Final Report: NJ Sea Grant Development Project R/6005/0002

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"Underwater survey and mapping of temperate artificial and natural reef habitats for modeling of productivity and trophic linkage to black sea bass and tautog fisheries."

Statement of the Problem:

One of the main functions for artificial reef development in New Jersey and throughout the country is to enhance sport fisheries. The goal of this pilot project was to survey and map artificial reef habitats for the purpose of developing an ecological model for use in evaluation of reef functions. Surveys were undertaken using advanced technology sonar and a remotely operated vehicle (ROV) with sonar and video capability recently acquired through a National Science Foundation grant to the PI's. Accurate distribution of organisms and habitat utilization maps will facilitate the development of an ecological model that can be used to assess the function of artificial reefs of varying structure. Development and testing of an ecological model will allow comparison of different types of artificial reefs and assess the idea that they enhance local productivity.

Objectives

1. Map the reef sites with geo-referenced images using side scan sonar.
2. Produce video of the reef sites to capture attached and mobile species (particularly black sea bass and tautog) use of the sites to quantify the habitat usage and to identify structures and correlate with sonar image maps.
3. Collect physical data such as salinity, temperature, pH and primary production on the reef as chlorophyll (for phytoplankton) using sensors attached to the ROV.
4. Synthesize the physical, biological and oceanographic data to develop a conceptual ecological model of the habitat that can be used to inform data collection to model the actual productivity determinants of the reef habitat.
5. Disseminate results of this study to scientific and public stakeholders.

Methodology

The site selected for this pilot study is the Little Egg (LE) Reef, a part of the New Jersey Department of Environmental Protection (NJDEP) Artificial Reef Program (Fig. 1). This reef is

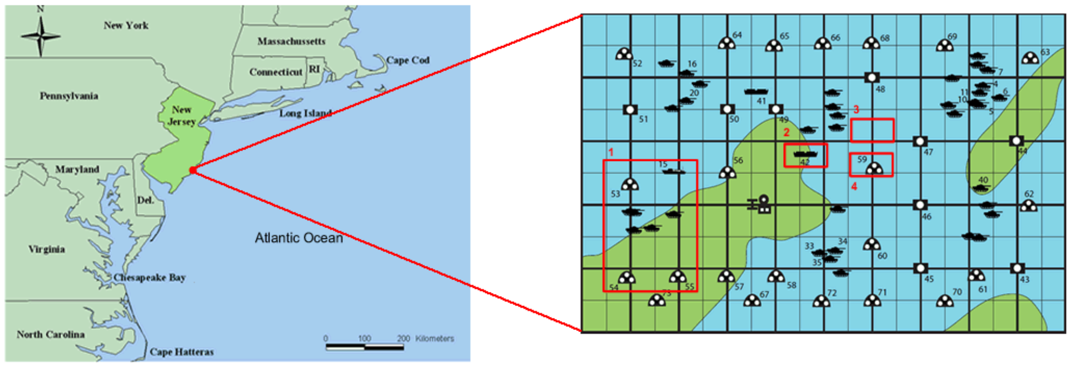

Fig. 1. NJ DEP, Little Egg (LE) reef off the coast of Little Egg inlet, NJ. Boxed areas were more intensively investigated.

convenient to access from Stockton's marine field station (~8 Km offshore), relatively shallow (~20 m) and close to historic monitoring stations at the Rutgers Marine Field Station (LEO 15) and Buoy 126 (just inside LE Inlet) a long term and active water quality monitoring station of the Jacques Cousteau National Estuarine Research Reserve (JCNERR). Stockton's R/V *Gannet* was the platform for the work and used to deploy the ROV *Shearwater*. Surveys were undertaken using a suite of technologies including digital side scan sonar (Klein 3900) and a remotely operated vehicle with sonar and video capability (SeaBotix LBV 300s[6]) and an attached YSI water quality sonde capable of measuring dissolved oxygen, pH, salinity, depth and chlorophyll A (Fig. 2).

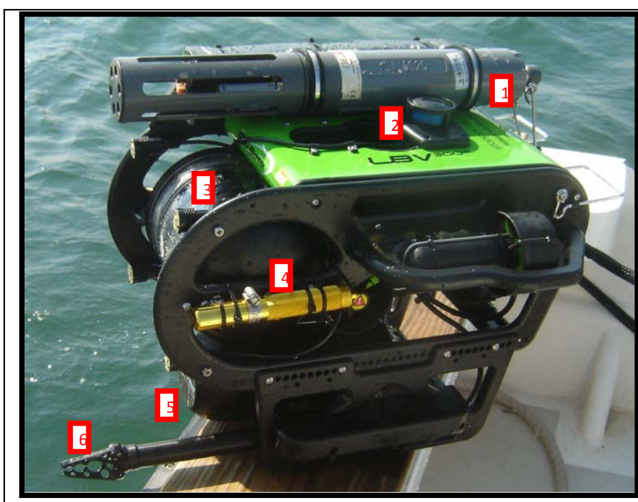

Fig. 2. Configuration of the ROV Shearwater.

1. YSI 6920 Water monitoring instrument: temperature, salinity, dissolved oxygen, pH and chlorophyll *a*.

2. Ultra Short Baseline tracking system: allows for spatial tracking of the vehicle at all times

3. Video cameras: two cameras are housed inside the view port. A B/W camera is used in most low light conditions. A color camera, capable of zooming to a few inches and further enhanced by external LED lighting and LYNN image software to increase image clarity.

