Habitat: Benthic Offshore

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In a nutshell:

- Benthic offshore habitats are used by valued fish and invertebrate species, such as red drum, pink shrimp, and stone crab.
- The live bottom fauna of the benthic offshore habitat is the source for the large variety of shells that comprise the beaches along the southwest Florida coast and are a distinctive feature of the region.
- Sand mining, for beach renourishment and fishing, affects benthic offshore habitats both directly and indirectly.
- Climate change and coastal eutrophication are major drivers of change in benthic offshore habitats.

Benthic offshore habitats in southwest Florida include hardbottom communities with a diverse epibiota of hard and soft corals and macroalgae that are used by abundant populations of fish species. The hardbottom areas are typically at intermediate depths where limestone outcroppings occur. A thin veneer of overlying sand, when combined with storms and waves, can cause scouring and dislodging of epibiota and transport to barrier island beaches. The shallow depths are colonized by pen shells and quartz sands with shells and other mollusks, such as fighting conchs (*Butrycon* spp.) and calico scallops (*Argopectin* spp.). Deeper depths contain low-relief limestone with barrel sponges interspersed with areas of crushed shell and carbonate sediments and occasional beds of paddle grass (*Halophila decipiens*), especially in the Cape Sable Province and northwestern Florida Bay.

The Hourglass expeditionary cruises, initiated by the Florida Board of Conservation Marine Research Lab, occurred from 1965-1967 (Joyce and Williams, 1969). The Hourglass program provided the first characterization of offshore benthic habitats. Researchers sampled only a small area of the total shelf on two transects offshore of Egmont Key and Sanibel Island. At shallow stations (6 m), they found quartz and crushed shell with living and dead mollusks (*Pinnidae, Butrycon* spp.). Mid-depth stations (18 m) contained abundant limestone outcroppings with up to 1 m of relief, colonized by sponges, alcyonarians, and stony corals (*Solenastrea hyades* and *Cladocora arbuscula*). The smooth areas in between were typically quartz sand colonized by *Halophila decipiens* and *Caulerpa* spp. Deep stations had low relief limestone and large barrel sponges. Smooth areas contained crushed shell and white calcareous silt. Calcareous algae (*Lithothamnion* spp.) and brown alga *Sporochnus* sp. were also observed at this depth. At 55 m, a generally smooth bottom with sponges and the bryozoans *Steganoporella magnilabris* and *Hippopetraliella marginata* was observed.

The live bottom was characterized by epifaunal assemblages associated with limestone outcroppings. Rarely, however, were these areas devoid of surficial sediments. Typically, the live bottom is covered by a layer of sand, shell, and carbonaceous silt from 1 to 10 cm in thickness. A substantial macroinfaunal community existed that far outnumbered the larger epifaunal components in taxa and individuals. This community differed markedly from the soft bottom infaunal community immediately adjacent, which did not exhibit the associated live bottom epifaunal components. There exists a rich flora on the shelf with seaweeds of tropical and subtropical genera (Dawes, 2004). A large number of perennial tropical species were collected in the 20-80 foot range. Seasonal patterns indicate a late spring to summer growth period, maturing in late summer and disappearing in the early winter.

Culter (1988) sampled macrofauna from the seafloor for both live bottom and soft bottom areas on the continental shelf. The live bottom infaunal habitat consisted of a thin veneer of sediments overlying a limestone bottom, marked by conspicuous epifauna such as sponges, gorgonians, and corals. The soft bottom was adjacent to the live bottom habitat and characterized by a lack of conspicuous epifauna and a thicker layer of sediments, although similar in sediment. Underwater video was used to target areas with the potential of becoming sand mining sites with the adjacent live bottom. For the live bottom stations, polychaetes accounted for an overall average of 38.6 percent (Sd., 10.7 percent); molluscs, 21.5 percent (Sd., 1.5 percent); crustaceans, 36.8 percent (Sd., 10.7 percent); with other minor groups accounting for an additional 3.5 percent of the fauna. For soft bottom stations, polychaetes averaged 50.6 percent (Sd., 9.1 percent) of the fauna; molluscs, 9.9 percent (Sd., 4.4 percent); crustaceans, 22.7 percent (Sd., 9.7 percent); and miscellaneous groups an additional 17 percent of the total fauna. A list of taxa indicative of live bottom and soft bottom were provided.

