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Andros Island Flora and Fauna in the New Millennium

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CONTENTS

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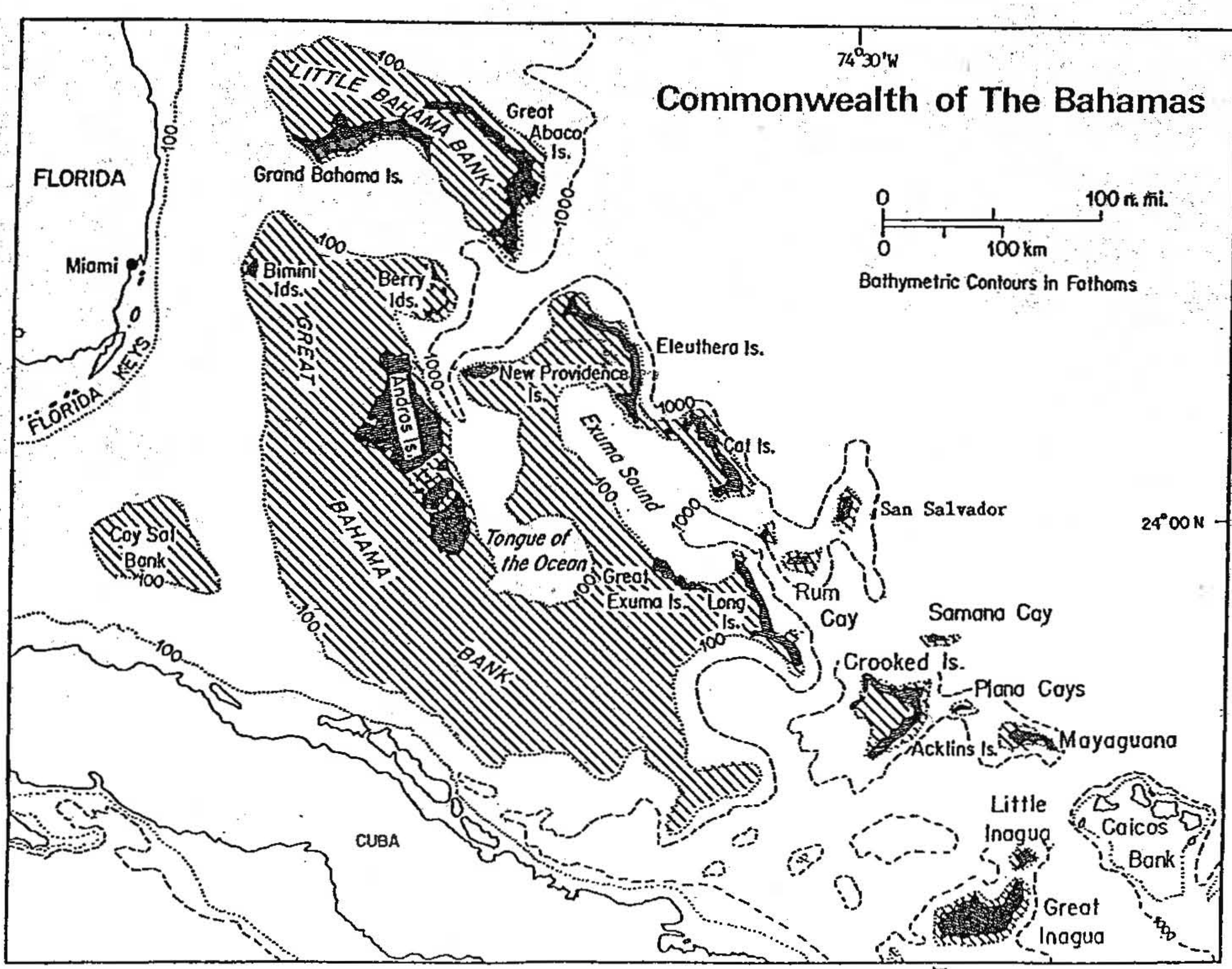

ANDROS ISLAND FLORA AND FAUNA IN THE NEW MILLENNIUM

JOSE V. LOPEZ, CHERYL L. PETERSON, FELIX MORALES AND LUTHER BROWN

"The clearest way into the Universe is through a forest Wilderness" - John Muir (1838-1914)

INTRODUCTION

Respected biologist, E.O. Wilson noted that there were essentially three kinds of "wealth" - economic, cultural and biological (Wilson and Peters, 1988; Wilson, 1992; Harmon, 1992). As is well known, Wilson and colleagues proceeded to champion the fundamental importance of "biological wealth", and its correlate, *biodiversity* (short for biological diversity) (Reaka-Kudla et al, 1997; Ehrlich and Wilson, 1991). Debates could continue indefinitely regarding which of the three is ascendant and most relevant to contemporary society, but would be eventually futile. Rather, the interconnectedness of all types of wealth should be emphasized.

There is no shortage of definitions stating what "biodiversity" means and encompasses. For example, biodiversity is generally considered "the total variability of life on Earth, or the variability among living organisms from all sources and the ecological systems of which they are a part, including diversity within species, between species and of ecosystems" (Lovejoy, 1980; Heywood and Watson, 1995). Because it is nearly all-encompassing, the concept of biodiversity should apply to not only a few, but be accessible to as many sectors as possible. Mass appeal is needed.