4. Laser scaling: paired red-light underwater lasers to allow for measurements of targets captured in video.

5. Forward scanning sonar: BlueView130 degree forward-scanning, 900 kHz sonar for imaging, navigation and collision avoidance.

6. Grabber attachment: interchangeable tool heads

Outcomes

Objective 1. Map the reef sites with geo-referenced images using side scan sonar. In order to define the study site precisely, side scan sonar was used to characterize the LE reef study site. Data was collected with a Klein 3900 digital side scan sonar towfish and bottom swaths were post-processed in Chesapeake Sonar Whiz to mosaic the swaths into a map that overlaid the nautical chart for the area (Fig. 3). Since the side scan swaths were geo-referenced, the map locates the various subsea structures precisely and will allow us to produce overlay layers of physical and biological data.

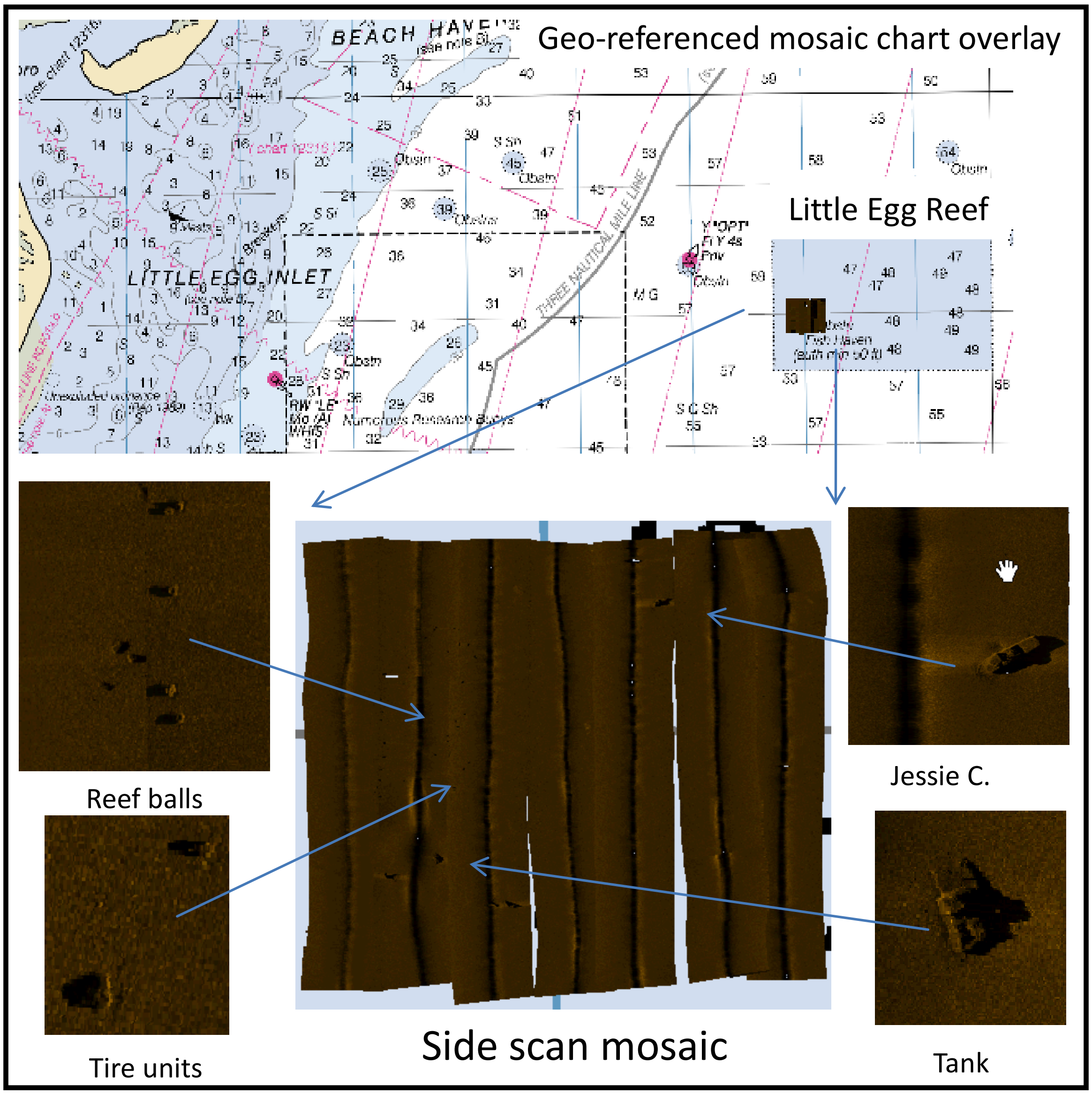

Fig. 3. Little Egg Reef study site chart with a mosaic of side scan sonar bottom swaths (enlarged in insets for bottom structure details).

Outcomes-Objective 2. Produce video of the reef sites to capture attached and mobile species (particularly black sea bass and tautog) use of the sites to quantify the habitat usage and to identify structures and correlate with sonar image maps

Biological Survey Results: Small, lower cost, ROVs (such as the ROV Shearwater) are revolutionizing access to important fishery habitats located between shallow near-shore zones easily accessible by SCUBA and deep-water sites more suitable for working class ROVs (Pacunski *et al*. 2008). Many New Jersey artificial reefs (small tanks and workboats, concrete castings, reef balls) occupy these shallow-to-intermediate depths that limit SCUBA bottom-time and are frequently of a scale not amenable to traditional line transects (i.e. discrete structures with organisms aggregating at different depth intervals).