The Minerals Management Service funded a biological inventory and sediment grain size analysis of an area offshore of Tampa Bay, and an extensive benthic offshore inventory containing species lists and descriptions was subsequently published (Brooks *et al.,* 2004; Brooks *et al.,* 2006). The continental shelf contained many shoal and ridge features and supported a diversity of polychaetes, bivalves, and amphipods (Posey *et al.,* 1998).

Role of the Ecosystem

Coastal waters are the spawning grounds, nurseries, shelter, and food source for numerous finfish, shellfish, birds, and other species. These areas also provide nesting, resting, feeding, and breeding sites for over 75 percent of Florida's waterfowl and other migratory bird species. Superimposed on these important coastal areas is the fact that they are the most densely populated areas in the U.S., accounting for only 17 percent by area, but more than 53 percent of our nation's population (Crossett *et al.,* 2004; EPA, 2008). All of the nation's coasts are popular vacation destinations, with about 180 million people visiting U.S. beaches each year. Beach monitoring and reporting data for 2008 indicated that more than 32 percent of the nation's beaches had at least one advisory or closure in effect during swimming season (EPA, 2008). These advisories or closings are typically issued as a result of monitoring by state agencies when elevated bacterial levels are detected in the water, often the result of rainfall runoff or sewage spills.

Fish use of benthic offshore habitats has been demonstrated for commercially valuable species. The low relief hardbottom habitats have been used by red snapper to feed on infaunal invertebrates (Szedlmayer and Lee, 2004; Wells *et al.,* 2008). Biogenic structures (e.g., tubes, mounds, pen shells, and burrows) constructed by invertebrates provide distinct habitat with which many juvenile fish have been found to use as a refuge from predation (Kaiser *et al.,* 1999).

Stone crabs (*Menippe* spp.) support a valuable commercial fishery in the Gulf of Mexico, with most of the catch occurring on the continental shelf. Florida landings increased from 172,000 kg per fishing season (15 October-15 May) in the early 1960s to over 1 million kg since 1988. The 1990 landings were valued at over $15 million (Restrepo, 1992). Given the value of this fishery, there is surprisingly little known about this essential habitat or prey items. There are reports on the life history and population information (Ehrhardt *et al.,* 1990; Gerhart and Bert, 2008); however, landings data are the principal monitoring tool used by fisheries management. No research has documented the effects of "ghost crabs" on other epibenthic organisms or fishes. Observations of ghost traps on the continental shelf suggest that gear impacts from the stone crab fishery needs further study (Milbrandt *et al.,* 2010; Grizzle *et al.,* 2010).

Attributes People Care About

There are many attributes of benthic offshore habitats that people care about. In the Barrier Islands Province, beaches are popular shelling destinations. The benthic offshore habitats are the source of the shells, which are transported to the barrier islands during tropical storms and cold fronts. Changes affecting the productive offshore habitats or delivery could threaten the tourism economy. In Lee County, tourism employs one out of every five people, with over five million visitors per year generating more than $3 billion in economic revenues (http://www.leevcb.com/statistics/index.php). Commercially valuable fish and invertebrate species (e.g., red drum, pink shrimp, stone crab) use the shelf and estuaries for part of their life cycle and depend on the offshore benthic habitats.

There are diverse molluscan communities that exist on the continental shelf and have made Sanibel Island a popular tourist destination for shelling. Among these are pen shells (*Pinnadae*), which were described on Sanibel beaches as abundant and potentially important attachment substrates for seaweeds and other invertebrates (Perry, 1936). In the northern Gulf, the suitability of pen shells as a habitat for marine invertebrates and algae was demonstrated for both sessile and mobile animals (Munguia, 2004). Experimental destruction of pen shell habitat resulted in loss of habitat for other animals or led to significant spatial rearrangement of the community that has effects on animal migration and location extinction rates (Munguia and Miller, 2008).

