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**Economic Valuation and Impacts of Artificial Reefs:
A Summary of Literature on Marine Artificial Reefs
in the United States**

December 1995

**Economic Valuation and Impacts of Artificial Reefs:
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Marine Artificial Reefs in the United States**

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The Atlantic States Marine Fisheries Commission

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Preface

The Artificial Reef Technical Committee of the Atlantic States Marine Fisheries Commission was established in 1984 to provide critical advice to the Commission on development of artificial reefs along the Atlantic Coast. The committee is composed of the senior state scientists responsible for marine artificial reef programs in eleven of the Commission's fifteen member states (Rhode Island, Massachusetts, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Florida). Representatives of the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and the Environmental Protection Agency also participate on the committee. The following report was produced under advice and review from this committee. Financial assistance for this project was provided by Federal Aid in Sport Fish Restoration Program of the U.S. Fish and Wildlife Service under a cooperative grant (no. 14-48-0009-95-1256) with the Atlantic States Marine Fisheries Commission.



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**Economic Valuation and Impacts of Artificial Reefs:
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Introduction

Artificial reefs have increased the opportunity to catch fishing by providing essential fishery habitat and target destinations for fishermen. Traditionally, artificial reefs have been developed in the United States with a priority toward supporting sport fishing activities. Such development has occurred in the United States for over one hundred years. However, the majority of reef development activities has been a much more recent phenomena occurring within the past ten years. The resurgence of reef development during this time was a direct result of the National Fishing Enhancement Act enacted in 1984 and the 1984 Wallop-Breaux Amendment to the Federal Aid in Sport Fish Restoration Act. This amendment greatly expanded the amount of federal assistance available to the states to undertake new sport fish restoration projects. Artificial reefs projects provided a natural fit for restoring sport fishing and increasing fishing opportunities through enhanced access to offshore fisheries.

In 1989, the Artificial Reef Technical Committee of the Atlantic States Marine Fisheries Committee examined priorities for artificial reef development along the Atlantic coast. One of the top priorities was to evaluate the economic and social importance of artificial reefs developed by the states. Such information was deemed essential to bolster support for artificial reef development and to enhance the ability of state and federal programs to carry out the mandates of the National Fishing Enhancement Act of 1984. Over the years, collection and analyses of such information has been sporadic. The expense of comprehensive studies has limited the type and quantity of data collected by anyone study. Information collected through these studies has been extrapolated broadly for application to artificial reefs regionally and nationally.

This literature review provides the first step to address the need for up-to-dated and more accurate information on artificial reef activities. In order to assess the types of studies which should receive funding priorities, the committee felt that critical review of existing information should be undertaken. Information on the social values of artificial reefs is virtually non-existent. Therefore, this study focuses on a comprehensive review of economic evaluation of artificial reefs nationwide.

The following report provides a review of published articles on the subject and includes gray literature generally unavailable through regular avenues. Omission of any relevant information is not intentional. The Commission welcomes notification of any information which will add to this compendium. It is the Commission intent that the information in this report will provide a better understanding of the value of artificial reef development and assist in a more focused approach to advance national mandates of the National Fishing Enhancement Act of 1984.

This report contains summaries of papers, articles and other professional communications which deal with economic aspects of artificial reefs. The studies were located during a comprehensive search¹ of Atlantic, Gulf and Pacific coast marine agencies, universities, state Sea Grant programs, professional associations (AFS, Agri-econ, etc.), media, electronic bulletin board services and other contacts provided by the ASMFC.

The summaries typically include five categories. The first four categories -- Geographic Area/Reef Studied, Extent and Method of Data Collection, Analyses Performed and Results -- are objective summaries of the contents of the paper. The fifth category, Comments, is a subjective review of the economic contents of the study.

Comments are drawn from several sources. First, the author's of the study in question will often provide caveats or highlight limitations of the methods and data used. Second, J. Walter Milon, a respected author and authority on economic valuation of artificial reefs, has reviewed and provided comments on several of the studies in this summary. His comments are often included in this section when applicable. Third, the current author will provide comments concerning the economic content of studies.

¹Thanks goes out to all of those who facilitated the literature search. A partial list includes Jim Kirkley, Robert Ditton, Donald Pybas, Henry Ansley, John Dodrill, Rod McLeod, Steve Murphey, Roger Pugliese, Mel Bell, Bill Figley, Bill Gordon, DeWitt Myatt, Jeff Tinsman, Frank Steimle, Dale Beaumariage, Jon Lucy, Jim Bohnsack, Steve Heins, Ron Lukens, Walter Tatum, William Seaman, J. Walter Milon, Jon Stevely, Mike Solum, Barbara Colin, Eric Hutchinson, Steve Heins, Mike Meier, Mark Helvey, Steven Phillips, Leroy Hushak, Fritz Schuler, Don Schultze, Dennis Bedford and Ray Buckley. The summaries' content and errors therein are the sole responsibility of the author.

These comments will often critique data collection methods, economic estimation methodologies, and the applicability of the study to estimating artificial reefs' economic value and impacts. Some studies involved in this summary are only peripherally related to economic valuation or impact analysis or concentrate on methodological issues rather than developing final economic evaluations. These types of observations will also be noted in the Comments section.

Shorter summaries are provided when the article or paper in question is an extension of work done by the same author in a study reviewed earlier in the summary. Short summaries also are given for studies which: 1) contain only limited economic information; 2) principally summarize or review other papers or theories; or 3) when the paper is purely theoretical.

Glossary of Economic Terms

Cost-Benefit Analysis: Compares the costs associated with a particular project (e.g., adding another artificial reef) with the expected economic benefits. Both costs and benefits are typically expressed in dollar values and sometimes converted into a ratio of the two numbers. This type of analysis is distinctly different from economic impact analysis, although both can be expressed in dollar terms.

Contingent Valuation Method: Expressing the expected economic benefits associated with a particular project in dollars is sometimes very difficult because improvements such as increased enjoyment of a fishing experience or an increase in recreational fish catch is not bought or sold in a market with prices. The contingent valuation method attempts to assign dollar values to these improvements by directly asking people potentially affected by the project how much they value the changes in dollar terms. This method has been somewhat controversial in economic circles because it involves directly asking people questions about the values of goods. However, contingent valuation studies that are well designed and implemented do lead to estimation benefits that are generally acceptable. The values gained by this method are typically larger than those obtained by the other major valuation technique, travel cost models. Some economists tend to think of values from contingent valuation as upper bounds on the true value.

Economic Impact Analysis: This type of analysis focuses on the sales, income and employment associated with an activity such as fishing and diving over artificial reefs. Appropriate analysis of a particular project requires looking at the impacts

both with and without the project so that the change associated with the project can be identified. However, many studies fail to do this. Total economic impacts from a project is composed of three types of impacts: (1) The direct impact of a project is the change in local spending; (2) Indirect impacts are the changes in output and employment to produce the goods and services required by businesses who receive the direct impact; (3) The induced impacts are the changes in demand for goods and services due to change in local employees' income brought about by the direct and indirect impacts.

Random Sample: A sample of individuals being questioned for primary data is random when each individual in the population of interest has an equal chance of being selected.

Travel Cost Method: This method attempts to estimate the economic benefits associated with a particular project by studying the past participation and spending behavior of those potentially affected by the project.

Willingness to Pay: A term that is sometimes used interchangeably with economic benefits, especially in contingent valuation studies. Contingent valuation studies often ask respondents to answer questions such as "What is the most you would be willing to pay for additional artificial reef in the bay?"

Study Reviews

The following are reviews of individual studies located in the literature search conducted for this report. These are reviewed in the order presented in the bibliography. Each review follows the format of: "Author(s);" "Title;" "Geographic Area/Reefs Studied;" "Extent and Method of Data Collection;" "Analyses Performed;" "Results;" and "Comments."

1. Anderson, Eric, and Dean Devereaux, 1986.

Title: "Testing for Two Kinds of Bias in a Contingent Valuation Survey of Anglers Using an Artificial Reef," Paper presented at the Annual Meeting of the Eastern Economic Association.

Geographic Area/Reefs Studied: The Chesapeake Light Tower artificial fishing reef

off the coast of Virginia.

