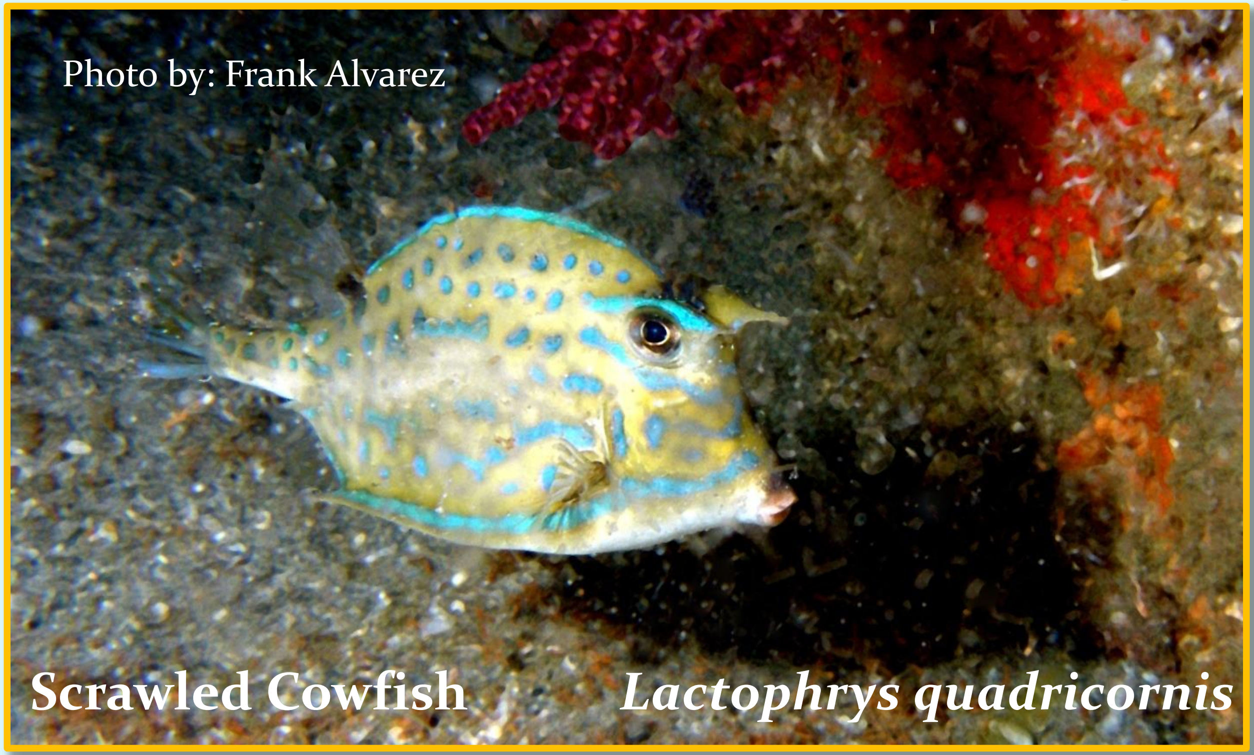
The Science Behind Volusia County's Artificial Reef Program



Definition of an Artificial Reef:

According to US Code, (a compilation and codification of the general and permanent Federal Laws[1]) "(*) The term "artificial reef" means a structure which is constructed or placed in water covered under this chapter for the purpose of enhancing fishery resources and commercial and recreational fishing opportunities." 33 U.S.C. § 2105(1) 2012

US Code Title 33 – Navigational and Navigable Waters
Chapter 35 – Artificial Reefs
Section 2105. Definitions

*It is important to note that other definitions exist depending on which user group (i.e. scientist, engineer, fisher) is associated with the definition.

(*) Title 1 of the Code as published by the office of the Law Revision Counsel

Why Build Artificial Reefs?

According to the 2007 National Artificial Reef Plan published by the National Oceanographic and Atmospheric Administration:

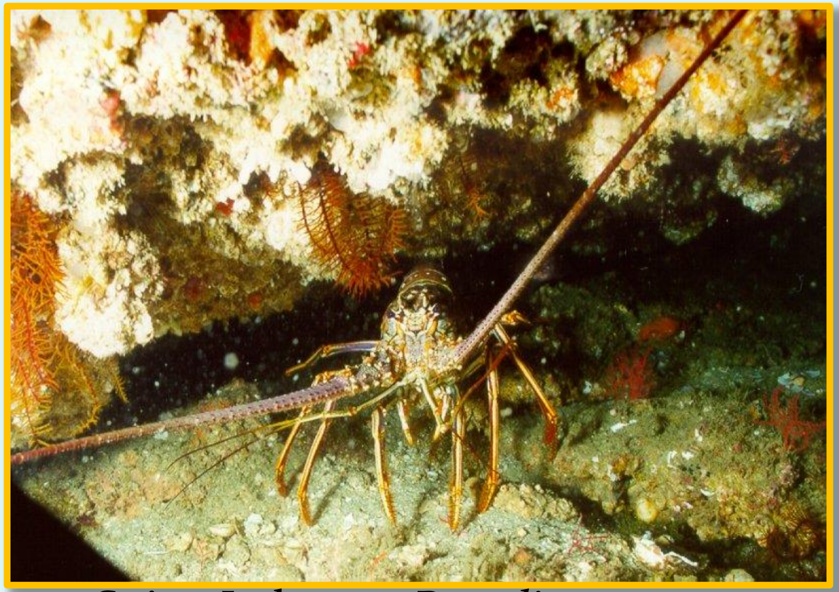
"Increasing demands on fish stocks by both commercial and recreational fishermen and losses of benthic habitat due to development, fishing pressure, and pollution, have had substantial effects on many reef-associated fish species." [1]

Benefits of Artificial Reefs To Volusia County

1. Creates habitat for plants, invertebrates and fishes in an otherwise featureless area of little interest to divers or fishers.

In an ecological sense it creates surface area that allows encrusting organisms to attach and grow on the reef. This creates a food source for other organisms and also a place to hide from larger predators that are attracted to the reef for food, i.e. fish and lobsters.

Photo Courtesy Volusia County Reef Research Dive Team.



Spiny Lobster *Panulirus argus*

Benefits of Artificial Reefs To Volusia County

2. Utilizes materials that would otherwise take up space in landfills. Such bulky materials are recycled as Artificial Reef Materials.

Materials for building artificial reefs must meet standards published in “Guidelines For Artificial Reef Materials” by the Atlantic and Gulf States Marine Fisheries Commissions. [2]

Artificial Reef Material being loaded onto a barge for deployment at Site 12.

Benefits of Artificial Reefs To Volusia County

3. Reduces fishing pressure on Natural Reefs.

Creating new artificial reefs reduces fishing pressure by providing more quality areas to fish. [3] In Volusia County, artificial reefs are created approximately 10-15 miles inshore of most of its natural reef system, providing easier access to fishers and divers.

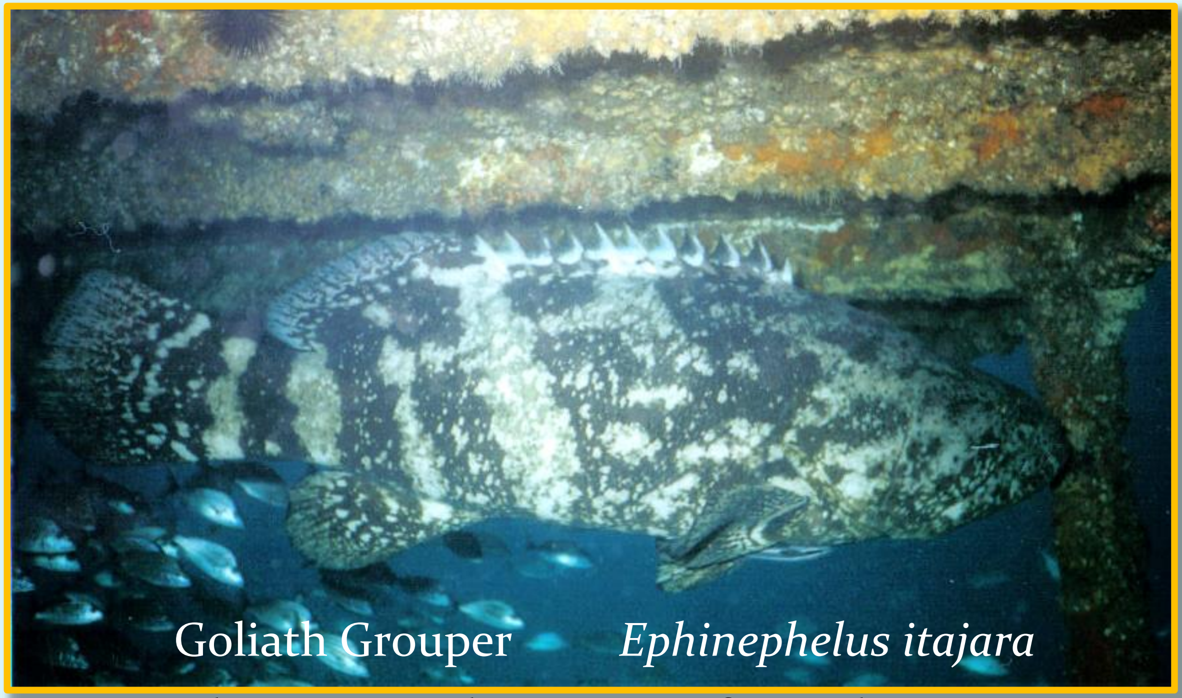


Photo Courtesy Volusia County Reef Research Dive Team.

