Research and Monitoring Accomplishments that Demonstrate Value of Oculina HAPC and OECA Management Actions

• Visual surveys by technical divers in March-April 2008 aboard the NASA vessel, Liberty Star provided evidence that two high-relief *Oculina* bioherms (Jeff's Reef and part of Chapman's Reef complex) remain relatively undamaged from trawling within the OECA. However, trawl damage is evident through the center of the intact part of Chapman's reef where Artificial Reef Blocks have been broken and scattered (C. Koenig, pers. comm.).

• Visual surveys ROV in 2011 aboard the NOAA Ship Pisces confirmed the integrity of the Jeff's Reef, Chapman's Reef complexes. Partially intact Artificial Reef Blocks were found and while the donor *Oculina* colonies were absent, many newly recruited colonies were present on the structures.

• Visual surveys provided new data showing extensive areas of various habitat types north of the OHAPC including the following:

1) Dense high-relief *Oculina* bioherms with relief of 15-20 m, covered with coral rubble and sparse intact standing coral
2) Isolated *Oculina* coral thickets on low-relief bottom, especially along scour zones
3) Plains of low-relief coral rubble
4) Extensive areas of moderate (1-3 m) to high (>3 m) relief live-bottom ridges extending through the North Florida Deep-Water MPA and southward towards the OHAPC.

• Discovery of these new *Oculina* bioherms led the SAFMC to extend the boundaries of the protected area northward and westward of the previous locations. Recent deepwater scientific exploration and research have identified areas of high-relief coral mounds and hardbottom habitat outside the boundaries of the existing OHAPC. In October 2011, the Coral AP recommended to the SAFMC the new boundary proposals. The SAFMC reviewed the recommendations and associated Vessel Monitoring System (VMS) analyses of rock shrimp fishing activity for the expansion of these areas, and approved the measures for public scoping through the Comprehensive Ecosystem-Based Amendment 3. The Coral, Habitat, Deepwater Shrimp and Law Enforcement APs developed and refined recommendations and provided input to the Council. During the June 2012 meeting, the SAFMC moved these actions from the Comprehensive Ecosystem-Based Amendment 3 to Coral Amendment 8. In September 2013, the SAFMC took all of the AP's recommendations into consideration and approved the preferred alternatives for the Amendment 8. The amendment was formally submitted to NMFS on November 26, 2013 and remains under review by the Secretary of Commerce. It is expected that the Amendment 8 may be published by April 28, 2014.

The *Oculina* HAPC West proposal was based in part on new data compiled from ROV and multibeam surveys assessing *Oculina* habitat and associated fish populations (Harter et al.

2009). The *Oculina* HAPC North proposal was based in part on new data collected from ROV and multibeam surveys with the NOAA *Pisces* ship in 2011. These data confirmed that the high-relief features evident on regional NOAA bathymetric charts are in fact *Oculina* coral mounds—these extend from the current northern boundary of the OHAPC up to approximately 29^{o} 44'N. These proposals were reviewed by the SAFMC Coral AP, Deepwater Shrimp AP, Habitat AP in determining the exact boundaries.

• In 2000 and 2001, a total of 205 reefballs and 900 small modules were deployed (50% with coral transplants) in the Sebastian Pinnacles area of the OECA (PI C. Koenig, FSU). In April-May 2008, a series of restoration modules were surveyed by C. Koenig and S. Brooke using a team of technical divers from UNCW and the NASA ship Liberty Star. Although the NURC divers were excellent; dedicated and professional, it was determined that this was not the most appropriate method of surveying the recruitment modules. They are limited by bottom time and are at the mercy of the often very strong currents in this habitat (even with the assistance of scooters) therefore have very limited search and survey capacity. The reefballs at Sebastian Pinnacles that were found did not support enhanced coral or fish populations, but definitive conclusions cannot be drawn because of the small sample size and suboptimal location of those that were observed. Chapman's Reef, while still considered a 'live' habitat, appears to have been impacted (possibly by trawling); coral and reef fish populations were not as prolific as reported in 2001 and recruitment blocks were completely destroyed. There was also a considerable amount of heavy fishing line observed in this area.

• Eleven publications regarding deep-water *Oculina* reefs since 2007.

• Recent visual surveys show increasing numbers of black sea bass within OECA compared to the 2007 Evaluation Report.

• Visual surveys continue to show evidence of fishing line, long line and trawl nets impacting coral habitat within the OHAPC and OECA.

• The consensus of the Research Evaluation Team is the proposal of the Shrimp Advisory Panel to open areas for trawling in the OHAPC/OECA would be extremely counterproductive and would put the few remaining dense stands of *Oculina varicosa* at risk.