The primary keys to fostering a greater understanding of biodiversity is through education (Orr, 1994; Norse, 1994; McManus and Vergara, 1998) and high profile programs such as the Systematics 2000 program, ReefBase, Diversitas, and the upcoming International Biodiversity Observation Year (IBOY, 2001 - 2002) to name but a few (Systematics 2000, 1994; Norris, 2000;). Moreover, there is an urgent need to obtain baseline information on biodiversity, which encompasses species inventories, categorization and classification, from all types of habitats. The above programs aim to answer the fundamental questions of "what comprises biodiversity, how many taxa are there and what do we call them"? (Reaka-Kudla et al, 1997) For many marine habitats such as coral reefs, this urgency may be even more profound, as increasing evidence from recent coral bleaching, ocean warming, nutrient overload phenomena, and assorted human activity-based impacts point to the accelerated degradation of many tropical ecosystems (Lapointe, 1999; Kleypas et al, 1999; Wilkinson et al, 1998; Lugo et al, 2000; Levitus et al, 2000). Other important considerations in these studies and the quantification of variation within marine populations are sympatric speciation (Palumbi, 1994; Mayr, 1970), the amount of gene flow between different populations via larval dispersal and recruitment (Stoner et al, 1996; Roberts 1997), and cryptic and sibling marine species (Knowlton, 1993).

Other difficult questions complete the conceptual framework: how do conservation-oriented Western entities bring the know-how or personnel for monitoring and grassroots legwork into the field? Can smaller, less industrialized nations in the Caribbean, such as the Bahamas, seek or afford such programs and the accompanying technology, which are mostly conceived and fabricated in the industrial world? Are biotechnological or bioprospecting strategies the real solutions to conserving dwindling biodiversity? (Pearce and Moran, 1994 ;Ehrlich et al, 1997; Grifo and Rosenthal, 1997) With these various facets of biodiversity in mind, the upper level college course, "Molecular Studies of Marine Biodiversity (MSMB) on the Indian River Lagoon, Florida and Andros Island, Bahamas", was offered through Harbor Branch Oceanographic Institution (HBOI). College credits were offered through George Mason University (Fairfax, VA, 1999) and Florida Institute of Technology (Melbourne, FL, 2000). HBOI supported the class in the United States, and The College of the Bahamas (Nassau) and George Mason University (Fairfax, VA) provided facilities at the Bahamas Environmental Research Center on Andros Island, the Bahamas.

The main focus of this unique biology course, developed and instructed by the first author (JVL), was on conveying the fundamental principles that underpin all of biodiversity - diversity or variation at the genetic level. The intensive, two week curriculum therefore encompassed several other broad disciplines - evolutionary biology, molecular genetics, population genetics, and the burgeoning fields of bioinformatics and genomics. Despite the huge breadth of the subjects and biogeographical areas (see below), the course was applied as an introduction and "portal" to the world of biodiversity, leading from the inside (of the cell) out to the expansive realms of functioning whole organisms and ecosystems. The following specific objectives to the course revolved around the topic of biological diversity:

♦ Discuss fundamental principles - scientific, socio/economical, cultural etc - underlying the characterization and maintenance of biodiversity (Vane-Wright et al, 1991; Reaka-Kudla et al, 1997; Dworkin, 1997; Ehrlich et al, 1997).

♦ Train students in practical molecular methods for generating and interpreting data on the genetic variation of individuals, populations and species. This included wet laboratory and computer (bioinformatics) exercises (Hillis et al, 1996; Graur and Li, 2000; Misener, 2000).

♦ Expose students to biodiversity *in situ*, through field trips that encounter organisms and ecosystems as well as local human communities adjacent to the habitats. From a natural history perspective, comparisons could be made due to the many similarities between South Florida and Bahamian habitats (Carr, 1996; Campbell, 1978).

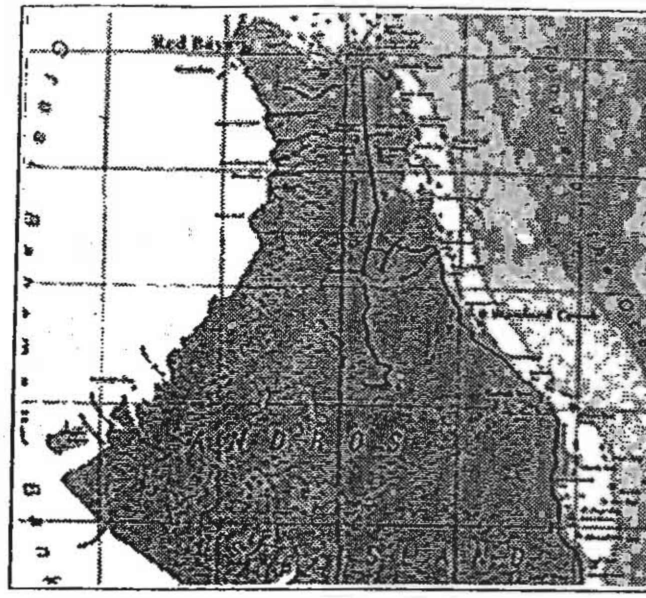

Figure 1. Map of Northern Andros Island. Location of primary field sites - Staniard Creek and Red Bays are indicated.

