Appendix

Template for Submission of Scientific Information

to Describe Ecologically or Biologically Significant Marine Areas

*Note: Please **DO NOT** embed tables, graphs, figures, photos, or other artwork within the text manuscript, but please send these as separate files. Captions for figures should be included at the end of the text file, however.*

Title/Name of the area: Bloody Bay Marine Park

Presented by (*names, affiliations, title, contact details)*

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Abstract (*in less than 150 words)*

We identify the coral reef ecosystem of the Bloody Bay Marine Park and the adjacent MPA's surrounding Little Cayman Island as ecologically and biologically significant areas (EBSA) with deep coral reef characteristics that require protection. Satisfying the criteria set forth in Annex I of the CBD/COP9, characteristics include the IUCN red listed – "endangered" Nassau Grouper (*Epinephelus striatus)* [(1)], a well-developed (unprotected) mesophotic coral-sponge community, and overall high coral cover (20 – 40%). The west end of the island has a vital Nassau grouper SPAG which after eight years of protection has finally (in 2012) resulted in robust recruitment of juveniles to the island. The coral community includes 7 of the 32 evolutionary distinct (EDGE) coral species on earth [(2)], of these, 2 are critically endangered, 3 have ocean acidification identified as a major threat, 1 has recommendations for further research, and 1 is on the IUCN red list of threatened species.

Introduction

(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models)

The features we are proposing include the Little Cayman coral reef ecosystem below 25 meters to (at least) 200 meters and the reefs at Bloody Bay Marine Park (located on the north side of the island) which extend from only a few meters down to several hundred meters. The deep reefs surrounding the island (approximately 35 km) are contiguous with spur and groove reefs, and shelf edge build-ups on a double terraced structure. In most areas, the deep reefs are either sheer walls or (narrow) but shallow sloping accumulations of reef structures, especially at the east end of the island. The coral reefs of Little Cayman are also isolated from continental and anthropogenic influences and support some of the most biologically diverse reef systems in the Caribbean.

The Cayman Islands are protected from open-ocean long-fetch Atlantic waves by the Antilles Island Arc, Hispaniola, and Cuba. Trade winds blow predominantly from the northeast but shift periodically to the east and southeast. The eastern side of the islands receive the highest wind and wave energy, whereas the western sides of all three islands are least exposed. Little Cayman is oriented northeast to southwest, so the southern side tends to be more exposed to prevailing winds and waves, and is periodically severely impacted by major storms crossing the Caribbean.

There are several signficant datasets that have also provided opportunities for modeling. Attached is a selected list research completed at the Little Cayman Research Centre (Appendix I).

- Environmental data from the NOAA CREWS ocean observatory installed at Little Cayman in 2009 is continuously available via the NOAA website for scientific modeling. The CREWS collects information on air temperature, winds, barometric pressure, sea temperature, salinity, tide, photosynthetically available radiation, and ultraviolet radiation above and below the water.
- Coral Bleaching Threshold Model. A model was developed to describe bleaching thresholds for the region and using IPCC climate scenarios, satellite data, and data collected by the CREWS are predict coral bleaching over the next century(3,4).
- Ecological Data. Twelve years of coral AGRRA data and fish data from Little Cayman (5), contributes to understanding decade-long trends of these reefs. Little Cayman has well established marine parks which could provide an opportunity to model conserved and non-conserved areas.
- Deep Reef Data. In 2008, Lesser and Slattery conducted a series of deep dives to survey and sample reefs to 80 m. They were permitted to collect sponges and have described these communities(6,7). In 2009, we explored the coral reefs surrounding Little Cayman to 140 meters using a SeaBotix ROV. Coral-sponge growth extends to at least 140 meters with abundant slow-growing black corals (Antipatharia) and ahermatypic corals. Video and photographic data are archived and available.
- Meiofauna Diversity. In 2011, many new species of Gastrotrichs were discovered by Dr. Hochberg and his scientific team. Based on preliminary results, Little Cayman represents an undisturbed site that could provide the meiofaunal scientific community an unprecedented opportunity for new discoveries.