• Many of the objectives in below have not been meet due to the lack of adequate funding rather than technical limitations. The Review Team strongly recommends the SAFMC seek further funding to address many of these critical issues.

Current status of specific questions and objectives delineated in the *Oculina* Evaluation Plan

I. Develop a research, monitoring and evaluation component for the *Oculina* Evaluation Plan

1. Will Oculina thicket habitat recover throughout the Oculina Experimental Closed Area without human intervention? What time frame will be needed for significant recovery? Will it be necessary to introduce artificial substrate to serve as an initial settlement surface?

Objective 1: Identify coral/fish recruitment pathways and compare settlement, growth, and survival rates on artificial substrate relative to settlement, growth, and survival rates on nearby unconsolidated coral rubble.

Efforts were undertaken in 2008 to evaluate the condition of Reef Balls and smaller modules deployed in the OECA between 1996 and 2001 as artificial substrate for coral recruitment. In total, 731 concrete experimental modules were deployed in various configurations. Some of these structures had been seeded with donor Oculina colonies harvested outside the OHAPC/OECA. High currents, low visibility and the restricted bottom time of the open-circuit technical divers used to examine the structures combined to degrade the effectiveness of this evaluation. Many of the Reef Balls and other structures had been destroyed or moved since their deployment, the cause of the movement cannot be proven, however, the mass of the Reef Balls suggest they could not have been moved by natural events or recreational fishing activity. A NOAA funded cruise in 2011 aboard NOAA Ship Pisces used an ROV to survey Jeff's and Chapman's Reefs. Two artificial structures were discovered and photographed. The donor Oculina colonies were no longer present, however natural recruits were abundant on the structures (pallets of concrete blocks).

Objective 2: Model biophysical, chemical, and physiological characters. Previous studies have shown the benthic environment of the Oculina reefs to be very dynamic and widely fluctuating due to upwelling events and meandering of the Florida Current.

Newly hired researchers at Florida Atlantic University are actively submitting grant proposals to model the biophysical characteristics of the Oculina Banks.

2. Determine and monitor the effect of the Oculina Experimental Closed Area on fish distribution and status?

Objective 1: Assess spawning aggregations of fishery species.

Spawning aggregations of dominant economically valuable reef fish have not been observed during this evaluation period. Spawning seasonality and lack of funding for Oculina research have been two causes of this outcome. For example, spawning

season for gag is during the late winter, a period when weather conditions often preclude vessel operations. With the difficulties in acquiring ship time, most researchers do not risk scheduling a mission during this time of year as the entire cruise can be easily lost to weather. Recent advances have provided a potential methodology to address this issue however. A buoyed acoustic device could be located on likely spawning aggregation sites and collect data year round for reasonable cost.

Objective 2: Track fish movement

No progress has been made on this objective since 2007. Active telemetry is an option to address this objective. This would require capture and surgical implantation of transmitters in target fishes as well as deployment and recovery of acoustic sensors to monitor fish movements. This procedure has been done in other areas of similar depth, but remains a logistically challenging undertaking.

Objective 3: Identify *Oculina* Experimental Closed Area fish population demographics

A proposal has been accepted by NOAA for FY2014-2016 which will utilize ROV surveys to evaluate fishes and habitat within the OHAPC/OECA. While there are known concerns about observational bias with ROVs and large fishes, this is a cost effective way to survey large areas. Abundance, distribution, size and habitat associations will be determined and compared with other protected and open-to-fishing areas off the Southeastern U.S. coast.

Objective 4: Determine pre-closure distribution of dominant harvested species in and outside the reserve areas, in order to provide historical context for subsequent assessments. Review landings; spillover effects (i.e., identify benthic and juvenile pathways, upwelling events, spill-over between deep and shallow reefs).

Re-examinations of submersible dives conducted during the 1980s may lead to better understanding of pre-closure distributions of dominant fish species, however the 2007 Evaluation team determined the potential information to be gained would not justify the cost and difficulty of this exercise.

Objective 5: Determine age distribution, nursery grounds, migratory patterns, and mortality rates for dominant harvested fish stocks.

This objective has not been addressed due to lack of funding. An appropriate examination of these questions would require very significant funding levels, a

major logistical commitment and would require destructive sampling of many of the remaining reef fish in the OHAPC/OECA.

