

SUWANNEE REGIONAL REEF PROGRAM

-Summary-

Off the mouth of the Suwannee River along Florida's north-central Gulf coast, University of Florida researchers began a program in 1990 to answer many questions regarding the use of artificial reefs for fishery management. Specifically, the program is seeking to answer two important questions: (1) How much fishing can take place at an artificial reef site before the fish caught exceeds the fish produced by that reef? And (2) To what extent can the balance between fish harvested and fish produced be shifted to maximize the sustainable fish populations at managed reef sites? In addition to answering these questions, the research is providing new information to improve reef designs and how to place them for best results.

At the onset of the program, 22 artificial reef sites known as the Suwannee Regional Reef System were developed as the largest experiment of its kind in the nation. Located along the 40-foot depth contour, the reefs are approximately 15 nautical miles offshore and bracket the mouth of the Suwannee River. Each site has six patch reefs spaced either 25, 75, or 225 meters apart. Each of the reefs consists of either four or 16 prefabricated concrete cubes with horizontal 55 gallon drums as central cavities. The reefs were constructed with funds collected from the sale of Florida saltwater fishing licenses.

With funding from the Department of Environmental Protection's Marine Resources Grants Program (saltwater fishing license revenues), the initial study of these reefs from 1991-1995 provided the following findings:

- Although it takes time, gag grouper eventually find that they like living on the artificial reefs. Gag populations increased steadily over the first five years of the project--especially on patch reef with 16 cubes. By the fifth summer of the program, the 16 cube reefs placed 225 meters apart had an average gag population of 400 fish per site. In fact, gag grouper accounted for almost 42% of the total fish weight at all reefs. However, as gag populations increased, the number of black sea bass and adult tomtate decreased from several hundred fish per site to virtually none.
- The total fish abundance and biomass was significantly greater on 16-cube reefs than on 4-cube reefs. But despite having four times as many cubes, there were only two to three times as many fish at the 16-cube sites.
- Some fish that shelter at the reefs and forage over sand bottom had a distinct preference for reefs spaced 225 meters apart. For example, black sea bass, white grunt, cubbyu and gray triggerfish all prepared to maximize the spacing between reefs. On the other hand, adult tomtate and sheepshead, both of which display the same shelter and forage characteristics, did not seem to care about reef spacing.

Suwannee Regional Reef Program Summary

October 1996

Goals for the Program:

- To help resolve the Attraction-Production issue by testing the leading hypotheses for how artificial reefs function ecologically.
- To relate the productivity of fishery species on reefs to behavioral, community, and ecosystem processes (e.g., habitat selection, species interactions, regional productivity, and forcing functions like river outflow) and to fishing pressure.
- To recommend artificial reef design and siting criteria for sustainable fisheries.
- To educate or inform people about what is scientifically known regarding artificial reefs and their applications in an ecosystem context.

Description of the Suwannee Regional Reef System:

- 22 reef sites along the 40 foot depth contour in the northeastern Gulf of Mexico, approximately 15 NM offshore and bracketing the mouth of the Suwannee River.
- The percent cover of natural hard-bottom habitat near these reef sites ranges from 0 to 33%, and rocky outcrops higher than 50 cm are not found in the vicinity.
- Each site has 6 patch reefs in a hexagon spaced at either 25, 75, or 225 m apart.
- Each patch reef has either 4 or 16 prefabricated concrete cubes (35³ inches) with horizontal 55 gallon drums as central cavities; all patch reefs on a site are the same size.
- The core experiment has 4 replicates for each of the 4 combinations of patch reef spacing and size (i.e., 4 & 16 cubes x 25 & 225 m spacing); the remaining sites are earmarked for intrusive experimental manipulations.
- Although others have tested reef size, this is the first experimental system in which reef spacing has also been included in order to test habitat patchiness *per se*.