Location

(Indicate the geographic location of the area/feature. This should include a location map. It should state if the area is within or outside national jurisdiction, or straddling both. It should also state if the area is wholly or partly in an area that is subject to a submission to the Commission on the Limits of the Continental Shelf)

The Cayman Islands lie in the middle of the Caribbean Sea between 19 - 20° North and 80 - 81° West, about 240 km south of Cuba (Figure 1a). They are comprised of three small (12–18 km long) low-lying, limestone islands with Little Cayman (LC) 125 km northeast of Grand Cayman and just 7.5 km to the southwest of Cayman Brac. Little Cayman Island is 10 miles long and 1 mile wide and over half the island consists of marine-protected areas (Figure 1b). We are proposing increased protection of the Bloody Bay Marine Park which is located on the north side of the island and the deep reefs surrounding the entire island. The areas are all within the boundaries of the Cayman Islands. The area is not subject to a submission to the Commission on the Limits of the Continental Shelf.

Feature description of the proposed area

(This should include information about the characteristics of the feature to be proposed, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, and then refer to the data/information that is available to support the proposal and whether models are available in the absence of data. This needs to be supported where possible with maps, models, reference to analysis, or the level of research in the area)

Little Cayman is one of the least developed tropical islands in the Caribbean and the island, therefore, affords rich opportunities for research to address global issues such as climate change, marine protection, fisheries management, and coral reef stress. A large volume of information is available from this location because in 2006, CCMI developed the Little Cayman Research Centre (LCRC). Appendix I provides a summary of the research scientists have completed at LCRC. Figures 2 and 3 illustrate the coal bleaching threshold model developed for this site.

Little Cayman's Bloody Bay is located on the leeward (northwest) side of the island where a reef crest is lacking. Narrow, low-to-medium relief spurs and grooves or shelf-edge reefs extend from water depths of a few meters to walls extending down to several hundred meters. With the exception of Bloody Bay Marine Park area, the island is surrounded by two shallow-sloping submarine terraces. At all other locations, the upper terrace extends from the shoreline to a mid-shelf scarp at depths of 8–15 m and a lower terrace from the base of this scarp to the edge of the shelf at 15–20 m. The reefs at all of the different depths have relatively high coral cover (up to 40%) on spur and groove structures.

The 'no-take' protection of the Cayman Islands extends only to 25m water depth. Below these depths fishing is permitted. Myriad studies have documented the decline of shallow coral reefs (< 25 m water depth), but the state of deeper, mesophotic reefs (> 30 m) is unknown. The 'deep reef refugia' hypothesis (DRRH) suggests that meophotic reefs may be repositories or refuges for shallow scleractinian coral species. Protecting a larger portion of the connected reef structure may result in increased resilience for the entire system. Using principle component ordination, two distinct community groups at 15 m and 25 – 35 m are described for the Little Cayman reefs. With the exception of *Montastraea cavernosa*, coral communities are distinctly different across these depths [(8)].

There are over 350 species of fish and 37 species of coral identified (Table 1) on the shallow reefs surrounding Little Cayman [(4)]. Over 100 species of sponges were identified on the reef walls down to 80 m as a result of the research conducted by Slattery and Lesser in 2008. The overall biological diversity of the deeper mesophotic reefs however, is largely unknown.

In addition to a diverse set of oceanographic circumstances, the mega-fauna including spotted eagle rays, one of the last spawning aggregations of the Nassau grouper, hawksbill and green turtles, and a diverse shark population - all protected by the Bloody Bay Marine Park authority. This combination of low human development, water quality, diverse coral and fish species, and abundance of large mammals and fish is also why Little Cayman is an ecologically important location.

Feature condition and future outlook of the proposed area

(Description of the current condition of the area – is this static, declining, improving, what are the particular vulnerabilities? Any planned research/programmes/investigations?)

A twelve-year dataset is available from shallow coral reef surveys [(4)]. This dataset provides information about the benthic status but also includes data on reef fish biodiversity and biomass. From 1999 – 2004 relative coral cover on the reef declined by 40%, but between 2009 – 2011 the coral cover has almost recovered (manuscript in preparation). Figure 4 illustrates this overall improvement trend.

