Cruise Report for R/V *Seward Johnson* Deep-sea Corals Cruise, 5-17 Aug 2009

Sponsored by

NOAA Deep-sea Coral Research and Technology Program

Cooperative Institute for Ocean Exploration, Research and Technology

US Geological Survey Deepwater Program: Diversity, Systematics, and Connectivity of Vulnerable Reef Ecosystems (DISCOVRE)

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BACKGROUND

Deep-water (aphotic) corals are important fish habitat, repositories of data on ocean climate and productivity, and are hotspots of increased biodiversity, including undescribed species. This is underscored by the growing literature and management concern directed toward these ecosystems. Deep-coral habitats are abundant, yet our knowledge is inadequate to address questions necessary to understand and conserve these vulnerable habitats. The southeastern US (SEUS) and Gulf of Mexico (GOM) may have the most extensive deep-coral areas in the US; however, these large regions remain poorly explored. The unique deep coral habitats have escaped detailed examination because of their great depths, rugged bottom topography, and extreme currents (i.e., Gulf Stream, Loop Current), and the lack of substantial fisheries in these depths. Most studies on deep-sea coral banks require expensive unconventional sampling techniques (e.g., manned submersibles, ROVs).

We have concentrated our work around *Lophelia pertusa* areas because of its abundance, wide distribution, and structure forming abilities, but our objectives are applicable to other hard substrata habitats including mixed corals and sponges, as well as artificial substrata (wrecks, oil platforms). This project builds upon previous work by the cruise participants. We plan to continue and expand ongoing research topics in order to increase our knowledge of these habitats as well as address major research gaps. As an integrated regional exploration of deep-reef physical structure and ecology, this interconnected, multidisciplinary approach should advance our understanding of critical deep-sea habitats. Using standardized methods throughout this large region will allow comparisons among complex habitats over great depth and latitudinal ranges.

This cruise is in collaboration with the U.S. Geological Survey (USGS) and Minerals Management Service (MMS) project "Exploration and Research of Northern Gulf of Mexico Deepwater Natural and Artificial Hard Bottom Habitats with Emphasis on Coral Communities: Reefs, Rigs and Wrecks." Only by examining deep reef habitats over a wide geographic range, including the GOM, SEUS and beyond, can we gain an understanding of how these ecosystems function (through comparative analyses) and the degree to which they are interconnected. Studies will be integrated and will rely on each other to address continuity and diversity of deep-sea reef habitats. The cruise documented in this report supports companion projects funded by USGS as part of a cooperative venture with MMS and NOAA.

This report details the first of four 2009 cruises to conduct research in deep coral habitats off the SEUS and in the GOM. This first cruise was supported by a variety of agencies and institutions. Ship support was provided through the NOAA Deep-sea Coral Research and Technology Program, and submersible support was provided through Florida Atlantic University (Harbor Branch Oceanographic Inst.) as part of the Cooperative Institute for Ocean Exploration, Research, and Technology. Other agencies contributing to this cruise were Univ. of NC at Wilmington (UNCW), USGS, NC Museum of Natural Sciences, ARTWORK, Inc., NOAA Fisheries, Marine Conservation Biology Inst., Scottish Association for Marine Science, and Temple Univ. An internet site (http://fl.biology.usgs.gov/DISCOVRE/discovre2008/index.html) documents progress and facilitates public awareness of these projects. This cruise report generally describes the field work accomplished during this cruise. Data analyses will follow and be reported later.

Cruise Objectives

This SEUS cruise had many different target study sites on deep coral banks in the Cape Canaveral area (see Fig. 1). This cruise supported data needs of the South Atlantic Fishery Management Council, in particular examining the distribution of deep coral habitat in relation to golden crab and golden crab fishery zones. In addition, this cruise provided critical samples to the

USGS/DISCOVRE research team in light of large scale deep coral studies. **Science Objectives** are: 1) Continue to define benthic fish and invertebrate community structures, 2) Classify reef and off-reef habitat zones and document faunal affinities, 3) Obtain proxy productivity records from black and bamboo corals, 4) Collect *Lophelia*, other corals, and associated fauna for phylogenetic, phylogeographic, and community genetics, 5) Test new technology for intense data collection within a coral framework via microlander, 6) Collect and hold live corals for growth studies, 6) Determine benthos/infauna around and near corals, 7) Describe coral microbial community, 8) Characterize fauna in the water column and benthic habitats around deep coral sites, 9) Collect samples for biomedical screening, 10) Collect samples for trophodynamics studies, 11) Collect corals for reproduction and physiology studies. **Education/Outreach Objectives** are: 1) Provide at sea education and real-time communication to the public, 2) Provide education/outreach products to a variety of audiences, 3) Develop an interactive webquest to complement cruise objectives, 4) Add to High Definition video and digital still images. Each dive will usually have multiple objectives, with some tasks given priority.

METHODS

Study Areas

All target study sites for this project are on the continental slope (> 300 m) generally off Cape Canaveral, FL (Fig. 1). Multibeam sonar data from past surveys was used to help identify dive and sampling sites as well as to improve submersible navigation. The deep coral study sites occurred in two general depth zones, one around 700-750 m and a shallower area of about 400-500 m (Fig. 2). Similar methodologies were applied at all sites.

Science Personnel

The science crew came from Wilmington, NC, Gainesville, FL, St. Petersburg, FL, Scotland, Harbor Branch, FL, Bellevue, WA and Washington, DC, assembling on the ship on 5 Aug. We conducted 24 hour operations. The scientific crew was divided into two watches: 12 hrs on-12 hrs off. The night watch was on duty from 1800 to 0600 hr, while the day watch operated from 0600 to 1800 hr. The main night responsibilities were mesopelagic sampling with MOCNESS trawls, CTD casts, surface sampling and specimen work up. Day responsibilities centered around submersible operations but also rotated between CTD, surface sampling, and specimen work up.

Personnel (+ assignments, * = watch chief)

Steve W. Ross* (UNCW, Chief Scientist, Lead PI) - Overall organization, Submersible ops.
Martha S. Nizinski (NOAA Fisheries Systematics Lab, day) - sub ops., organization of wet lab, invertebrate data (all collections)
Liz Baird (NC Museum Nat. Sci., day) - Coordinate all education/PR activities, web/email, sub ops.
Cheryl Morrison (USGS, day) - Genetics samples, coral samples, sub ops.
Amanda Demopoulos (USGS, day) – sediment coring, trophodynamics & stable isotopes
Julie Galkiewicz (USGS, day) – all microbiology sampling, Kellogg sampler, sub ops.
J. Murray Roberts (SAMS, day) - help with sonar surveys, microlander, sub ops.
Sandra Brooke (MCBI, day) – live coral maintenance, coral reproduction, sub ops.
Jenny McClain (UNCW, day) - Data management, CTD, sub support, video tape copying
John Reed (FAU, day) – site identification, sub ops., biomed collections
Art Howard - (ARTWORK, day) - Camera HD-TV work, tape copying, lab photography
Tara Casazza* (UNCW, night watch chief) - CTD, midwater trawling, gear management

Mike Rhode (UNCW, night) - video tape copying, sonar survey, GIS support, CTD
Cheryl Ames (NOAA Fisheries, night)- Invertebrate samples, assist all night ops.
Stacy Harter (NOAA Fisheries, night) – assist night ops.
Leslie Wickes (Temple Univ., night) – bushmaster samples, assist all night ops.

Field Methods

The R/V *Seward Johnson* cruise departed Harbor Branch on 6 Aug 2009 (0915 hr) and returned to the same place on 17 Aug 2009 (about 1930 hr). The first day the ship steamed for coral banks located off Cape Canaveral, FL, arriving around 1600 hr (in time for an afternoon dive). We worked in that area and offshore sites the next 4-5 days (7-10 Aug), moving among inshore, offshore and northern sites depending on the quality of the sites and objectives accomplished (see Table 1, Fig. 2). We gradually moved south, diving on coral mounds that are known targets as well as others discovered, ending the cruise on coral sites south of Cape Canaveral on 17 Aug.

JSL II Submersible (Fig. 3)

Although we planned to be as flexible as possible to respond to unforeseen events, most submersible dives followed a similar pattern, emphasizing bottom video transecting, collecting, and photographing specimens on or near the bottom. Usually, the bow scientist led the dive and controlled the external cameras (unless needed by the pilot) and the execution of all sampling. Generally, the JSL descended through the water column quickly. During descent we took notes/observations of distributions/behaviors of fauna. A position fix was requested as soon as the sub was on bottom. Additional position fixes were requested and logged throughout the dive, especially where collections were made or transects started and stopped. Specimen collecting (using submersible suction device into sampling canisters) usually began soon after landing on the bottom, unless target animal abundance was low. Amount of time spent in this activity and amount of moving the sub to optimize collections depended on the scientists on board. At various times during dives, the video camera was moved to pre-determined pan/tilt positions, set on wide angle, and the submersible ran 5-10 min (approximate) video transects per previous methods (see Parker & Ross 1986, Sulak & Ross 1996, Ross & Quattrini 2007). This was modified as needed in heavy coral/rock areas and as lighting needs changed. Transects were run across all habitat types, including both coral and non-coral areas, at slow speeds with the JSL as near to bottom as possible (S.W. Ross provided detailed video guidelines). Transects were executed on every dive; however, due to time constraints other activities outlined below were allocated to certain dives only. Additional specimen collecting occurred after these transects. Still photography (digital camera) and video photography was conducted throughout the dive (not just during transects). We attempted to document every collection with video. At several locations and depths (not necessarily every dive) sediments, corals, and benthic fauna were collected for genetics and other analyses. The bow collecting basket or biobox was used to house these samples. Coral samples for aging and genetics work were collected and stored in the work basket or individual buckets mounted in front of the work basket. A Bushmaster, Jr. sampling device (Fig. 3) was mounted on the JSL during two dives. This hydraulically operated device was used twice to enclose as much of a coral colony and associated fauna as possible. A specially built sampler ("Kellogg Sampler", Fig. 4), was fitted to the front work bars of the JSL and was used on two dives to collect and isolate coral samples for microbiology studies. Tubes cores (Fig. 4) were carried on most dives and samples were collected from sediments as close to coral colonies as possible as well as some distance away from coral habitat. Baited traps were deployed during a few dives, but these were not productive, probably due to short deployment times. Scientists in the bow and stern compartments had digital audio recorders, digital video cameras and still cameras for use within the sub. The scientist in the bow ran an internal Canon HD video camera, usually on wide angle, for the whole dive at least while on bottom and in the water column when needed. This film is a critical back up for both audio and video as well as providing a good record of what the internal bow observer saw.