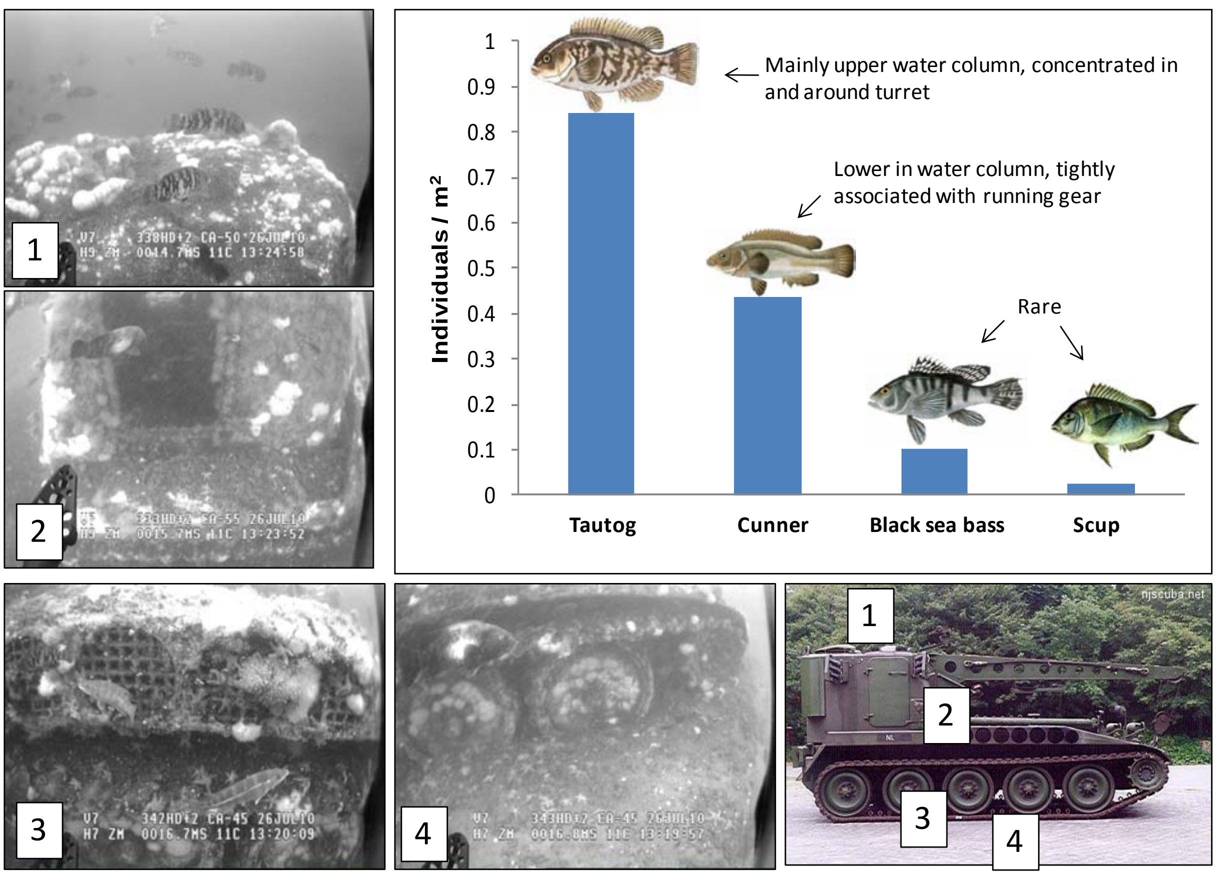

Fig. 4. – Results of M578 armored recovery vehicle preliminary survey with ROV Shearwater (July 26, 2010, Little Egg Artificial Reef) for four common reef species. Numbered “habitat” boxes refer to details.

Where transects were not appropriate, point count methods (modified Bohnsack and Bannerot diver method; Bohnsack and Bannerot 1986) were used to efficiently survey reef fishes and associated invertebrates outside, above, and inside a given structure within a predetermined volume of water column (Patterson *et al*. 2009). This method generally involves constructing a virtual cylinder around a given habitat and pivoting the ROV at fixed locations to conduct fish counts. The actual diameter and shape of the cylinder may vary somewhat depending on the type of structure being sampled (i.e. tank vs. reef ball vs. casting) – regardless, this methodology allows one to quantitatively calculate fish abundance (which can then be compared to other sampling dates, sites, structures, etc.). A "tiered" approach with respect to the height of the ROV reduces the likelihood of "double counts" (as opposed to simply circling the structure with the unit or running multiple, line transects at a fixed depth). A laser scaling system was incorporated to collect fish length data or size information of the structure itself.