The Nassau grouper (*Epinephelus striatus*), an iconic and once-abundant Caribbean species, is currently endangered, mostly because fishing is largely concentrated during annual spawning aggregations (SPAGs). In response to their decline, fishing at all six *E. striatus* SPAG sites in the Cayman Islands was banned in 2004 for eight years; a second eight year ban was implemented in December 2011. By far, the most viable SPAG site is located on the west end of Little Cayman, which retains up to 3500 adult fish. Since the ban, reports of *E. striatus* juveniles have been rare in Little Cayman. In January 2012, we discovered abundant juvenile and yearling fish taking refuge inside crevices in the hardpan limestone substrate interspersed among dense seagrass in Mary's Bay, located on the north side of Little Cayman. Our observations suggest that the closure of the Little Cayman SPAG site to fishing may be leading to re-establishing Nassau grouper populations.

Despite success with closing the SPAG for an additional eight years, and with current high levels of marine protection, there are still several threats. 1) Critical juvenile grouper habitats are just now being discovered. These habitats were not considered in the original planning of this MPA (25 years ago). 2) The deeper reefs are not protected. The reefs surrounding the island are all vulnerable to any immediate population growth, but with no protection, the deep reefs are highly vulnerable. 3) The island currently has no coastal zoning in place to control development. 4) The bleaching threshold model developed suggests that by 2050 these reefs will be bleaching annually.

Assessment of the area against CBD EBSA Criteria

(Discuss the area in relation to each of the CBD criteria and relate the best available science. Note that a candidate EBSA may qualify on the basis of one or more of the criteria, and that the boundaries of the EBSA need not be defined with exact precision. And modeling may be used to estimate the presence of EBSA attributes. Please note where there are significant information gaps)

<table>
<tr><th rowspan="2">CBD EBSA Criteria
(Annex I to decision IX/20)</th><th rowspan="2">Description
(Annex I to decision IX/20)</th><th colspan="4">Ranking of criterion relevance
(please mark one column with an X)</th></tr>
<tr><th>Don’t Know</th><th>Low</th><th>Some</th><th>High</th></tr>
<tr><td>Uniqueness or rarity</td><td>Area contains either (i) unique (“the only one of its kind”), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="6">Explanation for ranking
Healthy and recovering benthic communities are rare in the Caribbean. Abundant threatened and or EDGE (coral) species are identified at this location. Productive and protected Nassau grouper SPAG,</td></tr>
<tr><td>Special importance for life-history stages of species</td><td>Areas that are required for a population to survive and thrive.</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="6">Explanation for ranking
Endangered Nassau grouper SPAG and recent identification of juvenile grouper and grouper habitat. Some of the juvenile grouper habitats are currently not protected.</td></tr>
<tr><td>Importance for threatened, endangered or declining species and/or habitats</td><td>Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="6">Explanation for ranking
Currently reporting recruitment and establishment of Acropora palmata which has largely died off in the past 20 years at this site. Nassau grouper and grouper SPAG habitats currently protected but not all juvenile habitats may be protected.</td></tr>
<tr><td>Vulnerability, fragility, sensitivity, or slow recovery</td><td>Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="6">Explanation for ranking
Low threat by the human population because of the slow development, however, with any population growth, the entire reef system could be threatened by the lack of coastal management Deep reef black</td></tr>
</table>

coral had been previously exploited and appears to be recovering.					
Biological productivity	Area containing species, populations or communities with comparatively higher natural biological productivity.				**X**
Explanation for ranking *Highly productive SPAG site. Increasing and high coral cover for the Caribbean region.*					
Biological diversity	Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.				**X**
Explanation for ranking *All of the typical Caribbean coral reef (from shallow to deep reef) habitats are present. The entire system is largely intact making this one of the rare Caribbean sites with high diversity mega-fauna (sharks, rays, turtles),high diversity meiofauna, and high diversity reef benthic and fish communities..*					
Naturalness	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.				*X*
Explanation for ranking *No local human disturbance. Marine protected area has been in place with moorings for over 25 years. Low human development and enforcement of the MPA.*					

Sharing experiences and information applying other criteria (Optional)

Other Criteria	**Description**	**Ranking of criterion relevance** (please mark one column with an X)			
		Don't Know	**Low**	**Some**	**High**
Add relevant criteria					
Explanation for ranking					

References

(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to relevant audio/visual material, video, models, etc.)