Benefits of Artificial Reefs To Volusia County

4. Increases biomass of Volusia County's offshore environment.

Expanding the surface area of offshore habitats using artificial reefs increases the biomass of benthic organisms significantly. [4]

The encrusting organisms and associated invertebrates attract fish to the structure, providing food for smaller reef dwelling fishes as well as places to hide. Larger predators are attracted to the additional food source.

Photo Courtesy Volusia County Reef Research Dive Team.

Biomass – the mass of living biological organisms in a given area or ecosystem.

Benefits of Artificial Reefs To Volusia County

5. Increases Productivity of Volusia County's offshore environment???

Productivity relies on the assumption that there is a **generation of biomass over time**. [5] This may be true for plants and encrusting organisms that grow and live on the reef full time, but is harder to prove for fishes that move from reef to reef searching for food.

The question becomes do artificial reefs just attract fishes from other areas or do artificial reefs actually lead to the production of more fishes. This question remains to be answered. [6]

Benefits of Artificial Reefs To Volusia County

6. Positive Socioeconomic Impacts.

Artificial Reefs increase economic activity in local areas in the form of expenditures, incomes and jobs.

The offshore habitat in Volusia County differs from the offshore habitat in Southern Florida where natural reefs are much closer to shore. The creation of inshore artificial reefs in Volusia County makes the reefs more accessible to fishers and divers with limited monetary resources.


Sinking of the Antilles Star at Site 4 on 6/29/04.

Photo Courtesy Volusia County Reef Research Dive Team.

Such benefits also increases the value to non-user groups who see the creation of artificial reefs as beneficial to the environment and community. Such support helps justify future public expenditures on artificial reefs. [7]

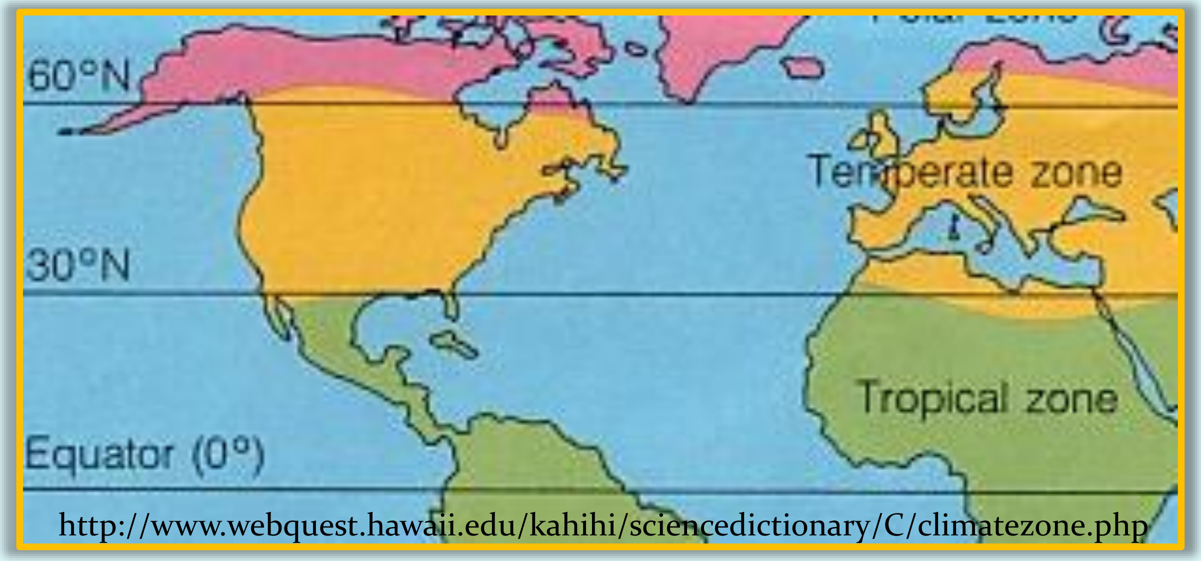
Benefits of Artificial Reefs To Volusia County

7. Increases the scientific and research opportunities in Volusia County.

Artificial Reefs increase scientific and research opportunities that can provide technical information to help reef managers and fishery biologists make good policy decisions.

Photograph of Site 11 culvert after 1 year of growth.

Characterizing Volusia County's Offshore Environment



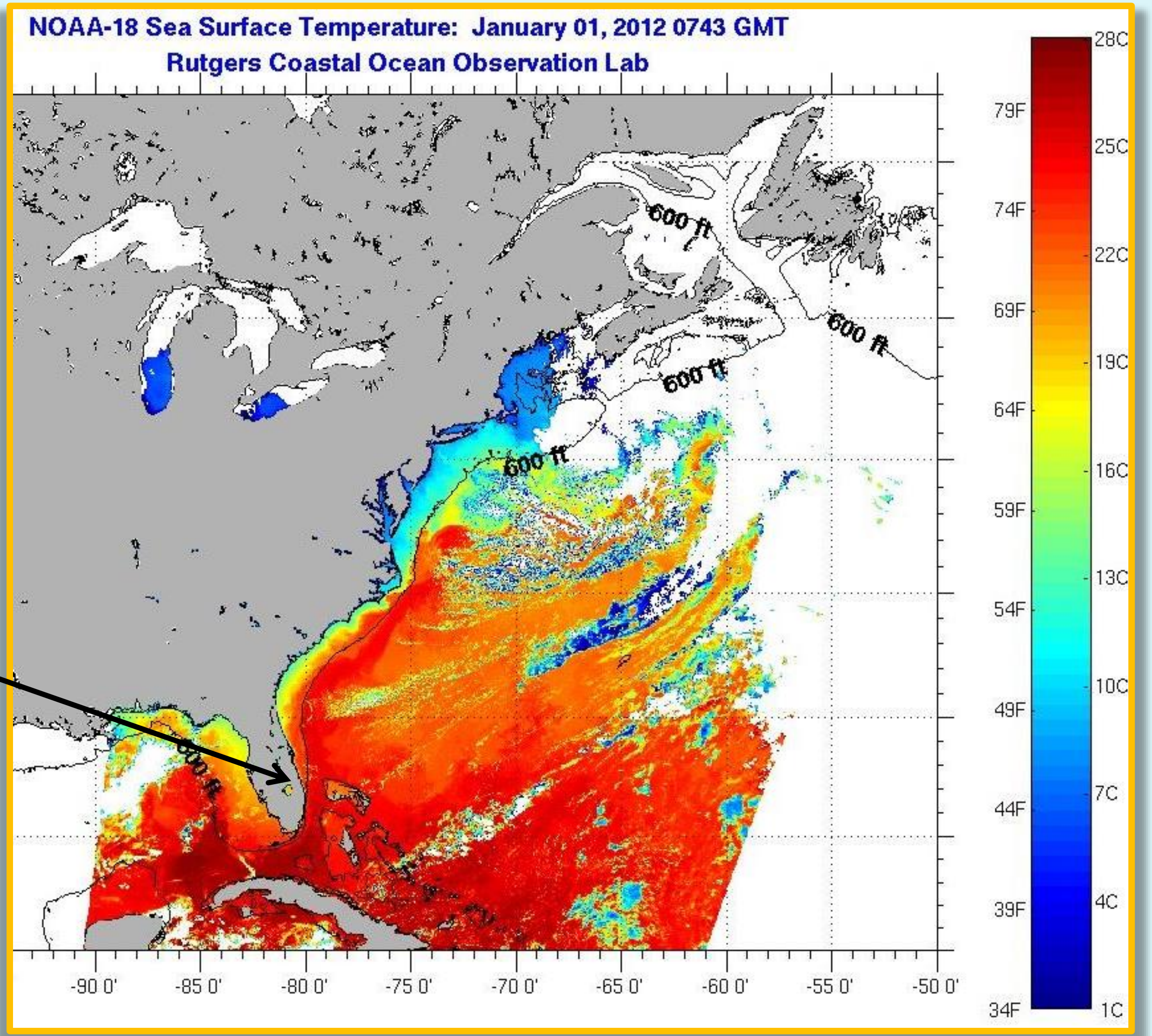
http://www.webquest.hawaii.edu/kahihi/sciencedictionary/C/climatezone.php

Volusia County lies at the border between the Tropical and Temperate Climate Zones which creates a geographically interesting area of tropical and temperate species.