THE HABITATS

The Indian River Lagoon (IRL) and Andros Island, Bahamas were chosen as the natural venues for this class due to their proximity and occurrence within the same Caribbean biogeographical province (Fig. 1), allowing comparisons of the abundant organismal diversity. The IRL spans a length of about 155 miles and is considered one of the most speciose estuaries in North America with over 4,315 different plant and animal species currently documented (Gilmore, 1985; Swain, 1995). The IRL is also home to 36 rare and endangered species, including the Green sea turtle (*Chelonia mydas*) and nearly one-third of manatees (*Trichechus manatus*) found in the US. The Smithsonian Marine Station at Ft. Pierce maintains an IRL species database - http://www.serc.si.edu/sms/IRLmain.htm. Furthermore, both the IRL and Andros support mangrove swamp ecosystems, which

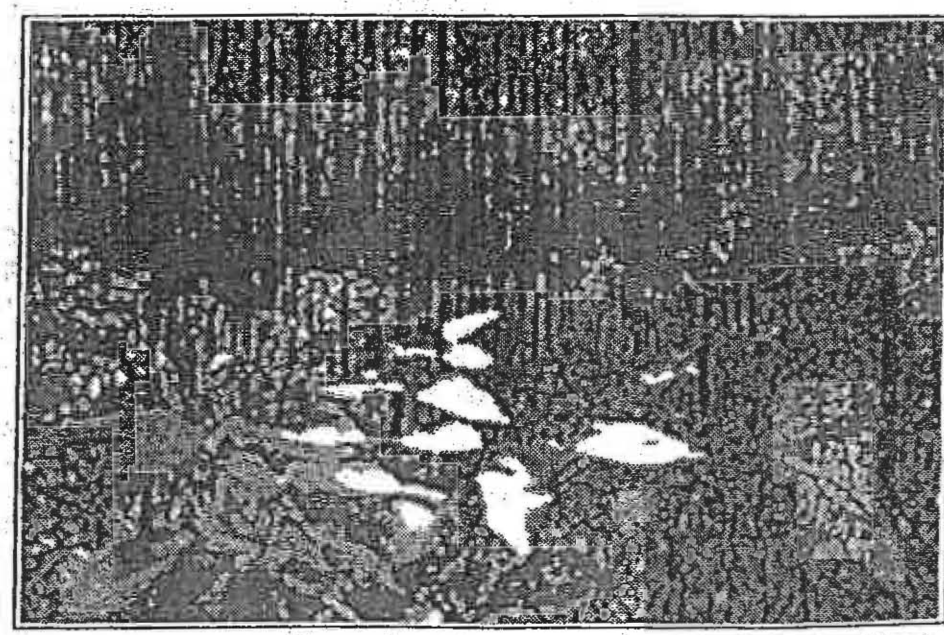

Figure 2. Caribbean pine (*Pinus caribaea*) forests dominate the inland of Andros Island. Poisonwood (*Metopium toxiferum*) is shown in the foreground.

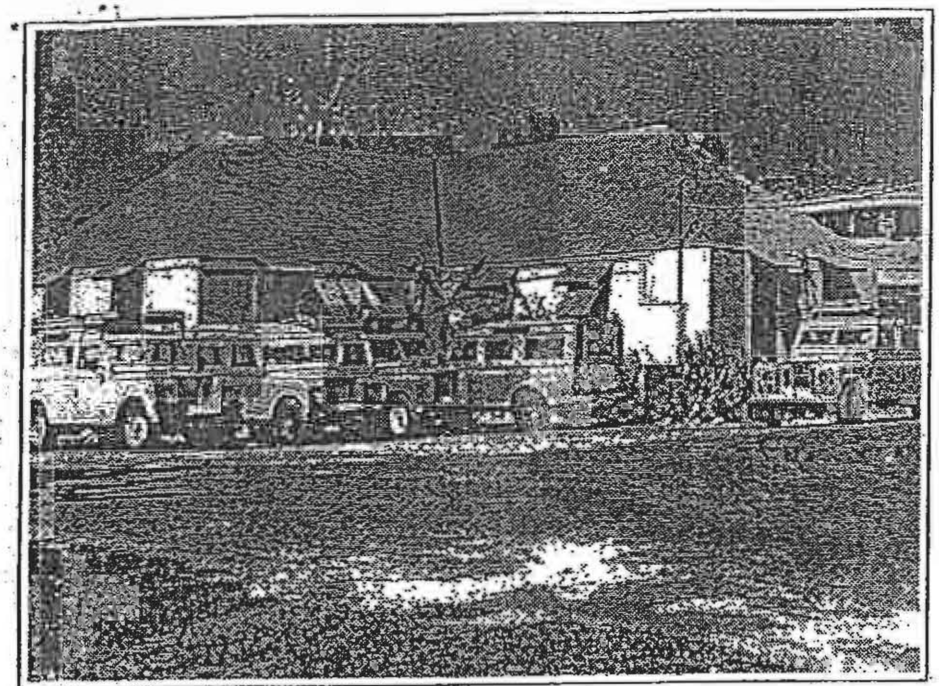

Figure 3. BERC schoolhouse with the Landrovers available for transportation in the foreground.

tend to parallel the geographical distribution of coral reefs, and thus often serve as refugia to various invertebrate and vertebrate larvae and juveniles from adjacent marine habitats (Twilley, 1988; Heywood and Watson, 1995; Bingham and Young, 1995).

Because of its more remote and tropical nature, more field time was planned during the eight day tenure on Andros island than in Florida. Located less than 100 miles southeast of Miami, FL, and 35 miles west of Nassau, Andros Island offers a variety of wildlife settings due to the relatively small human population of less than 10,000. With a total area almost as large as all of the rest of the Bahamas combined, Andros is by far the largest of the Bahamian islands, and includes over 150,000 acres of undeveloped endemic pine forests, savannas, wetlands, and scattered hardwood coppices (Fig. 2). Freshwater habitats are extremely abundant, and range from ponds to creeks and tidal rivers to the famous blue holes, which are similar to the cenotes of Central America (Campbell, 1978; Mylroie and Carew, 1995).

