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BIOLOGICAL SURVEY AND ANALYSIS OF FLORIDA'S ARTIFICIAL REEFS

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INTRODUCTION

In recent years throughout the United States there has been active interest in artificial reefs as a means of expanding the recreational and commercial fisheries for midwater and bottom fishes. Numerous studies have been conducted as a result of this growing interest by State and Federal agencies, universities, and the private sector. Ample information is available concerning different materials and how to construct artificial reef structures (Buckley, 1982; Hilbertz, 1981; Kilma and Wickham, 1969; Parker et al., 1974; Sheehey, 1981; Stone, 1975; Stone et al., 1974; Turner et al., 1969; Woodhead et al., 1982). Several excellent studies have addressed reef colonization, standing crop, and other aspects of artificial reef development (Fast, 1974; Hastings, 1979; Hastings et al., 1976; Lukens, 1981; Randall, 1963; Stone et al., 1979; Turner et al., 1969), but sufficient evidence is lacking which would serve as a guideline to increase or enhance the productivity features of an artificial reef.

Recent efforts were made to determine which physical variables influenced colonization of artificial reefs by assessing the available published and unpublished literature, and constructing a data matrix of physical and biological parameters. These data could have provided a basis for a statistical prediction of the standing crop of fishes under certain environmental conditions. Of the many studies available only 17 directly addressed the relationship between the physical features of a reef and the fish production (Bortone, 1976; Crozier et al., 1977; Fast, 1974; Hastings, 1979; Hastings et al., 1976; Hueckel and Stayton, 1982; Kilma and Wickham, 1969; Lukens, 1981; Parker et al., 1979; Randall, 1963; Smith et al., 1979; Sonnier et al., 1976; Steimle and Ogren, 1982; Stone et al., 1979; Turner et al., 1969; Walton, 1982; Wickham et al., 1973). In addition to the unequal methods, recording procedures and quantity of data presented made it impossible to accurately predict which physical parameters are related to population density or diversity.

The overall objective of our investigation was to conduct visual assessments of fish populations on a series of artificial reefs constructed of different types of materials existing under varied environmental conditions. Once obtained the information would be analyzed and the results used to establish a data base of physical and biological parameters which influence fish productivity and production. These data could then serve as basic guidelines to permit identification of factors which would require further investigation, and to construct testable hypothesis regarding future artificial reef research.

METHODS AND MATERIALS

During October and November of 1983 we made a series of SCUBA dives on 30 artificial reefs representing ten primary areas along Florida's coastline. The areas of investigation were selected based on zoogeographic zones, proximity to passes, protected harborages, and high recreational activities. At each major area specific reefs were selected to encompass the different types of materials used in artificial reef construction, reef profiles (high and low), depths at which reefs are placed, the distances from inshore and offshore topographical influences, and substrates upon which the reefs are placed.

The types of reef materials examined included ship hulls, barges, platforms, concrete rubble and culvert, rubber tires, steel rubble and culverts, and appliances. The type of material used in the construction of each reef was recorded as a percentage value. In instances where the composition was mixed an estimate of the percent of each material was used. Depths of the structures ranged from 3 meters to 29 meters, and distances from shore included sites as far as 20 nautical miles seaward.

The intent of the investigation was to gather as many physical variables as possible as well as to visually assess the fish population diversity and density. Two divers conducted 25 minute dives on each chosen structure. Four stations were selected on each reef, and one diver recorded the species and numbers of fish observed at each station during a five minute interval. The other diver collected water samples, temperature, core samples of the substrate, and made physical measurements of the size and height of the structure while making a visual assessment of the fish population.

Selected sites were photographed with a super 8 movie camera using photoflood and high speed Ektachrome film (ASA 160), with the focal distance set at 2 meters. Still photographs (35 mm) were also taken with a Nikonos IV using a Mark 150 strobe and Ektachrome file (ASA 64). These records were used later to verify the species and numbers documented by the divers.