3. What is the population structure of corals?

Objective 1: Research population genetics of *Oculina varicosa*

[R. Eytan, M. Hayes, P. Arbour-Reily, M. Miller, and M. Hellberg. 2009. Nuclear sequences reveal mid-range isolation of an imperiled deep-water coral population. Molecular Ecology 18:2375-2389.] Nuclear genetic sequences were used to test for population structure in Oculina coral off the southeastern U.S. sampled at 10 locations form North Carolina to the Florida Panhandle. Oculina varicosa from the deepwater Oculina coral banks (>70 m depth) off central Florida should that this was a single population and a strong genetic outlier from the other populations, despite close proximity (<36 km) to other sites. Genetic isolation of the Oculina Banks population suggests that focused efforts will be needed to conserve the foundation species of these monotypic reefs and that depth may play a role in isolating these populations and perhaps facilitating initial steps towards speciation. Although the deepwater Oculina is not considered a separate species, it may be time to push to make these a threatened sub-set of the species.

Objective 2: Identify cross-shelf relationships between shallow and deep *Oculina varicosa* populations.

This objective has not been addressed since the 2007 Evaluation Report.

Objective 3: Biogeography

This objective has not been addressed since the 2007 Evaluation Report.

4. What are the stressors affecting the Oculina Experimental Closed Area?

Objective 1: Identify natural and anthropogenic stressors (i.e., disease, gear impacts, poaching, enforcement)

The 2007 Evaluation Report downgraded this objective to low priority considering the other research needs present in the OHAPC/OECA. Considerable research on coral stressors have been conducted in other locations. It is highly likely corals in the OHAPC/OECA respond similarly and the limited research funds available would be better allocated to other objectives.

[S. Edge, T. Shearer, M. Morgan, T. Snell. 2013. Sub-lethal stress: detecting molecular responses of coral populations to environmental conditions over space

and time. Aquatic Toxicology 128-129: 135-146.] In order for sessile organisms to survive environmental fluctuations and exposures to pollutants and stressors, molecular mechanisms (i.e., stress responses) are elicited. Previously, detrimental effects of natural and anthropogenic stressors on coral health could not be ascertained until significant physiological responses resulted in visible signs of stress (e.g., tissue necrosis, bleaching. In this study, changes in gene expression patterns was used to detect early and sub-lethal effects in scleractinian corals on south Florida reefs. Although all the coral appeared healthy the corals were physiologically compensating for exposure to stressors. This is the first study to detect specific sub-lethal physiological responses to specific environmental conditions that are not visually detectable.

Objective 2: Determine the frequency and severity of sedimentation induced by benthic storms.

A researcher at HBOI/FAU has examined the effect of sedimentation on coral reproductive capacity. Continuous monitoring of environmental conditions, as would be possible with a buoyed instrument package (described above in Question I.2.1 and below in Question II.4.1), would be able to address this objective.

[Brooke S, Holmes M, Young CM (2009) Effects of sediment on two morphotypes of Lophelia pertusa from the Gulf of Mexico. Marine Ecology Progress Series 390: 137–144.] Brooke et al. investigated sedimentation effects on another deep-sea coral, Lophelia pertusa, in the Gulf of Mexico. Impacts on Oculina may be similar.

Objective 3: Identify physiological tolerances of the coral to environmental stressors.

This objective has not been addressed since the 2007 Evaluation Report. This objective could be easily addressed using small colonies or fragments of Oculina varicosa, which is easily obtained from nearshore ledges off central and southern Florida using SCUBA. The Evaluation team recommends increasing the priority of this objective.

5. What are the key trophodynamic functional groups?

Objective 1: Identify food web structure and dynamics.

This objective has not been addressed since the 2007 Evaluation Report. A rudimentary model of food webs in the OHAPC/OECA was described shortly before the 2007 Evaluation Report, see: George, R., T. Okey, J. Reed, R. Stone. 2005. Ecosystem based fisheries management: Food chain models for a northeast Pacific

gorgonian forest, the mid-Atlantic Corner Rise Seamount, and the Florida Oculina reefs. 3rd International Symposium on Deep-Sea Corals Science and Management, Miami, Florida, Abstract Book, p. 139.

6. Develop index of physical and chemical parameters that characterize a healthy *Oculina* coral ecosystem.

Objective 1: Develop index for coral health (including structural damage, recruitment, genetics, physiology, life history)

This objective was determined to be too expensive and logistically unfeasible to be pursued in the 2007 Evaluation Report. It has not been addressed during this evaluation period.

Objective 2: Develop index of community health for entire biota incl. coral (biodiversity, richness, biocomplexity).

This objective was determined to be too expensive and logistically unfeasible to be pursued in the 2007 Evaluation Report. It has not been addressed during this evaluation period.

Objective 3: Determine indicator species that are intimately tied with *Oculina* (invertebrates or vertebrates).

A proposal has been accepted by NOAA for FY2014-2016 which will utilize ROV surveys to evaluate fishes and habitat within the OHAPC/OECA. This multi-year project will directly address this objective.