Relevant to the stated marine biodiversity focus, Andros Island is bounded to the east by the third largest barrier reef in the world, which borders the 6000 ft. deep undersea canyon known as The Tongue of the Ocean (Fig 1). The size of this coral reef has attracted more extensive Andros barrier reef surveys in recent years and the promise of more to come (Ginsberg et al, 1998; Kramer et al, 1999).

The Andros base for class and field operations was the Bahamas Environmental Research Center, or BERC, situated at the Staniard Creek settlement (Fig 3). The physical structure of BERC stems from a once disused schoolhouse, more than 100 years old. BERC is presently equipped with basic laboratory supplies, (such as centrifuges, incubators, seawater tanks and pumps, distilled water stills, micropipettors, and advanced audio-visuals), and has recently acquired a "Mobile Molecular Lab" (MJ Research), which includes a PCR (polymerase chain reaction) thermalcycler, microcentrifuge, minigel apparatus, UV transilluminator and polaroid camera (see http://www.geocities.com/RainForest/Vines/8169/mjr.jpg). For the MSMB course, special molecular reagents (including several enzymes, buffers, and PCR primers) had to be transported to the island. Together, these comprise the essential elements of any modern molecular biology laboratory and were sufficient for the students to carry out genetic variation surveys while on the relatively remote Andros Island.

BERC is a unique partnership between two institutions of higher education and the local community in which it exists. This joint endeavour has recently been described in some detail elsewhere (Brown, 2000). It is based on a decidedly post-colonial approach to the "biological field station". This approach manifested itself in many ways, but from a student perspective, the most obvious manifestation involved the way in which students and researchers interacted with the island community. Students became acquainted with the residents of Staniard Creek as part of the "experiential learning" philosophy running through most courses held at BERC. For example, besides living within the community itself, BERC facilitated all dinner meals to be provided by local Staniard Creek residents at their locales. Fares often included freshly caught conch, hogfish or chicken, rice and vegetables, supplemented with the cheerful hospitality and sincerity that characterizes the people of Bahamian out-islands. Raucous domino playing by BERC neighbours, games by their children and even stories of the "Chickcharnie" (Campbell, 1978) could often be heard or seen near the lab. For recreation, BERC assistants and local citizens would organize a beach bonfire and drumming circle or pick up a game of basketball in the local courtyard.

With more than 20 years studying Andros habitats, Dr. Brown and the BERC staff were integral in guiding the MSMB and other classes to hidden blue holes (e.g. Cousteau's), patch reefs at Coconut grove and diverse human settlements, as well as providing a wealth of rich stories on the biology, history, and folklore of the area.

DISCUSSION

Compared to 10 students in 1999, the MSMB class of 2000 was composed of 8 students (Fig. 4). Three were full time graduate students at FIT. Another graduate student was about to defend her thesis at U.A.B.C (Ensenada, Baja California, Mexico). One student was about to begin a graduate program at Florida Atlantic University (Boca Raton, FL). The remainder of the class was comprised of one faculty member from Flinders University (Adelaide, Australia), an HBOI research assistant, and a senior undergraduate from the University of Central Florida (Orlando, FL). The J. Seward Johnson Education and Conference Center at HBOI was able to provide financial supplements which allowed some of the international students to travel to FL. Course fees paid for laboratory supplies, travel and board on Andros Island.

Figure 4. MSMB 2000 students discussing molecular genetics protocols at BERC.

During the first week at Harbor Branch Oceanographic Institution, students spent most of the time in lectures and computer laboratories learning the fundamentals of molecular evolution, the meaning of genetic variation and how to quantify it, conservation genetics and the various flavours (e.g. phenetic or cladistic) of molecular systematics and phylogenetic analyses (Avise, 1994; Graur and Li, 2000). Guest lectures by HBOI staff, such as Dr. Tamara Goulet and Dr. Shirley Pomponi on DNA fingerprinting and sponge taxonomy, respectively, rounded out the lecture topics.

Next the nuances of manipulating and interpreting molecular sequence information were explored in depth through individual time at computer workstations. As part of class assignments, students downloaded previously published DNA or protein sequence data to perform multiple sequence alignments using ClustalW (Thompson et al, 1994), compared varying substitution rates between different genetic loci, and then reformatted the sequence data for subsequent analyses in the most commonly used evolutionary sequence analyses and phylogenetic programs such as SEQUENCER, PAUP*4.0 and PHYLIP (Kessing, 2000 - http://nmg.si.edu; Hillis et al, 1996). Many of the essential sequence operations could be found at public virtual workbenches, such as the University of San Diego's Supercomputing facility (http://workbench.sdsc.edu).

Laboratory instruction began on Andros Island with proper ways to collect, handle and store tissues derived from field collections. Of course, visits to the vital habitats were necessary to procure biological specimens for experiments. Boat rides over glassy water to coral fringing and patch reefs such as Pigeon Cay (Johnson et al, 1994) or taking the Land Rovers an hour or two from the BERC to blue holes, Morgan's Bluff and sunken banana holes, were not uncommon. Students absorbed these tropical vistas– the *de facto* classroom and laboratory - with enthusiasm. At these sites, students identified as many organisms as possible with field guides (Humann, 1992), while any collections for lab work were judicious, often involving only small portions of an individual mangrove plant, *Gambusia hubbsi* fin samples, or portions of algae etc. Although ethanol has been traditionally used to store museum voucher specimens, alcohol can also make subsequent extractions of DNA/RNA more difficult for some marine taxa (France et al, 1996; Dawson et al, 1998). Therefore, other tissue storage solutions were used, such as dimethylsulfoxide (DMSO) or silica gel dessicant (Seutin and White, 1991).