The General 3-Step Hypothesis That Initiated This Program:

1. We assumed that reef structure provides motile species refuge from predation, and perhaps currents.
 2. Reef-dwelling species that forage off-reef on sand-dwelling benthic prey were expected to create a gradient of prey depletion around their refuge, resulting in a negative feedback to the reef dwellers' energy budgets, residency times, and local abundances.
 3. The patchiness of reef habitat was expected to affect the degree of prey depletion and the intensity of negative feedback, such that smaller, more widely spaced patch reefs may be more favorable to such reef residents than are larger, more closely spaced patch reefs.
- Together, this was termed the "resource mosaic hypothesis" as a specific extension of density-dependent habitat selection theory in behavioral ecology.
 - Results from our initial DEP project led to a broadening of this general hypothesis to also include coupling by gag grouper to pelagic baitfish, with presumably less prey depletion and negative feedback than expected exclusively from benthic prey.

Specific Testable Hypotheses and Descriptive Objectives:

Initial DEP Project (1991-1995)

- H₀: The size and spacing of patch reefs do not affect the abundance of fish.
- H_{alt}: Fish that shelter at reef structure but feed across the adjacent sand plain should be more abundant at widely spaced patch reefs than at closely spaced patch reefs.
- H_{alt}: Small fish that shelter *and* feed directly on a patch reef surfaces should be more abundant on larger patch reefs, but should not be affected by patch reef spacing.
- H_{alt}: Larger patch reefs should have more fish than smaller patch reefs, but the increase in fish abundance with increasing patch reef size should show a diminishing return.
- H₀: Reef age does not affect fish abundance patterns among reef treatments.
- H_{alt}: Effects patch reef size and spacing emerge over time as total fish abundance increases and feedback mechanisms operate.
- H₀: The size and spacing of patch reefs do not affect the abundance of macrobenthos in the adjacent sand plain.
- H_{alt}: Macrobenthos in functional guilds vulnerable to fish predation should increase in density with distance from reefs, and be least abundant around large, closely spaced patch reefs.

Current DEP/MARFIN Project (1995-1998)

- Obj: To determine residency times for juvenile to adult gag (200-800 mm TL) on patch reefs of contrasting sizes and distances apart, and to test the assumption that gag residency times differ with these measures of habitat patchiness.
- Obj: To estimate the frequency of movement between adjacent patch reefs, and to test the assumption that gag move freely among patch reefs spaced tens of meters apart, but move infrequently if at all among patch reefs spaced hundreds of meters apart.
- Obj: To test the assumption that young-of-the-year gag immigrate to intermediate, shallow-water reef habitat during an autumnal pulse of colonization, and to estimate their abundance relative to older cohorts.
- Obj: To confirm or refute that gag of reproductive size classes emigrate from shallow-water reef habitat during late fall-early winter, and immigrate to such habitat during late winter-early spring, as would be consistent with an offshore winter spawning migration.
- H₀: In the absence of directed fishing, gag growth rates and relative weights or condition do not differ among reefs of contrasting patch reef sizes and patch-to-patch distances (i.e., reef habitat patchiness).
- H_{alt}: Gag growth rates and relative weights or condition are greater on reefs supporting higher densities of gag (i.e., larger and perhaps more widely spaced patch reefs).
- H₀: Somatic growth of gag on designed experimental reefs is indistinguishable from somatic growth in the regional stock of gag as a whole.
- H_{alt}: The growth of gag on at least some experimental reef treatments (see prior H_{alt}) is faster, on average, than for the broader regional stock.
- H₀: Fishing pressure has no effect on growth and condition of surviving gag.
- H_{alt}: Reduced densities of gag as a consequence of fishing mortality magnify any effects of habitat patchiness on growth rates and condition of surviving gag.
- Obj: To determine the extent to which reduced gag density, as a consequence of fishing mortality, affects the community structure of local reef fish assemblages.

Initial DEP Project (1991-1995), continued

increased, however, abundances of black sea bass and adult tomtate decreased from several hundreds per reef site to virtually none, with a concurrent loss of reef treatment effects for these species.