The temperatures and salinities were recorded for the surface and the bottom, and core samples were obtained using a polyvinyl chloride (PVC) pipe 20 cm long and 4 cm I.D. as a coring tool. In each case the sample was taken approximately 4 meters outside the perimeter of the reef. The substrate was later washed in fresh water, dried at 60 degrees C, then separated using a series of seives (no's 10, 20, 40, 60, 80, and 120). Once separated each portion was weighed and the percentage calculated. In addition the percentage of shell hash was calculated for each size, and the total percentage recorded as one of the physical variables. In three instances the entire substrate was live coral and/or rock, and these values were also recorded as physical data. Where only a portion of the substrate was solid, a subjective estimate of the percentage was recorded.

We felt that two of the most significant physical factors to consider were the size of a reef and it's cryptic nature. The area of each artificial reef was determined by measuring the structure at the points of greatest dimension and recording the square meters of bottom area. The average height of the material was then used to calculate the volume of the structure, and the maximum height was recorded for profile analysis.

The cryptic nature of a structure was one of the most difficult to record because it required converting a qualitative evaluation into a numeric value. In doing this we carefully considered each type of structure, then assigned a range of numeric values between one and ten. The range of values enabled us to compare and evaluate similar and different structures individually and collectively. For example barges were assigned a numeric range of three, four, and five. If the barge being investigated was essentially intact, with few hiding places, it was rated a three. If there were numerous holes and debris, and many hiding places it was assigned a value of five. This method was applied to concrete, ships, tires, and other structures as well. The

Japanese artificial reef was rated highest at ten, and block-like solid structures were rated the lowest with a one.

Visibility was determined with a 20 cm Sechi disc by measuring horizontally from the disc to the point at which the shape of the disc was no longer clearly discernible. When visibility was less than two meters the dive was aborted.

Species lists and numbers of fishes recorded by divers were compared for completeness and accuracy. The species were arranged taxonomically according to Robins et al. (1980). Each family was listed chronologically from 1 to 193, and the species within each family were entered sequentially beginning with one through the last species. The total number of each species was recorded by reef which enabled us to compare families, selected portions of the reef community, of the total population with the recorded physical variables. For initial analysis the biological data were reduced to six families which represented the primary reef groups sought by recreational fishermen. They are described by the following codes:

109 = Serranidae
120 = Carangidae

124 = Lutjanidae
127 = Haemulidae

129 = Sparidae
142 = Labrida

A data matrix was constructed listing reefs on the vertical axis and the physical and biological variables on the horizontal axis. Reef identification numbers consist of a three digit code which follows the identification process in the Atlas of Artificial Reefs (Aska and Pybas, 1983). The following are the numbers and descriptions which can be used to identify non-permitted sites.

Reef	Description
349	Reef F, 4.4 nautical miles west of Caxambas Pass, Marco Island, Florida.
350	Reef E, 4.4 nautical miles west of Caxambus Pass, Marco Island, Florida.
351	Shrimp boat, approximately 6 nautical miles north of Key West, Florida.
352	Steel vessel, approximately 10.3 nautical miles northwest of Key West, Florida.
353	Steel vessel, approximately 10.4 nautical miles northwest of Key West, Florida.
354	Rock jetties, approximately 6 nautical miles north of Key West, Florida.
433	Japanese artificial reef, 10 nautical miles west of Clearwater Pass, Clearwater, Florida.

434	Cement culverts, 10 nautical miles west of Clearwater Pass, Clearwater, Florida.
600	Stage II platform, 2.2 nautical miles southwest of St. Andrews Pass, Panama City, Florida.
650	Eight washing machines, 4.5 nautical miles southeast of Pensacola Pass, Pensacola, Florida.

Physical variables recorded and used in the computer analysis are listed below.