1. IUCN (World Conservation Union) Red List of Threatened Flora and Fauna (NMFS, 2007).

2. http://www.edgeofexistence.org/coral_reef/top_ED_species.php

3. van Hooidonk, R., Manzello,D., *Moye, J., Brandt, M.E., Hendee, J., McCoy, C., Manfrino, C., 2011, Coral Bleaching at Little Cayman, Cayman Islands, Estuarine, Coastal, and Shelf Science, in Review, 8/2011.

4. Manfrino, C., van Hooidonk R., and Manzello, D., 2011, The Delineation of Coral Bleaching Thresholds and Future Reef Health, Little Cayman Cayman Islands, Session: Multi-Scale Ocean Modeling and Opportunities for Coastal Marine and Ecosystem Forecast Services II. American Geophysical Union Annual Meeting, Dec. 5-9, 2011, San Francisco, CA., Abs. OS53B-1780.

5. Coelho, V. and Manfrino, C., 2007, Coral Community Decline at Remote Caribbean Islands Marine No-Take Reserves Are Not Enough, Aquatic Conserv: Mar. Freshw. Ecosyst. 16:1-20.

6. Lesser, M.P., M. Slattery, J. J. Leichter, 2009, Ecology of mesophotic coral reefs, Journal of Experimental Marine Biology and Ecology, Volume 375, Issues 1–2, Pages 1-8.

7. Slattery, M., M.P. Lesser, D. Brazeau, M.D. Stokes, J.J. Leichter Connectivity and stability of mesophotic coral reefs, Journal of Experimental Marine Biology and Ecology, Volume 408, Issues 1–2, 15 November 2011, Pages 32-41.

8. Manfrino, C., Hernández-Pacheco, R., Hernández-Delgado, E.A., 2012, Upper Mesophotic to Shallow Reef Biodiversity, Bloody Bay, Little Cayman, Intl. Coral Reef Symposium, July 2012, Cairns, Australia.

Maps and Figures

Figure 1a: Map of the Cayman Islands located south of Cuba.
Figure 1b: Map of Little Cayman showing SPAG sites ▨ and marine protected areas.

Figure 2, Sea Surface Temperatures at Little Cayman from OISST v2 (black line), *in-situ* data from the CREWS station (green), and temperature loggers in Bloody Bay Marine Park (blue). The horizontal dashed line indicates the maximum monthly mean (29.5 ºC), the warmest temperature from the monthly climatology at Little Cayman. DHWs start to accumulate above this value (shaded red). (van Hooidonk et al., in review)

Figure 3, Maximum Degree Heating Weeks (DHW) per year for the period 1982-2010 calculated from OISST v2 data at Little Cayman. The horizontal line represents the optimal bleaching threshold of 4.2 DHWs. DHWs above this threshold are red, indicating that bleaching is predicted, whereas below this threshold the bars are colored blue and no bleaching is projected. (van Hooidonk et al., in review)

Figure 4. Graph showing the decline and recovery of the shallow coral community at Little Cayman. Between 1999 – 2004 the relative coral cover declined by 40 %. From 2009 – 2011 the average coral cover has almost increased to the 1999 levels. Mean coral cover ranges from 20 – 40% on the shallow reefs (Manfrino et al, in prep).

Table 1. List of hard coral genera and species found in Little Cayman during this study. Except for Millepora and Stylaster, which are hydrocorals (class Hydrozoa), all other coral genera are scleractinian (class Anthozoa, order Scleractinia) (from Coelho and Manfrino 2007)

Rights and permissions

(Indicate if there are any known issues with giving permission to share or publish these data and what any conditions of publication might be; provide contact details for a contact person for this issue)

Contact Rich Hochberg, University of Massachusetts (Lowell) to determine whether he will permit publishing his results on Gastrotrichs.