Attributes We Can Measure

Recently, a special issue on mesophotic coral reefs discussed the biology, ecology, and global distribution of deep coral reef habitats (Hinderstein *et al.,* 2010). Many of these habitats are difficult to sample because of the need for submersibles and technical diving. At the shelf break, 200 km from the southwest Florida coast, a mesophotic reef was discovered and named Pulley Ridge after Dr. T.E. Pulley, malacologist, founder and long-time director of the Houston Museum of Natural Science. Pulley Ridge is a 100 plus km long series of north to south drowned barrier islands on the SWFS (Jarrett *et al.,* 2005; Hine *et al.,* 2008). The ridge has been mapped using multibeam bathymetry, submarines, and remotely-operated vehicles, as well as a variety of geophysical tools. The ridge is a subtle feature about 5 km across with less than 10 m of relief. The shallowest parts of the ridge are about 60 m deep. At this depth, the southern portion of the ridge hosts an unusual variety of zooxanthellate scleractinian corals, green, red, and brown macroalgae and, typically, shallow water tropical fish. A more detailed description and imagery from the site were produced in an expeditionary cruise with submersibles and technical divers (Culter *et al.,* 2006).

A multi-institution effort was conducted from 2008-2010 to characterize the benthic communities off Sanibel Island and to understand the distribution and abundance of macroalgae (Loh *et al.,* 2010). Large areas of the shelf near Sanibel were mapped with hydroacoustic and underwater video. Prior to this, maps and characterization of the benthic habitats did not exist. Along with extensive mapping and characterization of the macroalgal communities, there were efforts to identify sources of nutrients, including a submarine groundwater analysis. Together with a hydrodynamic model and experiments to evaluate the effects of grazers on macroalgae, this was the first systematic research effort on the inner continental shelf since the Hourglass cruises in the 1960s. Extensive descriptions of the macroalgal community and periods of peak biomass are described at several stations on the continental shelf.

Drivers of Change

Benthic offshore habitats are usually considered to be geographically isolated from drivers such as landscape alterations and water management practices caused by development. However, eutrophication can cause pressures, such as algal overgrowth and an intensification of red tide or other phytoplankton blooms that may lead to pockets of hypoxia or loss of available light for corals and benthic macroalgae (Figure 1). Climate change is a farfield driver thought to bring increased frequency and intensity of storms which are thought to play a critical role in the creation and maintenance of hardbottom habitats. Development in southwest Florida, especially the development of beaches in the Barrier Islands Province, is also a principal driver. The need for beach renourishment projects emerged as a result of a combination of development plus storm waves and erosion. Sand mining is a pressure that can have direct and indirect effects on the live bottom patch reefs, pen shell

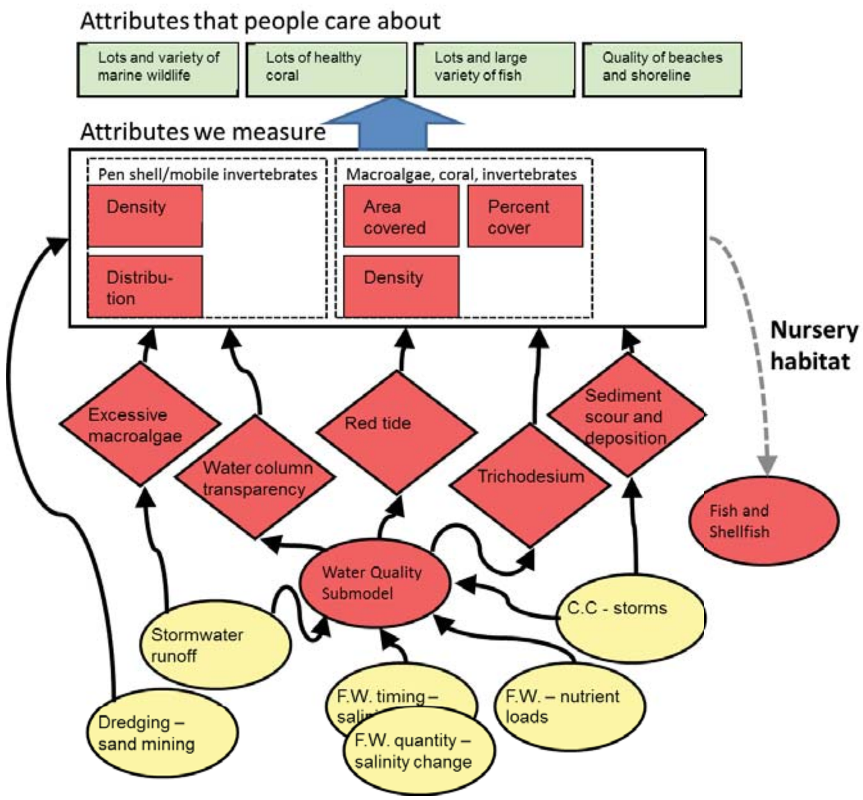

Figure 1. Benthic offshore submodel diagram for Southwest Florida Shelf.