MOCNESS trawl

Discrete depth trawling was emphasized in the depth range of near surface to about 300 m, in approximately 50 m bins. A MOCNESS system (335 μm mesh) initially set up with six nets was deployed off the starboard side for night sampling. However, due to ship operator error these nets were sucked under the vessel on first deployment, and most of the nets and buckets were lost. Henceforth, only two nets were rigged onto the MOCNESS frame, and this was fished only during the captain's and first officer's watches at night. When the nets reached the target depth, the first net was opened and was towed for 30 min against the current at about 2 kn ground speed. Then it was triggered closed, opening the second net which was also towed 30 min. After triggering this net closed the MOCNESS was retrieved. This was repeated as many times as possible during a watch with the objective of covering most of the area's upper water column during the time the ship occupied the sampling area. A temperature-depth recorder (TDR, SeaBird) was attached to the net frame to record time, depth and temperature during each trawl deployment. Actual fishing depth was controlled in real time.

Plankton nets and water samples

To obtain larvae and phytoplankton samples for isotopic data, a 1-m diameter plankton net (505 μm mesh) and a 0.5-m diameter plankton net (335 μm mesh) were towed for 30 and 15 min, respectively, on the surface. Samples from these nets were rinsed into the cod bucket, and the net catches were subsampled for general plankton isotope samples. To obtain phytoplankton samples, surface water was periodically collected with a bucket, and a measured volume was vacuum filtered onto pre-combusted filter paper. The paper was dried and saved for later stable isotope analysis.

CTD

Periodically, the ship's CTD array was used to record a full water column water chemistry description. A SeaBird 911*plus* with water sampling rosette was used for these profiles, and it measured turbidity (Seapoint), fluorescence (Chelsea Instruments), oxygen, altitude, depth, conductivity, temperature, salinity, and pH. CTD casts were taken at every sample site during the cruise.

Benthic Microlander

See Appendix A for a report on the benthic microlander (Fig. 5) provided by Dr. J.M. Roberts. While the two deployments of this device were mainly for testing, it recorded interesting data, showing strong tidal signals in water parameters on the bottom.

General Specimen and Data Treatment:

Non-isotope samples from all collections were preserved at sea (10% formalin-seawater solution or 70% ethanol) with various sub-samples from most collections being taken for stable isotope analyses. Invertebrate samples for genetic analysis were saved in 95% ethanol and later transferred to 70% ethanol. Tissue and/or gill arch samples were removed from fishes and stored in 95% ethanol for genetic analysis. At sea, tissue samples to be used for isotope analyses were removed from selected specimens soon after collection, dried and stored, and these specimens were saved separately. Isotope samples also came from plankton and sediment collections. Selected species were set aside for on board photography. Photo specimens were pinned out as needed and photographed on a light table under daylight balanced strobes by A. Howard. After being photographed, specimens were preserved separately.

FIELD RESULTS

Overall, 108 stations were occupied during this cruise (Table 1). All planned 22 JSL dives were successfully accomplished (Table 1, Fig. 2). Examples of bottom habitats are provided in Figure 6. While JSL dives were assigned one station number, all dives accomplished multiple objectives, which in many cases (e.g., microlander, Kellogg sampler) could be considered additional stations. Other ship based sampling included 28 CTD casts, 8 plankton net tows, 15 nightlighting stations, 24 MOCNESS tows and 11 miscellaneous collections (Table 1, Fig. 2).

The Roberts microlander (Fig. 5) was deployed during two JSL dives for an extended duration. See Appendix A for a report and preliminary results from this device.

A variety of samples were collected for many research topics (Table 2). For stable isotope analyses, 391 individual samples were collected from 70 taxa (Table 2). Most of these samples were dried on the ship and will later be processed for analysis of $\delta^{13}C$ and $\delta^{15}N$ as part of a larger study on the trophodynamics of deep reef ecosystems. Twenty isolated coral samples were collected for microbiology studies. At least 28 taxa were sampled for microbiology and/or biomedical screening. These samples were returned to Harbor Branch/FAU for further treatment. At least 70 taxa were photographed at sea (see examples, Fig. 7) which were representative of the samples (Table 2). These animals await final identification.

At least 33 taxa were subsampled for genetics studies. Overall, 552 tissue samples were collected, and these represent a valuable addition to our studies of connectivity among deep reef ecosystems. This region off central Florida was poorly sampled in previous cruises and represented a critical area for bridging the Atlantic and Gulf of Mexico study areas.

Ten coral taxa were subsampled (110 samples) for analysis of reproductive condition. These samples were preserved at sea and transferred to the UNCW lab for future analysis by S. Brooke. Colonies of three coral species (*Lophelia pertusa, Madrepora oculata, and Enallopsammia profunda*) were retained alive from several JSL dives. These were held in water baths at approximately 7°C in the ship cold room and were transferred to shore at the end of the cruise. These live corals are being held in cold rooms at both Harbor Branch/FAU and at the Oregon Inst. of Marine Biology and will be used in future coral growth studies. They will be stained and deployed on benthic landers off North Carolina in December 2009 (by S. Brooke).

All general station data sheets were electronically entered, checked, and archived on board ship and at the UNCW lab and are being edited as needed. All fish samples have been sorted and transferred to alcohol storage. Invertebrate samples are in storage and will be transferred to the Smithsonian Institution (M. Nizinski lab).

Preliminary General Observations

The least faunal diversity and least well developed coral habitats occurred in the deep northern most and central stations (Fig. 2, right panel). Once on the elevated topography of these areas the bottom was almost completely covered with mostly dead *L. pertusa*. The three inshore sites were some of the most interesting and were characterized by large colonies of living *L. pertusa* as well as large colonies of *Madrepora oculata*. These sites exhibited the most fish and macroinvertebrate activity. Golden crab (*Chaceon fenneri*) were common on these inshore sites, and the crabs were often in close association with the coral habitat (Fig. 6, lower left). The southern most deep sites were also characterized by extremely high invertebrate biodiversity. Most sites exhibited a well developed sponge community composed of many species, with *Aphrocallistes beatrix* being especially common. Antipatharian corals seemed rare as were bamboo corals. One large bamboo coral was collected for paleoecology research. Interactions of the benthic coral fauna with midwater animals was observed frequently and usually involved predation of benthic animals upon various midwater animals (e.g., galatheid crabs eating midwater fishes). As in past observations, several fish species appeared to be exclusively associated with coral habitat (e.g., *Eptatretus lopheliae*, *Lophiodes beroe*, *Laemonema melanurum*). Bottom currents at most sites were highly variable in direction and speed (ranging from 0.3 to 1.0 kn). Microlander data (see Appendix A) suggested strong tidal forcing of bottom currents. Although identifications of all species collected will take considerable time, it appears likely that several undescribed species of invertebrates were collected.

Media Day and Outreach

During the cruise we hosted a public relations and education event. On 12 Aug two small vessels brought visitors to the ship, representing NBC News, Associated Press, Orlando Sentinel, Daytona Beach News Journal, Florida Times Union, the South Atlantic Fishery Management Council, Florida Marine Law Enforcement, and NOAA Coral and Habitat Programs. These visitors were provided lunch, given a tour of the ship and submersible, and were allowed access to scientists for interviews. They were provided with video and still imagery for use in articles. This event generated a huge amount of generally positive exposure to the deep coral ecosystem. NBC Nightly News featured a story on 13 Aug. Later in the week articles followed in newspapers all over the country (e.g., see http://www.washingtonpost.com/wp-dyn/content/article/2009/08/18/AR2009081800578.html. This also lead to special articles in Coastal Heritage (vol. 23, no. 3, publication of SC Sea Grant), UNCW Research magazine, and Cape Fear's Going Green (see http://www.goinggreenpublications.com/currentissue.html). Although there was some misinterpretation by NBC News which created a minor controversy concerning fishery damage to habitats (this was later mitigated), we received many responses that this research story was amazing and interesting work.

Daily logs were posted to the DISCOVRE web site and the educator on board (L. Baird) mediated a question/answer session with schools and the public. School participation was low because of the timing of the cruise. A Facebook presence was created for the cruise on Art Howard's Facebook page, and video and photos were posted there. This was very popular and viewed numerous times. Cruise video was also posted to http://vimeo.com/6221700.

FUTURE WORK

Identification of specimens and analysis of most data from this cruise have been delayed in order to complete other cruises and establish a complete dataset. Analysis of much of these data will be secondary in priority to analysis of Gulf of Mexico project samples. We expect to begin working on these data by early to mid 2010. The first task for all samples is to identify the animals collected. The first priority is to identify samples used for isotope analysis, followed by photo specimens, and then the remainder of the catches. In general, submersible samples have the highest priority for sample treatment. Analysis of samples for stable isotopes of carbon and nitrogen will proceed along with the identification process. Analysis of fish diets will proceed after identifications and isotope analyses are complete. Other data treatments will proceed in various stages in the labs of the scientists who participated in this cruise. We expect data from this cruise to result in several peer reviewed publications in the future.