Extent and Method of Data Collection: Short form surveys, which identified anglers fishing experience and reef usage on the day of the interview, were administered to 201 anglers intercepted on launching ramps and docks. Respondents who were users of the artificial reef were asked to complete a longer form of the survey either by phone or by self-administered questionnaire filled out at home. Sport divers were also intercepted at dive shops. Reef users were asked to fill out longer forms of the survey at their homes. The response rate for long form surveys of reef users was about 60 percent.

Analyses Performed: Mean willingness to pay was estimated for the different subsamples involved in the survey, although these numbers were not reported. Regressions attempting to explain why individual's willingness to pay varied across the sample were presented.

Results: The mean willingness to pay estimate was found to be sensitive to the format of question asked. However, mean willingness to pay was not reported.

Comments: The main purpose of the paper was to test for biases in the contingent valuation format, not to value the artificial reefs. No economic benefit or impact numbers are reported. The respondents from which data is gathered were not a random sample, rather a convenience sample.

2. Bell, M., C.J. Moore, and S. W. Murphey, 1989.

Title: "Utilization of manufactured reef structures in South Carolina's Marine Artificial Reef Program," *Bulletin of Marine Science*, Vol. 44:818-830.

This article discusses alternative manufactured artificial reefs designs. Several designs are evaluated on their procurement, handling and transportation costs, as well as stability, durability and biological effectiveness.

While the study's main content is not economics, cost effectiveness of manufactured reefs is also discussed. However, as Milon (1991) points out, the cost effectiveness study is flawed because they compare costs of different reefs to economic impacts. Instead, costs should be compared to economic benefits. Economic impacts and economic benefits typically differ in magnitude.

3. Bockstael, Nancy, Alan Graefe, Ivar Strand, and Linda Caldwell, 1986.

Title: "Economic Analysis of Artificial Reefs: A Pilot Study of Selected Valuation Methodologies," Technical Report 6, Artificial Reef Development Center, Sport Fishing Institute, Washington, D.C.

Geographic Area/Reefs Studied: The subject of the report was all South Carolina artificial reefs. Particular attention to three reefs near Murrells Inlet on the northern coast of South Carolina. The three reefs near Murrells Inlet were made of old tires and various sunken vessels. At the time of the study, South Carolina had 13 offshore reefs, two estuarine reefs, and six offshore wrecks.

Extent and Method of Data Collection: This study used a combination of mail survey and on-site interviews. Interviews were conducted at several launching locations in Murrells Inlet. A convenience sample (no attempts at stratification were made) of 68 interviews were obtained from 70 interview attempts (97 percent).

Mail surveys were sent to 2,000 boat owners who lived within 100 miles of the coast and owned boats of 17 feet in length. Responses were received from 763 of the 1,753 deliverable surveys (44 percent response). This sample included boat owners who do not currently fish saltwater. Both survey samples included individuals who did not currently use the artificial reefs.

Economic Analyses Performed: This study estimated average economic benefits for both on-site and mail survey samples. The benefits or value of several different hypothetical changes conditioned on the fact that the boaters had already chosen a launch site were considered. These different scenarios included: a 20 percent improvement in reef catch, a doubling of costs associated with accessing reefs, reduction by half in chances of being 'skunked' at reef, and elimination of reefs. Methodologies used in estimating economic benefits included both contingent valuation and travel cost models.

Results: Qualitative. Fishermen contacted by the mail survey perceived little difference in the cost of fishing at or away from artificial reefs. They also believed that overall fishing fun and number and types of fish caught were 'better' at artificial reef sites, but that crowding was worse. One-third of respondents said that the presence of artificial reefs made them fish more often. Fishermen interviewed at Murrells inlet tended to report little difference in the perception of fishing quality between artificial reef and other sites. Those interviewed generally thought artificial reef sites required less travel time.

Participation. Fishermen interviewed at Murrells inlet split fishing effort roughly equally between artificial reefs and other sites. Anglers whose first fishing site of the day was an artificial reef were more likely to move to another location than those who started on natural bottom, but they tended to move to another artificial reef site. Of the respondents to the mail survey, about two-thirds of saltwater fishermen used artificial reefs to some degree, although few used artificial reefs exclusively. Travel cost methods showed that the probability of using artificial reefs increased with fishermen's experience and increased with an angler's perception of being 'skunked' at non-reef alternatives relative to artificial reefs.

Quantitative. The report provides four estimates of the average benefit per user of artificial reefs in South Carolina.

	Contingent Valuation Method	Travel Cost Method
Murrells Inlet Sample	\$893/yr.	\$242/yr.
South Carolina Boaters Sample	\$328/yr.	\$195/yr.

Those in the Murrells Inlet on-site sample valued the artificial reefs more than South Carolina boaters mail sample. This is not surprising because the Murrells Inlet sample are a self-selected sample who are more likely to take many fishing trips and use artificial reefs more often than those in the mail sample. As is typical, the contingent valuation method yielded higher benefit estimates. Often contingent valuation figures are considered upper-bounds on the benefits being estimated.

The study also estimates the benefits associated with several different changes in fishing costs and results potentially caused by reefs. These average values are all derived from the travel cost method and are conditioned on the fact that the boater has already chosen a launch area. That is, these numbers are not adjusted for the possibility that individuals could choose different launching areas. In other words, these numbers don't allow for substitution between sites. If the model allows for anglers to substitute between sites, the value placed on any single site would likely be less.

Change	Mural Inlet Sample	S.C. Boaters Sample
20% improvement in reef catch rate	\$12/trip	\$5/trip
50% reduction in chances of being 'skunked'		\$6/trip
Double Costs of accessing reefs		-\$21/trip
Eliminate reefs		-\$52/trip

Comments: The assessment of economic benefits associated with reefs was thorough. The use of both travel cost and contingent valuation methods help validate the general range of the economic estimates. All key variables in the models used for economic valuation were statistically significant. Both reef users and reef non-users were included in the sample. The unconditional valuation numbers in the first table of numbers above allowed for substitution between sites and was based upon a random sample of boaters.

The authors point out several limitations of the study:

- a). The study attempted to quantify the degree to which the existence of artificial reefs influence the number of anglers and the number of fishing trips taken per angler. Qualitative results from this study suggest that more trips are taken because of artificial reefs. However, the non-response of many individuals to certain questions caused the quantitative model to predict the number of angling trips poorly. Therefore results from this model were not included in final benefits estimate. If qualitative results are correct (artificial reefs cause existing anglers to fish more often) and/or artificial reefs draw new anglers, final benefit estimates be biased downward;
- b). The participants of the Murrells Inlet on-site sample, like most intercept surveys, were not randomly chosen. However this only affected one set of numbers presented; and
- c). Economic values related to charter or head boat fishing or recreational diving were not estimated.

4. Brown, Bernard, and Bill Figley, 1992.

Title: "An Economic Analysis of New Jersey's Wreck and Artificial Reef Fisheries: A Mailed Survey of Boater and Divers for the 1991 Season," report submitted to the New Jersey Dept. of Environmental Protection and Energy, Division of Fish, Game and Wildlife, Marine Fisheries Administration.

Geographic Area/Reefs Studied: Artificial reefs and wrecks off the New Jersey coast.

Extent and Method of Data Collection: Responses from a mail survey were received from 307 boat owners who had fished on artificial reefs or wrecks (46 percent response rate) and 162 Scuba divers (33 percent response rate).

Analyses Performed: Artificial reef and wreck usage statistics were estimated for

divers and anglers. Trip expenses were calculated and angler socio-economic characteristics were summarized for both groups.

Results: Participation. ANGLERS. The average angler surveyed took 34 fishing trips, of which 36 percent were over artificial reefs, wrecks or rock structures (about 12 trips). The average driver took about 8 trips to artificial reefs during 1991. DIVERS. Divers surveyed averaged about 19 diving trips of which eight were taken at artificial reef sites.

Qualitative. ANGLERS. Seventy-eight percent of anglers reported that they were satisfied with their artificial reef fishing experiences.

Quantitative. ANGLERS. Average expenses per trip to an artificial reef was \$92. Annual average equipment costs per angler was about \$4,000. The average increase in costs necessary to induce anglers to cancel a fishing trip was reported as \$106. DIVERS. Average per trip expenses for all divers surveyed was \$130/day.

Comments: This was principally a participation study that included a survey of costs incurred. The survey provides insight to typical usage and travel patterns of those who use the reefs as well as equipment inventories of reef users. No economic impacts or benefits were estimated as this was not the intent of the survey.