Specific organismal focus covered a wide spectrum governed by either sequence representation in GenBank or the students' primary research interests. For graduate students intending to learn the latest molecular biology protocols, their study taxa were often known *a priori* (Table 1).

As the primary focus of the instructor's laboratory at HBOI, the phylum Porifera remains a taxon worthy of extensive exploration due to

Table 1. Representative taxa studied by some MSMB students

Organism	Taxa	Methods of Analysis Attempted
Gastropods	*Strombus gigas*, *Coralliophila abbreviata* 18S	RFLP, AFLP
Marine sponges	*Aplysina fistularis*, *Halichondria sp.* *Chondrilla*	ISSR, 18S RFLP,
Marine sponge microbes	*various*	16S RFLP
Mangroves	*Rhizophora mangle*, *black-Avicennia nitida*, *white- Laguncularia racemosa*	18S RFLP
Mosquito fish	*Gambusia sp*	N/a
Sea cucumber	*Synaptula hydriformis*	N/a

- N/a - not attempted.

a) its evolutionary age and placement at the base of the metazoan tree (Müller et al, 1998),
b) it being a potential source for bioactive secondary metabolites (Garson, 1994; Pomponi et al, 1998) and
c) uncertain taxonomy of the >5000 known species (Hooper et al, 1999).

It is likely that many of the sponge (and other marine invertebrate) species on Andros reefs are not fully catalogued (Reaka-Kudla, 1997). In line with this focus, several samples of marine sponges, such as *Aplysina* and *Chondrilla* were collected from Andros mangroves and coral reefs for DNA extraction and analysis at the BERC laboratory. In addition, an FIT graduate student in this year's class was able to study the diversity of sponge microbial