- With respect to sand-dwelling macro-invertebrates, the densities of suspension feeders and burrowers within 75 m of reef structure were reduced relative to non-reef control areas. Suspension feeders and surface burrowers, in particular, were significantly affected by reef treatments, but the patterns of those effects are too complex for simple interpretation (i.e., apparently involving several direct and indirect effects).

Current DEP/MARFIN Project (1995-1998)

- The residency "half life" of juvenile to adult gag that have been tagged on Suwannee Regional Reefs to date is approximately 10 months, and as expected, the rank order of residency times among reef treatments corresponds to the rank order of gag abundance.
- Gag move among patch reefs on a site infrequently (0-2 movements per week when sampled at 24 hr intervals), and move significantly less at 225 m reef distances than at 75 or 25 m spacings. Furthermore, resightings of ultrasonically tagged fish suggest that gag stay at or return to a home patch reef.
- An autumnal pulse of immigration by young-of-the-year gag was not obvious during the fall of 1995, but an increased of 18-30 cm gag has been observed in the fall of 1996.
- A synchronous emigration of reproductive size classes was not obvious during late fall 1995, although the lowest average numbers in the largest size classes (i.e., 60-69 cm, 70-79 cm, and 80-89 cm) occurred in November (Dec. and Jan. sampling was missed). June 1996 also showed an increase in the largest size classes compared to prior months.
- Data pertinent to hypotheses regarding somatic growth, condition, and fishing effects will be gathered with the onset of directed fishing in November 1996.

Conclusions from Results to Date:

- The resource mosaic hypothesis survived its initial test. Because of unexpectedly high gag densities, however, the original hypothesis was broadened to include coupling to pelagic as well as benthic prey. These two sources for off-reef prey are expected to differ in their degrees of local prey depletion and density-dependent effects on reef fish.
- One can safely assume that gag residency is long enough and movements localized enough for reef treatment and fishing effects to appear as differences in growth and condition.
- Autumnal immigration by young-of-the-year gag directly onto Suwannee Regional Reefs may depend on year class strength. A highly synchronous emigration during late fall by gag of reproductive sizes has not been obvious; gag in these size classes can overwinter on Suwannee Regional Reefs. A hint of late spring returns of large fish is not yet conclusive.
- We now have a much better, but far from thorough understanding of how warm-temperate reefs function ecologically. While the resource mosaic hypothesis remains viable, others have been disproven. High densities of fish at artificial reefs are not simply a behavioral artifact (Carr and Hixon) and are not dependent on primary and secondary production associated with the reef itself (Bohnsack et al.). Reef structure provides refuge from predation (Hixon and Beets, Herrnkind and Butler), yet trophic linkages to off-reef prey must be important to the production of fishes from reef habitat.

Upcoming FSG Project (1997)

- H_o:** Hydrodynamic conditions induced by reef structure (e.g., turbulence, upwellings, persistent water masses, suspended sediment concentrations) do not differ between large and small patch reefs.
- H_{alt}:** Such conditions are more pronounced around large patch reefs than small ones.
- H_o:** Concentrations of nutrients, particulate organic carbon, and plankton in the water column do not differ between large and small patch reefs, nor between reefs and non-reef controls.
- H_{alt}:** Concentrations of nutrients, particulate organic carbon, and phytoplankton are greater around large patch reefs than small ones, and greater around reefs than non-reef controls, which corresponds to induced hydrodynamic features.
- H_{alt}:** Concentrations of zooplankton are greater around large patch reefs than small ones, and greater around reefs than non-reef controls, corresponding to hydrodynamic features.
- H_o:** Local standing stocks of baitfish at the same reef sites do not differ between large and small patch reefs, and are not correlated with hydrodynamically induced differences in nutrient and plankton concentrations.
- H_{alt}:** Baitfish abundance and biomass is greater at large patch reefs than at small ones, and correspond to hydrodynamic conditions induced by reef structure.
- H_{alt}:** Baitfish abundance and biomass at patch reefs is correlated with nutrient and phytoplankton concentrations.
- H_{alt}:** Baitfish abundance and biomass is correlated with zooplankton concentrations.