APPENDIX I. Summary of datasets and research projects at Little Cayman

2007

- Dr. David Bellwood, James Cook University/Dr. Andrew Hoey, James Cook University: Reef fish herbivory and resilience in the Caribbean.
- Dr. Vania Coelho, Dominican University: Coral disease management project.
- Dr. Roger Hanlon, Marine Biological Laboratory, Woods Hole: Grouper camouflage: how do large animals camouflage themselves?
- Dr. Scott Heppell, Oregon State University/Dr. Brett Gallagher, Oregon State University: Juvenile Nassau grouper recruitment project.
- Dr. Jim Hendee, NOAA, Atlantic Oceanographic and Meteorological Laboratory, Miami/Dr. Carrie Manfrino, Kean University and Central Caribbean Marine Institute (PI): Establishing an international Integrated Coral Observing Network at Little Cayman.
- Dr. Marc Slattery, University of Mississippi, NOAA Ocean Exploration Grant/Dr. Michael Lesser, University Of New Hampshire: Biogeography of deep coral reef ecosystems in the Caribbean. Team also included Dr. Cristina Diaz (Museo Marino de Margarita, Venezuela, and National Museum of Natural History, Washington, DC), Dr. Deborah Gochfeld (University of Mississippi), Beth Hines (Mountain Brook High School, Birmingham, AL), Elizabeth Kintzing (University of New Hampshire), Dr. Julie Olson (University of Alabama), Dr. Nicolás G. Alvarado Quiroz (NOAA OER).
- Dr. Carrie Manfrino (PI): Coral reef community structure and early history of coral recruits, Little Cayman.
- Dr. Elizabeth Whiteman (postdoc) University of East Anglia/Dr. Isabel Cote: Fish sex—hamlets
- Marilyn Brandt (Ph.D. student), University of Miami: Coral disease modeling

2008

- Dr. Marc Slattery/Dr. Michael Lesser: Biogeography of mesophotic coral reef ecosystems in the Caribbean.
- Dr. David Gruber, City University of New York, Baruch College /Dr. Vincent Pieribone, Yale University College of Medicine: Function of fluorescent proteins in corals.
- Dr. Elizabeth Whiteman, Public Library of Science(PLoS), and Central Caribbean Marine Institute Research Associate: Reef fish herbivory and resiliency.
- Dr. Carrie Manfrino (PI): Exploring the biological diversity and distribution of organisms to 170 meters deep using a SeaBotix Remotely Operated Vehicle (ROV).
- Dr. Jason Vasquez, California Department of Fish and Game, Marine Protected Area Project: Searching for lobsters

2009

- Jessica Jarrett (University of New Hampshire Ph.D. student, Dr. Michael Lesser's lab): Research interests: Nitrogen-fixing cyanobacteria symbionts in *Montastrea cavernosa* and other reef-building corals, ecological physiology, coral reef biology.
- Cara Fiore (University of New Hampshire Ph.D. student, Dr. Michael Lesser's lab): Research interests: Biology, ecology, and diversity of nitrogen-fixing bacteria in symbioses with corals and sponges.
- Dr. Jim Hendee /Dr. Carrie Manfrino (PI): CREWS (NOAA) Coral Reef Early Warning System.
- Dr. David Gruber /Dr. Vincent Pieribone: Ph.D. research project (2009–) The distribution and abundance of fluorescent proteins in the coral community surrounding Little Cayman, BWI.

2010

- Dr. Mark Hixon, Oregon State University: 3 Ph.D. research projects (2010–) The study of invasive species *Pterois volitans* (lionfish) within Cayman waters.
- Dr. Peter Minnett, University of Miami: Ph.D. research project with funding from NASA (2010–) Diurnal heating of shallow tropical ocean.

