ARTIFICIAL REEFS: Conference Proceedings

Edited by Donald Y. Aska

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ARTIFICIAL REEFS

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National Marine Fisheries Service
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Edited by
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Florida Sea Grant College
February 1981
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INTRODUCTION

Although many organizations and individuals have been involved in diverse aspects of artificial reef research, development and management, there have been surprisingly few efforts to bring these interests together for any central focus on this intriguing subject. Literature does exist in fair volume but, here again, no concerted effort has been made to organize and catalogue it into a form whereby it could be available for specific application. Similarly, few conferences and proceedings relating to artificial reefs have been sponsored whereby interested persons could engage in a forum to exchange experiences and information.

Florida Sea Grant College has been one of the organizations involved in artificial reef research and information dissemination. This involvement was spurred by obvious user needs, the potential of such reefs as resource enhancement platforms to meet these needs, the enthusiastic response to these projects and the encouraging application of recommendations stemming from its two conference ventures. The first of these, a local meeting in Sarasota in 1976 elicited considerable enthusiasm. A more broadly structured statewide conference in St. Petersburg, in 1977, expanded the focus and scope of the Sarasota experience. One unique virtue of the 1977 conference was the fact that each of the eight conference recommendations was implemented by one or another responsible agency, institution or organization.

One recommendation of the 1977 conference called for an expanded regional or national conference to provide a forum for spokesmen from the Southeast, or the country as a whole, to exchange their experiences and findings. The assembled proceedings from such a colloquium could then form a manual, from which interested persons could extract and apply information pertinent to their areas of interest or responsibility.

Florida does not claim origin for this concept. Earlier, in March 1974, Texas A & M University had convened a conference, international in scope, in Houston. Notwithstanding issuance of a proceedings, no concrete follow-up developed and, to the best of our knowledge, the 1976 and 1977 Florida conferences were the only subsequent assemblies to be sponsored on this subject.

To determine if there was a shared interest in a regional or national conferences, we met with representatives from neighboring states and were encouraged by their interest and willingness to cooperate. Thus was the genesis of the 1979 Daytona Beach conference. Our appreciation and credit for cosponsorship is extended to the Sea Grant Programs in Virginia, North Carolina, Georgia and Texas, to participating state agencies in South Carolina, Florida and Mississippi, the National Marine Fisheries Service, the Gulf Oceanographic Development Foundation, Inc., and Gregory McIntosh, Jr., for the services, funding support and
expertise they contributed to the planning and execution of this conference. A core planning group from these organizations developed the agenda, selected and recruited the speakers and generally stimulated public awareness of the conference site, dates, focus and value.

Unfortunately, attendance at the conference did not reach full expectation due to the unforeseen problems created by hurricanes David and Frederick. For those persons unable to attend, these Proceedings take on added significance since, fortunately, all scheduled speakers did attend and their papers are contained herein for reader reference and application.

In the conference summation, "Looking Ahead," Dr. Harris B. Stewart has distilled eight principal observations and recommendations from this two day meeting. We hope these recommendations, and the detailed papers will enable readers and participants to relate experiences and apply the recommendations to bolster and improve their respective areas of interest and responsibility.

This conference will have served its purpose, and Florida Sea Grant College will have served its catalytic role, if it facilitates the generation, refinement and distribution of even further information so essential if the exciting potential of artificial reefs is to be better understood and realized in fact.

Hugh Popenoe
Director,
Florida Sea Grant College
I would like to welcome you to the Regional Conference on Artificial Reefs. We regret that our attendance has been reduced below expectations due, primarily, to the difficulties experienced by many persons in Alabama and Mississippi as a result of Hurricane Frederick. Many who had preregistered have found transportation unavailable or have been forced to remain home because of severe storm damage. Also, Hurricane David, which swept along the East Coast is still affecting the area. In fact, the fishing and diving trip we had scheduled aboard the "Happy Dolphin" at the conclusion of this conference has been cancelled due to rough seas and water turbidity. Nevertheless, we are pleased to see such a large attendance and we feel all will benefit from the fine agenda prepared by the conference sponsors and planners.

The sessions we have scheduled for you today are excellent. I think you will find the General and First Technical sessions are filled with speakers who are familiar with all aspects of planning, constructing, evaluating and managing artificial reefs.