Because sample respondents were not chosen randomly, results based upon extrapolation of sample results to the entire state must be examined carefully. The sample may represent more avid artificial reef users and, therefore, the extrapolated results might overstate actual expenditures and use.

5. Buchanan, C.C., 1973.

Title: "Effects of an Artificial Habitat on the Marine Sport Fishery and Economy of Murrells Inlet, South Carolina," Marine Fisheries Review, Vol. 35, no. 9, pg. 15-22.

Geographic Area/Reefs Studied: Paradise Reef off of Murrells Inlet, South Carolina.

Extent and Method of Data Collection: Estimation of fishing effort was calculated by counting the number of private boat launchings at randomized time periods from June to September, 1972. From these observed launchings, boats' registration numbers were recorded and matched to addresses from State registry forms. From

these individuals, a random sample of about 20 percent were mailed a questionnaire; a 59 percent response rate was obtained. From this group who participated in the fishing survey, a second questionnaire was mailed to nonresidents to ascertain the importance of the reef in anglers' decision to fish at Murrells Inlet; 102 responses were received (no response rate given).

Analyses Performed: Angler usage of reefs and intensity of fishing over natural and artificial habitats were analyzed. Also, estimates of the number of anglers who would not return to the Inlet if the reef were not present was estimated. This allowed the authors to estimate the percent of current angler expenditures in the immediate area that were attributable to presence of the reef.

Results: Participation. Paradise Reef received nearly 35 percent of the offshore angler hours and yielded nearly 40 percent of the catch.

Quantitative. The second questionnaire asked nonresident anglers 1) if they utilized the Paradise Reef and 2) if the reef were no longer there, would they return to the area. About 86 percent of anglers utilized the artificial reef. Nearly 16 percent of the private boat anglers active in the ocean sport fishery during the June - September, 1972, were attracted to the area because of the reef. The portion of the anglers who would not return if the reef were removed was estimated to account for about 10 percent of money spent by ocean fishermen.

Comments: The study is an early attempt to isolate the impact of artificial reef with the use of a contingent use question in the second survey; it asks whether individuals would return if the reef weren't there. The sample size for the second questionnaire upon which the analysis was based is fairly small and no mention was made of randomness of sampling or the response rate. Also, only nonresident values were considered.

While the decrease in expenditures due to removal of the reef was estimated, multipliers were not applied to arrive at the estimated economic impacts of such a policy change. Also, the economic impact estimates associated with the removal of the reef applied only to the Murrells Inlet area. Milon (1991) points out that no attempt was made to see if anglers who would not return in absence of the reef would not fish at all or would simply fish in another area.

6. Chang, Semoon, 1986.

Title: "Siting Plans for the Establishment of Artificial Reefs: An Economic Analysis," Mississippi-Alabama Sea Grant Consortium and University of South Alabama.

This paper principally contains a theoretical economic model whose purpose is to calculate economic benefits associated with artificial reefs. No data is collected, and estimates of economic benefits or impacts are not presented.

As Milon (1991) mentions, the theoretical model is flawed as it suggests counting both economic benefits and economic impacts as benefits of artificial reef projects. Including both would over-inflate benefit estimates. The author also suggests deducting subsidies from government or charities from the artificial reef project costs. For the many instances when artificial reefs are publicly funded, this would undercount the project's costs.

7. Daniel, Donnie D. and Joe E. Seward, 1975.

Title: "Natural and Artificial Reefs in Mississippi Coastal Waters: Sport Fishing Pressure and Economic Considerations," Bureau of Business Research, University of Southern Mississippi, Hattiesburg.

Geographic Area/Reefs Studied: Six natural and six artificial reef sites in the Mississippi Sound.

Extent and Method of Data Collection: Fishing pressure data was collected by taking boat counts from aerial surveys of the sites in question. Survey flights were made on 59 days selected randomly from days with passable weather from April to December, 1974. A morning and an afternoon flight were made on the selected days.

Analyses Performed: This study estimates fishing pressure on various types of artificial and natural fishing reefs in the Mississippi Sound. The recreation benefits of fishing at the survey sites were obtained by multiplying estimated angler days at each site by per day economic values suggested by the Water Resources Council principles and standards for planning.

Results: A summary of the aerial surveys show that natural fishing reefs had heavier fishing pressure than the artificial reefs. All but one natural reef had greater

fishing pressure than the most heavily fished artificial reef. The authors conclude that artificial reefs increase total fishing pressure but do not generate the degree of fishing pressure that is generated by natural fishing reefs.

Aggregate monthly benefits estimates for angling at artificial reef sites varies from \$46 to \$3,466 while estimates at natural sites range from \$237 to \$4,463. The value at artificial sites was typically less than those at natural sites.

Comments: As the authors point out, this study only collects and analyzes one portion of the data needed to determine benefits associated with additional artificial reefs: the number of anglers using the artificial reefs. Thus the study does not evaluate the benefits of increased catches due to artificial reefs. The authors also remind us that the benefit numbers derived benefits associated with fishing at the survey sites, not because of the survey sites.

The authors also point out that aerial surveys were limited to good weather days thus potentially leading to some bias in the fishing pressure and benefits results upwards.

8. Daniel, Donnie. D., 1976.

Title: "Empirical and Theoretical Observations on the Potential Economic Benefits and Costs Associated with Mississippi-Alabama Liberty Ship Reef Programs," Bureau of Business Research, MASGP-77-002, University of Southern Mississippi, Hattiesburg.

This paper presents a cost-benefit analysis of the sinking of Liberty Ships off the Mississippi and Alabama coasts. The analysis is conducted from the point of view of the Mississippi and Alabama state governments. Costs of the reef materials (ships) are accounted as zero costs because they were gifts from the Federal government. The only costs accrued by the states involved deploying the ships to their chosen locales, while the only benefits quantified in the report were those gained from selling off parts of the donated ships which had to be removed prior to sinking. No benefits accruing to recreational or commercial anglers were quantified, although discussions of how this might occur are presented.

The project of deploying these Liberty Ships was estimated to provide net economic benefits to the states of Mississippi and Alabama. The author points out that these

net benefits might evaporate if states were charged the true acquisition prices for the ships.

9. Ditton, Robert B., Leslie D. Finkelstein, and Jeff Wilemon, 1994.

Title: "Use of Offshore Artificial Reefs by Texas Charter Fishing and Diving Boats," Texas Parks and Wildlife Dept., Austin, TX.

Geographic Area/Reefs Studied: All artificial reefs off the Texas Gulf Coast.

Extent and Method of Data Collection: An inventory of Texas party, charter and dive boats captains were identified and mailed surveys. A total of 118 captains responded to the survey for an effective response rate of 68 percent.

Analyses Performed: Participation statistics for both artificial reefs managed by the Texas Parks and Wildlife Department and all artificial reefs of the Texas coast were estimated. Both the number of trips and number of customers in total were estimated. Trip distributions among reefs and distances traveled were also presented. Qualitative information concerning trip site selection, preferred placement and construction of future artificial reefs, and opinions concerning artificial reef issues were analyzed. Summary statistics concerning the boat captains' socio-economic characteristics were also calculated.

Results: Participation. Party boats took about 36,000 customers on about 1,300 trips to artificial reefs off the Texas coast in the year previous to interviewing. Trips to artificial reefs accounted for 40 percent of the total trips taken offshore by this group of captains. Charter boats took about 16,000 customers on about 800 trips to artificial reefs. These trips accounted for 50 percent of the total trips taken offshore by this group of captains. Dive boats took about 6,000 customers on about 300 trips to artificial reefs. These trips accounted for about 40 percent of the total trips taken offshore by this group of captains.

Qualitative. Captains reported that one of the most important influences during trip planning was travel distance to a reef site. Captains' most preferred reef materials were oil production structures, ships, and barges. Of the captains surveyed, 93 percent agreed that there should be more artificial reefs placed in the Gulf, 64 percent supported placing their own structures in safe locations, and 62 percent opposed placing marking buoys on all artificial reefs.

Comments: This is one of the few studies to include analysis of the charter and dive boat users of artificial reefs. While no economic impact or economic cost/benefit analyses were performed, the usage statistics are thorough. The study attempted to contact the entire known universe of full-time captains. As the authors points out, part-time or opportunistic charter and dive boat captains were ignored.