- Dr. Andrew Bruckner, Khaled bin Sultan Living Oceans Foundation: 3 projects on coral reef resilience assessments.
- Dr. Roger Hanlon/Anya Watson: Dynamic camouflage patterning in Nassau grouper, *Epinephelus striatus*

2011

- Dr. Rick Hochberg, University of Massachusetts-Lowell: 4 researchers including 1 Ph.D. student (2011–) Gastrotrich (meiofaunal invertebrates) in the Caribbean.
- Dr. Tom Frazer, University of Florida: 3 M.S. research projects (2011)
  - An investigation of *T. testudinum* (turtle grass) and *H. incrassada* carbon production dynamics in Little Cayman (with Savanna Barry, LCRC research assistant)
  - Age and diets of lionfish at Little Cayman (with Morgan Edwards)
  - Sex ratios of the early invasion of lionfish in Little Cayman (with Pat Gardner)
- Dr. Carrie Manfrino (PI)/Dr. Tom Frazer/Chuck Jacobi (University of Florida): Can culling lionfish improve native fish biomass and biodiversity? (with Savanna Barry and Katie Lohr, LCRC research intern)
- Dr. Michael Lesser: Ph.D. research project (2011–) Biology, ecology, and diversity of nitrogen-fixing bacteria in symbioses with corals and sponges.
- Dr. Roxie James, Kean University: Pathways and distribution of marine debris on a remote Caribbean island, Little Cayman (with 4 undergraduate researchers)
- Emma Camp, CCMI and University of Essex Ph.D. student (2011–): Measuring ocean acidification: Climate change and coral reef stress in different marine habitats around Little Cayman.

Special activities hosted

- 2007: *Think Tank #5*: A workshop co-hosted by CCMI and NOAA took place at the Little Cayman Research Centre. Titled "Ocean Acidification: a strategic planning session for ocean acidification research", the workshop was attended by Rebecca Albright, Dr. Ken Anthony, Felipe Arzayus, Dr. Mark Eakin, Dr. Richard Feely, Dr. Dwight Gledhill, Lew Gramer, Abbie Rae Harris, Dr. James Hendee, Dr. Joanie Kleypas, Dr. Chris Langdon, Dr. Carrie Manfrino (PI), Dr. Derek Manzello, Dr. Christopher Moses, Dr. Chris Sabine, Dr. Lisa Robbins, John Tomczuk, and Dr. Kim Yates. Results were published: Proceedings of Think Tank Number 5, Little Cayman Research Centre, December 3–7, 2007.
- 2010: *Coral Disease Assessment and Mitigation Training workshop*: Held at LCRC and run by Dr. Andy Bruckner (NOAA), assisted by leading coral disease specialists Dr. Cheryl Woodley (NOAA) and Dr. Esther Peters (NOAA). Training was aimed at improving diagnostic capabilities of regional scientists. Cayman Islands government marine park scientists, students, and other professionals were trained in the most current techniques in coral disease diagnostics and surveillance. A disease first response team was established. The workshop was attended by Katie Alpers (Indigo Divers), Tim Austin (Cayman Islands Department of Environment), John Bothwell (Cayman Islands Department of Environment), J.D. Dubick (NOAA), Paul Henneke (St. Matthew's University, Grand Cayman), Julie Higgins (NOAA), Amber Little (CCMI), Flower Moye (CCMI), Natasha Pisani (Cayman Islands Department of Environment), Samantha Shields (St. Matthew's University), and Scott Taylor (St. Matthew's University).

Selected Data Sets and Research

Gastrotricha

University of Mass.-Lowell scientist Dr. Rick Hochberg and Ph.D. student Sarah Atherton, along with German scientists Alexander Kieneke and Birgen Rothe, and Cheryl Thacker and Daniel Gouge conducted surveys of littoral and sublittoral sediments from diverse marine environments around Little Cayman Island in June 2011. They have produced new geographic records of Gastrotricha, and they provide the first general survey of meiofauna from Little Cayman. New records for the taxa of Acoela (Acoelomorpha), Acochlidia (Mollusca: Opisthobranchia), Annelida (Nerillidae, Protodrillidae, Syllidae), *Gnathostomula* (Gnathostomulida), *Halammohydra* (Cnidaria: Actinulida), *Echinoderes* (Kinorhyncha), *Gyratrix* cf *hermaphroditus* and several higher taxa of Platyhelminthes (Kalyptorhynchia, Macrostomida, Proseriata, Tricladida, “Typhloplanoida”), *Platyhedyle* (Mollusca: Sacoglossa), Neomeniomorpha (Mollusca: Opisthobranchia), *Nermetillina* (Nemertea), *Rotaria* (Rotifera: Bdelloidea) and Tardigrada were reported.