Volusia County's Offshore Habitat Is Heavily Influenced By The Gulf Stream

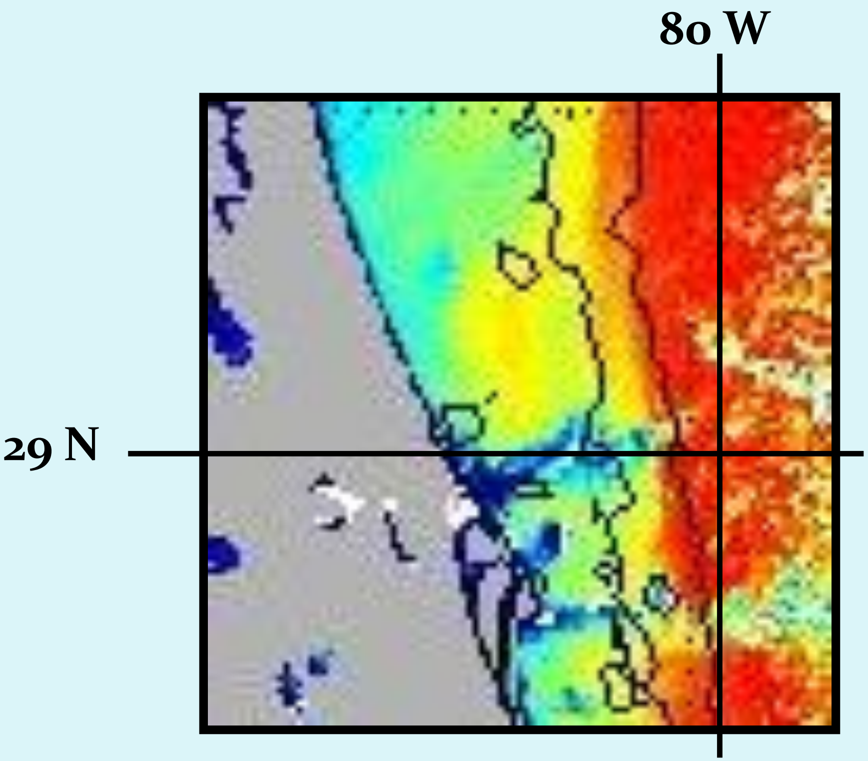
The Gulf Stream is a warm water current that starts in the Straights of Florida and moves up the coast of Florida and East Coast. The warm, clear waters provide nutrients necessary for coral reefs to grow.

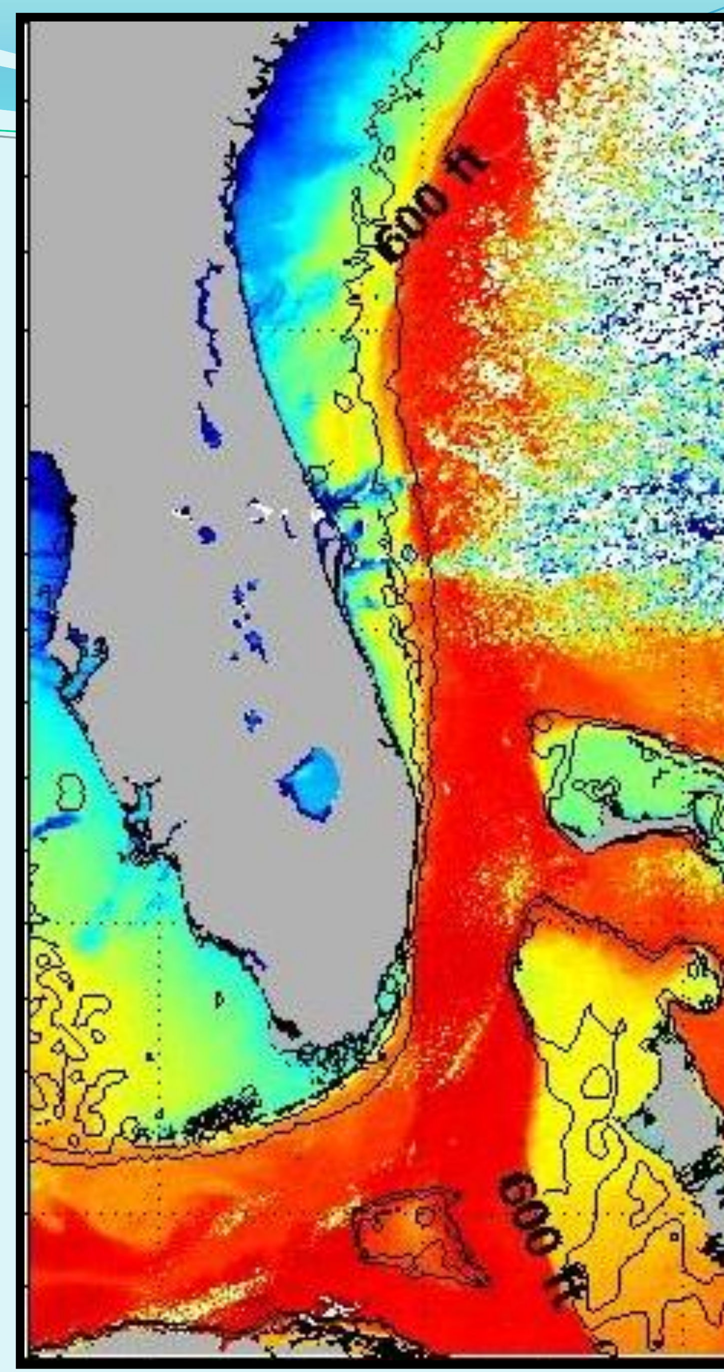
Notice how it hugs the Florida Coastline in the south and moves offshore as it follows the Continental shelf.



Volusia County's Proximity To The Gulf Stream

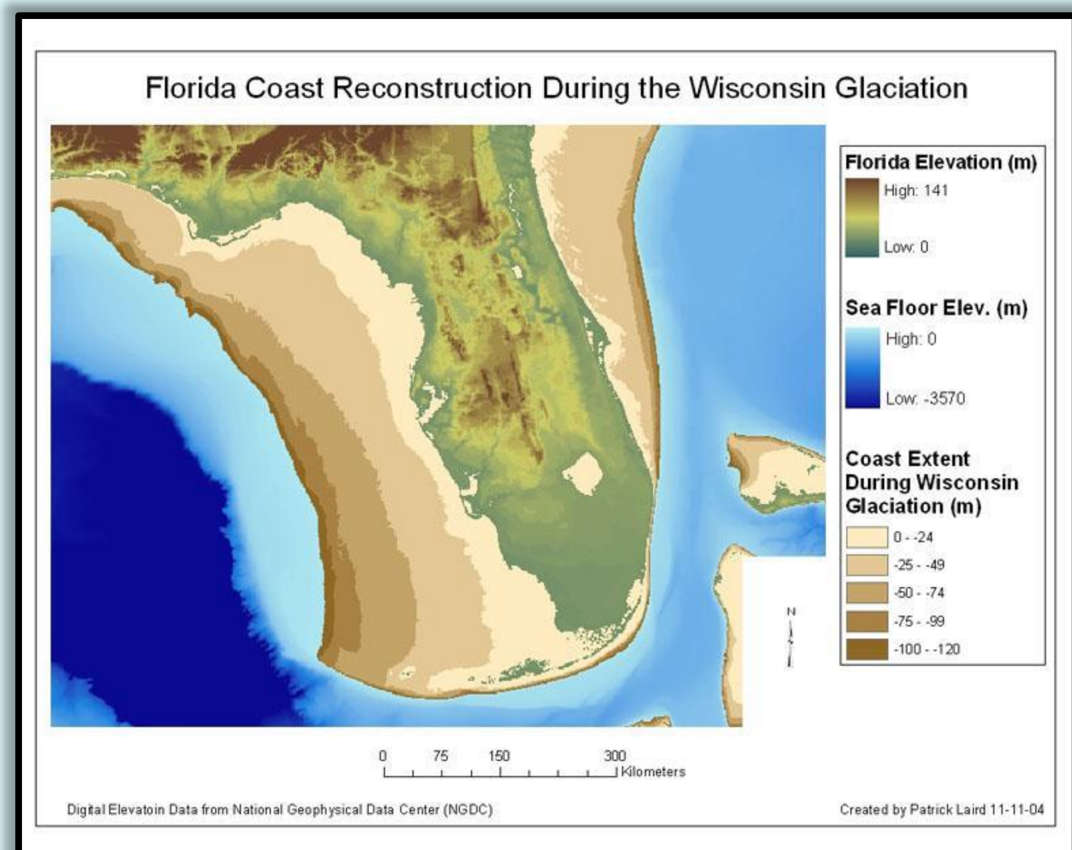
Ponce Inlet is on average 42 miles from the western edge of the Gulf Stream.





Photos courtesy Rutger's Coastal Ocean Observation Lab

A distinct difference occurs in the continental shelf between South Florida and Volusia County's offshore environment. This is evident during this reconstruction of Florida during the last glacial period. [8]