This conference is sponsored by the Florida Sea Grant College, the Virginia Institute of Marine Science Sea Grant Program, the North Carolina Sea Grant Program, the South Carolina Wildlife and Marine Resources Department, the Georgia Sea Grant Program, Florida Department of Natural Resources, the Gulf Oceanographic Development Foundation, Inc., the Gulf Coast Research Laboratory, the Texas A & M University Sea Grant College and the National Marine Fisheries Service. You can see that this is a colloquium of institutions and organizations that crosses many state and functional lines.

This conference is a follow up to a conference that was sponsored in Houston, Texas, March 20-22, 1974, by the Texas A & M University, and a later conference in St. Petersburg, Florida, June 10-11, 1977, by the Florida Sea Grant College. The Houston conference provided an international forum for the exchange of information, experiences and thoughts among persons involved with, or interested in, any aspect of artificial reef research, construction, or use. The St. Petersburg conference, in contrast, concerned itself primarily with southeastern regional experiences and recommendations. I think that conference was unique in accomplishment for out of the eight recommendations that emanated therefrom all eight have been implemented from the first which was "to facilitate the permitting processes" to the last, which proposed "a regional conference with expanded scope," which you are attending today.

Program Director, Coastal Plains Regional Commission, Charleston, South Carolina
I represent the Coastal Plains Regional Commission which covers the Virginia-Florida section of the East Coast and is concerned with the economic development of these five states. About a year ago, December, 1978, this Commission sponsored a marine resources conference and in that conference we examined five or six areas of the marine related economy. One of the areas was commercial and recreational fishing. A recommendation that came out of that particular working area was that a five state committee be organized in the Southeast to evaluate, monitor and promote artificial reefs. Naturally, when I was advised of this conference I was very happy and was especially delighted to be designated conference chairman.

At this time I would like to introduce a very prominent resident of Daytona Beach and an ardent, and uniquely successful, offshore sport fisherman. He is an officer of the Halifax Sport Fishing Club, chairman of that club’s artificial reef committee and a prominent local attorney. He is eminently qualified to address this body on the basis of experience as an organizer, planner and user of artificial reefs and I am delighted to introduce Mr. Peter Heebner to the audience.
OFFICIAL WELCOME

Mr. Peter Heebner

We in Daytona Beach and particularly those of us who represent the Halifax Sport Fishing Club are particularly pleased that you selected this city as the site for this fine conference. In the interest of time and your personal comfort I would like to dispense with the usual amenities and invest the limited time to outline some of the experiences we have had and progress we have made in promoting better fishing through artificial reef construction in this area.

Our local and offshore waters contain many excellent natural reefs but the most extensive and productive are between 17 and 22 miles offshore, at least in travel time from the Ponce de Leon Inlet, which is our local doorway to the sea. This is a difficult journey for the smaller craft because of the travel time involved and because of the sudden weather changes which characterize this area. Also, because of the limited number of accessible reefs and the concentration of effort on them by local and transient fishermen, the populations of the more popular species, especially the snappers, have gradually become reduced. Also, commercial fishermen are attracted to the most productive reefs to "top off" their catch or work it more heavily if they have not been successful on the more distant banks. The growing popularity and use of Loran C has made it more easy for both groups, recreational and commercial, to zero in on the "money holes."

As a result, about 3 years ago, we determined there was a need to provide artificial reef sites inshore. We knew from experience that where boats had sunk and settled to the bottom or where plane crashes at sea put airplane frames on the bottom that fishing improved around these sunken objects. Our problem in planning a reef program was a common one -- lack of available funds. So we had to obtain most of our materials and transport services through persuasion and local volunteer action.

The first step was to select sites. The Florida Sea Grant College has made a significant contribution to what we have been able to do. Bottom surveys were made by Dr. Heyward Mathews and his team of underwater divers who are so well qualified to select proper substrate for reef sites. Also Sea Grant's Joe Halusky and Don Aska gave us a lot of help with local and other references and advice.

We finally decided upon three sites. We were concerned about proper materials for reef permanence because several years previously the County of Volusia had dumped a lot of tires on a mud slough that had disappeared

Daytona Beach attorney and official of the Halifax Sport Fishing Club,
Daytona Beach, Florida
in about three months. We wanted no recurrence of that type of situation. So, we got professional advice so Corps of Engineers permits were no real problem. Actually, the Corp gave us a lot of help on the project.