habitats, and shell hash habitats typical of the continental shelf. Increased fishing pressure can change the trophic structure and affect benthic offshore habitats.

In a recent assessment of climate change impacts on U.S. coastal areas, several key climate change drivers were evaluated (Scavia *et al.,* 2002). Sea level change, alterations in precipitation patterns, changes in the frequency and intensity of coastal storms, and increased levels of CO_2 were all viewed as threats to benthic offshore habitats.

With an increase in storm frequency and intensity, the principal pressures are scouring and sediment transport. The natural history and geology of the continental shelf was elaborated in a recent review by Hine and Locker (2011). The SWFS is described as a very wide, low energy, sediment-starved shelf seaward of the west-central Florida barrier islands system. This inner shelf presents a wide variety of sand ridges up to 4 m thick and separated by extensive areas of exposed limestone. This geomorphology of the barrier islands subregion suggests that circulation is an important driver of the location and complexity of epibiotic communities. A thin veneer of sediments overlays the productive live bottom habitats and suggests that scouring is an important physical disturbance mechanism. Frequent strandings of large numbers of invertebrates and large amounts of macroalgae on barrier island beaches supports this hypothesis (Perry, 1936; Dawes, 2004).

Development of landscapes adjacent to beaches is an important driver. As development has increased on the barrier islands along the southwest coast, the need for beach renourishment projects has emerged as a result of a combination of storm waves and erosion (Stapor *et al.,* 1991). Sand mining is a pressure that can have direct and indirect effects on the live bottom patch reefs, pen shell habitats, and shell hash habitats typical of the continental shelf.

Overfishing is a driver that has changed the trophic structure of many marine ecosystems (Jackson *et al.,* 2001), resulting in changes to benthic habitats. This results in a pressure such as algal overgrowth of coral reefs (Hughes, 1994). Potential gear impacts as pressures include hook and line litter and damage, vessel groundings, and ghost traps.

Mechanisms of Change

Nutrient-laden freshwater discharges from Lake Okeechobee and loading from the heavily laden agricultural watershed are cited as the principal drivers for water quality degradation (SFWMD, 2009), seagrass losses, and harmful algal blooms (Brand and Compton, 2007) in the Caloosahatchee Estuary. The loss of the continental shelf habitats due to stormwater runoff is largely unknown. The hardbottom and pen shell habitats occupy much of the continental shelf which may not be affected directly by sudden decreases in salinity, but the effects of stormwater runoff may be the result of an indirect effect, such as sedimentation, decrease in light penetration to benthic habitats, or eutrophication. These documented losses and environmental problems have negative effects on the public's perception and aesthetic value of shelf and barrier island habitats. It is expected that southwest Florida will continue to provide opportunities for fishing and diving, with an abundance of large fish, wading birds and shorebirds, and marine mammals.

Benthic offshore habitats are usually considered to be geographically isolated from drivers such as landscape alterations and water management practices. However, eutrophication can cause pressures, such as algal overgrowth and an intensification of red tide or other phytoplankton blooms (Brand and Compton, 2007), which may lead to pockets of hypoxia or loss of available light for corals and benthic macroalgae. The timing and delivery of freshwater and stormwater runoff are important drivers in the bays and estuaries and in the nearshore environment. Given the broad and far-reaching geomorphology of the SWFS, much of the benthic offshore habitats are not affected by local runoff or nutrient loading. However, regional patterns in climate and runoff caused by discharges of nutrient-rich water to the Gulf of Mexico can occur from large systems (e.g., Mississippi River, Peace River, Lake Okeechobee via the Caloosahatchee River).