ACKNOWLEDGMENTS

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Table 1. Stations sampled off Cape Canaveral, FL (6-17 August 2009). D=Day (0700 to 1830 hr EDT), N=Night (1830 to 0700 hr EDT), M=Morning (0700 to 1200 hr EDT), A=Afternoon (1200 to 1830 hr EDT). CTD=Seabird SBE 911+, M=MOCNESS (1x1m, 335 µm), NL=nightlighting, OD=on deck, PN=plankton net (1.0 m diameter), Phyto=phytoplankton sample, JSL=Johnson-Sea-Link submersible. Submersible depth range data are only for the period when the JSL was on the bottom. For MOCNESS trawls that fished discrete depths, depth ranges are the minimum and maximum of all mean depths calculated per tow. For nets that failed to close and for the CTD casts, depth ranges include the absolute maximum depth of the sample to the surface (S). * = no depth data recorded.

Station #	Gear	Date	Time	Total Time (min)	Start Latitude	Start Longitude	End Latitude	End Longitude	Depth Range (m)
JSLII-2009-Atl-3700	JSL	06-Aug-09	A	168	28° 18.979'N	79° 45.123'W	28° 19.329'N	79° 45.052'W	450-425
JSLII-2009-Atl-3701	JSL	07-Aug-09	M	138	28° 47.511'N	79° 37.457'W	28° 47.584'N	79° 37.311'W	760-732
JSLII-2009-Atl-3702	JSL	07-Aug-09	A	96	28° 47.529'N	79° 37.281'W	28° 47.570'N	79° 37.366'W	754-713
JSLII-2009-Atl-3703	JSL	08-Aug-09	M	134	28° 27.845'N	79° 37.650'W	28° 27.802'N	79° 37.657'W	701-704
JSLII-2009-Atl-3704	JSL	08-Aug-09	A	118	28° 26.854'N	79° 38.229'W	28° 28.050'N	79° 38.272'W	726-730
JSLII-2009-Atl-3705	JSL	09-Aug-09	M	141	28° 46.306'N	79° 37.024'W	28° 46.526'N	79° 36.955'W	778-744
JSLII-2009-Atl-3706	JSL	09-Aug-09	A	115	28° 47.425'N	79° 37.369'W	28° 47.478'N	79° 37.334'W	758-729
JSLII-2009-Atl-3707	JSL	10-Aug-09	M	130	28° 19.092'N	79° 36.886'W	28° 19.426'N	79° 36.926'W	735-714
JSLII-2009-Atl-3708	JSL	10-Aug-09	A	169	28° 19.102'N	79° 45.155'W	28° 19.237'N	79° 45.135'W	454-398
JSLII-2009-Atl-3709	JSL	11-Aug-09	M	149	28° 19.041'N	79° 45.604'W	28° 19.286'N	79° 45.537'W	439-419
JSLII-2009-Atl-3710	JSL	11-Aug-09	A	120	28° 16.271'N	79° 37.002'W	28° 16.555'N	79° 37.059'W	747-712
JSLII-2009-Atl-3711	JSL	12-Aug-09	M	149	28° 18.772'N	79° 45.504'W	28° 19.226'N	79° 45.554'W	440-412
JSLII-2009-Atl-3712	JSL	12-Aug-09	A	131	28° 19.092'N	79° 45.495'W	28° 19.257'N	79° 45.521'W	439-408
JSLII-2009-Atl-3713	JSL	13-Aug-09	M	167	28° 27.254'N	79° 43.410'W	28° 27.520'N	79° 43.392'W	532-499
JSLII-2009-Atl-3714	JSL	13-Aug-09	A	166	28° 23.152'N	79° 45.989'W	28° 23.342'N	79° 45.986'W	446-408
JSLII-2009-Atl-3715	JSL	14-Aug-09	M	172	28° 23.186'N	79° 45.901'W	28° 23.349'N	79° 46.016'W	446-407
JSLII-2009-Atl-3716	JSL	14-Aug-09	A	144	28° 27.343'N	79° 43.331'W	28° 27.516'N	79° 43.395'W	534-492
JSLII-2009-Atl-3717	JSL	15-Aug-09	M	122	28° 10.328'N	79° 36.777'W	28° 09.682'N	79° 36.789'W	747-737
JSLII-2009-Atl-3718	JSL	15-Aug-09	A	135	28° 02.088'N	79° 36.867'W	28° 02.492'N	79° 36.862'W	737-694
JSLII-2009-Atl-3719	JSL	16-Aug-09	M	150	28° 02.120'N	79° 36.748'W	28° 02.483'N	79° 36.873'W	720-692
JSLII-2009-Atl-3720	JSL	16-Aug-09	A	133	28° 02.204'N	79° 36.780'W	28° 02.326'N	79° 36.991'W	726-691
JSLII-2009-Atl-3721	JSL	17-Aug-09	M	150	28° 02.303'N	79° 36.759'W	28° 02.469'N	79° 36.887'W	684-709

SJ-2009-Atl-001	CTD	06-Aug-09	N	25	28° 19.265'N	79° 45.181'W			S-437
SJ-2009-Atl-002	CTD	06-Aug-09	N	60	28° 46.078'N	79° 36.831'W			S-755
SJ-2009-Atl-004	M	07-Aug-09	N	30	28° 47.329'N	79° 37.531'W	28° 47.489'N	79° 37.277'W	248-430
SJ-2009-Atl-005	M	07-Aug-09	N	30	28° 47.489'N	79° 37.277'W	28° 48.705'N	79° 38.146'W	219-391
SJ-2009-Atl-006	CTD	08-Aug-09	D	25	28° 27.219'N	79° 38.125'W	28° 28.043'N	79° 38.272'W	S-721
SJ-2009-Atl-007	Phyto	08-Aug-09	D		28° 28.828'N	79° 37.995'W	28° 28.828'N	79° 37.995'W	S
SJ-2009-Atl-008	PN	08-Aug-09	D		28° 28.249'N	79° 37.787'W	28° 28.249'N	79° 37.787'W	S
SJ-2009-Atl-009	PN	08-Aug-09	D	15	28° 28.249'N	79° 37.787'W	28° 28.016'N	79° 37.667'W	S
SJ-2009-Atl-010	Phyto	08-Aug-09	D		28° 28.002'N	79° 37.660'W	28° 28.002'N	79° 37.660'W	S
SJ-2009-Atl-011	M	08-Aug-09	N	60	28° 28.766'N	79° 38.517'W	28° 33.638'N	79° 39.000'W	S-193
SJ-2009-Atl-012	M	08-Aug-09	N	25	28° 33.638'N	79° 39.000'W	28° 35.299'N	79° 39.039'W	*
SJ-2009-Atl-013	CTD	08-Aug-09	N	57	28° 34.028'N	79° 38.629'W			S-734
SJ-2009-Atl-014	CTD	08-Aug-09	N	27	28° 38.217'N	79° 39.619'W	28° 40.879'N	79° 39.786'W	S-703
SJ-2009-Atl-015	Phyto	08-Aug-09	N		28° 42.857'N	79° 40.734'W	28° 42.857'N	79° 40.734'W	S
SJ-2009-Atl-016	CTD	08-Aug-09	N	27	28° 43.882'N	79° 40.780'W	28° 46.099'N	79° 40.813'W	S-699
SJ-2009-Atl-017	PN	08-Aug-09	N	15	28° 44.246'N	79° 40.837'W	28° 44.849'N	79° 40.818'W	S
SJ-2009-Atl-018	M	08-Aug-09	N	30	28° 44.216'N	79° 40.476'W	28° 46.535'N	79° 39.975'W	37-49
SJ-2009-Atl-019	CTD	09-Aug-09	D	28	28° 47.798'N	79° 37.175'W	28° 48.604'N	79° 37.067'W	S-751
SJ-2009-Atl-020	CTD	09-Aug-09	D	27	28° 47.775'N	79° 37.107'W	28° 48.679'N	79° 36.964'W	S-745
SJ-2009-Atl-021	M	09-Aug-09	N	29	28° 43.216'N	79° 38.056'W	28° 44.796'N	79° 37.342'W	161-182
SJ-2009-Atl-022	M	09-Aug-09	N	30	28° 44.796'N	79° 37.342'W	28° 45.309'N	79° 38.363'W	133-168
SJ-2009-Atl-023	Phyto	09-Aug-09	N		28° 43.065'N	79° 38.021'W	28° 43.065'N	79° 38.021'W	S
SJ-2009-Atl-024	PN	09-Aug-09	N	15	28° 44.150'N	79° 38.010'W	28° 44.800'N	79° 37.450'W	S
SJ-2009-Atl-025	PN	10-Aug-09	N	15	28° 15.787'N	79° 36.651'W	28° 17.161'N	79° 36.783'W	S
SJ-2009-Atl-026	CTD	10-Aug-09	D	28	28° 18.085'N	79° 36.724'W	28° 19.354'N	79° 36.526'W	S-725
SJ-2009-Atl-027	CTD	10-Aug-09	D	19	28° 19.460'N	79° 45.200'W	28° 20.424'N	79° 45.033'W	S-438
SJ-2009-Atl-028	M	10-Aug-09	N	30	28° 17.286'N	79° 44.932'W	28° 19.181'N	79° 45.203'W	102-147
SJ-2009-Atl-029	M	10-Aug-09	N	30	28° 19.181'N	79° 45.203'W	28° 20.961'N	79° 45.176'W	86-167
SJ-2009-Atl-030	CTD	10-Aug-09	N	16	28° 22.014'N	79° 45.265'W	28° 22.816'N	79° 45.253'W	S-413
SJ-2009-Atl-031	PN	11-Aug-09	N	17	28° 18.663'N	79° 45.171'W	28° 18.893'N	79° 45.241'W	S