Through the assistance of the Gulf Oceanographic Development Foundation, Inc., we were able to use their fine vessel, "Happy Dolphin" as a platform for an amalgam of local divers to put down bottom type buoys, continuously survey the bottom areas and note the changes and observe growth in the reefs as the material was placed down. It was sort of an underwater college for artificial reefs which will help other areas in the country who are interested in the same sort of reef project(s). Hopefully, from our experiences they can determine what are the best areas, what is the best kind of material for the particular site, survey the substrate for reef permanence, and perhaps seed the reefs so they can be productive in a quicker time.

This is being done here right now and we are benefited by the local community college and diving club. We have 700 tons of culvert pipe available, at no cost and delivered to the transport barge. The County of Volusia provided CETA personnel. We have 20,000 units of tire material to be placed on the reefs.

Finally, and probably the most significant development, has been the acquisition of the Liberty ship. Florida had a number of these ships allocated to it by the Maritime Administration but none were sunk on the East Coast. We decided we needed one and sought the help of our local U.S. Congressman, Bill Chappell. After about 2 1/2 years working with the Maritime Administration and the Governors office a contract has been signed with a salvage firm in Jacksonville to bring the Liberty ship "Hindina" from the James River, Virginia, base to Brunswick, Georgia, where it will be processed this next summer. It will then be sunk offshore of Daytona Beach in about 80 feet of water, hopefully, in May, 1980. This is a 440 foot vessel and will make about 6 1/2 acres of reef with about a 35-40 foot relief from the bottom. We believe this will be the foundation to our local artificial reef program and we are really excited about it.

All the efforts described have been done with no money but with all kinds of volunteer effort by a large number of people. We are extremely optimistic about this program and are hopeful that it will provide the residents and visitors with satisfying fishing year around and within safe operating limits for large and small craft.
CONGRESSIONAL GREETINGS AND PROJECT SUPPORT

Congressman Bill Chappell

Thank you for the opportunity to address you by phone. I truly apologize for not being able to address you in person, but because of last-minute, absolutely essential and pressing business on the House floor, I was unable to leave as scheduled.

As you know, this is a subject of great interest to me and I am pleased my Administrative Aide, Ed Stout, was able to deliver my remarks in my absence.

I have always had a long and deep interest in the marine environmental area. This includes my efforts to obtain a Liberty Ship for salvage and ultimate sinking in the Ponce Inlet as well as introducing and co-sponsoring legislation to provide a comprehensive aquaculture program.

We have known for centuries that fish and other sea life prefer a sheltered, reef-like habitat. Unfortunately, nature has not always provided such an environment in locations that are convenient for man.

In an attempt to rectify that situation, we have devised a number of alternatives to create artificial reefs. One of the most successful attempts in recent years has been to utilize surplus ships. In 1971, Alabama Congressman Bill Dickinson introduced legislation to dispose of World War II Liberty ships no longer useful to national defense which could be used to provide "skeletons" for artificial reefs.

That legislation, which became law, has proven to be one of the most all-round beneficial programs we have had in recent years. The 30-odd ships were allocated to shoreline states including five to Florida and we acquired a sixth from Virginia.

These artificial reefs in Florida and off the coasts of other states have proven that man can contribute effectively and constructively to the improvement of ecology, as well as to the local economy. The reefs are bringing significant numbers of sportsmen and vacationers to those areas and everyone stands to benefit.

Again, I sincerely regret I am unable to be with you today but I hope Ed's delivery of my remarks is enlightening and constructive. If you are happy with his speech, remember they are my remarks, and if you are not happy, remember, he was doing the talking.

__________________________
United States Congressman (D-Fourth District, Florida)
CONGRESSIONAL INTEREST IN LOCAL REEF PROGRAMS

Ed Stout

I am pleased to relay Congressman Bill Chappell's support to this conference and to the purpose to which it is directed. In reviewing your agenda we were both impressed with two particular points which he expressly asked me to emphasize — first, that it differs from the pie-in the sky esoteric conference and, second, that it is structured on the "How to do it" theme and on that sound foundation much good information, readily applicable by interested users, should come from it.

