
2004	Northern Cay		17.4947	-87.7848	0	2 eggshells, 3 unhatched
2004	Northern Cay		17.4955	-87.7845	0	4 eggshells
2004	Northern Cay		17.4912	-87.7843	0	5 eggshells, 1 unhatched
2004	Northern Cay		17.4963	-87.7836	0	7 eggshells
2004	Northern Cay		17.4962	-87.7837	0	16 eggshells
2004	Northern Cay		17.4962	-87.7837	0	2 eggshells, 1 unhatched