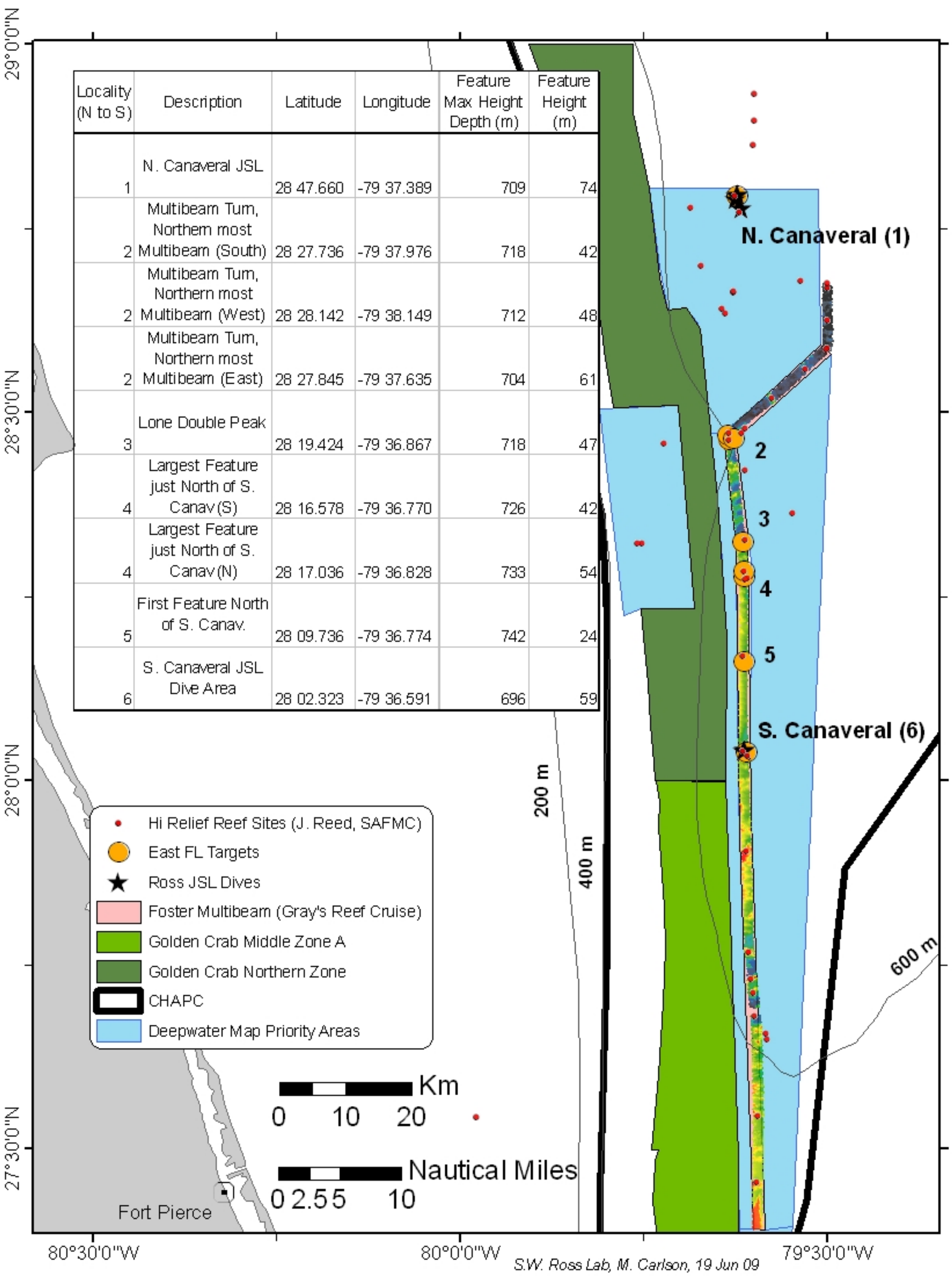
SJ-2009-Atl-032	CTD	11-Aug-09	N	18	28° 19.096'N	79° 45.152'W	28° 19.851'N	79° 45.153'W	S-416
SJ-2009-Atl-033	M	11-Aug-09	N	30	28° 19.399'N	79° 45.467'W	28° 20.836'N	79° 44.551'W	53-111
SJ-2009-Atl-034	CTD	11-Aug-09	D	17	28° 19.055'N	79° 45.380'W	28° 19.742'N	79° 45.391'W	S-431
SJ-2009-Atl-035	CTD	11-Aug-09	N	31	28° 15.771'N	79° 36.805'W	28° 17.033'N	79° 36.880'W	S-713
SJ-2009-Atl-036	M	11-Aug-09	N	30	28° 13.783'N	79° 44.737'W	28° 15.396'N	79° 45.623'W	57-97
SJ-2009-Atl-037	NL	12-Aug-09	N	30	28° 07.960'N	79° 44.987'W	28° 09.864'N	79° 45.374'W	S
SJ-2009-Atl-038	NL	12-Aug-09	N	30	28° 09.864'N	79° 45.374'W	28° 12.148'N	79° 45.783'W	S
SJ-2009-Atl-039	NL	12-Aug-09	N	30	28° 12.148'N	79° 45.783'W	28° 14.345'N	79° 46.141'W	S
SJ-2009-Atl-040	NL	12-Aug-09	N	30	28° 14.345'N	79° 46.141'W	28° 19.330'N	79° 45.120'W	S
SJ-2009-Atl-041	NL	12-Aug-09	N	30	28° 19.330'N	79° 45.120'W	28° 18.427'N	79° 46.723'W	S
SJ-2009-Atl-042	M	12-Aug-09	N	30	28° 15.900'N	79° 47.109'W	28° 17.359'N	79° 45.846'W	71-87
SJ-2009-Atl-043	CTD	12-Aug-09	N	20	28° 18.630'N	79° 45.570'W	28° 19.753'N	79° 45.572'W	S-391
SJ-2009-Atl-044	M	12-Aug-09	N	30	28° 19.871'N	79° 46.396'W	28° 21.421'N	79° 46.816'W	119-203
SJ-2009-Atl-045	M	12-Aug-09	N	30	28° 21.421'N	79° 46.816'W	28° 22.986'N	79° 47.925'W	82-197
SJ-2009-Atl-046	NL	13-Aug-09	N	30	28° 18.632'N	79° 44.458'W	28° 20.542'N	79° 44.908'W	S
SJ-2009-Atl-047	NL	13-Aug-09	N	30	28° 20.542'N	79° 44.908'W	28° 22.498'N	79° 45.475'W	S
SJ-2009-Atl-048	NL	13-Aug-09	N	30	28° 22.498'N	79° 45.475'W	28° 24.460'N	79° 45.987'W	S
SJ-2009-Atl-049	NL	13-Aug-09	N	30	28° 24.460'N	79° 45.987'W	28° 26.902'N	79° 46.447'W	S
SJ-2009-Atl-050	NL	13-Aug-09	N	30	28° 26.902'N	79° 46.447'W	28° 28.724'N	79° 46.822'W	S
SJ-2009-Atl-051	NL	13-Aug-09	N	30	28° 28.724'N	79° 46.822'W	28° 30.760'N	79° 47.240'W	S
SJ-2009-Atl-052	NL	13-Aug-09	N	30	28° 30.760'N	79° 47.240'W	28° 32.777'N	79° 47.726'W	S
SJ-2009-Atl-053	CTD	13-Aug-09	D	20	28° 20.713'N	79° 45.539'W	28° 20.713'N	79° 45.539'W	S-502
SJ-2009-Atl-054	CTD	13-Aug-09	N	20	28° 22.584'N	79° 45.857'W	28° 23.535'N	79° 45.821'W	*
SJ-2009-Atl-055	M	13-Aug-09	N	30	28° 20.829'N	79° 45.583'W	28° 22.945'N	79° 45.528'W	75-104
SJ-2009-Atl-056	M	13-Aug-09	N	30	28° 22.945'N	79° 45.528'W	28° 24.631'N	79° 45.506'W	64-95
SJ-2009-Atl-057	Phyto	14-Aug-09	N		28° 15.132'N	79° 45.868'W	28° 15.132'N	79° 45.868'W	S
SJ-2009-Atl-058	NL	14-Aug-09	N	30	28° 17.363'N	79° 46.181'W	28° 19.433'N	79° 46.678'W	S
SJ-2009-Atl-059	NL	14-Aug-09	N	30	28° 19.433'N	79° 46.678'W	28° 21.524'N	79° 47.232'W	S
SJ-2009-Atl-060	NL	14-Aug-09	N	30	28° 21.524'N	79° 47.232'W	28° 23.584'N	79° 47.789'W	S
SJ-2009-Atl-061	M	14-Aug-09	N	30	28° 21.079'N	79° 47.358'W	28° 22.987'N	79° 46.248'W	73-101