Objective 4: What is the age of the coral substrate, and geological formations (last 15,000 years) (Death rates)? Also look at associated mollusks and other biota and their changes.

This objective has not been addressed since the 2007 Evaluation Report. Although a complete core of an Oculina bioherm has never been taken, a short core taken during a lockout dive (J. Reed) on the flank of Jeff's Reef revealed a date of ~850 yrs and an estimated age of several thousand years for the bioherm.

Objective 5: Are paleo-data (age) associated with past climate and oceanographic conditions?

This objective has not been addressed since the 2007 Evaluation Report.

Objective 6: Are there other paleo-data from elsewhere in the world that will give perspective on Oculina growth? (ice cores, deep-water sediment cores)?

This objective has not been addressed since the 2007 Evaluation Report.

7. Conduct research on coral feeding ecology.

Objective 1: Define feeding dynamics.

This objective was partially addressed in the following doctoral dissertation but has not been expanded upon since:

Brooke SD (2002) Chapter 3: Growth, energy allocation and respiration. Ph.D Dissertation. Southampton Oceanographic Center, University of Southampton UK. 160pp.

II. Assessment Planning Projects

1. What is the effect of management measures in the *Oculina* Experimental Closed Area on the status of fishery stocks?

Objective 1: Characterize (including distribution and abundance patterns, size and age distribution, spawning aggregation presence, sex ratios, etc.) major fishery species within the *Oculina* Experimental Closed Area compared to reference sites.

A proposal has been accepted by NOAA for FY2014-2016 which will utilize ROV surveys to evaluate fishes and habitat within the OHAPC/OECA. This multi-year project will directly address this objective.

Objective 2: Characterize fish communities, inside and out, including habitat utilization patterns, trophic interactions, ontogenetic changes, predator-prey relationships, etc.

A proposal has been accepted by NOAA for FY2014-2016 which will utilize ROV surveys to evaluate fishes and habitat within the OHAPC/OECA. This multi-year project will directly address this objective.

Objective 3: Connectivity to the broader seascape (larval sources and sinks, spill-over effects).

This objective was partially addressed in the following doctoral dissertation but has not been expanded upon since:

Brooke SD (2002) Chapter 6: Larval dispersal and recruitment. Ph.D Dissertation. Southampton Oceanographic Center, University of Southampton UK. 160pp.

2. What and where are the major habitat types in the *Oculina* Experimental Closed Area, the Oculina Bank Habitat Area of Particular Concern and adjacent hardbottom areas?

Objective 1: Complete high definition bathymetric mapping 1) within the *Oculina* Experimental Closed Area; 2) coral areas adjacent to the Habitat Area of Particular Concern; 3) in Habitat Area of Particular Concern within coral zone 50-100 m; 4) soft bottom habitat east of the coral zone within the Habitat Area of Particular Concern and 5) suspected and known hard coral areas north and south of the Habitat Area of Particular Concern, specifically from Cape Canaveral to the north and from St. Lucie mound and Jupiter Inlet to the south.

A proposal has been accepted by NOAA for FY2014-2016 which will utilize ROV surveys to evaluate fishes and habitat within the OHAPC/OECA. This multi-year project will directly address this objective.

Objective 2: Complete habitat characterization 1) within the *Oculina* Experimental Closed Area; 2) coral areas adjacent to the Habitat Area of Particular Concern; 3) in Habitat Area of Particular Concern within coral zone 50-100 m; 4) soft bottom habitat east of the coral zone within the Habitat Area of Particular Concern and 5) suspected and known hard coral areas north and south of the Habitat Area of Particular Concern, specifically from Cape Canaveral to the north and from St. Lucie mound and Jupiter Inlet to the south.

A proposal has been accepted by NOAA for FY2014-2016 which will utilize ROV surveys to evaluate fishes and habitat within the OHAPC/OECA. This multi-year project will directly address section 1,2, and 3 of this objective. Sections 1, 2, and 3 have also been addressed in Harter, S.L., M.M. Ribera, A.N. Shepard, and J.K. Reed. 2009. Assessment of fish populations and habitat on Oculina Bank, a deep-sea coral marine protected areas off eastern Florida. Fish Bull. 107:195-206.

3. What are the magnitude and causes of changes in habitat structure and functionality over time?

Objective 1: Determine causes and timing of coral death.

This objective has not been addressed since the 2007 Evaluation Report. The 2007 Evaluation Report downgraded this objective to low priority considering the other research needs present in the OHAPC/OECA.