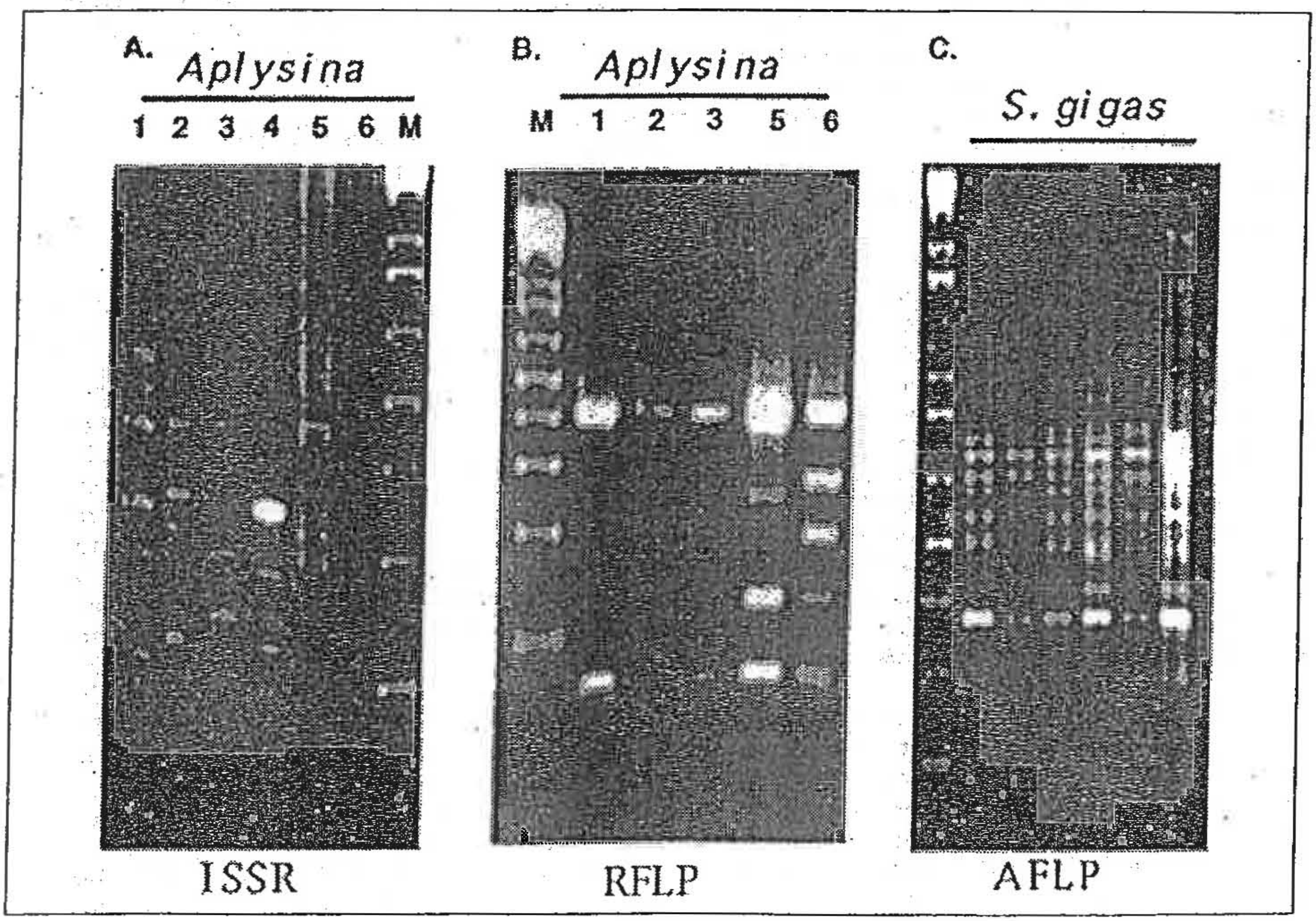

Figure 5. Three different DNA fingerprinting techniques tested on Andros Island fauna:
A - ISSR banding patterns from different *Aplysina* sponge samples from the following locations (Sample numbers 1 - 3: Pigeon Cay; 4 - Coconut Grove; 5,6 - AUTEC reef at ca. 60 feet depth). 100 kb molecular weight markers in lane M range from 200 - 850 bp.
B - 18S rRNA RFLP results mirrored the ISSR patterns by distinguishing Pigeon Cay samples from more Northern (Coconut Grove) and deeper (dive-related) samples. Identical sample numbers and locations from gel A apply.
C - Representative AFLP banding patterns derived from queen conch (*Strombus gigas*) genomic DNA suggest uniformity among Andros Island populations with this technique and the AFLP primer - GAG (Lopez and Knowlton, 1997).

symbionts and associates by plating diluted sponge extracts onto marine agar or low nutrient agar petri plates, using seawater as a control (Pace, 1997; Lopez et al, 1999), and culturing the microbes for subsequent DNA analysis.

Laboratory instruction continued with the students finding the best way of extracting DNA from their samples using the various methods available, then determining which molecular method was most appropriate for analysing the diversity of the taxon they chose.

By being the means to rapidly obtain large quantities of specific DNA fragments (a "genetic copying machine"), the PCR remains the core technique of modern molecular biology, and was the basis for the DNA fingerprinting techniques used in the class. Therefore discussion and demonstrations on methods to design proper oligonucleotide PCR primers, program cycling profiles, reaction setup and interpretation of results was extensive (Hillis et al, 1996). Molecular techniques were generally grouped into either a) single genetic locus characterized by DNA sequencing or b) multiple locus fingerprinting methods, with accompanying strengths and weaknesses for assessing genetic variation (Ross et al, 1999; Sunnucks, 2000). Choice of the most optimal molecular method will often depend on the taxonomic level under investigation - population, species or higher phyla.

Mitochondrial DNA (mtDNA) with its maternal, haploid inheritance and accelerated (up to 10-fold higher) substitution rate over most nuclear genes (Avise, 1994), is considered a single-locus technique and was highlighted as a common molecular tool, along with microsatellite DNA loci, which are repeats of very simple DNA sequences (e.g. CACACACA, or ATATATATA etc). Because both types of sequences evolve very rapidly relative to other genetic loci in eukaryotic genomes (Bruford et al, 1996; Culver et al, 2000; Wolfe et al, 1998), mtDNA and microsatellites are often chosen for comparisons within and among different populations of the same species, or even between individuals of a single population (e.g. parentage analyses). ISSR (interspersed simple sequence repeat) is a multi-locus PCR technique which produces banding patterns of products based on microsatellites which are located on opposing DNA strands within an amplifiable distance of one another. A student in this year's course used ISSR to gauge genetic differences (polymorphisms) among *Aplysina fistularis* individuals within and between different Andros reefs (Fig 5A). The results indicated detectable intraspecific differences in the sponge banding profiles (but could not distinguish the contribution from microbial associates) between separate Andros Island reef areas.

In contrast to microsatellite DNA, the small subunit (18S) ribosomal RNAs are ubiquitous components of almost every living cell, and thus evolve more slowly due to evolutionary constraints on their essential functions. Nevertheless, as another single-locus technique the 18S rRNA gene can be used to obtain species-specific sequences or band patterns (Fig 5B) via restriction fragment length polymorphism (RFLP) assays of the amplified rRNA molecule.

A multi-locus DNA fingerprinting technique, amplified fragment length polymorphisms (AFLP), relies on the PCR to generate DNA fingerprint patterns that can be used to distinguish cryptic or sibling species, a common occurrence among marine taxa, such as the reef building coral, *Monastraea sensu lato* (Lopez and Knowlton, 1997; Knowlton 1993). In this year's course, one student (F. Morales) was able to generate AFLP fingerprinting patterns from genomic DNA derived from a 1 cm^3 piece of foot from the queen conch (*Strombus gigas*) as part of pilot studies to his doctoral dissertation that aims to characterize intraspecific genetic variation in the Western Atlantic. To date, sparse genetic data is known for this vital organism of Bahamian fisheries (Stoner et al, 1996). The preliminary results (shown in Fig 5C) suggest a relatively uniform, species-specific fingerprint pattern for all of the Andros Island *Strombus* samples (n > 15 to date), although many more conch specimens from widespread Caribbean locales await sampling. Other multi-locus fingerprinting techniques such as RAPD (rapidly amplified polymorphic DNA) were also applied on other organisms at the BERC (Wolfe et al, 1998).

BAHAMIAN CULTURE AND HIGHER DIRECTIONS

An explicit lesson meant to be conveyed during the course, was that the preservation and study of biodiversity cannot neglect the local citizenry and its culture, who act as the stewards to cherished habitats and resident flora and fauna (Brush and Stabinsky, 1996). Therefore, the last major classroom emphasis was on the ethics of biodiversity protection, and the role of economics (Pearce and Moran, 1994; Grifo and Rosenthal, 1997; Dworkin, 1997). For example, "bioprospecting" is the search for natural products which hold potential medicinal or industrial value to human society and permitted the introduction of the complex topics of intellectual property rights and equitable sharing. These, in turn, lead to questions such as "Who really owns a country's biodiver-sity? How should economic value be assessed? What are the appropriate goals of bioprospecting etc.?" More than likely, these concepts and ques-