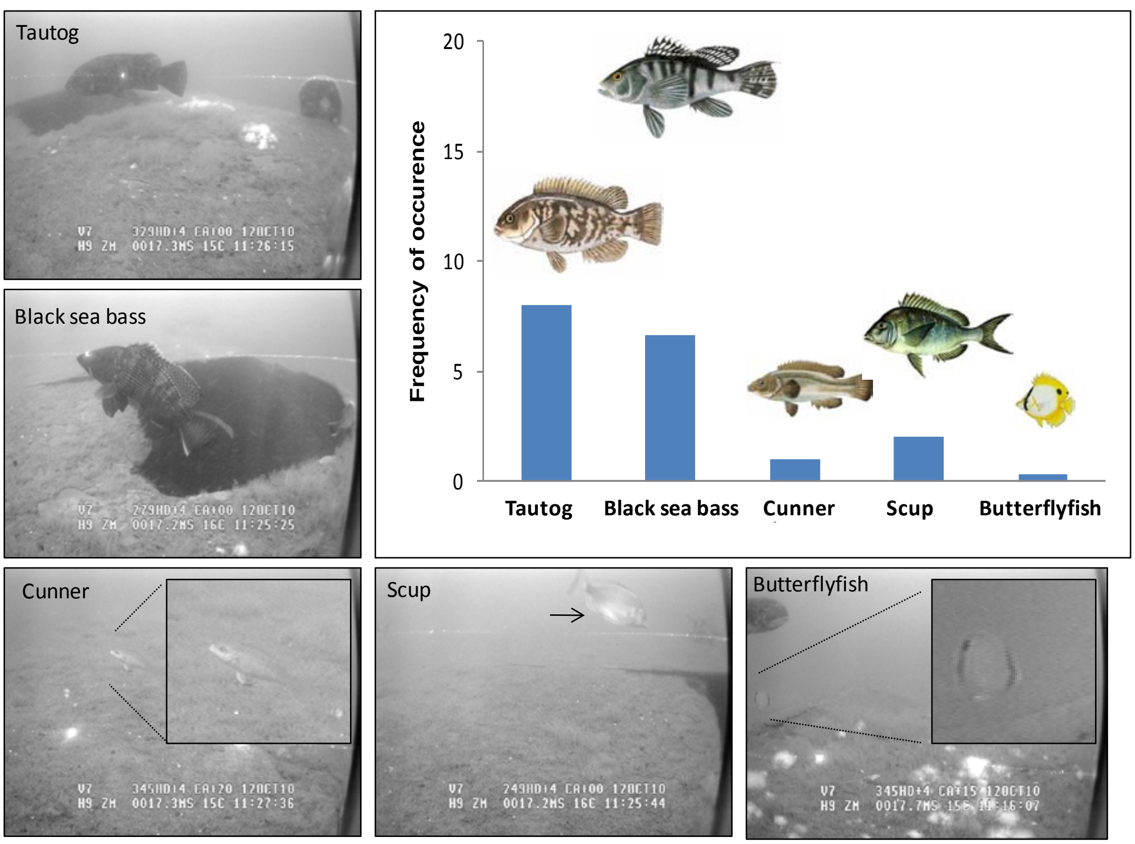

Fig 5. – Results of Southwick's Barge survey with ROV Shearwater (October 12, 2010, Little Egg Artificial Reef). Digital video stills of each species are shown for reference purposes.

Both techniques proved to be minimally invasive and allowed for multiple, rapid, cost effective surveys throughout the sampling season (in some cases capturing multiple life stages of a given species – i.e. juvenile, male and female adults - Fig. 6). With respect to the armored recovery vehicle, tautog (above turret) and cunner (alongside running gear) showed clear preferences for different regions of the overall structure (Fig. 4). The armored recovery vehicle generally harbored more attached organisms than Southwick's Barge and displayed a higher concentration of fish as well.

A "proof of concept" inventory using a modified version of this technique (two tiers only) was conducted on an M578 armored recovery vehicle on July 26, 2010 (Little Egg Artificial Reef, New Jersey – Fig. 4). In this instance, the ROV Shearwater was initially flown ~1 m above the seafloor and pivoted ~180 degrees to survey fishes in and around the tank's running gear. A second segment was recorded ~1 m above the turret to capture individuals aggregating further away from the structure in the water column. This survey captured high quality video that was later quantified frame-by-frame in the laboratory (Fig. 4).

Fig 6. – Top (left to right): Multiple life stages of black sea bass imaged by the ROV Shearwater (October 12, 2010, Southwick's Barge, Little Egg Artificial Reef). Note paired lasers in upper right frame. Bottom (left to right): Still images from M578 armored recovery vehicle survey (July 26, 2010, Little Egg Artificial Reef).