It is time for action to tap the vast marine resources of this island nation. I would like to address this challenge from the standpoint of one aspect, that of using Liberty ships to provide underwater reefs. Under the provisions of PL 92-402, the Secretary of Commerce is authorized to provide Liberty ships to the states upon application by the Governor or his designee. Of the 30 Liberty ships available under this program, 5 were allocated to Florida and all were sunk on its West Coast. When the Daytona Beach group approached the Congressman on the matter of obtaining an additional ship for positioning off Daytona we recognized we had a problem since Florida had already received and used its allocation of 5 ships. We realized we had a lot of administrative hurdles to overcome and it did take over a year and a half of hard work to clear the various Federal and state bureaucracies. However, we did manage to get the required authorization for release of one ship from the allocation of another eligible state. The "Mindinao" will now be made available to the Daytona Beach area and is scheduled for sinking early 1980. This successful culmination of effort by a lot of concerned and resourceful people demonstrates that joint action can bring results. Joint positive action instead of bureaucratic nit-picking can be effective and the public interest can be served.

I think there are two critical items on your agenda. The first, planning and implementing, can visibly enhance local economies and fishing opportunities and done in such a way that full consideration is directed toward protecting the environment. The other is really the key to the conference, "looking to the future."

We must realize that our country, as well as the world, must address the problem of how to best meet the food crisis that is facing us. Most people don't realize that this country consumes some 7 billion pounds of fishery products each year and by the year 1990 that figure is expected to reach a 10 billion pound rate. Of, this 7 billion pounds, approximately 75 percent is imported. Also, in 1978 we had 2.1 billion dollars leaving this country to pay for imported oil. Therefore, we need offsetting

Aide to Congressman Bill Chappell, (D. Fourth District, Florida)
export wealth. Up to now agriculture has carried the load, but our agricultural yields are about at the optimum and there are no foreseeable major agricultural increases to continue this export flow. It is imperative that the United States increase its fisheries productivity.

One promising method is through aquaculture. Congressman Chappell introduced an aquaculture bill the National Aquaculture Development Act, that passed the Congress but the President pocket-vetoed it, claiming that many of the programs were already emplaced in the existing agencies of the government. While this is a correct comment the unfortunate part is that there are too many agencies in the act. A central force or agency is essential to coordinate this massive federal effort, if not, nothing will get done. Parochial interests must be overcome. The legislation is again in the will and Congressional passage is anticipated. Hopefully, the President will sign this version.

These, then are the Congressman's principal points -- explore the "how to" and then develop the required coordination between state and federal governments to move forward. The Sea Grant Program can be instrumental in pulling all of these efforts together. Working in consort with other responsible groups the net result can be significant contribution to our meeting and overcoming this serious world supply problem.

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Ed. note: The above is an abridged summary of Congressman Chappell's and Mr. Stouts comments; unfortunately, the tapes of the actual presentations were erratic and a verbatim transcript was not possible.
GENERAL SESSION

Chairman: "A National and Regional Overview of Artificial Reefs"
Richard Stone
National Marine Fisheries Service,
Washington, D.C.

Speakers:
"Biological Aspects of Artificial Reefs"
J. Ananda Ramasinghe,
Dauphin Island Sea Laboratory,
Dauphin Island, Alabama

"Engineering Considerations for Artificial Reefs"
Dr. Raymond F. McAllister
Florida Atlantic University
Boca Raton, Florida

"Social and Economic Considerations for Artificial Reef Deployment and Management"
Dr. Robert B. Ditton
The Texas A & M University System
College Station, Texas

"An Overview of State Programs"
Charles R. Futch
Florida Department of Natural Resources
Tallahassee, Florida

Rapporteurs Report:
Ronald L. Schmied
National Marine Fisheries Service
St. Petersburg, Florida
A NATIONAL AND REGIONAL OVERVIEW OF ARTIFICIAL REEFS

Richard Stone

Before I start my general comments, I would like to reiterate that Senator Richard B. Stone will be calling during the course of our session and I will rearrange our schedule accordingly. Before the Senator calls, I would like to read a short statement from Congressman Edward Stack (D. Fla.).

"Dear Friends:

The opportunity to express my views to the Regional Conference on Artificial Reefs is very much appreciated. I regret that due to my official duties in Washington I am unable to address you personally, but I do wish to indicate my strong support for your work on artificial reefs. I would like to congratulate you on your efforts, and hope that you will have a most successful convention. I appreciate the assistance that my staff and I have received in our work on artificial reefs from Mr. Dick Stone of the National Marine Fisheries Service, and Mr. Donald Aska of the Florida Sea Grant College.