10. Ditton, Robert B. and Alan R. Graefe, 1978.

Title: "Recreational Fishing Use of Artificial Reefs on the Texas Gulf Coast," Texas Agricultural Experiment Station, Texas A&M University, College Station.

Geographic Area/Reefs Studied: All offshore oil rigs and other artificial reefs in the vicinity of the Brazoria, Galveston, and Chambers County coasts in Texas.

Extent and Method of Data Collection:

The study surveyed registered boat owners in the eight county area surrounding the Houston and Galveston metropolitan areas. Questionnaires were sent to a random sample of 1,500 owners of boats less than 26 feet as well as all 1,953 owners of boats 26 feet or longer. Response rates for both groups was 50 percent.

Charter and party boat captains working in this same area were also surveyed concerning their use of artificial structures. The study contacted 47 of 53 captains (89 percent response).

Analyses Performed: Saltwater anglers usage of artificial reef structures was estimated and angler characteristics effecting artificial reef usage were explored.

Rough calculations of aggregate expenditures by artificial reef anglers are also presented using per trip estimates from other studies of salt water anglers in other states as bounds for expenditures by anglers in the eight county area in Texas.

Results: Participation. About 38 percent of all boaters fishing in the Galveston Bay took trips near oil platforms, while nearly 11 percent took trips over artificial tire reefs. For offshore fishermen, oil platforms attracted more fishing attention than any other natural or artificial structures; 87 percent of all boat owners taking offshore fishing trips utilized oil platforms. About 50 percent of all offshore fishing trips occurred relative to offshore oil platforms.

About 53 percent of party and charter boat captains representing 72 percent of charter and party boats said they used the Liberty Ships artificial reef structures. Of those boats utilizing the Liberty Ships reefs, about 12 percent of all trips were taken to these artificial reef sites. About 23 percent of offshore trips were made to oil platforms.

Quantitative. By importing per trip cost estimates from studies of saltwater anglers in Mississippi and South Carolina and multiplying by the estimated number of trips made to artificial reef sites in the eight county area, the authors arrive at estimates of artificial reef related expenditures of \$6.1 million to \$7.7 million.

Comments: This study investigates participation of both private boat owners and charter/party boat anglers in an eight county area near the artificial reef sites. Data is collected either by attempting to reach all parties or by using random sampling procedures.

While a benefits transfer approach is used to estimate total expenditures by artificial reef anglers, economic impacts or benefits are not estimated. The amount of potential participation by anglers outside the eight county area was not addressed for the analysis of private boat owners. However, many of these 'tourists' were likely captured under the party/charter boat analysis.

11. Ditton, Robert B., Alan R. Graefe, Anthony J. Fedler, and John D. Schwartz, 1979.

Title: "Access to and Usage of Offshore Liberty Ship Reefs in Texas," Marine Fisheries Review, 25-31.

This article summarizes the participation results from Ditton and Graefe's 1978 study.

12. Gordon, W.R. Jr., 1987.

Title: "Predicting Recreational Fishing Use of Offshore Petroleum Platforms in the Central Gulf of Mexico." Ph.D. dissertation, Texas A&M University, College Station.

Material requested, but not yet received.

13. Graefe, Alan R., 1981.

Title: "Social and Economic Data Needs for Reef Program Assessment," in Artificial Reefs: Conference Proceedings ed. Donald Y. Aska, Report No. 41, Florida Sea Grant College.

This paper identifies what types of social and economic information about artificial reefs existed at the time of the study and presents an overview of methods used to draw samples from which to obtain socio-economic data.

No economic impact or benefit analyses are performed. Some participation numbers found in Ditton and Graefe (1978) are presented.

14. Greene, Gretchen, Charles B. Moss, and Eric M. Thunberg, 1993.

Title: "Estimation of Recreational Anglers' Value of Reef Fish in the Gulf of Mexico," mimeo, Food and Resource Economics Department, University of Florida, Gainesville.

Geographic Area/Reefs Studied: This study deals with the Gulf of Mexico recreational reef fishery in general - all artificial reefs in the Gulf of Mexico are included as well as all natural structures and bottom that attract reef fish species.

Extent and Method of Data Collection: A total of 863 reef anglers were involved in data collection for this study. These anglers were chosen from a list of individuals formed during on-site intercept surveys of recreational marine anglers conducted for the National Marine Fisheries Service (known as the MRFSS). All 863 anglers had taken a trip targeting reef fish in the Gulf of Mexico in the last two years. Of the 863 anglers, 221 were interviewed by phone once and then agreed to maintain a log of fishing activity for two months following the telephone interview. The other 642 were interviewed by telephone and then re-interviewed two months later concerning their fishing activity over the past two months. No response rates were provided.

Analyses Performed: Participation statistics are estimated, fishing trip expenditures are summarized and economic impacts are given. Also changes in participation due

to changes in catch rates and travel costs are estimated. Economic benefits numbers are also estimated for Florida, single day trip reef anglers.

Results: Participation. The average respondent took about 11 trips to the Gulf of Mexico targeting reef fish in the last year. About 87 percent of the reef fish angling trips reported in the first telephone survey were taken by private boat.

Quantitative. The study indicates that an increase of one fish caught per trip increases the number of trips taken every two months by 0.292 for Florida anglers only (this is the state from which the majority of observations come). An increase of one dollar per trip cost was estimated to decrease the number of trips taken every two months by 0.005.

Total expenditures for the state of Florida were extrapolated from this study's data by applying total population estimates provided by Milon. Expenditures by anglers in Florida targeting reef fish were projected to be \$385.6 million per year. A hypothetical decrease in catch rates was estimated to decrease expenditures by \$32.1 million per year. Per trip economic benefits for the Florida single day trip reef anglers was estimated at \$676 per trip. A hypothetical decrease in catch rate by one fish decreases economic benefits by \$64 per trip.

Comments: This study considered the expenditures and benefits associated with fishing for all reef species. The authors do not attempt to estimate values associated with artificial reefs.

The anglers selected to receive surveys all came from a pool of individuals intercepted at fishing sites. This might suggest that these individuals were self-selected heavy or avid anglers. Therefore, the values estimated may tend to overstate the value of the average angler and, when extrapolating results, tend to overstate total benefits and impacts.

Only expenditures associated with reef fishing trips were reported. Total estimated economic impact would require application of the economic models or multipliers associated with each type of expenditure.

Economic benefit estimates rely on economic parameter estimates which were not statistically significant. This calls into question the validity of benefit estimates.

15. Hanni, Eila, and Heyward H. Matthews, 1977.

Title: "Benefit-Cost Study of Pinellas County Artificial Reefs," Florida Sea Grant College Program, Technical Paper No. 1.

Geographic Area/Reefs Studied: Clearwater Reef, Pinellas County, Florida.

Extent and Method of Data Collection: Average costs of angling and diving trips were collected from surveys from anecdotal evidence collected from interviews with anglers, charter and party boat captains and others who participated in recreational reef activities in Pinellas County.

Analyses Performed: Benefit cost ratios were estimated for the Clearwater Reef under several scenarios: if use of the reef were restricted to use only by 1) 'Sunday anglers', and 2) divers. In both scenarios the reef is used to full capacity.

Results: Benefit cost ratios greater than one were calculated under the scenario of full utilization of the reef exclusively by Sunday anglers. Benefit cost ratios of greater than one signify projects in which expected benefits exceed expected costs. The benefit cost ratio calculated under the scenario of full capacity, divers only use range from 0.37 to 0.69.

Comments: This paper provides thorough estimates of project costs. However, the estimation of benefits is problematic.

Benefits estimates should be based upon observed behavior of anglers. Price and cost data are not collected systematically with random sampling, but rather from anecdotal evidence.

Construction of the demand curve from which angler benefits are derived is very arbitrary and not based upon econometric estimation. For example, Figure 6 suggests that no 'Sunday anglers' would access artificial reefs if the cost of fishing exceeded \$40 which is the average charter boat rate per person. Clearly the cost per day that completely eliminates usage will be higher than the average charter boat rate. Therefore benefits are underestimated.

Total benefit estimates are based upon the assumption that each reef will be used to full capacity. However, no estimate is made as to whether full capacity usage is possible (do enough people visit reef sites) or whether full capacity usage would steal customers away from other reef sites and therefore decrease the benefits at

other sites.