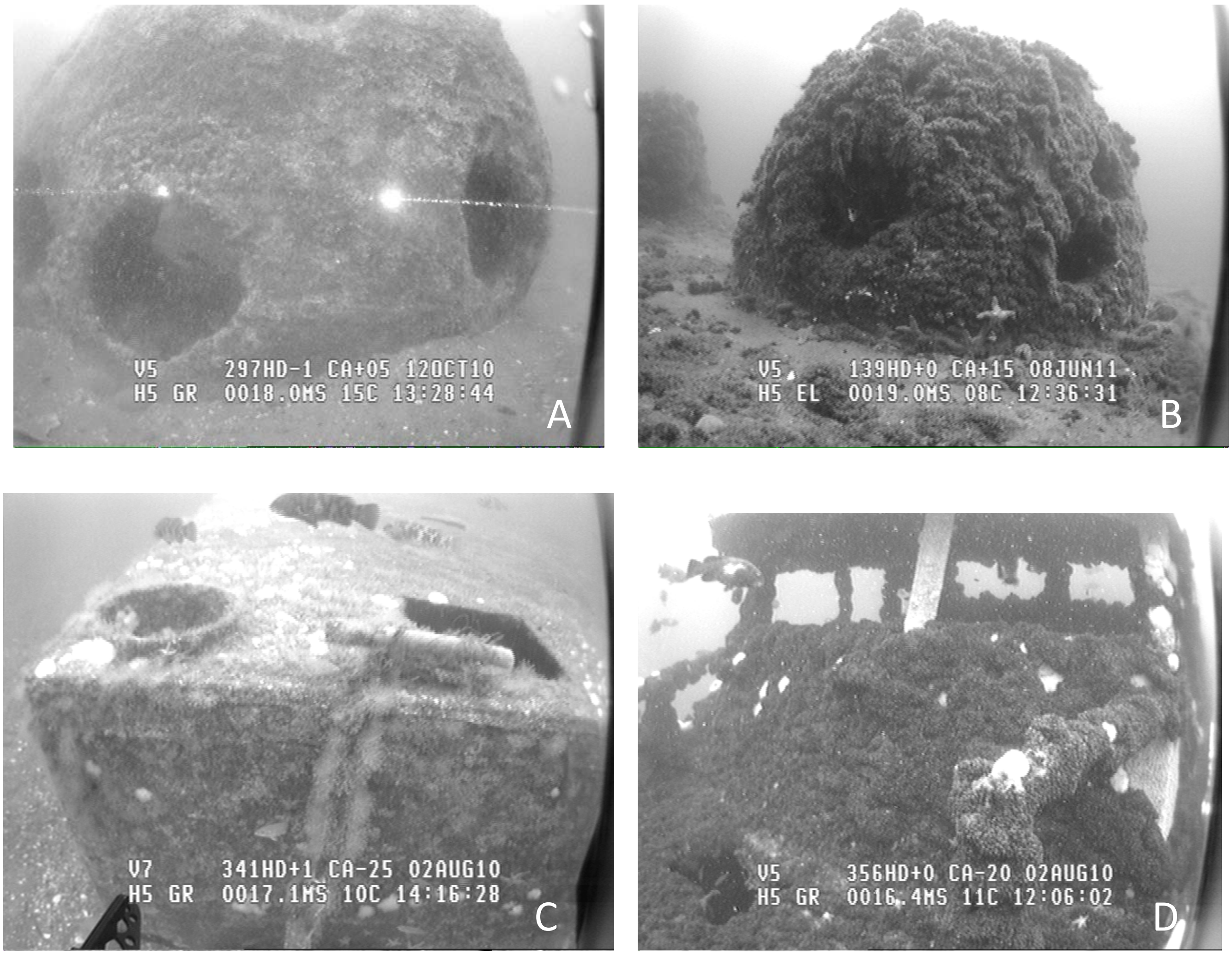

Fig. 7. Distribution of organisms on the Little Egg reef structures is patchy. A and C are Reef ball and barge (Southwick's) structures from the northeast central part of the reef. B & D are reef ball and deck boat (Jessie C) from the southwest corner of the reef. B & D are heavily encrusted with blue mussels and other sessile invertebrates and appear to attract larger concentrations of fish.

Due to the flat, elongated nature of the structure, a more traditional ROV transect survey was conducted at Southwick's Barge on October 12, 2010 (Little Egg Artificial Reef, New Jersey – Fig. 5, 6). In this case, average frequency of occurrence was calculated over three discrete digital video intervals.

Point counts were also made at reef ball sites and on the Jessie C. crew boat site within the Little Egg Artificial Reef system. Reef balls in general were highly variable in terms of attached epifauna (see Fig. 7 A vs. B reefballs) and fish diversity (tautog, black sea bass, cunner, etc.). Compared with the barge structure (see Fig 7 C), the Jesse C crew boat (see Fig 7 D) was very highly productive of mussels, and other attached sessile invertebrates and also harbored a much larger concentration of tautog and black sea bass. More work needs to be done to identify the exact sources of this variability (i.e. seasonality, local currents, nutrients, soak time, location, etc.).

Outcomes Objective 3. Collect physical data such as salinity, temperature, pH and primary production on the reef as chlorophyll (for phytoplankton) using sensors attached to the ROV.

During the 2010 sampling season a YSI 6600V2-4 was used to collect data during ROV flights over the LE Reef site. Data was recorded every 15 seconds for depth, DO, Chlorophyll, salinity, temperature and pH. Data graphs in Figure 8 have been trimmed to remove the vertical profiles attributed to the descent and ascent of the ROV and to highlight data recorded while on or near the bottom and the reef structure being observed. Areas within the data sets shown in Figure 8 where the vehicle did ascend above the structure clearly show changes in all observed parameters demonstrating the instrument's capability to record fine scale data near artificial reef structures. Of particular interest are changes in DO and chlorophyll concentrations that may be attributable to varying respiration rates of organisms utilizing the reef structures as well as the community of primary producers that may be associated with shallower reef systems.

Outcomes Objective 4. Synthesize the physical, biological and oceanographic data to develop a conceptual ecological model of the habitat that can be used to inform data collection to model the actual productivity determinants of the reef habitat.