SJ-2009-Atl-062	CTD	14-Aug-09	D	18	28° 20.712'N	79° 45.539'W	28° 24.574'N	79° 46.113'W	S-420
SJ-2009-Atl-063	CTD	14-Aug-09	D	22	28° 25.613'N	79° 43.558'W	28° 26.512'N	79° 43.593'W	S-499
SJ-2009-Atl-064	CTD	14-Aug-09	N	21	28° 26.847'N	79° 42.912'W	28° 28.049'N	79° 42.889'W	S-476
SJ-2009-Atl-065	M	14-Aug-09	N	30	28° 29.992'N	79° 43.203'W	28° 31.149'N	79° 43.029'W	98-124
SJ-2009-Atl-066	M	14-Aug-09	N	30	28° 31.149'N	79° 43.029'W	28° 32.730'N	79° 43.759'W	50-101
SJ-2009-Atl-067	CTD	15-Aug-09	D	29	28° 09.573'N	79° 36.547'W	28° 10.626'N	79° 36.673'W	S-745
SJ-2009-Atl-068	CTD	15-Aug-09	D	24	28° 01.371'N	79° 36.754'W	28° 02.410'N	79° 37.003'W	S-678
SJ-2009-Atl-069	CTD	15-Aug-09	N	25	28° 02.986'N	79° 35.015'W	28° 04.035'N	79° 35.227'W	S-670
SJ-2009-Atl-070	Phyto	16-Aug-09	N		28° 03.470'N	79° 35.034'W	28° 03.470'N	79° 35.034'W	S
SJ-2009-Atl-071	PN	16-Aug-09	N	15	28° 03.631'N	79° 34.997'W	28° 03.966'N	79° 35.024'W	S
SJ-2009-Atl-072	Phyto	16-Aug-09	N		28° 03.470'N	79° 35.034'W	28° 03.470'N	79° 35.034'W	S
SJ-2009-Atl-073	CTD	16-Aug-09	N	25	28° 02.918'N	79° 36.617'W	28° 03.815'N	79° 36.497'W	S-722
SJ-2009-Atl-074	Phyto	16-Aug-09	N		28° 02.918'N	79° 36.617'W	28° 02.918'N	79° 36.617'W	S
SJ-2009-Atl-075	M	16-Aug-09	N	30	28° 03.207'N	79° 36.937'W	28° 04.937'N	79° 35.825'W	11-33
SJ-2009-Atl-076	CTD	16-Aug-09	D	28	28° 00.901'N	79° 36.927'W	28° 02.097'N	79° 36.925'W	S-705
SJ-2009-Atl-077	CTD	16-Aug-09	D	25	28° 01.441'N	79° 36.623'W	28° 02.497'N	79° 36.825'W	S-682
SJ-2009-Atl-078	CTD	16-Aug-09	N	27	28° 03.496'N	79° 36.481'W	28° 04.451'N	79° 36.815'W	S-725
SJ-2009-Atl-079	M	16-Aug-09	N	30	28° 05.221'N	79° 37.392'W	28° 06.443'N	79° 37.792'W	103-259
SJ-2009-Atl-080	M	16-Aug-09	N	28	28° 06.443'N	79° 37.792'W	28° 08.086'N	79° 38.212'W	*
SJ-2009-Atl-081	Phyto	16-Aug-09	N		28° 04.865'N	79° 37.487'W	28° 04.865'N	79° 37.487'W	S
SJ-2009-Atl-082	Phyto	17-Aug-09	N		27° 52.370'N	79° 35.130'W	27° 52.370'N	79° 35.130'W	S
SJ-2009-Atl-083	PN	17-Aug-09	N	15	27° 52.493'N	79° 35.088'W	27° 52.699'N	79° 34.976'W	S
SJ-2009-Atl-084	CTD	17-Aug-09	N	35	27° 54.143'N	79° 34.749'W	28° 20.713'N	79° 45.539'W	S-678
SJ-2009-Atl-085	OD	17-Aug-09	N		28° 20.712'N	79° 45.538'W	28° 20.712'N	79° 45.538'W	S
SJ-2009-Atl-086	M	17-Aug-09	N	30	27° 56.960'N	79° 35.041'W	27° 59.080'N	79° 34.547'W	23-43

Table 2. Summary of the types of subsamples taken for various study topics during 6-17 August 2009 in the western Atlantic off the east coast of Florida. The number of taxa is based on tentative identifications conducted in the field. Number of taxa subject to change as data are analyzed.

Sample Type	No. Taxa	No. Samples
Isotope (trophic study)	70	391
Genetic	33	552
Photo	70	174
Microbiology samples from *L. pertusa*	--	20
Biomedical (J. Reed, mostly sponges)	28	41
Coral reproduction & biology (S. Brooke)	10	110
Bushmaster*	52	2

* underestimation since identifications on ship were tentative and incomplete.



Locality (N to S)	Description	Latitude	Longitude	Feature Max Height Depth (m)	Feature Height (m)
1	N. Canaveral JSL	28 47.660	-79 37.389	709	74
2	Multibeam Turn, Northern most Multibeam (South)	28 27.736	-79 37.976	718	42
2	Multibeam Turn, Northern most Multibeam (West)	28 28.142	-79 38.149	712	48
2	Multibeam Turn, Northern most Multibeam (East)	28 27.845	-79 37.635	704	61
3	Lone Double Peak	28 19.424	-79 36.867	718	47
4	Largest Feature just North of S. Canav (S)	28 16.578	-79 36.770	726	42
4	Largest Feature just North of S. Canav (N)	28 17.036	-79 36.828	733	54
5	First Feature North of S. Canav.	28 09.736	-79 36.774	742	24
6	S. Canaveral JSL Dive Area	28 02.323	-79 36.591	696	59

Figure 1. Target study area for Aug 2009 R/V *Seward Johnson* deep coral cruise illustrating past submersible dives, mound locations from past surveys, and golden crab fishing zones.

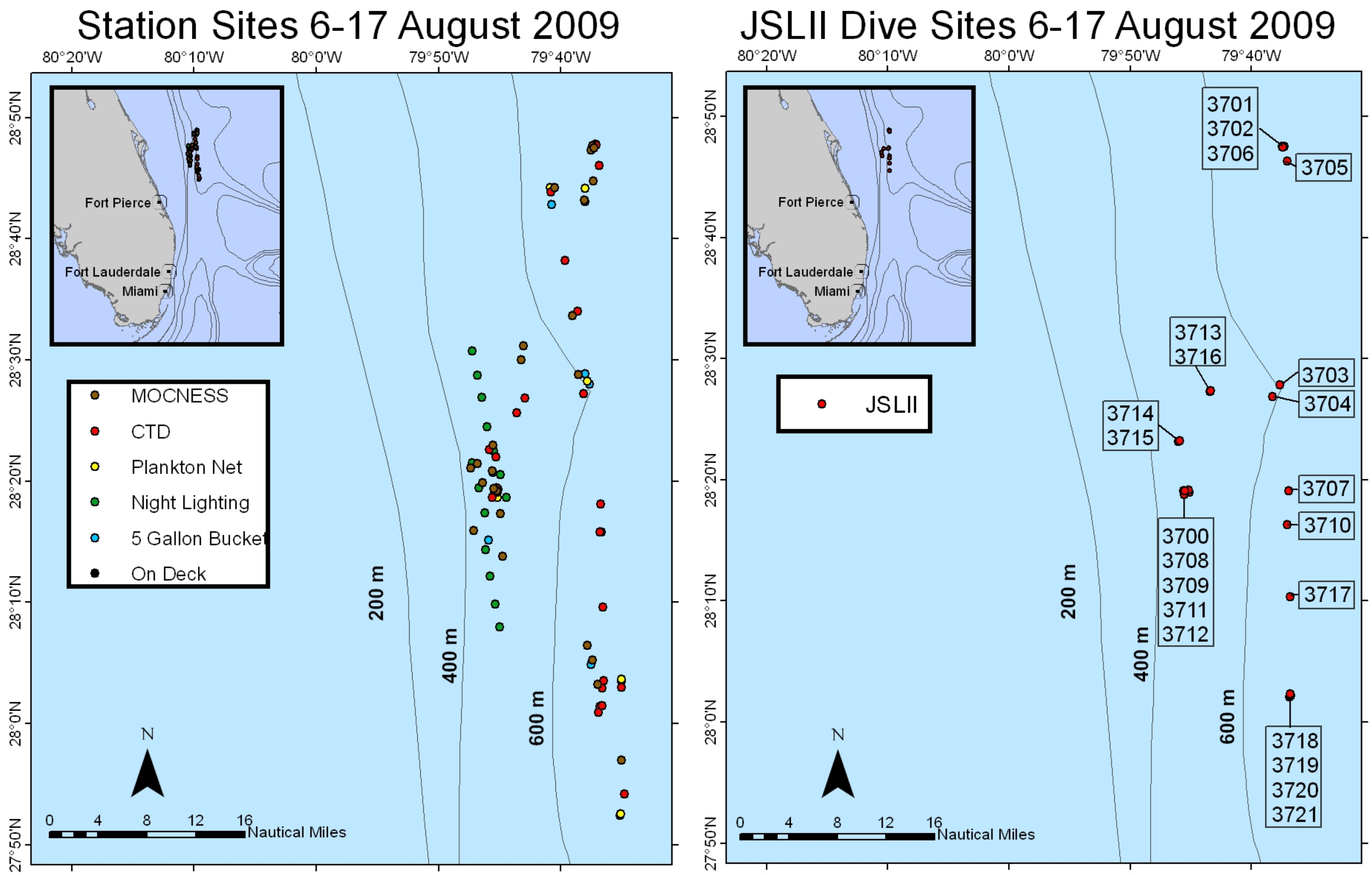


Figure 2. Locations of ship based sampling stations (left) and *Johnson-Sea-Link II* submersible stations (right) on deep coral mounds off Cape Canaveral, FL sampled 6-17 August 2009.

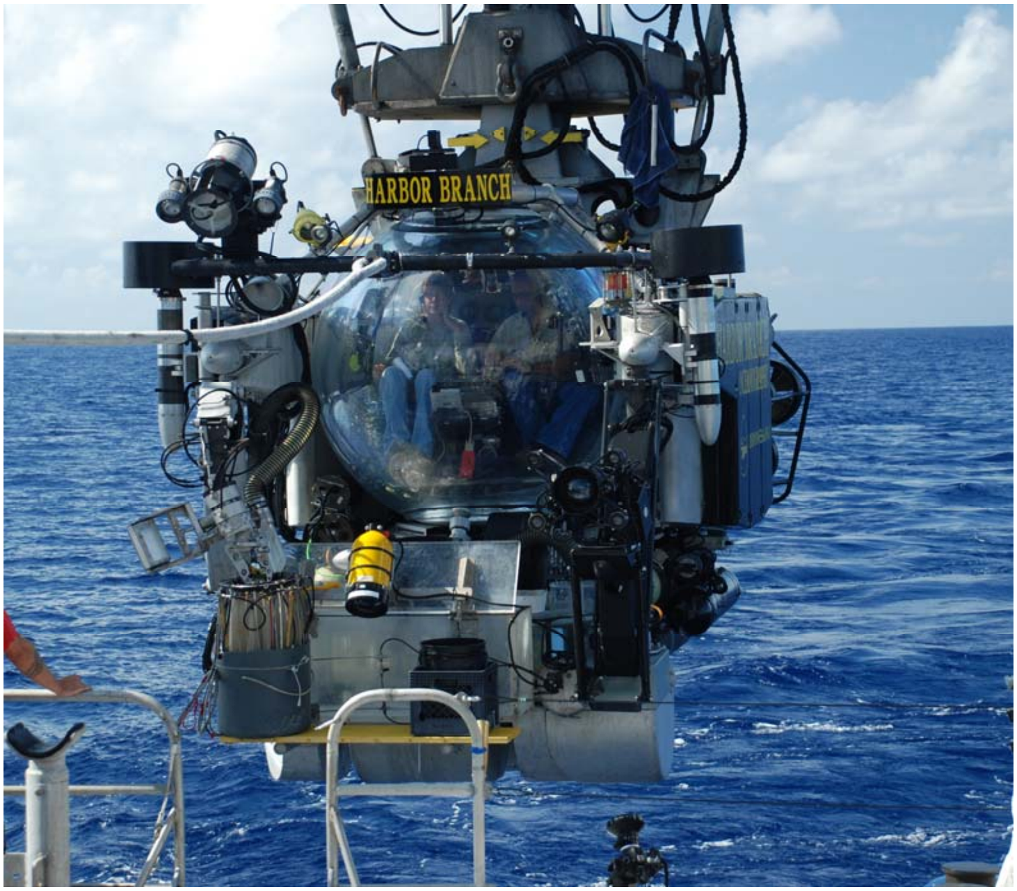


Figure 3. *Johnson-Sea-Link II* submersible, 13 Aug 09, Dive JSLII-3714. Note Bushmaster, Jr. in bucket on starboard side and digital still camera (yellow) mounted on biobox lid.