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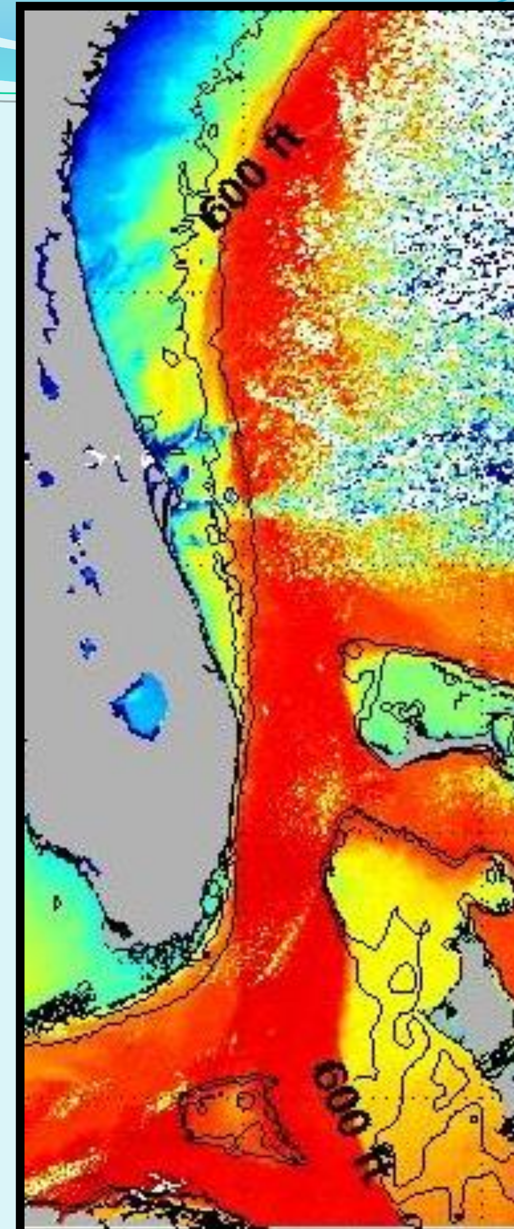
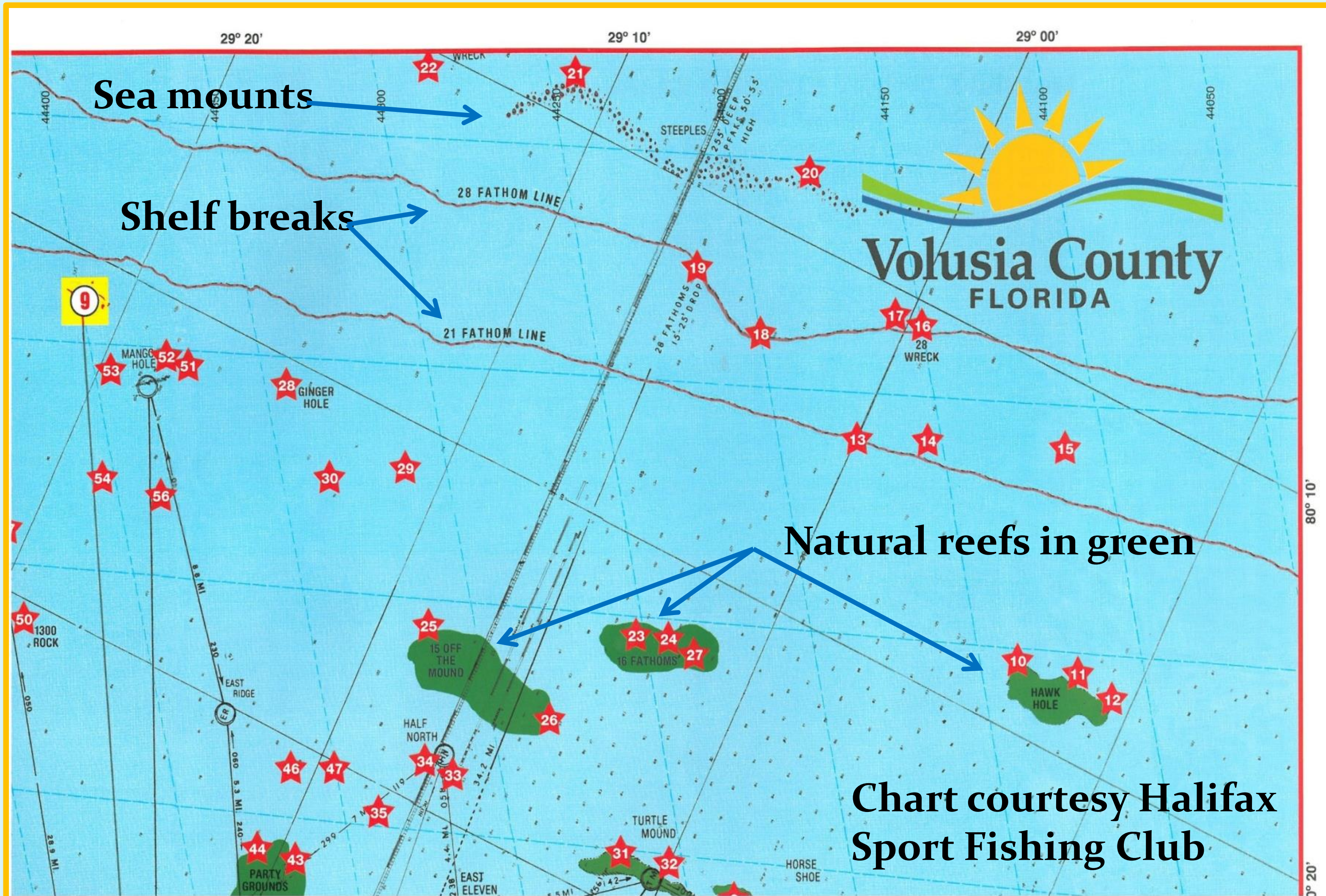


The increased area of continental shelf in Volusia County allows for a separation between artificial and natural reefs sites. Characterizing the offshore habitat helps reef managers design and plan artificial reefs and fisheries management policies.

Chart showing shelf breaks, sea mounts and natural reefs of Volusia County.



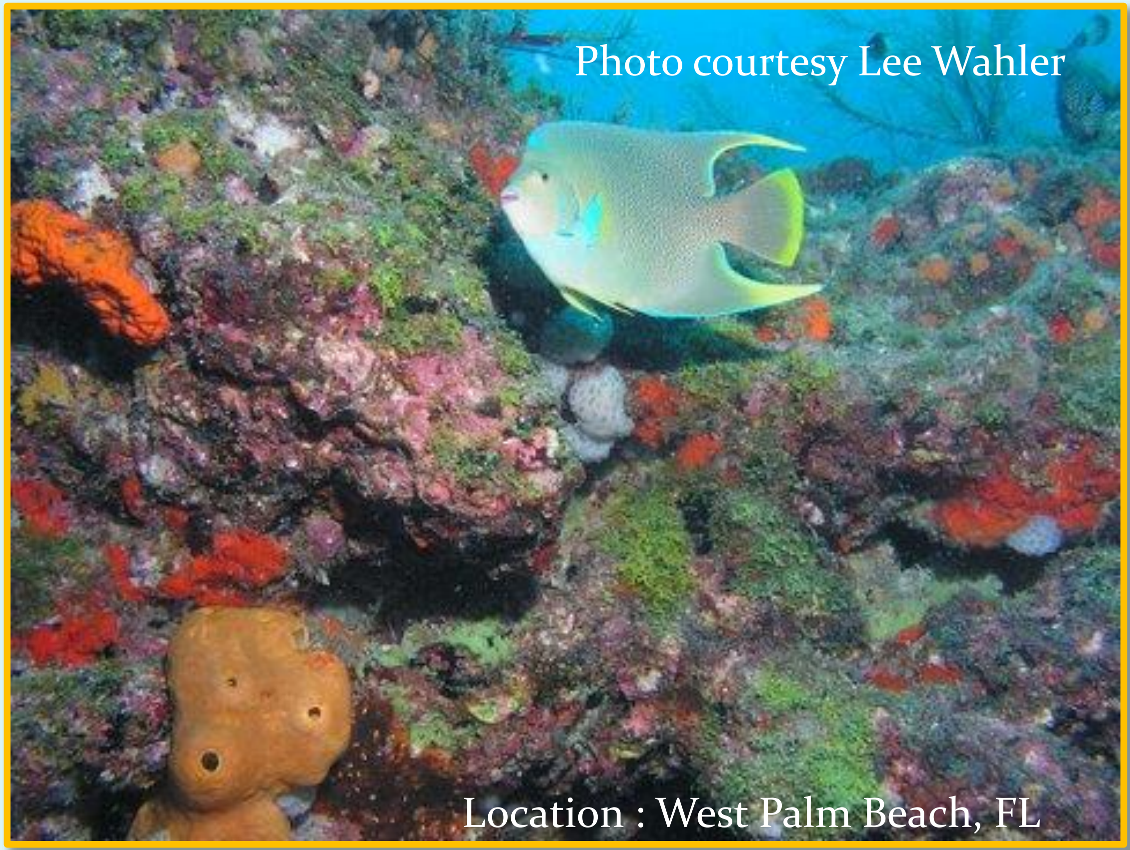
Volusia County's Natural Reefs

Volusia County's Natural Reefs are characterized by having lower relief than natural reefs in South Florida. Diving conditions are less consistent (visibility) than the more favorable conditions found farther south where the Gulf Stream is closer to shore and shallow water (Traci Grubbs, personal communication, 18 October, 2012).

Caribbean Reef Octopus, *Octopus briareus*

South Florida's Natural Reefs

South Florida's Natural Reefs are characterized by having higher relief and a greater diversity of species. Diving conditions are more favorable where the Gulf Stream is closer to shore and provides a more consistent water temperature (Joe Knott, personal conversation, 21 October,2012).



Designing Artificial Reefs

The design of artificial reefs is critical to effectively meet the requirements of targeted species and support community structures.