In order to build a conceptual framework for our studies of the LE reef ecosystem, we recruited Dr. Jessie Jarvis, a new Assistant Professor of Marine Science at Stockton. Dr. Jarvis has a good modeling background and working off of our observations and intent, she was able to produce a conceptual production model of the reef ecosystem (Fig. 9.) which serves to synthesize our salient observations and points to a comprehensive approach to data collection that we can pursue to build a working model of reef production. This model of reef production can then be

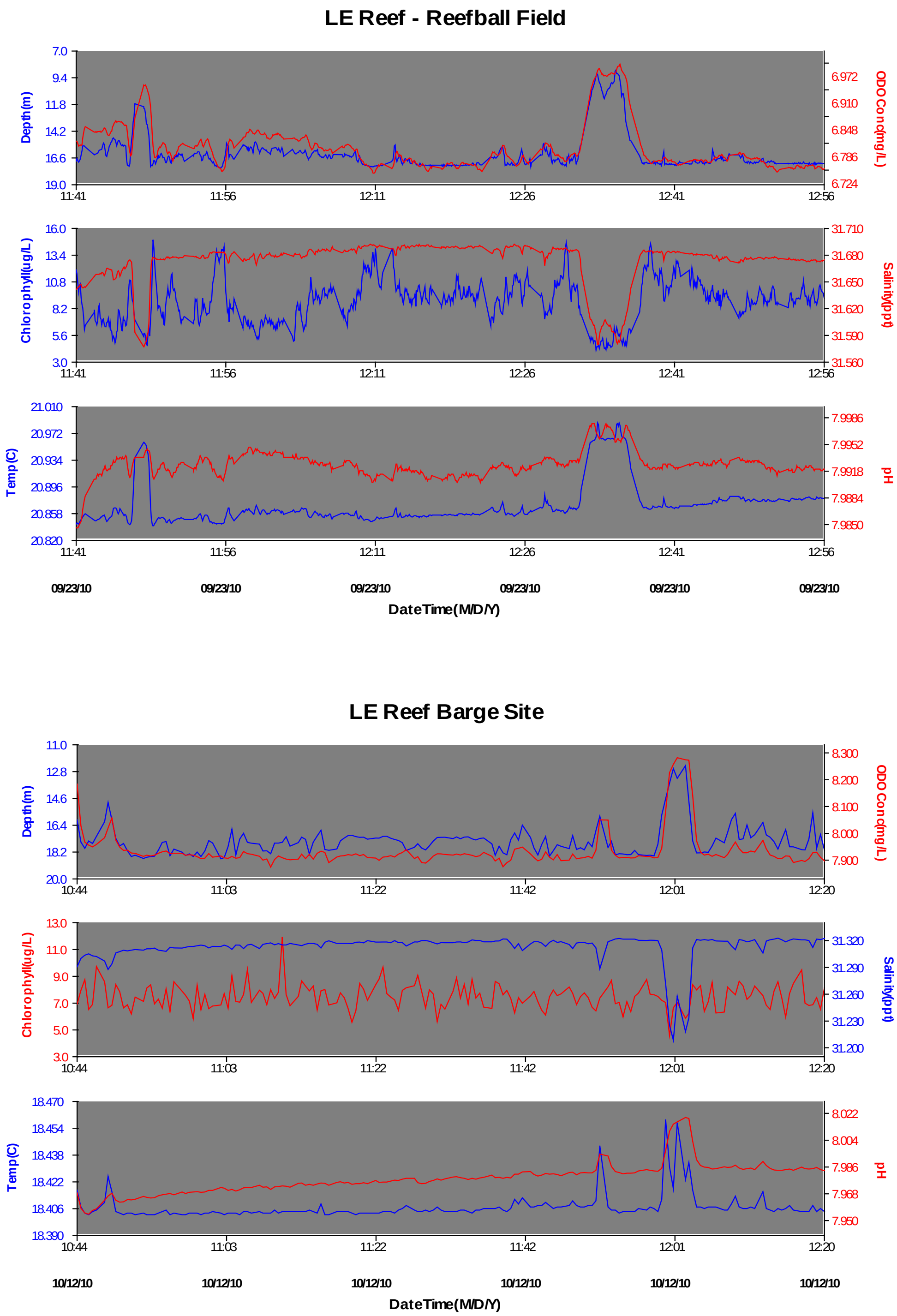

Fig. 8. Data from YSI 6600 V2 water quality sonde deployed on the ROV *Shearwater*at the LE reef site over a reefball field and the Southwicks barge. Data reduction and graphing in YSI ecowatch software.

used to develop a model of fish production (Fig. 10) which would tie together the physical data, primary production, prey secondary production and ultimately fish production. In our recent New Jersey Sea Grant omnibus submission, “From Primary Production to Fish Production: Understanding the Functional Role of Artificial Reefs in Coastal New Jersey Food Webs,” we have proposed to do this.