The Caloosahatchee River/Estuary is a conveyance for excess water in Lake Okeechobee, and large releases have been associated with large-scale increases in benthic macroalgae. Given that the coastal waters are nitrogen limited (Brand and Loh, 2011), it is logical to conclude that large NOx and NH_3 loading from stormwater runoff would result in excessive algal biomass. There is a decreasing gradient of nitrogen and phosphorus from Lake Okeechobee to the Gulf of Mexico, suggesting that Lake Okeechobee is a major source of nutrients to the coastal waters through a combination of conservative (dilution with Gulf waters) and non-conservative (algal/plant uptake) processes. Algal tissues near the mouth of the Caloosahatchee Estuary demonstrated elevated δN15 ratios, suggesting that nutrients in stormwater runoff are being assimilated into macroalgal biomass (Lapointe and Bedford, 2007; Milbrandt *et al.,* 2010).

Status and Trends

Changes affecting the productive offshore habitats could threaten an area well known for shelling and healthy beaches and could have tremendous economic consequences. In Lee County, tourism employs one out of every five people, with over five million visitors per year generating over $3 billion in economic revenues (http://www.leevcb.com/statistics/index.php). Diminished coastal resources and habitats adversely affect the regional economy. Degraded water quality from heavy rains in 2004-2005 resulted in an estimated $40 million loss to the Lee County economy. The Caloosahatchee Estuary shows typical signs of eutrophication (i.e., extreme nutrient levels), including intense algal blooms and periods of low dissolved oxygen levels (or hypoxia) or anoxia (Xia *et al.,* 2010). Other problems that result from coastal development include degraded benthic communities, a decrease in the extent of seagrasses, and the loss of functioning oyster reefs.

Topics of Scientific Debate and Uncertainty

Connectivity of the southwest Florida benthic offshore habitats to the estuaries and Florida Keys is likely but not well understood. Fish and invertebrate species (e.g., red drum, pink shrimp, stone crab) use the shelf and estuaries for part of their life cycle. Population genetics suggest that the estuaries may have subpopulations, but there are high rates of gene flow along the estuaries of the SWFS (Lester, 1979; Gold and Turner, 2002; McMillen-Jackson and Bert, 2004). A competitive grants program was recently initiated by NOAA/AOML to study the potential of deep water reefs to provide larvae and serve as a refugia for fish populations on the SWFS and Florida Keys (Palumbi, 2003). Circulation models support a north to south prevailing current pattern (Weisberg *et al.,* 2009), which translates into connectivity between biological communities on the SWFS, the Florida Keys, and Dry Tortugas.

There is currently no evidence that areas such as Pulley Ridge, or other critical fisheries habitats far from shore, are affected by stormwater runoff. There has been no evidence, to date, of hypoxic conditions affecting the broad SWFS in southwest Florida. The question remains, however, at what threshold of loading does a phase shift occur (Valiela *et al.,* 1997) where unusually large amounts of macroalgae out compete and smother benthic habitats and invertebrates, such as corals and pen shells. The scenario posed by Valiela *et al.* (1997) was applied to bays in Massachusetts where seagrass habitats (little to no stormwater runoff/loading) were displaced by macroalgae under moderate to high stormwater runoff/loading conditions. While not well documented, a period of above-average rainfall and tropical storm activity resulted in excessive macroalgal biomass near the tidal passes and on artificial reefs. As the macroalgae senesced or fragmented in storms, the macroalgae accumulated on barrier island beaches in unusual quantities. In a series of hydrodynamic modeling runs with a particle tracking model (Fugate, 2010), macroalgae from the mouths of the major river ended up in the nearshore environment and affected benthic offshore habitats. Other stormwater runoff from gulf-wide sources is poorly understood. The large plume and hypoxic zone is well documented in the northern Gulf of Mexico from the Mississippi River (Rabalais *et al.,* 1994).

Acknowledgments

The author would like to thank M. Savarese, A. Volety, and L. Coen for the invitation to participate in the development of models for the SWFS. This contribution was supported by a grant from the City of Sanibel, West Coast Inland Navigation District, and the Tourist Development Council of Lee County. The author would also like to thank Pamela Fletcher and William Nuttle for their assistance throughout the process.

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