16. Holland, Stephen M., 1991.

Title: "Demographic Indicators of the Relative Need for Artificial Reefs in Florida," Coastal Management, 19(219-238).

Geographic Area/Reefs Studied: All of Florida's artificial reefs.

Analyses Performed: The study formulated an index of the demand for artificial reefs within each of Florida's 35 coastal counties. Eight different categories dealing with a county's fishing pressure, fishing boat inventory, or population growth were considered and 'scored'. Four points were assigned in one of the categories if the county was in the highest quartile of all counties analyzed, while three, two, or one points was assigned if the county ranked in the second, third or fourth quartiles, respectively. These scoring points were then added across all eight categories to form a total of demand points for each county. A normalized index was then created by dividing each county's by the number of artificial reefs currently in use off each county's coast line. Recommendations for future reef placement were then drawn from the normalized index calculated for each county.

Extent and Method of Data Collection: Data for each Florida coastal county was collected from previously published sources for each of the following categories: resident saltwater boat angler population, nonresident saltwater boat angler population, tourist (non-Floridian) saltwater boat angler usage, nonboat saltwater angler population, number of saltwater fishing clubs, number of charter/headboat services, number of registered pleasure boats (>15 ft.), and rate of population growth.

Comments: This study offers a unique approach to artificial reef program evaluation. The appeal of this approach is that it offers a simple ordering of counties where future artificial reef developed should be focused based upon previously published statistics. However, several inherent problems exist with the approach.

While the approach helps identify which coastal Florida county is most deserving of additional artificial reefs, it can't estimate if the benefits associated with additional reefs in any county outweigh the associated costs. This approach may suffice if money is already budgeted but not yet allocated, but may be of little use to justify expenditures.

The index arbitrarily assumes a linear form with each category receiving identical weight or importance in the final calculation. That is, the fishing pressure from tourists is scored equally to fishing pressure from county residents. If residents typically spend more total dollars than tourists and place a higher value upon additional artificial reefs than tourists, the index may misrepresent each county's relative demand. This could result in improper ranking of the counties' relative demand.

17. Hushak, Leroy J., and David O. Kelch, 1992.

Title: "Economic Valuation of Artificial Reefs: The Case of the Lorain County, Ohio Artificial Reef," research plan for Ohio Sea Grant Project.

Paper requested, but not yet received.

18. Liao, David S. and David M. Cupka, 1979.

Title: "Economic Impacts and Fishing Success of Offshore Sport Fishing Over Artificial Reefs and Natural Habitats in South Carolina," Technical Report 38, South Carolina Marine Resources Center.

Geographic Area/Reefs Studied: The 10 artificial reefs off the coast of South Carolina (all reefs existing in 1977).

Extent and Method of Data Collection: PRIVATE BOAT OWNERS. Data was gathered from both an annual survey and from 9 monthly surveys. For the annual survey, a random sample of the population of registered recreational boat owners in South Carolina counties (boats \geq 16 feet) was contacted. About 24 percent of deliverable surveys (1,055 surveys) were completed and returned. The monthly surveys were mailed to a randomly selected sample of South Carolina boat owners; 12.5 percent were completed and returned.

HEAD BOAT CAPTAINS. Personal interviews were completed with 14 of 16 South Carolina headboat captains (88 percent response) and 1,052 head boat anglers completed survey forms.

CHARTER BOAT CAPTAINS. Personal interviews with 20 of 32 South Carolina charter boat captain (63 percent) were completed. Charter boat anglers were randomly selected from charter boat captains' log books and 75 were contacted by telephone.

Analyses Performed: This study investigates participation in fishing over artificial reefs and non-reef sites, provides average per trip expenditures to reef and non-reef sites, estimates the economic impact of reef and non-reef fishing to coastal communities and the state, and compares fishing success at reef and non-reef sites. These analyses are completed for private boat owners, head boat anglers, and charter boat anglers.

Results: Participation. PRIVATE BOAT OWNERS. The study estimates that about 20 percent of all South Carolina boat owners participate in offshore fishing while about 11 percent of South Carolina boat owners participate in artificial reef fishing. Reef users averaged 23 days of offshore fishing with an average of 8.5 of those days fishing over artificial reefs. Aggregated days fishing over artificial reefs by boat owners is estimated at 33,550.

HEAD BOAT ANGLERS. The study estimated that 10,920 head boat anglers utilized reefs during 1977.

CHARTER BOAT ANGLERS. Thirteen of the twenty charter boat captains used artificial reefs as fishing sites. Total annual fishing trips for these reef users were 54 trips. Extrapolating provides an estimate of 315 artificial reef charter boat trips.

Quantitative. PRIVATE BOAT OWNERS. Average trip expenses per artificial reef angler was almost \$30, while expenditures per fishing party per trip were nearly \$67. The estimated aggregate trip expenditures across all boat owners was \$2.24 million for 1977, while equipment expenditures by boat owners associated with reef fishing was estimated at \$2.28 million. After applying economic multipliers, the total economic impact associated with private boat owners' reef fishing activities was estimated at \$9.09 million. Private boat owners utilizing artificial reefs caught an average of about 2 pounds of fish per hour over both reef and non-reef sites while those fishing only non-reef sites averaged about 4 pounds of fish caught per hour.

HEAD BOATS. Average trip expenditure per angler was estimated at \$23 which extrapolates to aggregate expenditures of \$254,436 for 1977. Including the multiplier effect of these expenditures, a total economic impact of \$582,658 was estimated.

Anglers in groups using reef sites caught slightly more pounds of fish than those groups utilizing only non-reef sites.

CHARTER BOATS. Average trip expenditures per charter boat reef angler was \$85 for an estimated total aggregate expenditure of \$160,430. Applying the appropriate economic multipliers provides an estimate of economic impact associated with charter boat fishing over artificial reefs of \$373,801. Pounds of fish caught by reef users averaged 28 pounds while the non-reef users caught about 36 pounds on average.

Comments: Random sampling is used to form sample of private boat owners while attempts are made to survey all charter and head boat captains. Random sampling used to contact head and charter boat anglers.

No economic benefit-cost analysis is provided, only participation and economic impact estimates.

The economic impact analysis of artificial reef angling refers to all trips taken over artificial reefs. As Milon (1991) points out, if artificial reefs were removed some anglers would increase non-reef fishing activity. That is, loss of all the artificial reefs would not cause loss of all the estimated economic impact. No estimate of the magnitude of the economic impact stemming strictly from the presence of the artificial reefs was provided.

19. Maher, Tom, 1994.

Title: "Fish/Dive Charter Questionnaire Summary," Memorandum: Department of Environmental Protection.

This memo summarizes the responses to a mail survey of Charter Boat captains in the Florida Panhandle area concerning usage of artificial reefs. At the time the memo was written, the survey was still in progress, but 53 responses were received from fishing charters and 12 from diving charters.

Results: The average fishing charter utilized 327 artificial reefs and 88 natural reefs in the course of a charter season, while the average diving charter used about 123 and 12 artificial and natural reefs, respectively. Fishing charters have placed, on average, about 137 reefs during their career while diving charters have placed about 60 reefs.

20. Milon, J. Walter, 1987.

Title: "The Economic Benefits of Artificial Reefs: An Analysis of the Dade County, Florida Reef System," Florida Sea Grant Report SGR-90.

Geographic Area/Reefs Studied: Seven offshore artificial reef sites in Dade County, Florida.

Extent and Method of Data Collection: This study used a mail survey of 3,600 randomly selected registered recreational boaters in Dade County, Florida (45 percent response rate).

Analyses Performed: Boaters' activity and artificial reef usage patterns were analyzed. Annual economic benefits per boater associated with adding an additional reef site were estimated using several formats of both contingent valuation and travel cost methods. Annual economic benefits for an additional artificial reef were aggregated over the entire Dade County recreational boating population. Estimated present value of benefits associated with the entire Dade County artificial reef system.

Results: Participation. Saltwater fishing was the most common boating activity (75 percent of total boating days). About 29 percent of respondents who fished used an artificial reef. About 13 percent of responding sport divers used an artificial reef.

Qualitative. Artificial reef anglers cited the chance to catch more fish as the main reason for using reefs, while many nonusers did not know of about artificial reef sites. Anglers using reefs generally enjoyed greater fishing success than did non-reef anglers. However, the author was unable to determine if reef anglers were simply better anglers or if the reefs improved the anglers' success.