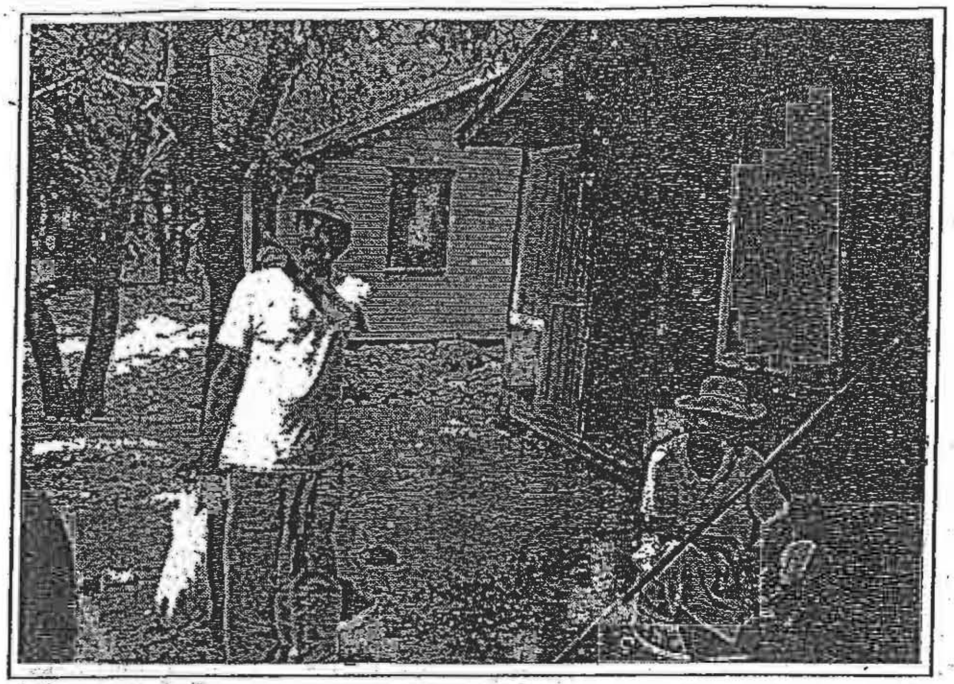

Figure 6. Dr Luther Brown and Mrs. Omelia Marshall discuss the diversity of plant life surrounding the Red Bays settlement.

tions will continually be revisited and addressed, as the habitats and the products that human societies find useful become more stressed or depleted (Reaka-Kudla et al, 1997; Ehrlich et al, 1997; Brush and Stabinsky, 1996).

As has been pointed out many times, more industrialized countries and their offspring multinationals, must learn to constructively interact and work with the people who actually reside and act as the caretakers of biodiversity (Gadgil and Vartak, 1993; Orr, 1994; Brush and Stabinsky, 1996). This entails proactively considering direct benefits to local residents or at the very least, recognizing their sovereignty over their biological realm. These proper considerations were clearly established in policy with *the United Nations Convention on Biological Diversity* (1992) and emphasized during course lectures and activities.

With the above ideals in mind, The MSMB class attempted to leave a service legacy to the island, by performing a reef survey through the standard ReefCheck Protocol (Hodgson, 1999; www.ReefCheck.org). In addition, a preliminary species list for all sighted Andros Island taxa is now under construction and will be available on the MSMB course website , http://www.geocities.com/RainForest/Vines/8169/). (In case this website is not supported in the future, BERC will have MSMB links available from the permanent BERC web domain -http://www.bahamas researchcenter.com). Although additions to this database may be made by contacting the authors or manual entry of taxa at the above course site, continual maintenance of this database will not match more extensive inventory projects such as Species 2000 (http://www.sp2000.org/) or NSF's Global Biodiversity Information Facility (GBIF). However, another special link will be initiated next year via the official endorsement of the MSMB course as an approved International Biodiversity Observation Year (IBOY 2001-2002) project (http://www.nrel.colostate.edu/IBOY).

Furthermore, cultural field trips on Andros Island included visits to:

- Horizontal freshwater wells
- Silver palm basket vendors
- Sponge fishing at Red Bays
- Lowe's Sound and queen conch shell mounds
- Androsia batik factory
- Red Bays settlement and a visit with Omelia Marshall

The last visit on this list illustrates how culture affects the way students view biotechnology. Mrs. Omelia Marshall (Fig 6) is a locally famous healer and teacher. For decades she was the only midwife and healer available, relying largely on local herbal remedies (bush teas). The arrival of a Western trained physician displaced her as a doctor, and caused her to turn her attention to teaching local people and visiting students. She has subsequently received a spate of laurels such as the 1999 Cacique award.

For a few moments under the Jamaica apple and dilly (sapodilla) trees at her home in Red Bays, there was time to ponder and contrast how different cultures treat biodiversity. The industrialized view of biodiversity, such as through bioprospecting for natural products or the computerized mining of genomics appears far removed from the traditional healing methods of Mrs Marshall. Yet, both routes share the human quest to comprehend the larger worlds beyond us. The aesthetic beauty of Andros island (Fig 7), the "unquantifiable" aspect of biodiversity, was not lost to class members, despite the flurry of activities, as recorded in one student's journal entry:

" Coconut Grove was an enchanted place, with reclining coconut palms and Caribbean pines, and scattered conch shells and coral pieces on the shore. We snorkelled here, and the diversity was absolutely amazing. Even right up to the shore, the underwater world was full of spiny urchins (*Echinometra*), corraline algae, coral such as brain coral *Diploria* sp. and *Porites porites*, numerous colourful sponges, gorgonian, and numerous colourful, tropical fish.