Objective 2: Origin and functional characterization of rubble zone

This objective has not been addressed since the 2007 Evaluation Report. The 2007 Evaluation Report downgraded this objective to low priority considering the other research needs present in the OHAPC/OECA.

4. How do oceanographic conditions and episodic events affect production, coral condition, reproduction and growth?

Objective 1: Quantify the extent, intensity and frequency of episodic events (upwelling, storms, etc.).

This objective has not been addressed since the 2007 Evaluation Report. A benthic lander or mooring with a current meter and Seabird SBE 19 or similar could easily capture these events. The Evaluation Team believes this objective should move up in priority.

Objective 2: Assess the impact of episodic events (upwelling, storms, etc.).

This objective has not been addressed since the 2007 Evaluation Report.

Objective 3: Optimize design of restoration efforts.

This objective has not been addressed since the 2007 Evaluation Report.

Objective 4: Characterize impacts from anthropogenic sources of pollution nutrients/sedimentation).

This objective has not been addressed since the 2007 Evaluation Report.

Publications Concerning the Deep-water Oculina Reefs from 2007 to present.

(in descending order by year)

1) Reed, J.K., C. Messing, B. Walker, S. Brooke, T. Correa, M. Brouwer, T. Udouj, and S. Farrington. 2013. Habitat characterization, distribution, and areal extent of deep-sea coral ecosystem habitat off Florida, southeastern United States. Journal of Caribbean Science 47: 13-30.

2) Reed, J.K. and S. Farrington. 2010. Distribution of deep-water commercial fisheries species-golden crab, tilefish, royal red shrimp- in deep-water habitats off eastern Florida from submersible and ROV dives. South Atlantic Fishery Management Council and NOAA National Marine Fisheries Service. 163 pp.

3) Harter, S.L., M.M. Ribera, A.N. Shepard, and J.K. Reed. 2009. Assessment of fish populations and habitat on Oculina Bank, a deep-sea coral marine protected areas off eastern Florida. Fish Bull. 107:195-206.

4) Reed, J. K., C. Koenig, A. Shepard, G. Gilmore. 2008. Long term monitoring of a deep-water coral reef: Effects of bottom trawling. Pages 169-179, in Pollock, N. Godfrey, J. (eds.), Diving for Science 2007. Proceedings of the American Academy of Underwater Sciences 26th Symposium.

5) Messing C.G., J.K. Reed, S.D. Brooke, and S.W. Ross. 2008. Deep-water coral reefs of the United States. *In*: Riegl B.M. and Dodge R.E. (Eds) Coral reefs of the USA. Springer, New York. 767–792.

6) Reed, J. K., C. C. Koenig, and A. N. Shepard, 2007. Impacts of bottom trawling on a deep-water Oculina coral ecosystem off Florida. Bulletin of Marine Science 81: 481–496.

7) George, R. Y., T. A. Okey, J. K. Reed, and R. P. Stone. 2007. Ecosystem-based fisheries management of seamount and deep-sea coral reefs in U. S. waters: conceptual models for proactive decisions. *In*: George, R.Y. and Cairns, S.D. (Eds.) Conservation and adaptive management of seamount and deep-sea coral ecosystems. Rosenstiel School of Marine and Atmospheric Science, University of Miami. Miami, FL. 9-30.

8) Morgan, L.E., C.F. Tsao, and J.M. Guinotte. 2007. Ecosystem-based management as a tool for protecting deep-sea corals in the USA. *In*: George, R.Y. and Cairns, S.D. (Eds.) Conservation and adaptive management of seamount and deep-sea coral ecosystems. Rosenstiel School of Marine and Atmospheric Science, University of Miami. Miami, FL. 39-48.

9) Reed, J.K., C.C. Koenig, A.N. Shepard, and R.G. Gilmore, Jr. 2007. Long Term Monitoring of a Deep-water Coral Reef: Effects of Bottom Trawling. *In*: Pollock N.W. and Godfrey J.M., (Eds.) Diving for Science 2007. Proceedings of the American Academy of Underwater Sciences 26th Symposium. Dauphin Island, AL. 169-179.

10) Ross, S.W. M.S. Nizinski. 2007. State of deep coral ecosystems in the Southeast region: Cape Hatteras to Southeastern Florida. *In*: Lumsden S.E., Hourigan T.F., Bruckner A.W., and Door G. (Eds.) The State of Deep Coral Ecosystems of the United States. NOAA Technical Memorandum CRCP-3, Silver Spring, MD: 233–270.

11) Roth, K. 2007. Can the last deep-sea Oculina coral reefs be saved?: A management analysis of the Oculina Habitat Area of Particular Concern. Master's Thesis, Duke University, Durham, NC. 48 p.