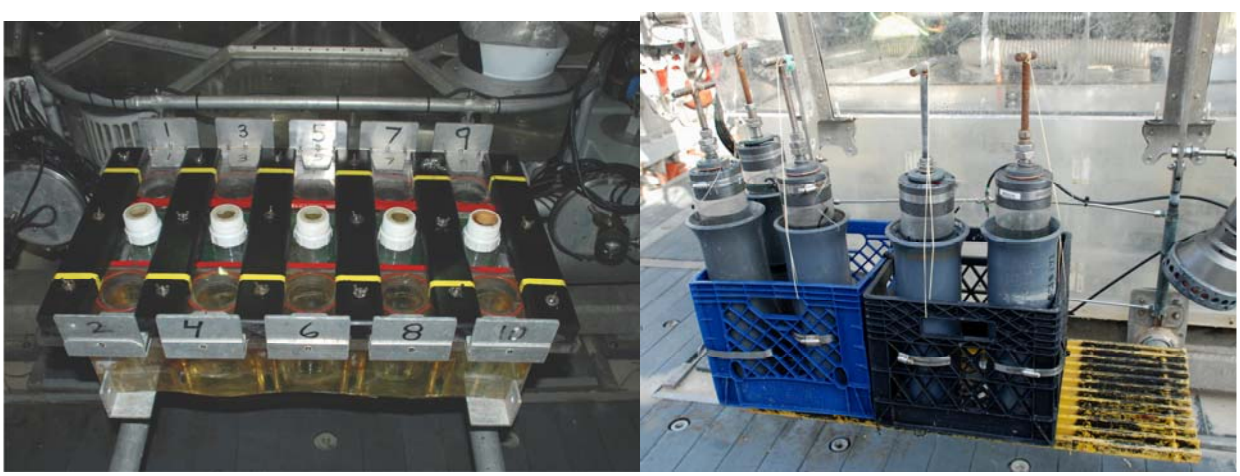


Figure 4. Kellogg sampler (left) for collecting isolated coral samples and push tube cores (right) used for sediment collections. Both are mounted to the bow of the JSL submersible.

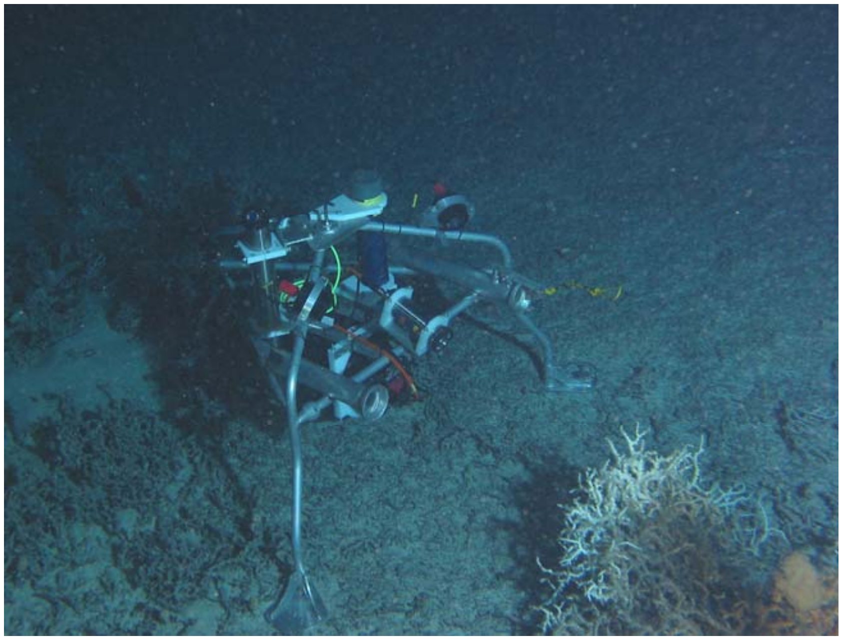


Figure 5. Roberts microlander on bottom in about 750 m (9 Aug 09) positioned by JSL submersible to record time lapse video with infrared lighting of activity around a small coral colony. Lander also measures bottom currents, temperature and salinity. See Appendix A.

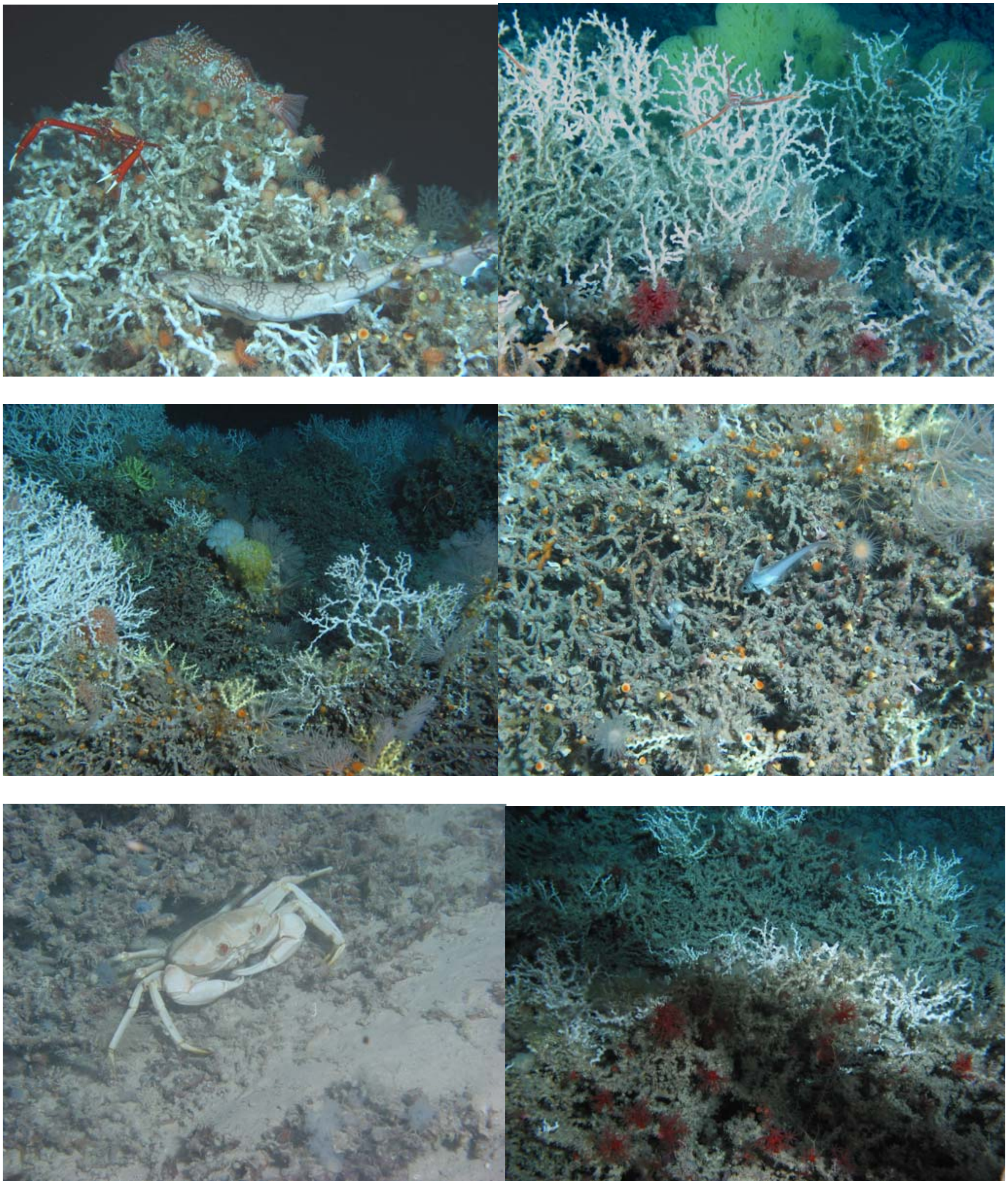


Figure 6. Selected photographs of habitat and fauna on deep coral banks off Cape Canaveral, FL, 6-17 Aug 2009.

Figure 7. Examples of selected invertebrates and fishes photographed at sea, resulting from various collections, Aug 2009. All photos by Art Howard.