As you may know, I introduced H.R. 4413 on June 11, 1979, as a companion bill to Senator Richard Stone's bill in the Senate. The bill which I introduced would establish a program to develop, maintain, and monitor marine artificial reefs in waters of United States jurisdiction. In addition to the program to develop artificial reefs as set forth in the Senate bill, I have added a provision for monitoring and maintaining reefs as suggested by Mr. Greg McIntosh, an Associate Director for Marine Resources.

The bill has been referred to the House Committee on Merchant Marine and Fisheries, on which I serve. In my opinion, with your assistance, we can generate broad support for this legislation. I intend to call for hearings in my committee as soon as possible. The support you generate among the members of Congress from your respective states will be instrumental in determining whether or not we can get the bill through the Congress.

After the conference, I look forward to meeting with Dick Stone to learn the results of this conference. In the near future, I will re-introduce my bill to include the recommendation of the conferees.

Again, I appreciate the opportunity to present my views to you. You have my assurance that I stand ready to work with you in the coming months on making a national artificial reef program a reality."

I can assure you he is sincere and interested in following up on this matter and getting the artificial reef legislation through Congress. Both Senator Stone and Congressman Stack are interested in suggestions that you might have for revisions to their respective bills. We already have received some suggestions from the states as to rewording of the bills and I have discussed this with both the sponsors aides and they are receptive to the comments we have received to date. The States were concerned about the wording of the bill, since they have, in many cases, been responsible for building the reefs, both in the territorial sea and beyond, and would be interested in continuing those efforts. Of course, we would want to make it possible for others to participate in building reefs as well. Also, there is some indication that the freshwater states would like to be involved. The Great Lakes States are particularly interested.

Senator Stone was the first in Congress to call for a nationwide artificial fishing reef program and is dedicated to seeing that this legislation passes. I know that Senator Stone and Congressman Stack, and others interested in this bill will definitely follow up if you indicate sincere interest. It is going to take effort on your part, though, to see that these bills work their way through Congress.

First some general comments regarding this General Session. This session is intended to give you an overview, particularly insofar as my comments are concerned. I'm not going to dwell on how we solve problems because we have a number of very fine speakers coming up in the course of these two days and they are going to have some excellent suggestions. I'm going to discuss briefly where we have gone since the 1974 conference in Houston (see Ed. Reference). At the time of that conference the National Marine Fisheries Service had an artificial reef program and we were finishing up some of the quantitative work that we had started in Biscayne National Monument. In 1975, NMFS terminated its active artificial reef research efforts. Since then, I have continued to provide technical assistance and literature to anyone that is interested and have tried to keep up with what is going on in the states and throughout the country.

Fortunately, there are a number of specific exceptions to the comments I am going to make, but generally, the progress in artificial reef research and development hasn't exactly equaled that of the women's lib movement. They can say we've come a long way but we have to look closely to find where we have made progress and then try to determine

why there hasn't been more progress. Attendees at the 1974 meeting in Houston were encouraged by the comments that some of the states made at that meeting. In particular, North Carolina, South Carolina, Georgia, and Texas outlined some very ambitious programs. These programs all resulted in a number of excellent reefs, and documentation of these efforts indicated they were successful in improving fishing and in some cases, had a beneficial impact on the economy of the coastal communities. Unfortunately, most of these programs are now operating on a skeleton budget.

Other states have had similar experiences. Active and productive programs have been started and then curtailed because of the lack of funds. This is an area that I know is going to be discussed later today. The lack of adequate, consistent funding has been one of the major roadblocks to artificial reef research and construction efforts. There are, as I said before, a number of exceptions. You have already heard about the fine work that is going on in the Daytona area. Many local and state efforts are continuing in spite of the shortage of funds. Charlie Futch will tell you more about the status of the Florida programs during this session. Also, I think you will find Dan Sheehy's discussion of the magnitude of the Japanese artificial reef effort most interesting. It is quite a contrast to the efforts that we've made.

PHONE CALL FROM SENATOR STONE

"Hello, Senator. This is the NMFS Dick Stone. We are certainly pleased to have you address us today. I have already introduced you and told everyone about the excellent work that you have done since your first efforts in the Miami River, and now on the legislation that you've introduced, so without further ado please proceed with your comments."