The main reason cited by divers for using artificial reefs was that the sites were easy to locate. Many nonusers did not know about artificial reef sites or thought them difficult to locate. Those utilizing the reefs typically had more boating equipment, were more likely to belong to fishing and diving clubs, and were slightly younger.

Quantitative. Respondents were asked contingent valuation questions which

focused on the annual value of an additional reef site off the Dade County shore. Boaters who currently used artificial reefs had average values ranging from \$18/yr to \$27/yr. The range of values is necessary because different questioning formats yielded different average values. Average values of nonusers ranged from \$1 to \$32.

Benefits associated with adding another artificial reef site were also estimated using travel cost methods which are based upon observed behavior of surveyed boaters. Several different travel cost methods were used. Some methods only assessed the values held by current artificial reef users while others also included the value of nonusers in the per boater annual benefits average. The benefit estimates for current users ranged from an average of \$6/yr to \$21/yr while the estimate which considered nonusers was \$3/yr.

Total annual boater benefits from an additional artificial reef site, as estimated from the contingent valuation methods, ranged from \$121,937 to \$706,974. These values include both use and nonuse values of the Dade County boating population. Total annual benefit estimates, as estimated by travel cost methodologies, range from \$30,387 to \$102,279. These values include use values only and apply only to anglers who currently access the artificial reefs. The present value of the Dade County artificial reef system, using 'best estimates' from the various benefit estimate methodologies, ranged from \$17.5 million to \$128.3 million.

Comments: Overall, this is a thorough study. Random sampling of boaters provides both users and nonusers of the artificial reefs. A fairly tight range of economic benefit estimates emerges from a broad range of data methodologies and estimation techniques. The values presented do not include benefits from anglers and divers using charter boats. As the author points out, benefit estimates derived from some of the travel cost methods may contain upward bias if users consider non-reef sites as substitutes to artificial reefs.

21. Milon, J. Walter, 1988.

Title: "A Nested Demand Shares Model of Artificial Marine Habitat Choice by Sport Anglers," Marine Resource Economics, Vol. 5, pg. 191-213.

Geographic Area/Reefs Studied: Seven offshore artificial reef sites in Dade County, Florida.

Extent and Method of Data Collection: This study used a mail survey of 3,600 randomly selected registered recreational boaters in Dade County, Florida (45 percent response rate).

Analyses Performed: This paper estimates how responsive anglers' site decisions are to changes in artificial reef characteristics such as travel cost, travel time and catch rates per unit of fishing effort.

This paper uses travel cost methodology to calculate economic benefits associated with the hypothetical addition of an artificial reef at three different sites. Benefit levels are estimated for anglers falling into different income classes.

Results: The responsiveness of anglers' site choice allocations to changes in reef characteristics are quantified by the use of elasticities. These elasticities represent how different angler user groups sites (near-shore, offshore/natural habitat, offshore/artificial habitat) would reallocate the current number of trips to a given site if certain characteristics of the site increased by 10 percent. The characteristic that caused the greatest angler response in trip allocation was a change in catch rates per unit of effort, followed by travel cost and travel time. Anglers who were in user groups who principally fished offshore were the most responsive - they were the most likely to alter trip allocation if site characteristics changed.

Total annual benefits for the addition of a new reef was estimated at \$31,329. Using capitalization rates of three and seven percent yields net present values of \$1,044,300 and \$447,557, respectively.

Comments: This paper extends the analysis in Milon's 1987 paper. The provision of elasticity or responsiveness estimates allows for some indication of which reef characteristics alter trip site decisions. Also, this is the only study that considers the benefits accruing to different income classes from the addition of another artificial reef. Other comments from the 1987 paper also apply.

22. Milon, J. Walter, 1988.

Title: "Travel Cost Methods for Estimating the Recreational Use Benefits of Artificial Marine Habitat," Southern Journal of Agricultural Economics, (87-101).

Geographic Area/Reefs Studied: Seven offshore artificial reef sites in Dade County, Florida.

Extent and Method of Data Collection: This study used a mail survey of 3,600 randomly selected registered recreational boaters in Dade County, Florida (45 percent response rate).

Analyses Performed: This paper uses several variants of travel cost methodology to calculate economic benefits associated with the hypothetical addition of an artificial reef at three different sites.

Results: Mean annual use benefits per angler from the hypothetical addition of another artificial reef range from \$1.80 to \$38.59. The lowest value is derived from a methodology that explicitly considers all anglers, including those who did not utilize any artificial reefs during the year of the study, and considers the fact that natural and near-shore sites are potential substitutes to fishing at artificial reefs. Larger benefits estimates were generally associated with models that failed to include the prices or quality associated with substitute fishing sites or only included anglers who actually took trips to artificial reef sites.

Comments: This paper clarifies and extends the various travel cost methods used in Milon's 1987 paper. It provides a clear explanation of the nuances and pitfalls associated with the various travel cost methodologies used in this literature.

23. Milon, J. Walter, 1989.

Title: "Artificial Marine Habitats Characteristics and Participation Behavior by Sport Anglers and Divers," *Bulletin of Marine Science*, Vol. 44, No. 2, pg. 853-62.

Comments: This paper is a summary of the participation analysis conducted in Milon's 1987 paper. Both anglers and divers participation at artificial reef sites is considered. It extends the original analysis by incorporating qualitative characteristics of individual reefs into reef site choice models. No economic impact or benefit estimates are provided.

24. Milon, J. Walter, 1989.

Title: "Economic Evaluation of Artificial Habitat for Fisheries: Progress and Challenges," *Bulletin of Marine Science*, 44(831-43).

This paper does not contain any new estimates of economic impacts or benefits, but does summarize estimates from numerous pre-1989 papers that are summarized in this paper.

25. Milon, J. Walter, 1991.

Title: "Social and Economic Evaluation of Artificial Aquatic Habitats," in *Artificial Habitats for Marine and Freshwater Fisheries*, eds. William Seaman, Jr. and Lucian M. Sprague, Academic Press.

This book chapter provides an overview of the role of social and economic evaluation methods in artificial reef management and critiques several economic studies of artificial reefs. The chapter provides a good introduction to the different types of economic analysis that might be useful for project evaluation. Milon summarizes willingness to pay estimates from five different studies in Table 7.4 and critiques more than ten studies from the 1980's and early (all the studies are also summarized in this study).

26. Murray, James D. and Carter J. Betz, 1991.

Title: "User Views of Artificial Reef Management in the Southeast," University of North Carolina Sea Grant College Program, UNC-SG-91-03.

Geographic Area/Reefs Studied: Artificial reefs in North Carolina, Florida, and Texas.

Extent and Method of Data Collection: This study used a mail survey of sport fishermen, sport divers, commercial fishermen and environmentalists. Of a total mailing of 1,654 questionnaires, 721 were returned for a 44 percent response rate. Individuals were contacted by developing mailing lists from various clubs and associations that were thought to have members knowledgeable of artificial reefs.

Analyses Performed: Measured the awareness and use of artificial reefs by different user groups; examined the priorities placed on artificial reef building activities in relation to other fishery issues; identified major concerns of artificial reef programs by user groups; and reported on the acceptance of various management measures which could be used to minimize artificial reef conflicts.

Summary of Results: Participation. Overall, 82 percent of respondents somewhat or very familiar with their state's artificial reefs and 63 percent had used their state's artificial reefs. Average respondents took 2.3 fishing trips, 5.1 diving trips and 2.8 combined activity trips to artificial reefs in the previous year.

Qualitative. Respondents were highly satisfied with the North Carolina and Florida artificial reef programs, but somewhat dissatisfied with the Texas program. Most respondents (79 percent) reported some type of crowding or other conflict over competing uses of the artificial reefs. Respondents were willing to accept different potential management schemes to decrease conflict and preserve the resource. Commercial fishermen were the least accepting of the user groups to these management schemes, and the designation of times of day for specific uses of the reef was the management method receiving the least support from all groups.

Quantitative. Respondents were asked how they would react to having to purchase a stamp to fish or dive on artificial reefs if the funds were earmarked for artificial reef programs. Those who were in favor of such a stamp were then asked how much they would be willing to pay for such a stamp (< \$5, \$5, \$10, \$15, \$20, or > \$20). 57 percent of respondents were in favor of the proposed stamp, while 23 percent were opposed and 20 percent were indifferent. The median willingness to pay for those in favor of the proposal was \$10, while the reported mean value was \$11.81.