APPENDIX A

Sùil na Mara (Eye of the Sea) Microlander Cruise Report

J Murray Roberts, Scottish Association for Marine Science (SAMS)
16 August 2009

Concept & approach

The Sùil na Mara[1] microlander is a small aluminium framework designed to deploy from manned research submersibles or large ROVs. For the Seaward Johnson cruise 'Revealing the Deep', the system was configured with an infra-red digital video recorder (Kongsberg Maritime 0461-6001), a Doppler acoustic recording current meter (Nortek 6000 m Aquadopp) interfaced with a conductivity-temperature sensor (Valeport miniCT) and a recording hydrophone assembled by Dr. Ben Wilson (SAMS).

The framework was adapted at Harbor Branch Oceanographic Institution in the two days before the cruise began. Two aluminium tubes were welded onto the framework so the microlander could be held firmly in place on the poles that project from the bow of the Johnson-Sea-Link submersible. A hook mechanism was incorporated onto one of these tubes so that the microlander framework could be locked into place over a locking collar bolted around the starboard pole (Fig. 1). A floating rope was attached to this hook allowing the submersible's manipulator arm to attach and lift the hook clear of the locking collar.

The microlander system was designed to deploy on the rough substrata and in the high current velocities associated with cold-water coral habitats. The lander frame forms a tripod structure with the heaviest housing clamped low and directly beneath the apex of the frame so maintaining a stable centre of gravity. The video camera and two infra red lamps face from one side and the two vertical housings, current meter and hydrophone, are clamped vertically on either side of the centre point.

Fig. 1: Photographs showing the microlander frame about to be lifted onto the poles projecting from the bow of the JSL submersible and the hook mechanism that locked the frame to the submersible.

[1] Scots Gaelic for 'Eye of the Sea'

Microlander deployment & recovery

The two microlander deployments are summarised in Table 1. During the first recovery dive the front right leg (as one faces the camera) was bent slightly outwards and one of the infra red lamp brackets slightly bent. During the second deployment dive the rear leg was badly bent in towards the large black DVR housing. This happened while a sample was being taken earlier in the dive and caused by the submersible inadvertently pushing the lander into the seafloor. During the second recovery the T-bar on the top of the lander became loose making it hard to turn the frame round to face into the submersible.

Dive information	Time	Depth	Comments
Deployment 1	1924	2472 ft	Lander slid from front poles using
Dive #3702	(2324z)	754 m	manipulator to pull rope attached to hook
Pilot: P Sanders	1927		Hook clear of locking collar. Manipulator arm
Scientist: JM Roberts			attached to T-bar on top of frame pulling
8 Aug 2009			lander back
28° 47.5228N	1940		Lander released from front poles
79° 37.3158W	1944		Submersible manoeuvring to pick up lander
	1946		Lander picked up from T-bar
	1947		Lander moved into position approx. 0.5 from a small live *Enallopsammia* thicket
Deployment time	**23 minutes**		
Recovery 1	1840		Preparing to pick up lander with manipulator arm
Dive #3706			
Pilot: D Liberatore	1845		Moving the submersible to pick up the lander
Scientist: MS Nizinksi	1847		Picked up lander to slide onto sub's tubes
9 Aug 2009	1851		Lander on tubes, now need to slide in toward submersible and lock in place
	1854		Lander locked in place
Recovery time	**14 minutes**		
Deployment 2	0944	1615 ft	Lifting hook to release lander. Rope attached
Dive #3713	(1344z)	492 m	to hook breaks.
Pilot: D Liberatore	0948		Attempting to lift hook with manipulator jaws.
Scientist: JM Roberts	0952		Lander released from front poles
13 Aug 2009	0959		Lander set down on seabed
28° 27.5090N	1007		Lander in final position approx. 1 m from live
79° 43.4020W			*Lophelia* thicket. Lander cameras facing 245°.
Deployment time	**23 minutes**		
Recovery 2	1846		Beginning lander recovery. T-bar turns
Dive #3716			making it hard to turn lander to face into
Pilot: C. Caddigan			submersible's poles. Proves hard to attach
Scientist: J Reed			lander as before and eventually it is lifted from the side and held in place with rope and the manipulator arm.
14 Aug 2009	1925		Lander secured.
Recovery time	**39 minutes**		
Total submersible time	**1 h 39 min**		

Table 1: Microlander deployment summary

Recommendations to refine frame design and deployment:

- To increase their strength, cut and re-weld the legs so they descend directly beneath triangular frame rather than flaring beyond.
- Add aluminium plate to cross brace legs against horizontal tubing.
- Replace existing T-bar with a longer stainless steel T-bar or loop that locks firmly into place at the top of the lander frame.
- Strengthen infra red lamp brackets.
- Use stronger rope to form monkey fist on lander's locking hook. Consider replacing with wire rope and small float.

Equipment report

First deployment:

- Digital video recorder successfully logged 19 hours time-lapse video (one frame every 20 seconds).
- Hydrophone contained total of 57 files. The 27 kHz pinger used to help relocate the lander during the deployments was heard throughout deployment. Submersible voice communications and manipulator arm were recorded. There is evidence for other ambient sounds on initial review.
- Current meter recorded full dataset.

Second deployment:

- Digital video recorder failed to write Quicktime movie file, but hard disc contained 75 hidden .ffv files, each approximately the size expected for the video programmed. Since unable to examine these files at sea, a message was sent to the manufacturer for more information.
- Hydrophone contained 48 files, but on initial review no clear sound recording could be heard. Further work required post-cruise.
- Current meter recorded full dataset.

Deployment sites

The first site (754 m depth) was selected for a safe initial microlander deployment and recovery on a predominantly flat seabed that would allow easier submersible access. As a result, the first site had relatively little coral habitat in the vicinity and the bottom was not very topographically complex. By contrast the second site was not only shallower (492 m), but a very much more complex coral habitat. At the second site, the microlander was deployed just beyond the summit of the overall mound. On the southern facing flank of the mound large *Lophelia* colonies formed a series of terraces with dense live polyps facing into the predominant northward-flowing currents. The lander sat beyond the crest of this mound in a small 'valley'. The lower current velocities in the lea of the mound crest were noted during the deployment dive and confirmed by the microlander's current meter data.

Initial results

Digital video recorder deployment 1

The first deployment produced a 19 hour long time-lapse record of the *Enallopsammia* colony. When reviewed quickly at sea the following observations were noted:

- Illumination on the pale, live coral was too intense slightly overexposing the live coral. Lamps to be turned further to feather the lighting across the subject in the next deployment.
- Resolution of the individual frames is not good enough to discriminate anything but the largest animals. For example, although small crustaceans can be seen moving within the coral framework it is hard to identify what these may be.
- The record did however record larger animals, such as the golden crab in the example images below (Fig. 2).

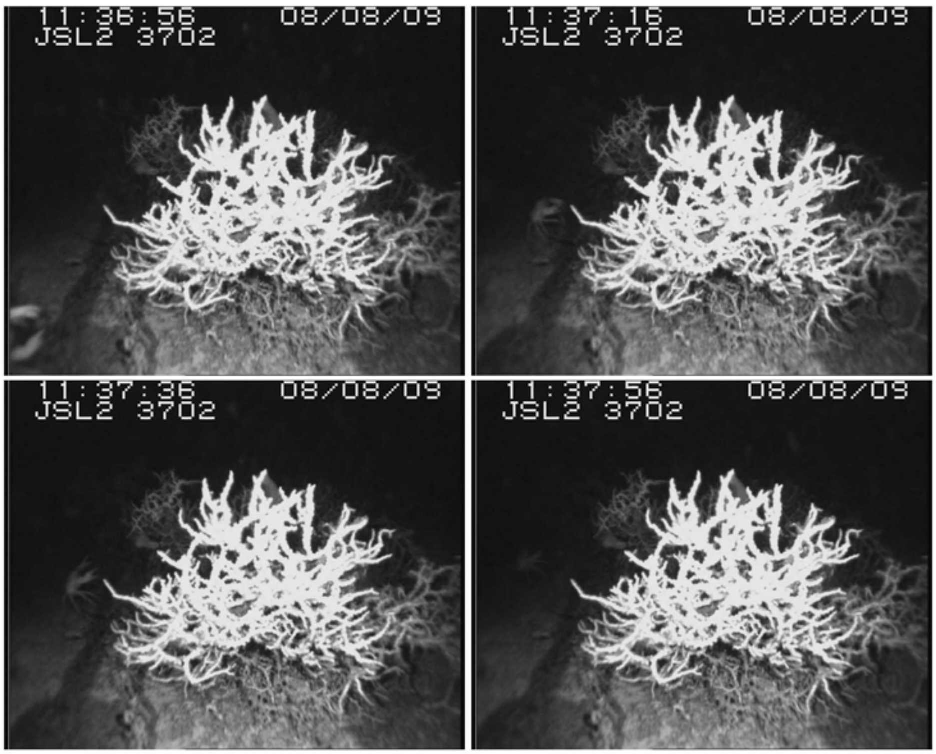


Fig. 2: Four images taken over one minute showing live *Enallopsammia* colony illuminated with infra red light. A large golden crab (probably *Chaceon fenneri*) can be seen moving past the colony on the left hand side of the image.

Current meter deployment 1

The current meter recorded a minimum flow of 10 cm s^{-1}, a maximum flow of 46 cm s^{-1} with a mean velocity of 26.5 cm s^{-1}. Residual flow was strongly unidirectional to the NNE, reflecting predominant influence of the Gulf Stream. There was evidence for clear periodicity in pressure (6 hourly) indicating evidence of semi-diurnal tidal signature. Over the last 12 hours of the deployment pressure dropped noticeably and water temperature increased by 1°C. Examples of these data are given in Fig. 3.