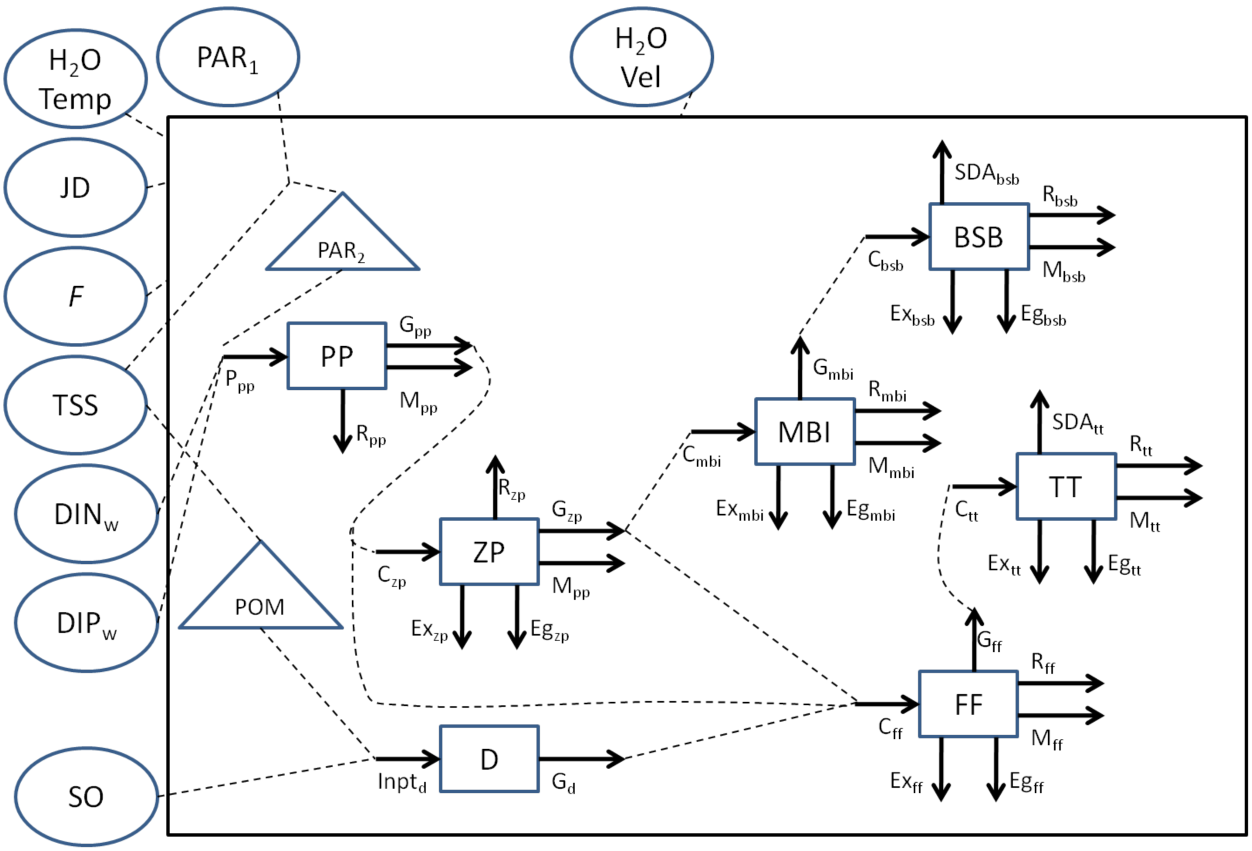

Fig. 9. Conceptual diagram for artificial reef production model. circles = forcing functions, triangles = modifiers, squares = state variables, thick arrows = flows, and dashed lines = interactions. Forcing functions include H_2O vel = water velocity, PAR_1 = ambient light (µmol m^{-2} s^{-1}), H_2O temp = water temperature (°C), JD = Julian day, *F* = photoperiod, TSS = total suspended solids (mg L^{-1}), DIN_w = dissolved inorganic nitrogen in the water column (µmol L^{-1}), DIP_w = dissolved inorganic phosphorus in the water column (µmol L^{-1}), and SO = sediment organic content (%). Modifiers include PAR_2 = modified light (µmol m^{-2} s^{-1}) and POM = particulate organic matter (mg L^{-1}). State variables include PP = phytoplankton, D = detritus, ZP = zooplankton, FF = benthic filter feeders, MBI = mobile benthic invertebrates, TT = tautog, amd BSB = black sea bass. Carbon flows include P_n = photosynthesis, G_n = grazing, R_n = respiration, M_n = mortality, C_n = consumption, Ex_n = excretion, Eg_n = egestion, and $Inpt_d$ = input.

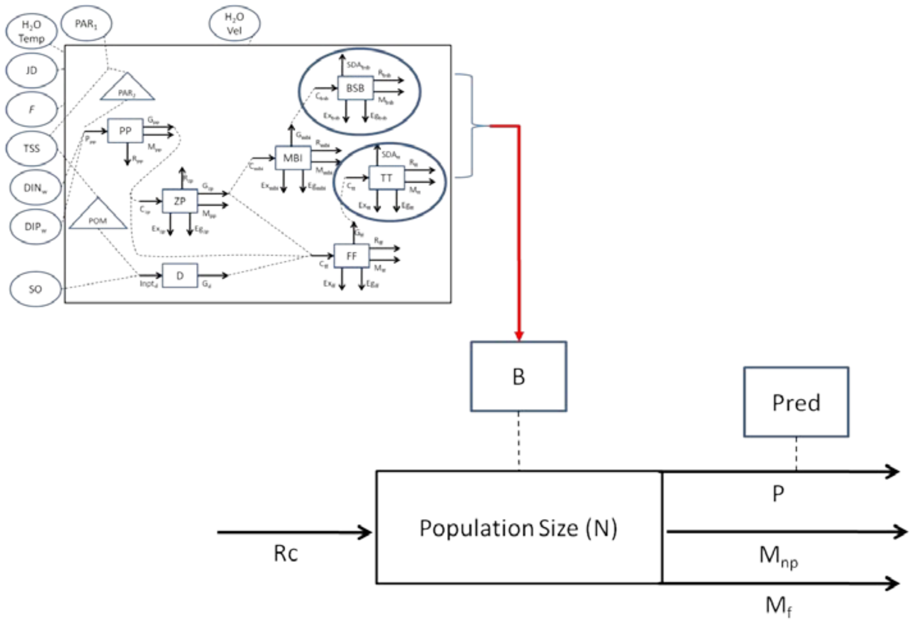

Fig. 10. Conceptual diagram for the combined reef production and population models. circles = forcing functions, triangles = modifiers, squares = state variables, thick arrows = flows, red line = flow from production to population model, and dashed lines = interactions. Production model is defined by B = population biomass, Rc = recruitment, Pred = predator abundance, P = predation, M_{np} = non-predation mortality, and M_f = fishing mortality. Modified from (Latour *et al*. 2003).