The tide was so low that some coral was visible above the surface, and snorkelling in a few areas had to be done with caution, due to the spiny urchins, the rough coral, and especially the fire coral (*Millepora*) and *Tedania ignis* (fire sponge). The colours in this world were incredible, and there were schools of beautiful fish, unconcerned for my presence. I saw parrot fish (*Scarus taeniopterus*) biting into what looked like pastel yellow sponges, and then a small school of beautiful fish with bright blue heads and yellow bodies (*Thalassoma bifasciatum*) saw me, then kept me company for several minutes. Thinking of how being still, part of the landscape, allows one to see more animals on land, I decided to try the same tactic underwater, and not move a muscle, but float. Within moments, I saw many fish come out of crevices in coral and rock, resume eating or other activities, saw a flamingo tongue (*Cyphoma gobbosum*) resting on a gorgonian, and saw a fish apparently sleeping on the bottom (I could see movement like breathing). The large spiny lobster (*Panulirus argus*) crawled out of a hole right under me – his size and the length of his spines startled me and I moved. He started and faced me with his spines in defence, which scared me so I tried to bolt out, which scared him, and we both scurried in fright in opposite directions. The marine plant life was as diverse, beautiful and interesting. There were tiny "pine trees" (*Rhipocephalus phoenix*) growing on the coral tops, dark flat bladed plants (*Avramvillea nigracans*), a delicate cup-shaped plant (*Acetabularia sp.*), and dark clumps of flat-leafed plants (*Halimeda opuntia*)."

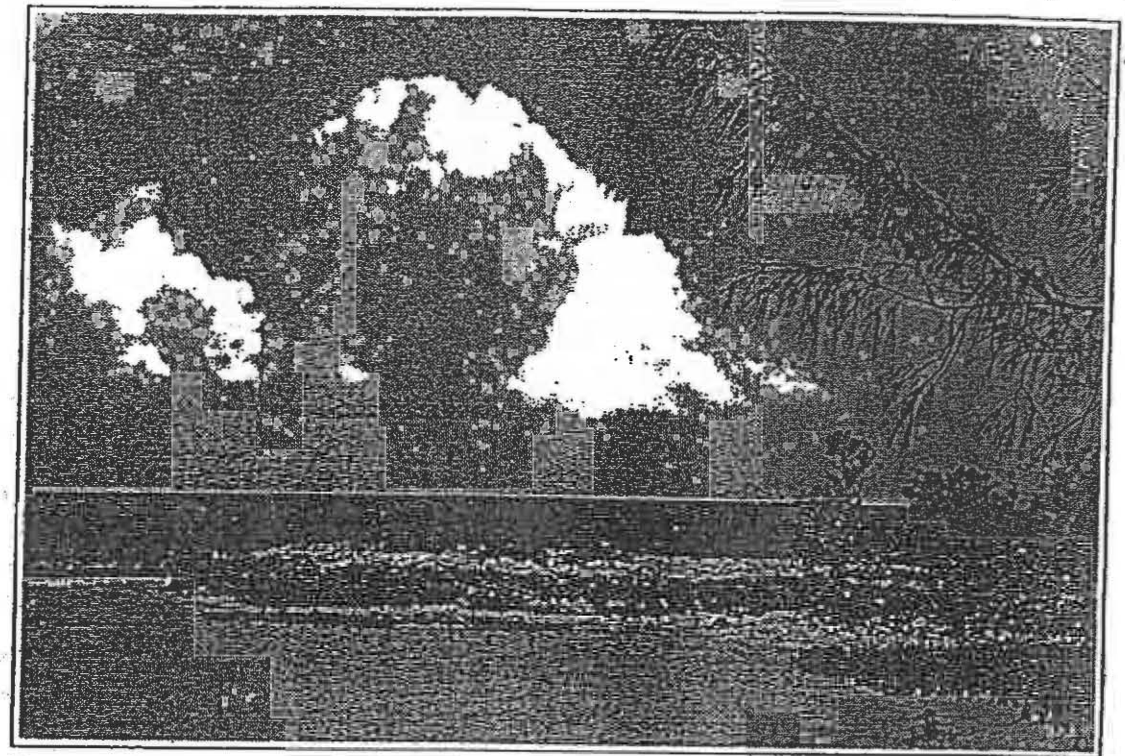

Figure 7. View of Pigeon Cay, less than 3 km from the BERC facility, looking east across the Tongue of the Ocean.

Other student entries and raw experimental data are available on the MSMB course website.

CONCLUSION

Many of the students reported leaving the course with a new awareness of the biology of the Caribbean, as well as a greater appreciation of the issues and challenges facing conservation of tropical biodiversity as we move into this next century. Yet at the same time, they were inspired with research ideas using the tools of molecular biology as a way of supporting and deeply exploring the biodiversity they experienced.

In the end, words, numbers, and even pictures cannot capture the true essence of a wildlife locale (Orr, 1994). We must continually be smitten by the sublime in nature, by frequent forays in the field, or at the very least as ecotourists, lest our memories become dull with the increasing hum of technology's motors. If necessary, it may be possible to live happily without these. Perhaps this feeling was sufficiently captured by Henry David Thoreau (1854):

> " If I were confined to a corner of a garret all my days, like a spider, the world would be just as large to me while I had my thoughts about me...Do not seek so anxiously to be developed, to subject yourself to many influences to be played on; it is all dissipation...If you are restricted....you are but confined to the most significant and vital experiences; you are compelled to deal with the material which yields the most sugar and the most starch. It is life near the bone where it is sweetest."

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