Therefore, their design must consider the purposes of the reef, the specifications of the environment, and what fisheries applications must be meet. [9]

Materials Selection

Artificial Reef Materials are selected to meet the primary goal of a reef project while taking into consideration cost and availability. [3]

Photo Courtesy Joe Nolin, County of Volusia

Materials Selection

Guidelines for Artificial Reef Materials are outlined by the Atlantic and Gulf States Marine Fisheries Commissions. [3]

Criteria For Selecting Materials

1. Function – the ability to attract and hold aquatic organisms

2. Compatibility (with environment) – materials must be evaluated to determine what risks there are to the environment, i.e. leaching of hazardous chemicals

3. Durability – materials must be resistant to the harsh chemical and physical forces of the marine environment

4. Stability – materials must be stable enough to remain in its original configuration and permitted site

Materials Selection

Concrete, made from Portland Cement, is composed primarily of lime, a component of limestone. Limestone is sedimentary rock made up of the skeletal remains of marine creatures including corals. These features make it an excellent habitat for settlement and growth of encrusting organisms. [3]

Materials Selection

Benefits of Using Concrete:

1. Can be recycled secondary material
2. Extremily compatible with the marine environment
3. Durable – "Based on the 32 to 34 year performance observations…All concretes exhibited a high level of durability in seawater exposure" (Portland Cement Association, per communication) [3]
4. Stable – heavy enough to stay in position
5. The flexibility to cast in a variety of forms
6. Excellent habitat for encrusting organisms

Drawbacks of Using Concrete:

1. Heavy – need heavy equipment to handle, making it dangerous to haul and deploy at sea
2. Tendency to sink into softer substrates [3]

Materials Selection

Steel-Hulled Ships are especially popular with divers. In 2003 the FWC held 487 vessels as artificial reefs in their database. This constituted ~ 25% of public artificial reef records. [3]

200' barge before deployment in 2011. Notice large holes cut out for diver and large fish access.

Materials Selection

Benefits of using Steel-Hulled Ships:

1. Make interesting dive locations
2. Durable – may last 60+ years
3. Produce high vertical profile – this attracts transient pelagic fishes as well as demersal fishes (feed on or near the bottom)
4. Reuse may be more economical than scrapping
5. Vessels, under certain conditions, provide habitat for spawning aggregations of certain managed fishes such as groupers and amberjack. [3]

Antilles Star before sinking, site 4, 6-29-2004

Photo Courtesy Volusia County Reef Research Dive Team.

Materials Selection

Drawbacks of using Steel-Hulled Ships:

- Expensive to clean and remove of hazardous materials.
- Vessels typically provide less shelter for demersal fishes.
- Steel-hull surface is less favorable for colonization of epibenthos than concrete or rocks.
- Vessels may be more prone to damage and movement during hurricanes and large storms.
- Maintaining adequate navigational clearance can be a challenge in shallower waters. [3]

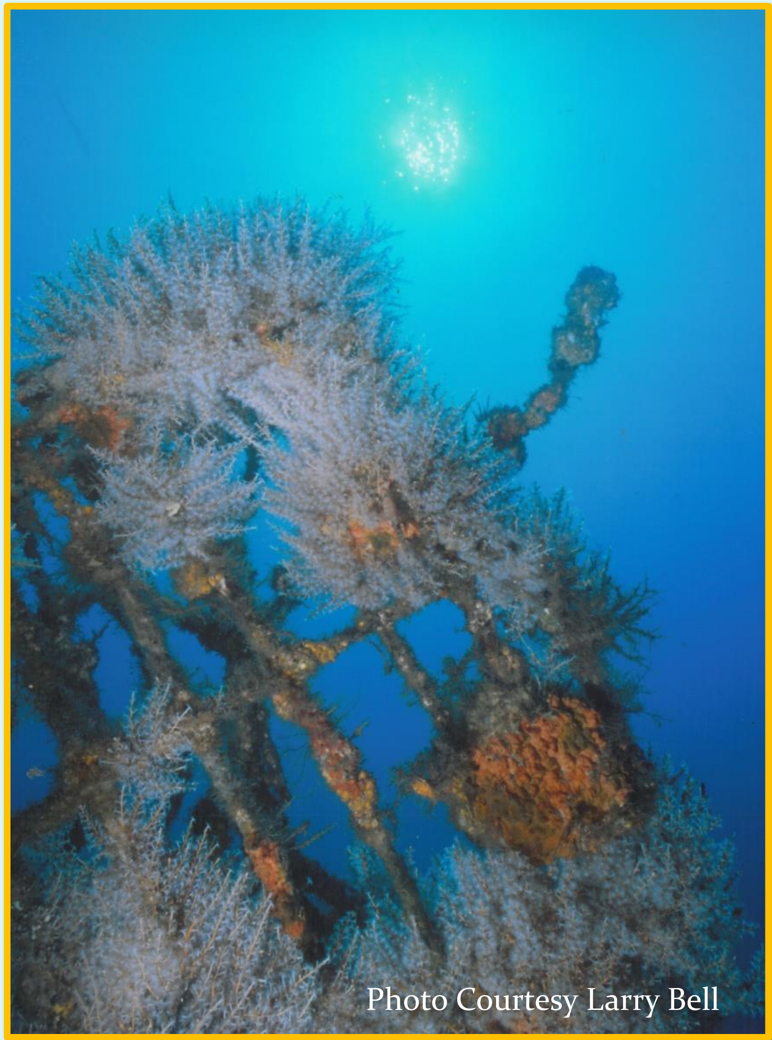


Photo Courtesy Larry Bell

Materials Selection

Designed Structures specifically used for artificial reefs have increased in popularity. This trend develops as reef managers and scientists research different design structures to improve artificial reef effectiveness. [10]

Red Snapper swimming around a Reef Ball at Site 1.

Materials Selection

Benefits of Using Designed Structures:

1. Can be designed to meet specific goals of an Artificial Reef Program, i.e. targeting species, life stages, scientific studies, etc.
2. Designed structures can be constructed as needed, therefore decreasing the reliance on secondary materials.
3. Can be constructed to fit the criteria of reef materials, including durability, stability, and compatibility with marine organisms.
4. Design flexibility to maximize characteristics such as complexity, hole size, and number of holes to meet the specific goal of the study or project.

Drawbacks of Using Designed Structures:

1. Heavy – need heavy equipment to handle making it dangerous to haul and deploy at sea
2. Tendency to sink into softer substrates [3]

Design of Reef Structure

The effectiveness of artificial reefs depends on the design of the reef structure, specifically whether meets the habitat requirements of its targeted species. [11] If the purpose of artificial reefs is to improve fisheries management, then this is one of the most important considerations.

Jackknife Fish school around a culvert at Site 11.

Reef Size

Several studies have shown that reef size significantly influences biomass, total number of species, diversity of species, and fish density. [12][13] A few trends have been proposed with a significant amount of research to support them.

Site 4 photo with extensive coral and other epibenthic growth.