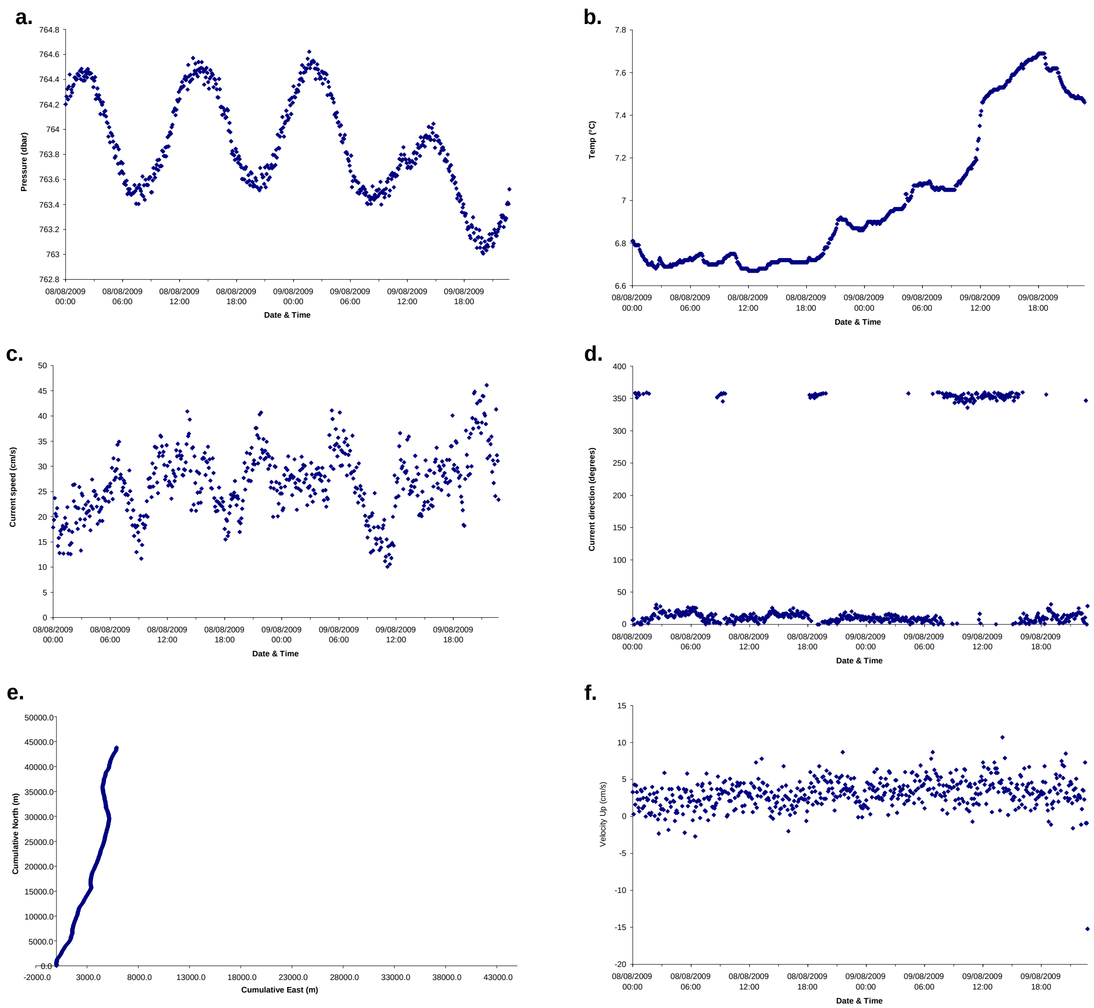


Fig. 3: Summaries of current meter data from first microlander deployment (dive #3702). (a) Pressure; (b) Temperature; (c) Current speed; (d) Current direction; (e) Cumulative vector diagram; (f) Upward current velocity.

Current meter deployment 2

The current meter recorded a minimum flow of 0.1 cm s^{-1}, a maximum flow of 12.5 cm s^{-1} with a mean velocity of 5.6 cm s^{-1}. The cumulative vector diagram shows a more variable flow with a residual direction to the south and east. The differences between this and the first deployment are likely to reflect to very different settings of the two deployments; the first made on a relatively open, flat expanse of seabed exposed to predominantly northward-tending flow, the second in the lea of large coral colonies in an area likely to be far more locally turbulent. This interpretation is borne out by comparing the upward velocity data from the first site (Fig. 3f, relatively constant data), with that from the second (Fig. 4f, highly variable data). Interestingly there is some initial evidence for a positive correlation between upward velocity and temperature (Fig. 5) and further analysis is required to investigate this further.

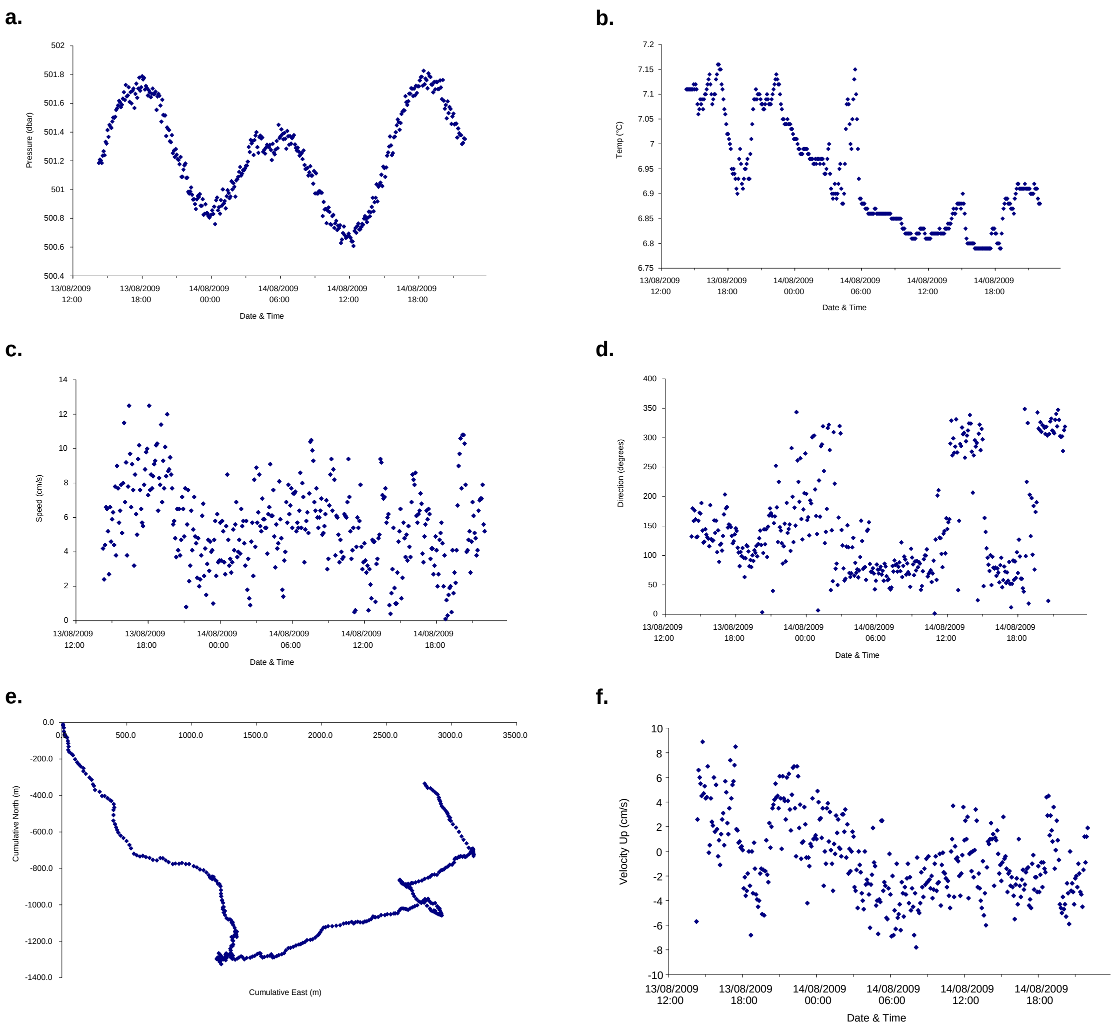


Fig. 4: Summaries of current meter data from second microlander deployment (dive #3713). (a) Pressure; (b) Temperature; (c) Current speed; (d) Current direction; (e) Cumulative vector diagram; (f) Upward current velocity.

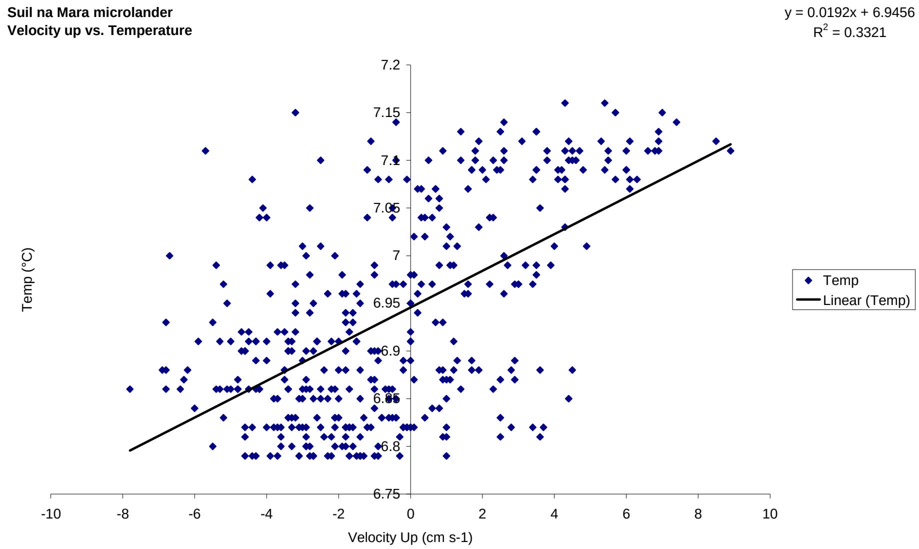


Fig. 5: Relationship between upward velocity and seabed temperature recorded during second microlander deployment (dive #3713).

Conclusions

Immediately after this cruise the microlander frame will be repaired and strengthened as outlined above. Work will continue to refine these initial data interpretations and attempt where possible to link the hydrographic, acoustic and visual information. The contrasting hydrographical regimes of the two deployment sites will allow comparisons of these two areas to be drawn.

Acknowledgements

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