Camouflage findings
Dr. Roger Hanlon (Woods Hole) has been working on the adaptive camouflage of cephalopods for decades, and he and his students have visited LCRC on several occasions. In 2010, graduate student Anya Watson described “Dynamic camouflage patterning in Nassau grouper, *Epinephelus striatus*” (accepted May 2010). Camouflage evolved as an anti-predator defense in many species but aside from cephalopods, the rapid adaptive camouflage phenomenon is rarely studied in other animals. Mechanisms and functions of (rapid adaptive) camouflage in the Nassau grouper (Watson, A.C., Siemann, Liese A., Hanlon, Roger T., Dynamic adaptive camouflage by Nassau groupers on a coral reef, *The American Naturalist*, 12/2011, in review.). She suggests that there are different patterns related to defensive and offensive behaviors and that the rapidity in pattern changes are suggestive of direct neural control of skin chromatophores.

Coral bleaching model
In 2009, CCMI and NOAA-AOML installed an Integrated Coral Observing Network pylon as part of the Coral Reef Early Warning System project (CREWS) that operates to continuously measure standard oceanographic and meteorologic data at the Little Cayman Research Centre. This collaboration between NOAA scientists at the AOML lab (Dr. Jim Hendee, Dr. Derek Manzello, and Dr. Ruben van Hooidonk) and Dr. Manfrino’s field research team has resulted in a highly “tuned” coral bleaching model for the area. Establishing a local threshold for bleaching based on observational ecological evidence improved the skill of the predictive method. Using satellite-derived sea surface temperature (SST) data, the group quantified thermal anomalies at Little Cayman for the past 29 years (1982–2010). By combining SST data with observations of bleaching, a refined, site-specific thermal threshold was established. In addition, the team was able to establish species specific responses (and recoveries) after the bleaching episode. Using this site-specific threshold and the new Intergovernmental Panel on Climate Change (IPCC) assessment, they report five models to project future coral bleaching under four climate scenarios. Unfortunately, the model predicts annual bleaching stress by year 2050. (van Hooidonk, R., Manzello, D., Moye, J., Brandt, M.E., Hendee, J., McCoy, C., Manfrino, C., Coral Bleaching at Little Cayman, Cayman Islands, *Estuarine, Coastal, and Shelf Science*, 8/2011, in review; and Manfrino, C., van Hooidonk R., and Manzello, D., The Delineation of Coral Bleaching Thresholds and Future Reef Health, Little Cayman Cayman Islands, Session: Multi-Scale Ocean Modeling and Opportunities for Coastal Marine and Ecosystem Forecast Services II. *American Geophysical Union Annual Meeting*, Dec. 5–9, 2011, San Francisco, CA., Abs. OS53B-1780.)

“Twilight zone” and mesophotic reef structure studies
Dr. Michael Lesser and Dr. Marc Slattery worked over two seasons on the deeper extent of coral reefs. To do this, they conducted an expedition to study deep reef communities and look at the transition zone between tropical reef and aphotic deep reef communities. They illustrated that abiotic processes including internal waves and the attenuation of light play important roles on the structuring of deep reef communities (Lesser, M.P., Slattery, M., Leichter, J.J., 2009, Ecology of

mesophotic coral reefs, *Journal of Experimental Marine Biology and Ecology*, Volume 375, Issues 1–2, Pages 1–8.). Further work describes the zonation of the major coral and sponge communities in the mesophotic coral ecosystems (Slattery, M., Lesser, M.P., Brazeau, D., Stokes, M.D., Leichter, J.J. Connectivity and stability of mesophotic coral reefs, *Journal of Experimental Marine Biology and Ecology*, Volume 408, Issues 1–2, 15 November 2011, Pages 32–41). In addition, they collected samples of sponges from various depths, and are testing their extracts for antibacterial activity.