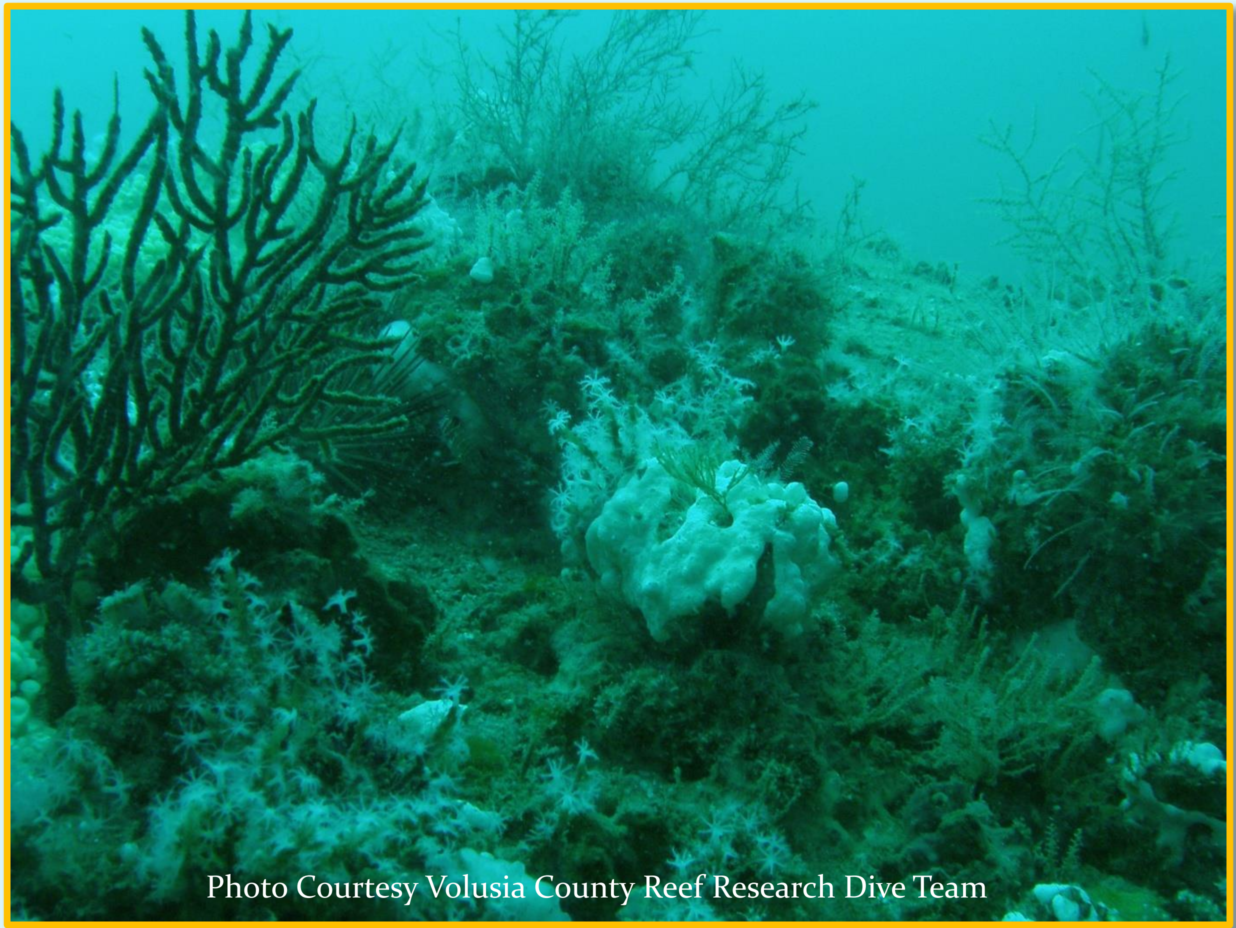
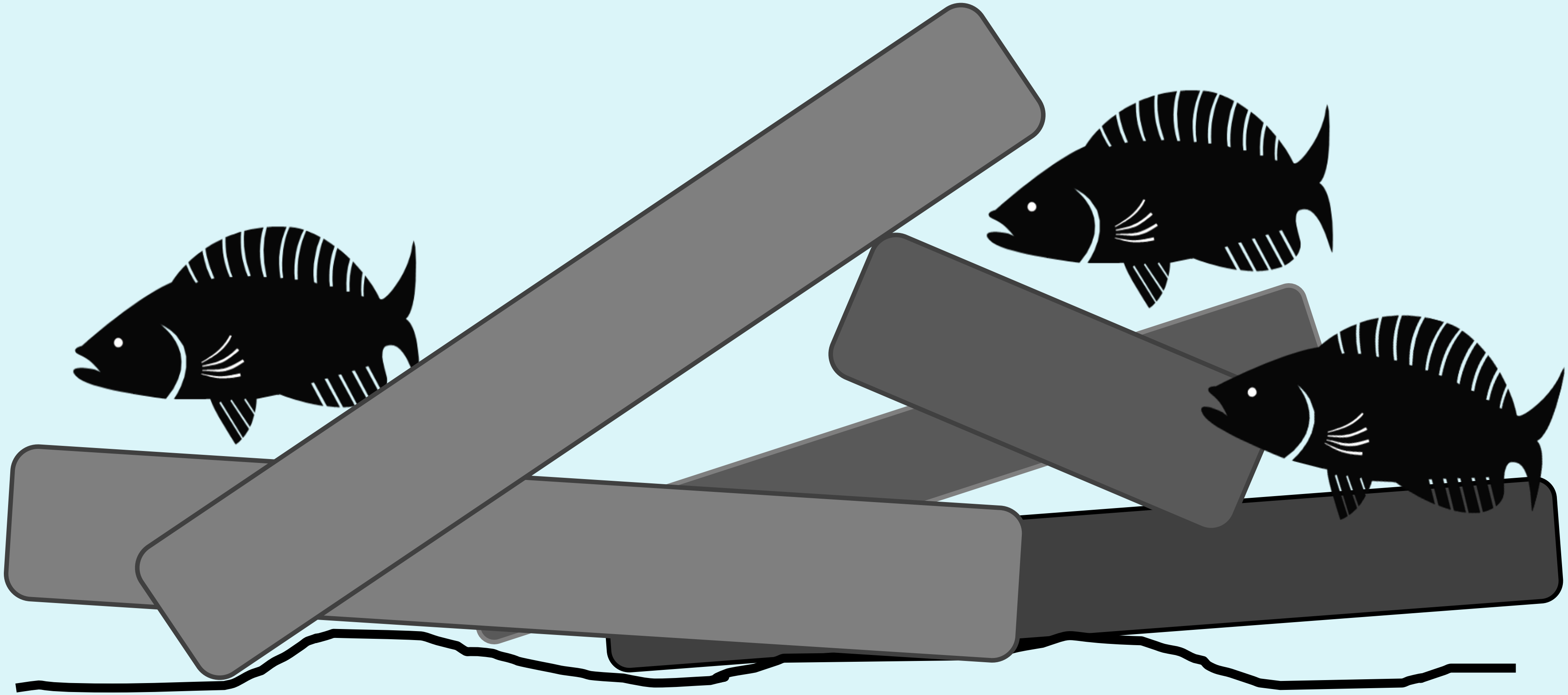


Photo Courtesy Volusia County Reef Research Dive Team

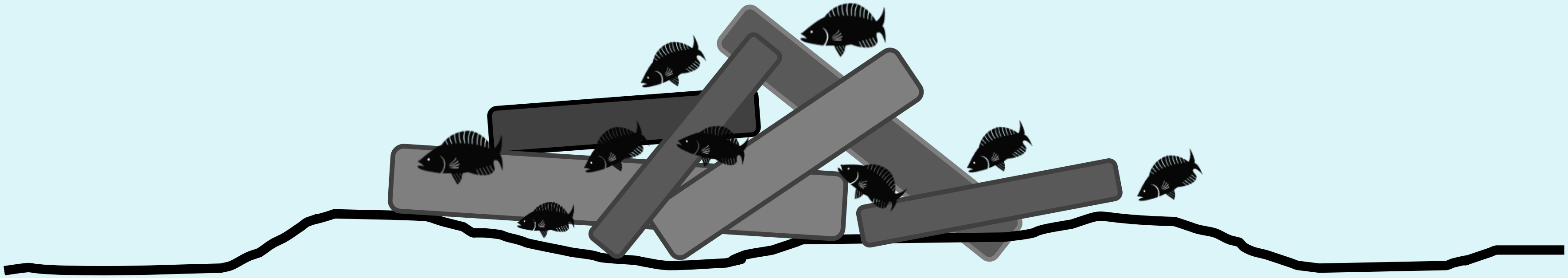
Reef size

Larger reefs may have higher biomass densities (including invertebrates, algae, and fishes, etc), but may be composed of fewer, but larger fishes. This may be due to the success of larger individuals through competition and predation of smaller fishes, including juveniles. [12]



Reef Size

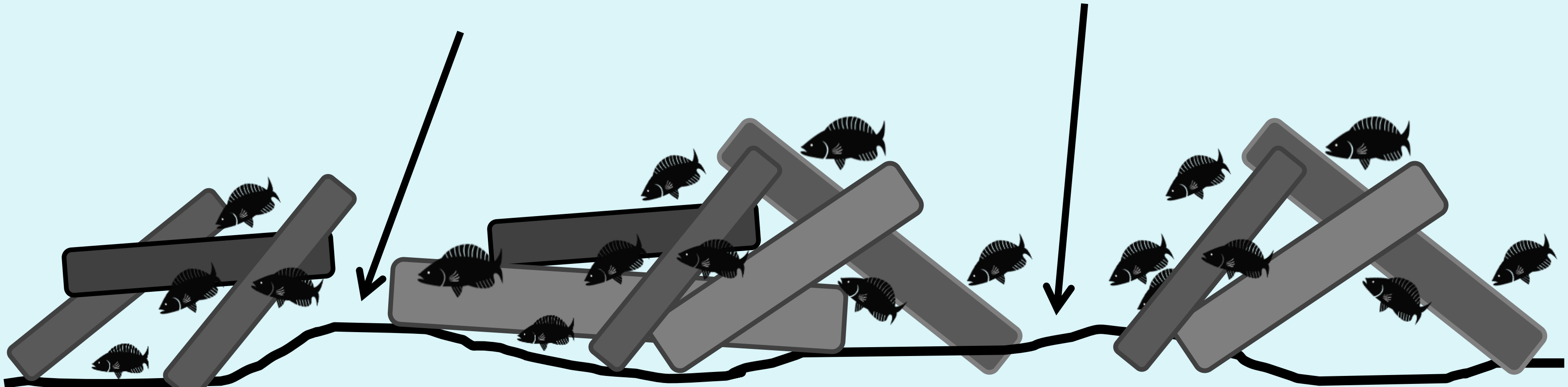
Smaller Reefs may have an increased density of fishes (aggregated closer together) as well as a greater diversity of fish species than larger reefs. [14][12]



Reef size

Multiple Smaller Reefs have been shown to provide more fish biomass and diversity than a larger reef of equal area and volume . [14]

Margins between smaller reef units increases the availability of soft bottom food sources [15] and also increases transitional zones between reef and open seafloor.



Considerations of Depth In Reef Construction

1. **User Considerations** – depth is an important consideration to making reefs accessible to fishers and divers

Purplemouth Moray

Deeper Depths are farther from shore, making it more challenging to divers (due to increased currents, reduced sunlight, and lower temperatures), and require more fuel to reach the destination.

2. Biological Considerations

Physical properties vary with depth that affect the biological properties of a reef at depth.

↑ Depth ↓ Light ↑ Pressure ↑ Current ↓ Temperature (at bottom)

Deeper reefs can have stronger currents that deliver more larvae for settlement (invertebrate and fishes), supply more planktonic food for residents, and can scour more of the bottom (remove sand layer) that provide more hard bottom and therefore more available space for growth. [16]

Carolina Hake, *Urophycis earllii*, at Site 4, notice the hard growth on the substrate indicating scouring of the bottom.