Outcomes Objective 5. Disseminate results of this study to scientific and public stakeholders.

Outcomes for this objective are two scientific presentations, four public outreach activities, inclusion of information in a large number of classes at Stockton, submission of an omnibus grant application to NJ Sea Grant and dissemination through a Sea Grant page on our underwater sciences website.

Scientific Presentations:

Straub, P. F., S. P. Evert, T .L. Harmer Luke and M.C. Sullivan (2011). Acoustic and video evaluation of coastal habitats by side scan sonar coupled with remotely operated vehicle (ROV) survey. Coastal and Estuarine Research Federation Conference: Societies Estuaries and Coasts; Adapting to Change. November 6-10. Daytona, Beach, FL. (oral presentation abstract accepted).

Straub, P. F., S. P. Evert, T. L. Harmer Luke and M. C. Sullivan (2010). Evaluation of coastal artificial reef habitats by remotely operated vehicle (ROV) surveys. Atlantic Estuarine Research Society, Kitty Hawk, NC. November 4-6. Fall Meeting Abstracts p. 24. (poster presentation abstract)

Public Outreach Activities

Long Beach Island Arts and Sciences Foundation, Loveladies, NJ
Science Saturday Series, March 26, 2011
Public presentation: "Side Scan Sonar and Remotely Operated Vehicles: Applications for Coastal Research" Steven Evert
http://www.youtube.com/watch?v=NTK_iuhWRoI&feature=related

NJSG Coast Day, October 10, 2010
Cape May, NJ
Public Presentation, Video and ROV. Steven Evert, Peter Straub, Mark Sullivan.

NJSG Ocean Fun Days, May 22, 2011
Island Beach State Park, Seaside Heights, NJ
Public presentation, Video and ROV, Steven Evert, Peter Straub, Tara Harmer Luke.

Greater Egg Harbor School District
Professional Development Program, June 24, 2011
Richard Stockton College Marine Field Station, Steven Evert, Tara Harmer Luke, Mark Sullivan
K-12 teacher conference presentation, 24 teachers

Richard Stockton College of NJ
Marine Science and Environmental Field Station
Course lectures:
S. Evert: Oceanography, Marine Geology, Introduction to Marine Biology, Coastal Processes
M. Sullivan, Ichthyology, Introduction to Marine Biology.

P Straub, Underwater Science & Exploration, Summer Intensive Research Experience: NJ Benthic Studies.
T. Harmer Luke, Deep Sea Biology

Websites

Websites listed below have links to video data, instrumentation, posters and other relevant information about the development project.

Stockton underwater science main page
http://stockton-underwater-science.pbworks.com/w/page/10226064/FrontPage

Stockton underwater science NJ Sea Grant research pages
http://stockton-underwater-science.pbworks.com/w/page/42081782/NJ%20Sea%20Grant%20Research

NJ Sea Grant Omnibus Submission

Based on data and hypotheses generated from our development grant, we have submitted an omnibus grant application to NJ Sea Grant for this reef work. In particular, we recruited a production modeler, Dr. Jesse Jarvis (as stated above) and also a hydrodynamic modeler, Dr. Russ Manson. Given the patchiness of production on the reef we were especially interested in looking at local hydrodynamic conditions (currents and tides) and their effects on productivity.

From Primary Production to Fish Production: Understanding the Functional Role of Artificial Reefs in Coastal New Jersey Food Webs," PI's, Peter Straub, Mark Sullivan, Tara Harmer Luke, Steven Evert, Jessie Jarvis and Russell Manson. May, 2011.

Literature Cited

Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Technical Report. 18 pp.

Latour, R.J., M.J. Brush, and C.F Bonzek,. 2003. Toward ecosystem-based fisheries management. Fisheries 28(9):10-22.

Pacunski, R.E., W.A. Palsson, H.G. Greene, and D. Gunderson. 2008. Conducting visual surveys with a small ROV in shallow water. In: Marine Habitat Mapping Technology for Alaska. Alaska Sea Grant College Program, University of Alaska Fairbanks, pp. 109-128. http://doc.nprb.org/web/research/research%20pubs/615_habitat_mapping_workshop/Individual%20Chapters%20High-Res/Ch8%20Pacunski%20et%20al.pdf

Patterson, W.F., M.A. Dance, and D.T. Addis. 2009. Development of a remotely operated vehicle based methodology to estimate fish community structure at artificial reef sites in the Northern Gulf of Mexico. Proceedings of the 61st Gulf and Caribbean Fisheries Institute: 263-270. http://uwf.edu/wpatterson/Patterson%20et%20al.%202009.%20ROV%20sampling%20methods.%20%20GCFI.pdf

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