REEF: Reef identification number.
YR_BLT: Year reef placed on site.
MAT_S: Percent steel in the composition.
MAT_C: Percent cement.
MAT_R: Percent rubber.
MAT_W: Percent wood.
COMP_1: Percent solid substrate.
COMP_2: Percent substrate larger than 2.0 mm.
COMP_3: Percent .850 - 2.0 mm.
COMP_4: Percent .425 - .850 mm.
COMP_5: Percent .250 - .425 mm.
COMP_6: Percent .180 - .250 mm.
COMP_7: Percent .125 - .180 mm.
COMP_8: Percent less than .125 mm.
LATITUDE: Latitude of the site.
Cryptic: Potential hiding places provided by the structure.
AREA_M2: Bottom area in space meters.
AREA_M3: Estimate of the volume of material in cubic meters.
MAX_HGHT: Highest point of the structure. Recorded in meters.
DEPTH: Recorded in meters.
DST_SHRE: Distance from shore in nautical miles.
DST_100F: Distance from 100 fathom in nautical miles.
DST_PASS: Distance to pass or entrance of the closest drainage. Recorded in nautical miles.
VOL_SHD: Mean volume of discharge of the nearest drainage.
WIND_DIR: Predominant direction in degrees from which the wind blows.
WIND_VEL: Mean wind velocity recorded in nautical miles per hour.
CURR_DIR: Resultant water current entered in degrees. Recorded as the direction the current sets.
CURR_VEL: Mean current velocity recorded in nautical miles per hour.
VISIBILITY: Visibility recorded in meters.
LONGITUDE: Longitude of the site.
TIDE_TYPE: S = semidiurnal; D = diurnal; M = mixed (Fernald, 1981).
W_STMP_L: Lowest winter surface temperature in Farenheit.
W_STMP_H: Highest winter surface temperature.
W_STMP_A: Average winter surface temperature.
S_STMP_L: Lowest summer surface temperature.
S_STMP_H: Highest summer surface temperature.

S_STMP_A: Average summer surface temperature.
W_BTMP_L: Lowest winter bottom temperature.
W_BTMP_H: Highest winter bottom temperature.
W_BTMP_A: Average winter bottom temperature.
S_BTMP_L: Lowest summer bottom temperature.
S_BTMP_H: Highest summer bottom temperature.
S_BTMP_A: Average summer bottom temperature.
F_STMP: Fall surface temperature.
F_BTMP: Fall bottom temperature.
W_SSAL_L: Lowest winter surface salinity.
W_SSAL_H: Highest winter surface salinity.
W_SSAL_A: Average winter surface salinity.
S_SSAL_L: Lowest summer surface salinity.
S_SSAL_H: Highest summer surface salinity.
S_SSAL_A: Average summer surface salinity.
W_BSAL_L: Lowest winter bottom salinity.
W_BSAL_H: Highest winter bottom salinity.
W_BSAL_A: Average winter bottom salinity.
F_SSAL: Fall surface salinity.
F_BASL: Fall bottom salinity.
SHELL: Percent shell hash in substrate.
FAMILY: Family identification number.
FALL: The abundance of observed species.

The biological data were reduced to the sum of those species observed in each of the six selected families and merged with the physical variables (Appendix 2). Basic descriptive and correlation coefficient analysis were performed for all physical variables for each family (Appendix 3).

Stepwise regression analysis is limited to using approximately 20 independent variables. The factors which we removed from the set of physical data were variables such as temperatures, salinities, tidal variations, current and wind directions and velocities, and volume of water sheds. It was felt that these conditions could not be directly influenced by persons involved in improving or constructing artificial reefs, and were therefore the best choices for elimination. This succeeded in reducing the number of physical variables in the set to 21. Missing information for reef 354 made it necessary to remove it from the data set which reduced the number of observations containing adequate information to 27 reefs. The reduced physical data containing 21 variables for each observation were than merged with the reduced biological data (Appendix 4).