Photo Courtesy Volusia County Reef Research Dive Team

Biological Considerations

Kruer and Causey (1992) compared natural and artificial reefs at varying depths for two years and concluded that natural reefs showed an increase in species diversity and total numbers with increased depth, but that artificial reefs showed an increase in numbers at shallower depths (14m compared to 24m). They attributed the increase in numbers at the shallower site to increased scouring. [17]

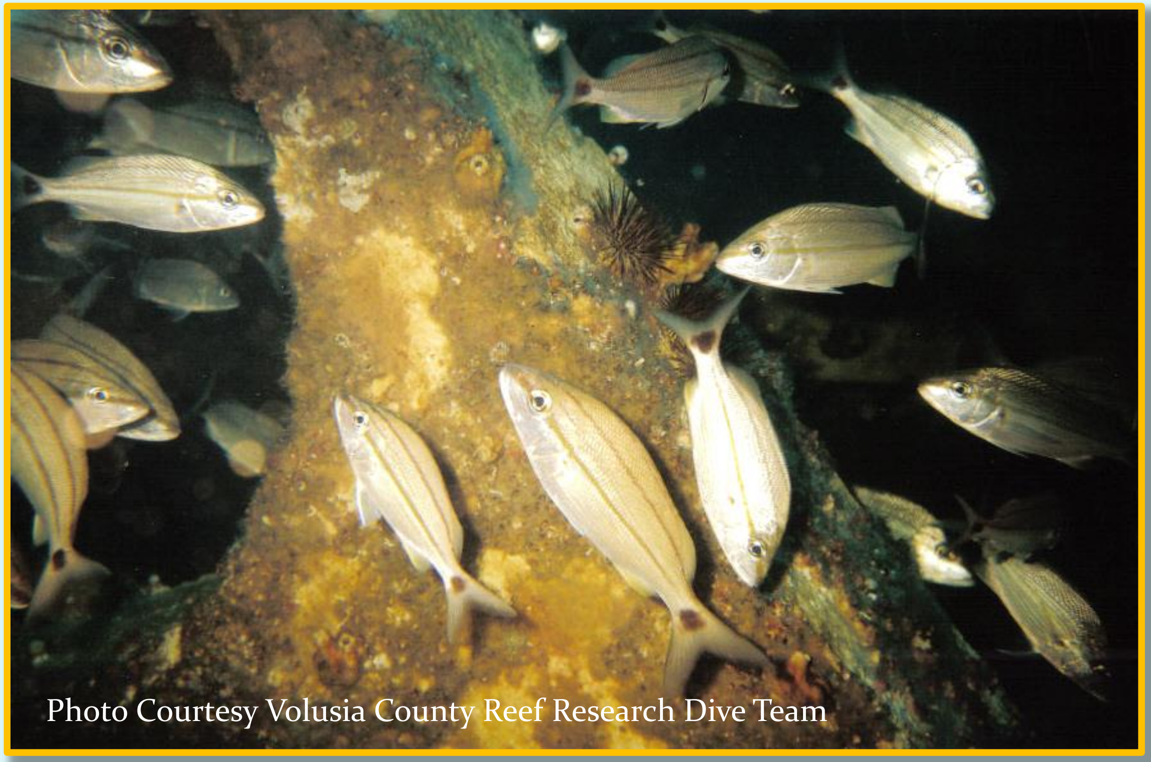
Srinivason (2003) stated that fine-scale factors vary with depth that make it difficult to separate influences and differences of depth. [18]

An Oyster Toadfish, *Opsanus tau*, camouflaged to resemble growth on the artificial reef.

Biological Considerations

Referring back to designing artificial reefs to attract your targeted species. It is not always the targeted species, but the forage base (prey items) that must be considered. For example, recruitment of grunts provides an excellent forage base for larger piscivorous fishes such as groupers and snappers. [16]

Inshore sites provide excellent habitat for Tomtates, *Haemulon aurolineatum*, which feed on small, bottom dwelling invertebrates.



Biological Considerations

Release Mortality Rates

Studies show a relationship between survival and capture depths. Shallower depths have shown an increased chance of release survival. [19]

These studies also point out many factors that affect release survival rate.

Release Mortality Rates

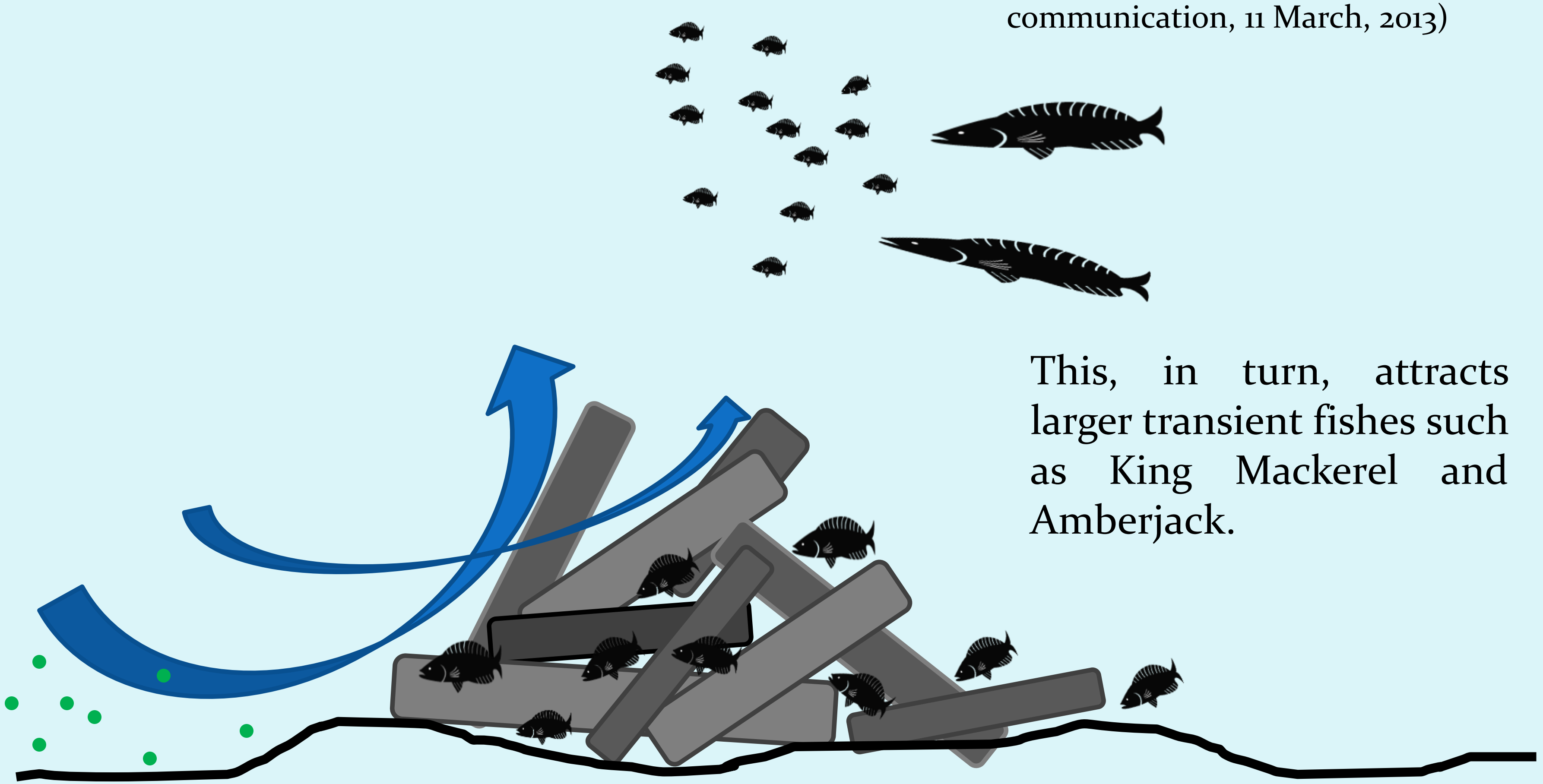
These studies point out that many factors affect survival rate including:

- Capture depth
- Venting
- Retrieval Rate
- Hook Type – circle hook vs. J-hook
- Surface to depth temperature difference
- Presence of surface predators
- Handling – proper release techniques
- Hook location – relevant to hook type [20]

Fisheries Management depends the survival rate of commercially and recreationally important species.

Reef Height and Profile

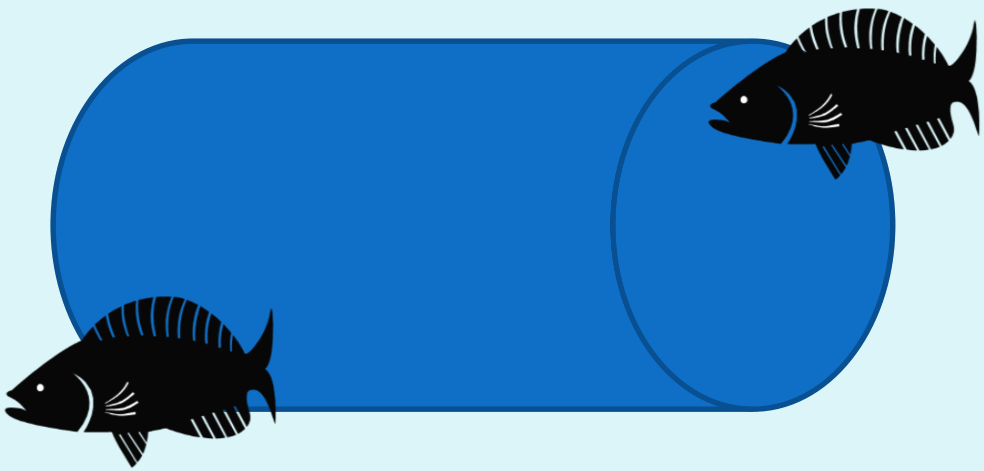
Increased Profile increases upwelling that provides planktonic food source to smaller, schooling fishes.
(Hayward Mathews, personal communication, 11 March, 2013)



This, in turn, attracts larger transient fishes such as King Mackerel and Amberjack.