Coral reef health and seawater heating

Dr. Peter Minnett and Ph.D. student Xiofeng Zhu worked in collaboration with the resident manager at the Little Cayman Research Centre to install and download monthly data from four subsurface self-recording pressure and temperature loggers in January 2011). The objective was to improve our understanding of the diurnal heating of the surface layer of the ocean over a coral reef and to improve interpretation of satellite-derived oceanic signals and to better use this information (from satellites) to monitor and understand the health of coral reefs (Minnett P.J., Zhu, X., Hendee J., Manfrino, C., Berkelmans, R., Diurnal heating in shallow water—implications for satellite remote sensing of sea-surface temperature and monitoring coastal environments, *International Geoscience and Remote Sensing Symposium*, Munich, July 2012.). This work improves our understanding of the physical processes that permit us to predict the temperature at the corals themselves given the satellite retrievals of SST at the surface. What sets the Little Cayman Research Centre site apart from other sites in the region is that there is little tidal influence on surface temperature, as well as the NOAA CREWS pylon providing near-real time continuous data.

Coral reef disease modeling

Dr. Marilyn Brandt completed her Ph.D. while she was based at the Little Cayman Research Centre, and developed a modeling tool to test how coral diseases were spread through diverse coral populations. With coral diseases being the leading cause of mortality in coral communities (at Little Cayman) and with few tools to test hypotheses of disease incidence and control, she developed a new model called the Simulation of Infected Corals (SICO) model. With a long-term monitoring program ongoing since 1998 at Little Cayman (Manfrino C., Riegl, B., Hall, J.L., Graifman, R., Status of Coral Reefs of Little Cayman, Grand Cayman & Cayman Brac, British West Indies in 1999 & 2000 (Part 1: Stony Corals & Algae), Lang J.C.,(ed.), Status of coral reefs in the western Atlantic: Results of Initial Surveys, Atlantic & Gulf Rapid Reef Assessment (AGRRA) Program, *Atoll Res. Bull. 496*, p. 204–225; Coelho, V. and Manfrino, C., 2007, Coral Community Decline at Remote Caribbean Islands: Marine No-Take Reserves Are Not Enough, *Aquatic Conserv: Mar. Freshw. Ecosyst.* 16:1-20.), Brandt had six years of monitoring data on the forereefs of Little Cayman. She was able to, for the first time, demonstrate that when coral diseases were introduced at regular intervals and transmitted within limited areas, the model most accurately simulated patterns observed at the study sites (Brandt, M.E. and McManus, J.W., Dynamics and impacts of the coral disease white plague: insights from a simulation model, *Diseases of Aquatic Organisms*, Vol. 87: 117–133.).

Lionfish eradication

Dr. Carrie Manfrino (PI) and Dr. Tom Frazer teamed up to examine the potential eradication of lionfish which is considered an unlikely proposition. On Little Cayman a major community culling effort provided an opportunity to determine what level of harvesting might ameliorate deleterious impacts by lionfish. We showed that targeted removal programs can alleviate detrimental effects from lionfish predation. Culling reduced the number of lionfish found at reef sites off Little Cayman Island, a key step in reducing predation pressure. Furthermore, culling shifted the size frequency distribution of remaining lionfish toward smaller individuals that ate less and fed primarily on invertebrates not subject to harvesting. This shift reduced predation pressure on economically and ecologically important reef fish, including juvenile groupers and grazers such as parrotfish, surgeonfish and damselfish. Our results illustrate the benefit of moving beyond unsubstantiated debates and models containing uncertain parameters to rigorous testing of the efficacy of removal as a management tool. (Frazer, T.K., Jacoby, C.A., Edwards, M., Barry, S., Manfrino, C., Coping with lionfish: culling can alleviate detrimental effects, Bull. Mar. Sci. in review, 02/2012.)