Stepwise regression was conducted on the merged data and the significant (.15 level) independent variables identified (Appendix 5). These results were then used in the multiple linear regression analysis for the construction of the prediction mathematical models (Appendix 6).

RESULTS

Physical and biological data were recorded for 28 of the proposed sites. The remainder were not surveyed due to rough water, reduced visibility, or the inability to locate the site by using loran. These provided 28 observations for physical variables and 494 observations for biological data (Appendix 1).

Greatest family diversity (15) occurred on site 629. This is an intact steel barge located 4.6 nautical miles southwest of Destin Pass in 21.6 meters of water on a predominately sand bottom containing 18% shell hash. It encompasses 1300 square meters of bottom area and its maximum height is 3 meters. The highest species diversity (29) was sound on site 353, a non-permitted site in Florida Bay. This is a sunken steel ship which broke in half after running aground approximately 10.3 nautical miles northwest of Key West in 9.4 meters of water. It rests on a hard coral and rock bottom, and covers 708 square meters of bottom area with a maximum height of 5.9 meters.

Lowest diversity (7 species in 4 families) was recorded for site 432. This reef consisted of concrete culverts and rubble located 2.9 nautical miles west of Bradenton, Florida. It is situated 10.4 meters deep on a sandy bottom containing 9% shell hash, and covers 1200 square meters of area with a maximum relief of 1.2 meters.

The largest standing crop of fishes was recorded at site 600, which is also a non-permitted reef. This platform structure is constructed similar to an oil platform. It stands in 18.4 meters of water 2.6 nautical miles southeast of St. Andrews Pass in Panama City. The structure extends above the surface and covers 324 square meters of sand bottom containing 12% shell hash.

The results of the correlation analysis are condensed and presented here for the parameters found significant (.05 level) during the calculations.

Serranids

Abundance was positively correlated to the distance from shore and the distance from the pass. Negative correlations include fall and winter surface temperatures, summer surface and bottom salinities, winter bottom salinity, and reef area in cubic meters.

Carangids

Abundance was positively correlated to visibility and medium grained (.250 to .425 mm) sandy substrate.

Lutjanids

Abundance was positively correlated to rubber tires, fine grained (.125 to .250 mm) sandy substrate, area in square meters, depth, low summer bottom temperature, average summer bottom salinity, and low surface salinity.

Haemulids

Abundance for the family was positively correlated to 14 factors, and there were no negative correlations. These variables include: medium grained sandy substrate; maximum height of the reef; volume of the water shed; low winter bottom temperature; all summer bottom temperatures; high and low winter surface and bottom salinities; low summer surface salinity; and average and high summer bottom salinity.

Sparids

Positive correlations were noted for coarse (larger than 2 mm) substrate and the reef area in square meters. Abundance was negatively correlated to the average summer bottom salinity.

Labrids

Family abundance was positively related to solid substrate, depth, current velocity, and visibility.

Regression analysis produced mathematical models for all six families in the reduced biological set. Variables which were identified as being significant (.15 level) in the models indicated both positive and negative influences. An overview of these variables is presented for each family along with comments concerning other factors in the models.

Serranids

Parameters determined significant in the model indicate positive correlations to the size of a reef in square meters of bottom area, and the distance from shore. Negative relationships were noted for steel and rubber construction materials, the cryptic nature of the reef, the volume of materials in cubic meters, and fall surface temperature.

Carangids

Models parameters for this family included only four variables. Positive correlations for maximum height and visibility, and negative affiliation with depth and fall bottom salinity.

Lutjanids

The variables in this model which reflect positive relationships are rubber tires, bottom area in square meters, maximum height, fall surface and bottom temperatures, average summer surface salinity, and fall bottom salinity. Negative influences were noted for the area in cubic meters and fall surface salinity.

Haemulids

Only 3 of the 21 independent variables were identified as significant in the model. Maximum height and distance to the pass were both positively correlated to fall abundance, while the distance to shore has a negative relationship.