Comments: The study uncovers key issues and usage statistics of heavier users of the artificial reefs. The survey is extensive and allows analysis across different user groups within the state - sport fishermen, sport divers, commercial fishermen, and environmentalists. The report helps gauge awareness of these users to the states' artificial reef programs and identify usage conflicts that can be addressed by reef managers.

To ensure enough responses from people familiar with artificial reefs, the study probably oversamples heavy users of the artificial reefs. The opinions of light users of the resource may be too lightly valued, especially if states wish to expand usage of reefs by current light and non-users.

Quantitative economic benefits, costs, or impacts were not calculated. This was not one of the study's objectives, however.

27. Prince, E.D., and O.E. Maughan, 1978.

Title: "Freshwater Artificial Reefs: Biology and Economics," Fisheries Vol. 3, 5-9.

This paper contains only three paragraphs concerning economics. Only cost-side considerations are mentioned. The authors point out that costs can be decreased by making the construction of a reef a community effort. By enlisting donated labor and scrap materials for construction, costs can be held within managing agencies' budgets.

28. Rhodes, Raymond J., Melvin Bell and David Liao, 1994.

Title: "Survey of Recreational Fishing Use of South Carolina's Marine Artificial Reefs by Private Boat Anglers," Project No. F-50 Final Report, Office of Fisheries Management, SC Wildlife and Marine Resources Dept.

Geographic Area/Reefs Studied: The 28 artificial reefs off the coast of South Carolina (all reefs existing in 1991).

Extent and Method of Data Collection: Data was collected from two sources. The first source was an annual mail survey of registered boat owners' saltwater fishing activities during 1991. The second source was through the use of three periodic mail surveys which surveyed boat owners about saltwater fishing activities during a three month period in 1992. Samples for the annual survey were drawn randomly from the population of registered boat owners in all South Carolina counties with powered boats greater than or equal to 16 feet. Samples for the periodic survey were drawn randomly from the subset of the previous population that lived in a county within 50 miles of the coast. Overall response rate from the annual survey was 49 percent while the overall response rate to periodic surveys (which contained more questions than the annual version) was 23 percent.

Analyses Performed: The study estimates the regional economic impact associated with private boat fishing activities on South Carolina's marine artificial reefs as well as exploring the relationship between artificial reef characteristics (placement, age, etc.) and the level of fishing activities at the reef. Resident anglers' usage of the reefs is also reported.

Results: Participation. Overall, 31.5 percent of respondents to the annual survey fished in saltwater from a boat. Of these 47.8 percent indicated they had fished on an artificial reef during 1991. About 27 percent of respondents' near and offshore

fishing days were primarily trips to artificial reefs. The average respondent spent about 9 days in 1991 fishing exclusively over artificial reefs. Extrapolating yields about 74,000 exclusive artificial reef fishing days along the entire coast. Average catches per trip over artificial reefs were 13.6 fish weighing 36.2 pounds.

Qualitative. Based on the 1991 annual survey sample, 35 percent of respondents who fished on artificial reefs indicated that the presence of artificial reefs resulted in a change in their recreational fishing activities in 1991. Of these, 93 percent said they fished more days because of the reefs. Factors affecting an individual artificial reef's usage were found to be the age of the reef, the distance from shore the reef is located, and the time of year fished.

Quantitative. Estimated aggregate expenditures associated with artificial reef fishing in South Carolina was projected to be approximately \$10 million. After accounting for a multiplier effect of these expenditures of 1.7, the aggregate coastal economic impact on 1992 by all artificial reef fishing boaters was estimated to be about \$17 million. These estimates may be conservative due to exclusion of smaller boats and boaters in non-coastal counties.

Comments: This is one of the most current studies involving artificial reefs. Random sampling is used to obtain all population samples. The study involves several sources of survey data. The survey requiring a greater recall period (one year) was balanced with a shorter form to ensure greater response. Key usage statistics are externally verified by comparison to other survey results of similar populations.

No economic benefit-cost analysis is provided - it was not one of the study's goals.

29. Roberts, Kenneth J., Mark Thompson, and Perry Pawlyk, 1985.

Title: "Contingent Valuation of Recreational Diving at Petroleum Rigs, Gulf of Mexico," Transactions of the American Fisheries Society, 114(214-19).

Geographic Area/Reefs Studied: Artificial reefs formed by abandoned petroleum structures off the Louisiana coast.

Extent and Method of Data Collection: Surveys were sent to a random subset of National Association of Underwater Instructors in Louisiana members and Skin Diver magazine subscribers residing in Louisiana. In addition half the roster of

members of the Louisiana Council of Underwater Diving Clubs were also mailed surveys while the other half of the roster were contacted for personal interviews. Divers who indicated artificial reef usage were then contacted by telephone and asked an iterative bidding, contingent valuation question. A 44 percent response rate was achieved for surveys which were delivered (644 total responses). Of the mail respondents, 165 had used the reefs in question; 121 were administered the contingent valuation questions (73 percent). Finally, 23 of 35 personal interviews were completed (66 percent).

Analyses Performed: Qualitative information concerning purpose of dive trips, methods of access and principal fish species sought were obtained from survey respondents. Summary statistics concerning the number, timing and location of dive trips were presented. In addition, expenditures on diving trips, investments in diving equipment and diver income levels were summarized. Also, estimates for annual mean willingness to pay for diving near the artificial reefs in question were provided.

Results: Participation. The survey of 1981 activity revealed that 23 percent of respondents took at least one sport diving trip to a petroleum structure. Those who took trips averaged 5.7 trips during the year. Most people accessed the artificial reefs by a private boat which they owned.

Qualitative. The most popular purpose motivating surveyed diving trips was spearfishing (44 percent). Red snapper was the most sought after and caught species by spearfishers.

Quantitative. The sample average equipment cost was \$1,835 while the average per diving trip expenditure was \$107. The sample's average willingness to pay for diving activity around Louisiana offshore oil and gas structures was \$163. The sum of willingness to pay over the entire sample is \$20,538. The estimated 95 percent confidence interval for willingness to pay summed over the offshore divers in Louisiana was given as \$435,200 to \$608,000 annually.

Comments: This is one of the few studies that estimates benefits derived by spearfishermen and divers. The willingness to pay estimates for the sample of sport divers surveyed has a fairly tight confidence interval. The study also provides good insights into trip motivations and frequencies.

30. Rockland, David B., 1990.

Title: "An Economic Benefit Analysis of the San Luis Obispo County Artificial Reef," Report to Pacific Gas & Electric.

Geographic Area/Reefs Studied: The San Luis Obispo County Artificial Reef, San Luis Obispo, California.

Extent and Method of Data Collection: A total of 713 personal interviews were conducted between mid-July 1988 and mid-July 1989. Respondents were party boat anglers leaving from Port San Luis and Morro Bay.

Analyses Performed: Party boat fishing participation and catch rates are summarized as are socio-economic characteristics of party boat anglers. The economic impact associated with Diablo Canyon partyboat fishery in San Luis Obispo County is estimated as is the associated economic benefits.

Results: Participation. Yearly party boat participation in San Luis Obispo County for 1987 and 1988 was about 38,000 anglers. The average angler caught about 10 fish.

Quantitative. The average party boat fisherman spends about \$66 per trip in San Luis Obispo County. County wide expenditures associated with the Diablo Canyon area partyboat fishery is \$725,879. Resulting total county economic impact is estimated at \$981,242 in industry output.

Estimated consumer surplus associated with Diablo canyon partyboat fishery was estimated via several methods. Travel cost methods yielded estimates ranging from \$385,328 to \$1,083,529. Contingent valuation methods resulted in estimated consumer surplus of \$274,889.

Comments: The economic impact analysis and economic valuation results are based upon accepted methodologies. However, the portion of these impacts or values that are attributed to the existence of the reef are not estimated. That is, how much of the economic impact or economic benefits would disappear if the reef were destroyed or were never built was not estimated.

Economic benefits or impacts associated with other types of recreation (angling from individual or charter boats, diving, etc.) were not addressed, though this was not one of the study's goal.