Research Findings to Date:

Initial DEP Project (1991-1995)

- As expected for fishes that shelter at reefs and forage over sand, the black sea bass, white grunt, cubbyu, and gray triggerfish were all significantly more abundant on patch reefs spaced at 225 m than at 25 m. Adult tomtate and sheepshead, which also shelter at reefs and forage over sand, were not affected by reef spacing. Adult tomtate, however, were more abundant in summers on 16-cube patch reefs where juvenile tomtate had previously recruited in great swarms, while sheepshead were abundant only in winter spawning aggregations at 16-cube patch reefs.
- As expected for the small fishes very closely associated with reef surfaces, the seaweed blenny and belted sandfish were significantly more abundant on 16-cube patch reefs than on 4-cube reefs. The seaweed blenny was unaffected by patch reef spacing, but the belted sandfish was more abundant at 25 m than at 225 m spacings.
- Total fish abundance and biomass was significantly greater on 16-cube reefs than on 4-cube reefs, but the four-fold difference in reef material yielded only a two- to three-fold difference in fish numbers.
- Reef age significantly affected abundance patterns of fishes among reef treatments but in an unexpected way. Gag increased significantly in abundance over the first five years, and the rate of increase was greater on 16-cube reefs than on 4-cube reefs. The increase in gag corresponded in both time and reef type to an increase in summer baitfish abundance. By the fifth summer, gag abundance at 16-cube x 225 m reefs averaged almost 400 fish per site (rank order of gag abundance: $16 \times 225 > 16 \times 25 > 4 \times 25 = 4 \times 225$) and gag accounted for almost 42% of total fish biomass across all reefs. As abundances of gag

Remaining Research Priorities:

H.R.F.I.A.

SEAFISH
Petersen

- Make direct comparisons of growth rates and condition (e.g., relative weights, lipid concentrations, enzyme activity) between reef fish (e.g., gag) occupying Suwannee Regional Reefs and natural hard-bottom habitat of the region.
- Quantify relationships of reef fish abundance (e.g., gag) with pelagic production (primary, secondary and tertiary) and hydrodynamic processes across spatial and temporal scales.
- Characterize and quantify significant pathways of energy flow and material transport in coastal ecosystems using the Suwannee Regional Reefs and contemporary ecological techniques (i.e., stable isotope analyses).
- Test the hypothesis that resident reef fish production (e.g., gag) is tied to the seasonal transport of tertiary production from inshore habitats (e.g., seagrass).
- Experimentally manipulate fish densities (e.g., gag) on replicate patch reefs for a direct test of density-dependence in residency times, growth rates, and condition; fish densities and these measures are expected to re-equilibrate over time.
- Experimentally manipulate reef cavity volume for a direct test of refuge control on gag abundance and reef fish community structure.
- Develop quantitative models of fish abundance and production derived from the research to date and a coupling to regional productivity and ecosystem processes.
- Continue visual fish counts on the Suwannee Regional Reefs, thereby extending the 6-year time-series of *offshore* fisheries independent monitoring in order to:
 - • Determine if reef fish assemblages attain equilibrium or climax conditions;
 - • Distinguish trends in reef fish abundance from natural cycles and variability;
 - • Relate reef fish abundance to *inshore* fisheries independent monitoring;
 - • Identify temporal patterns of abundance indicative of species interactions;
 - Validate quantitative models of reef fish abundance (see above).
- Answer the very practical questions, "*At what level of fishing pressure does the harvest from a reef equal or exceed the fish production attributable to that reef?*" and "*To what extent can that equilibrium point be shifted to maximize sustainable fish production in a managed ecosystem?*"