Reasonable to excellent R-square values were obtained for all families which strongly suggests that the models are well constructed, and that the parameters have a high probability of significance. Mean square error values were moderate to excessive which tend to weaken the models. Wide latitude in the confidence levels existed for most of the models, and variations between predicted abundance and observed values were generally wide ranged except for Serranids. Overall consideration indicates that the models are of minimal value as they presently exist.

DISCUSSION

The preliminary results of stepwise and linear regression analysis reflect high R-square values which leave little doubt that the models are of value. The other less positive aspects of the analysis requires further explanation.

Successful construction of a mathematical model for predicting fish populations on a given reef requires several things: 1) an adequate volume of the data must be gathered; 2) the samples must be representative of the entire population; 3) the data must be properly manipulated and analyzed to account for variations in the samples. Each of these conditions was examined and the following comments are extended.

We feel that the number of investigations was smaller than required for the task. High R-square values can be obtained with limited assessments, but a low mean square error (reported high in our models) is needed, and is adversely influenced by a small number of observations.

In addressing the representative sampling factor and how it effects out results several points are important. Our investigations were conducted at a time when seasonal faunal changes normally occur. Some members may have already migrated to deeper, more stable water. Samples were taken shortly after the end of the heaviest seasonal fishing period. It's possible that significant numbers of key families were harvested during that time. On three of the sites we assessed spearfishermen were actively engaged in taking fish from the reef. On another site divers were harvesting stone crab claws, and concurrent fishing occurred on one other structure. These activities may have caused key species to move out of the area thereby altering the results of the sample. A red tide bloom occurred two weeks before we assessed the area between Tarpon Springs and Sarasota. Local biologists reported dead grouper and snapper as well as small reef fish. All of these conditions can cause variations in the abundance of fish recorded for the different sites. If there were significant variations in the observed values they would have an adverse effect on the model, and especially on the predicted values and confidence levels obtained for each observation.

Two things which minimize these effects and strengthen the models are to obtain more information through additional observations, and to manipulate the raw data. The effects of wide variations in data can be reduced by transforming the values to a logarithm scale. This wasn't done initially because good results obtained with raw data are more powerful statistically than those obtained from transformed data. Other actions such as transforming percentage values recorded in raw terms (90%, 45%, etc.) to values such as .90 and .45 or to a logarithm scale would reduce excessive variations and enhance the process of analysis.

Grouping entire families into one abundance value may cause undesirable results in analysis. In this instance we are trying to construct a predictive model for catchable fish, but we are including the population of their noncatchable relatives in analysis. Selection of specific members of key families would reduce the adverse effect and align the models to our specific needs.

The important point is that although the models are, at present, loosely constructed they appear reliable enough to warrant transforming the data, and if significant improvements are noted efforts should be made to field test the results.

CONCLUSION

Additional analysis is needed on the existing data to eliminate some of the excessive latitude noted in the models. To do this several steps should be taken.

1) A recently modified program which enables us to include abundance data of selected families as part of the set of independent variables should be used in the analysis.

2) Recorded percent values, raw abundance data, and other factors should be transformed in some manner to minimize excessive variance.

3) The biological data set should be reduced to specific groups within each key family.

The existing data are inadequate and suspected of being non-representative of the annual population. Therefore this type of study should be repeated to:

1) Provide more data through increased observations.

2) Expand the results to include all seasons.

3) Account for variations due to seasonal changes and other influencing factors.

4) Field test the improved models.

LIST OF APPENDICES*

1. Raw physical and biological data (14 pages)

2. Merged physical and reduced biological data (16 pages)

3. Descriptive statistics and correlation coefficient analysis (39 pages)

4. Merged reduced physical and reduced biological data (8 pages)

5. Stepwise regression (20 pages)

6. General linear model (18 pages)

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*Editorial Note: Due to the number of pages and format of the computer print out, the appendices are not reproduced in this report. Interested readers may request this highly technical information from the senior author at the address noted on the title page.

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