31. Samples, Karl C., 1986.

Title: "A Socioeconomic Appraisal of Fish Aggregation Devices in Hawaii," Marine Economics Report No. 33, University of Hawaii Sea Grant College Program, Honolulu.

Geographic Area/Reefs Studied: The system of buoys or fish aggregation devices (FADs) surrounding the Hawaiian Islands.

Extent and Method of Data Collection: Data was collected by a mail survey of registered sea vessel owners who had identified themselves as a FAD user in a previous survey. The sample was chosen (stratified) to ensure that recreational, commercial and mixed commercial-recreational boat owners were adequately represented. The sample was also stratified by the owners' island of residence to ensure the sample adequately represented the various islands. Of 800 questionnaires mailed, 622 usable returns were collected (78 percent response rate).

Analyses Performed: Qualitative summaries of the socio-economic characteristics of FAD users are provided. Participation and catch rate statistics are estimated for 1983-84. A benefit-cost analysis of the FAD program is also presented.

Results: Participation. Most respondents (72 percent) reported fishing about the same since FADs were installed, while 24 percent report increased fishing since FADs were deployed. The average respondent visited FADs about 26 times annually (this includes visiting multiple FADs during the same trip). Recreational anglers used the FADs the least (about 18 times/year) while the mixed commercial-recreational anglers were the heaviest users (about 37 visits/year). Most anglers limited their use to three sites or fewer.

Qualitative. About 70 percent of anglers agreed that overall fishing fun and the number of fish caught was better at FADs. About half thought the types of fish caught at FADs was better while 31 percent thought fish size was better at FADs. Sixty percent thought crowding was worse at FADs. Commercial anglers generally felt that FADs were placed too close to shore and were more concerned about crowding. The most cited reason for using FADs by all anglers was that there was a better chance to catch fish.

Quantitative. Anglers reported an average of 9.1 fish caught near FADs during their most recent FAD visit while 4.4 fish per visit was the annual average anglers reported. The authors explain that higher average from the most recent trip may stem from the fact that these trips were taken during the traditionally more successful spring and summer fishing month while the annual averages are based

upon trips scattered across the entire year.

Two formats of contingent valuation questions were asked to determine the value of FADs to anglers. Average annual benefit estimates ranged from \$29 to \$89 depending on the format of the question asked. Annual aggregate economic benefits was estimated at \$184,906. Annualized costs of the program were estimated at \$182,000.

Comments: This is one of the few studies of artificial reefs in the Pacific. This contains a plethora of qualitative and usage statistics. The author cautions that the aggregate benefit estimates may be biased downward because the study does not attempt to estimate benefits accruing to pole-and-line tuna boat owners.

32. Samples, Karl C. and D. Schug, 1985.

Title: "The Economic Impact of Fish Aggregation Devices on Hawaii's Charter Boat Fishing Fleet, Part 1. Have Vessel Operating Costs and Revenues Changed?" Sea Grant Quarterly 7(1):1-6. University of Hawaii Sea Grant College program, Honolulu.

Geographic Area/Reefs Studied: The system of buoys or fish aggregation devices (FADs) surrounding the Hawaiian Islands.

Extent and Method of Data Collection: In 1983, 73 charter boat owners were surveyed (61 percent response rate) concerning vessel operating conditions in 1982.

Analyses Performed: Charters boats' usage of FADs was reported as was catch rates for light and heavy users of FADs. Charter boat captains estimates of cost reductions due to FADs is also reported.

Results: Participation. An average of 30 percent of all charter fishing excursions involved at least some fishing near a FAD.

Qualitative. About 65 percent of captains agreed that congestion from other boats around FADs is great enough to reduce chances of catching fish.

Quantitative. Light users of FADs (boats that fished near FADs on less than one-fourth of all excursions) averaged 37 kg of fish caught per trip versus heavy users

who average 76 kg per trip. Nearly 60 percent of respondents report lower fuel and oil costs for trips to FADs. The study estimated that FADs decreased the aggregate costs of charter captains by about \$224,000 per year. Twenty-three percent of captains maintained that use of FADs increased the number of customers.

Comments: No economic benefits or impacts are estimated (this was not one of the study's objectives). The authors comment that although many captains reported a cost savings from using FADs, average reported operating expenses between those who report saving and those who did not differ. That is, those who said fishing at FADs reduced costs had the same costs as those who reported no savings.

33. Samples, Karl C. and J. T. Sproul, 1985.

Title: "Fish Aggregating Devices and Open-Access Commercial Fisheries: A Theoretical Inquiry," *Bulletin of Marine Science*, Vol. 37:305-317.

This is a theoretical paper; no data is collected or analyzed. The models discussed below are not statistically tested or verified. The models analyzed deals with the impact of fish aggregating devices upon fish harvests, gross revenues, employment and fishermen's profits over the long run when the fishery is open access. Bioeconomic models of fish population and fishermen's profits are developed under two competing assumptions. In the first model it is assumed that high levels of fishing effort over the aggregating devices do not reduce the biological productivity of the underlying fish stock. The second model relaxes this assumption of biological resiliency. Under either assumption, the model suggests that the aggregating devices will not increase fishermen's total profits in the long run. They also find that if the aggregating devices prove to be very efficient at aggregating the fish and lower fishing costs, long run harvests, employment, and gross revenues may be diminished. They suggest that caution may be required if aggregating devices prove to be 'too efficient'; limited entry schemes, licensing and user fees may be required to properly manage common property fisheries.

34. Sato, Osamu, 1985.

Title: "Scientific Rationales for Fishing Reef Design," *Bulletin of Marine Science*, Vol 37(1): 329-335.

This article principally discusses the state of the art and the extent of scientific

rationales which could be applied to fishing reef practices. It also provides an economic justification for deployment of artificial reefs in Japan between 1952 and 1966. However, the cost effectiveness analysis is flawed because it compared total revenues from harvested biomass per unit of reef deployed to total costs of the artificial reefs. Profits, which includes fishermen's total revenues as well as operating costs is the correct dollar figure to compare to the cost of artificial reef deployment. Therefore, estimated benefits from deploying the reefs is overestimated.

35. Schug, D., 1978.

Title: "Political and Economic Aspects of Artificial Reefs in Pinellas County, Florida." Masters Thesis, Department of Marine Science, University of South Florida, Tampa.

Material requested, not yet received.

36. Solum, Michael, 1995.

Title: "Sarasota County, Florida, Artificial Reef User Survey: 1994-95," Memorandum: Natural Resources Department, Sarasota County Government.

This is a summary of a mail survey included with all Sarasota County boat registration notices. The response rate was about 15 percent (2,566 or 17,500 surveys).

Results: About 87 percent of respondents thought artificial reefs have made an improvement to fishing and diving in the area. About 7 percent of respondents experience conflict on artificial reefs in Sarasota Bay while 23 percent experienced a conflict the Gulf of Mexico. However, it was not clear if this was the percent of all boat owners or the percent of those who used artificial reefs.

37. Sproul, J., 1984.

Title: "Estimating Net Economic Benefits Received by Hawaii's Pole and Line Tuna Vessel Owners as a Result of Utilizing a Network of Fish Aggregation Devices: 1980-1983." M.S. Thesis, Department of Agricultural and Resource Economics,

University of Hawaii, Honolulu.

Material has been requested.

Comments from Milon's review in his 1989 Bulletin of Marine Science article about this study: "Sproul (1984) provides a correct assessment of the change in producer's profits for a commercial fleet using artificial fish aggregation devices (FADs) off Hawaii. Interview data from boat captains and owners revealed that producer's profits increased by approximately three percent on average due to higher revenues and reduced costs. However, since the FAD system also has noncommercial users who were not included in this study, no attempt was made to compute a benefit-cost ratio."

38. Talhelm, D.R., 1985.

Title: "The Economic Impact of Artificial Reefs on Great Lakes Sport Fisheries," in *Artificial Reefs: Marine and Freshwater Applications*, ed. by F.M. D'Itri, pgs. 537-43, Lewis Publishers, Chelsea, MI.

This article summarizes the economic concepts behind both benefit-cost analysis and economic impact analysis. It also reports economic benefits and impact numbers associated with general angling on the Great Lakes. The increased economic benefits and impacts from hypothetical increases in catch rates for all anglers are then calculated. However, no effort is made to tie the increases in benefits and impacts from the hypothetical increases in catch rates to the existence or improvement of artificial reefs.

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