Reef Complexity / Shelter

One way to increase carrying capacity and biomass of artificial reefs is to provide shelter from predation to its inhabitants. [21]



The use of large artificial reef units provide little refuge for juvenile and smaller fishes important to the reef's overall health.

"The use of a mixture of different kinds of materials of different sizes and void spaces in irregular piles facilitates creation of a complex cavity network of small interconnected chambers which appear to provide benefits for many fish species – both predators and prey – that may find features that suit their specific requirements." [22]

Studies suggest that the variation in habitat type and size created by artificial reefs removes some factors (environmental bottlenecks) that may affect productivity. The increase in complexity may have positive impacts on fish abundance, species richness, and diversity. [23]

A decrease in juvenile to adult succession could lead to an environmental bottleneck

A Seaweed Blenny hides amongst artificial reef growth.

Habitat Complexity is important to juvenile reef fish and invertebrate survival.

Natural reef complexity is also formed by extensive epibenthic growth on the reef.

One study found 20,000 individual organisms living among the branches of 42 small Oculina colonies, including 230 species of mollusks, 50 species of crabs, 47 species of amphipods (small crustaceans), 21 species of echinoderms, and numerous other groups of organisms. [24]

Arrow Crabs and Damsels forage around a head of Oculina coral.

Photo Courtesy Volusia County Reef Research Dive Team

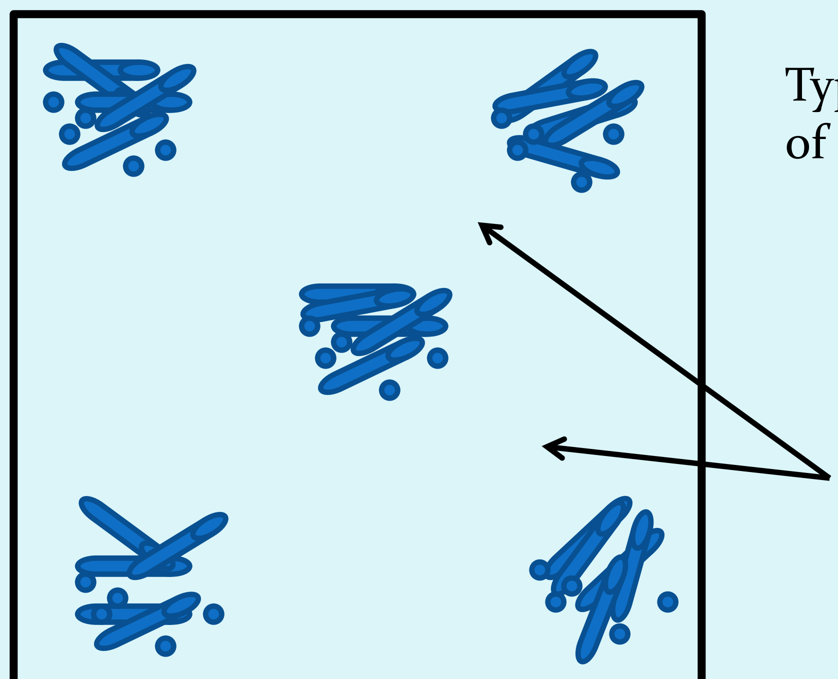
Artificial Reef Permitting

The U.S. Army Corp of Engineers (ACOE) is responsible for the construction and maintenance of artificial reefs in federal waters. [25] Local coastal governments undergo a lengthy permit process that can last 12 months.

Permits within State Waters are fulfilled by the ACOE and the Florida Department of Environmental Protection. [26]

A typical Volusia County Artificial Reef is permitted as 1 square mile.

Typical arrangement of deposits



Deposits are usually 2/10 of a mile apart.

Subsequent deposits will start to fill in spaces.

Artificial Reef Construction

Extreme care must be taken during the construction phase of creating artificial reefs.

- Deposits must be deployed within a specific permitted site.
- Weather conditions must be carefully monitored because of the large, heavy load being transported to the site.
- Loading the barge is a safety concern while preparing to haul concrete culverts and materials.
- Deploying materials at the site is also a huge safety concern.
- The sinking of steel-hulled vessels is conducted by cutting holes at the water line and then pumping water into the vessel.

Preparing the barge for a deployment of materials to site 4.

Succession Of Artificial Reefs

Typically, algae and invertebrates colonize new reef structure rapidly, but the biomass and species diversity changes drastically until an equilibrium is reached several years later. [27]

Dominant species change, through competition, over the succession of a new reef. Eventually an equilibrium is reached where the benthic biomass and species diversity remains somewhat constant.

Fouling organisms, such as this Red Encrusting Sponge, provide a complex habitat that is preferred by more complex organisms such as corals. [28]

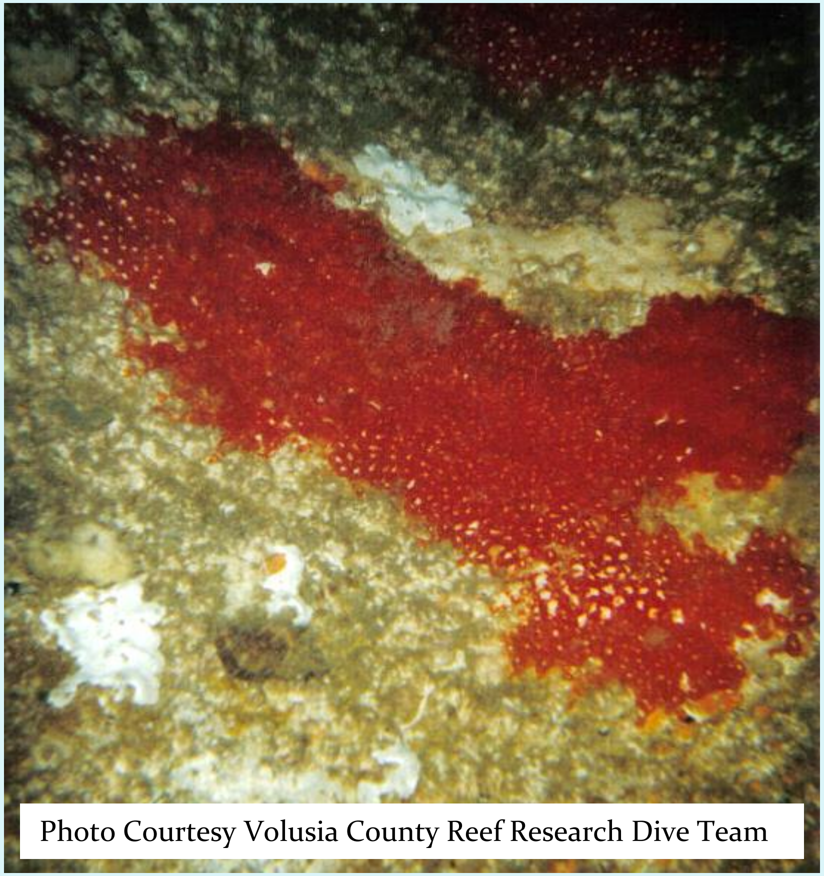


Photo Courtesy Volusia County Reef Research Dive Team

Monitoring Artificial Reefs

Monitoring artificial reefs is conducted by the Volusia County Reef Research Dive Team

Monitoring the locations, biological activity, and seasonal differences is very important to maintaining permitted sites and gauging the overall health of the reef site. These parameters are recorded using Diver Survey Forms. Changes before and after reef equilibrium is meet are documented through the use of these reef survey forms.

Survey Forms are recorded then analyzed and stored in Volusia County. This data is also shared with "Reef Environmental Education Foundation" (REEF). The data is loaded into REEF's online database, where a variety of reports can be created on species diversity, distribution, and population trends. This can be accomplished for a specific reef or large geographic region.

http://news.nationalgeographic.com/news/2011/03/pictures/110404-sharks-lionfish-alien-fish-invasive-species-science/

Solving User Conflicts

Conflicts between user groups can be very detrimental to an Artificial Reef program.

Recommendations To Help Solve User Conflicts:

- Common courtesy is key to sharing the reef areas. Everyone has access to reef areas and these areas should be shared with equal respect.
- Communication – use your VHF radio to communicate with other boats about their activities, intentions, and estimated time remaining on the site.
- Follow safe "Diver Down" Regulations. If you approach within 300 feet of a "Divers Down Flag", you must approach no faster than necessary to maintain headway. Diving is inherently dangerous and following this rule closely is very important to being respectful to divers.
- If an area is being fished, avoid diving that deposit or communicate openly with the fishermen to gauge their openness to diving that area.
- Designate different sites for preferred usage, i.e. fishing, underwater photography, spearfishing.

Solving User Conflicts

• Increase reef sites to dilute user concentrations and conflicts.
• Organize meetings between user groups to open communication and problem solve issues. Conflicts between user groups at sea could be lessened by familiarity between groups.

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