"Well first of all, Dick, let me thank you and say that this country needs all the Dick Stones it can get. I appreciate all of your help, seriously, and that of the NMFS. Let me say that a number of people have been helping with this program and with this conference. Don Ask, Florida Sea Grant College, Bob Jones of the Southeast Fisheries Association, and Roger Anderson of the Gulf and South Atlantic Fisheries Development Foundation, are deserving of praise and support, and we thank you. The reef bill needs both your analysis and your suggestions. This conference will be very helpful in providing comments on a debated basis. Instead of simply having a whole list of ideas and concepts sent up separately, you will be able to discuss them, dialog about them, boil them down, and give us the essence. Then as we prepare a revised artificial reef bill, which we will be doing soon, we'll have the benefit of your thinking and it will be the kind of thinking I have described.

(Ed. note: Arrangements were made for Senator Stone to speak to the conference via telephone amplification.)
We think we can pass the bill, hopefully, this year, but certainly
during this Congressional Session. It is the kind of activity that
almost everybody is for, but the problem is not just to get them for it,
its to get their commitment for passage and funding; and when we get all
of that done, then we will be showing some progress to all of the people
that care about this. Are there any questions?"

Mr. Stone: "Senator, I have suggested that those interested get
together this evening after our regular session and talk about suggestions
that I could bring back to you from the conference. I have already
heard from a number of people that are anxious to get together and talk
about the things that they would like to suggest to you, so, although
we don't have any questions from the audience at the moment, we do have
quite a bit of interest in helping you to get the bill through Congress."

Senator Stone: "Well, that will be very helpful, and make sure that
they are taking notes so that the good ideas don't go by the board when
they're discussed. When the conference is over let me have the comments
and we'll put this bill into this year's form and file it. Again, I
want to thank you all for your commitment to this project and hope to
see you soon." (End of telephone discussion, NMFS Richard Stone —
continued).

As you heard him say, he's looking for comments from us, so this
evening after this session, let's see what we can do to suggest some
changes that we think would be beneficial to the legislation, and take
it back to him. I know he's anxious to get this legislation going again.

I was in the process of telling you that we haven't really made a
whole lot of progress in some areas since our 1974 conference; however,
I did state that there are exceptions to that. Certainly, at the local
level, and in some of the states, very active programs are continuing
while in other states the programs have dried up completely, or have
been curtailed considerably. There are other areas of progress that I
think we can be proud of, though, and one of them was mentioned this
morning.

Certainly, the Liberty Ship program has been very successful. In
1974 that program was just starting. Now it is almost completed since
more of the Liberty Ships have been used. Also, the use of midwater
reefs has been tested and put to use in some states. I know South
Carolina and Georgia, along with several other states, have used these
midwater reefs in conjunction with the normal reefs that they have put
out as trolling alleys. These are areas where the fishermen can troll
and catch pelagic species, such as the mackerels, very effectively.
Hawaii has recently committed resources to install 26 floating structures
to improve fishing for pelagic species in those Western Pacific waters.
These would be species such as the tuna, billfish, dolphin, and wahoo.
This is another example where some practical research was utilized by the
state. The NMFS Honolulu laboratory had earlier experimented with several of these floating structures and had considerable success. The state then was able to take this information and go to their Legislature to get approval for funding to establish 26 of these structures. In the State of Washington, and perhaps several other states, there have been fishing piers built with reefs associated with them and these have been extremely effective. I think we'll see more of these efforts in the future.

The NMFS was pleased at the progress it made in research on artificial reefs. The program was initiated in 1966 and much of the effort in the first few years was spent trying to figure out how to effectively sample the reefs and gather quantitative data. The project was initiated at the Sandy Hook Lab in New Jersey and gradually moved southward. In 1972, the program moved to the Beaufort Laboratory in North Carolina, but even then, we had to extend it a little further south to do the quantitative research which was conducted in the Biscayne National Monument off Elliott Key. We worked with our Miami laboratory, the National Park Service, and with a number of the states and individuals in that area to complete what I think was a very successful effort in determining that artificial reefs can, in fact, increase total fish biomass.

We constructed a small artificial reef adjacent to a natural coral patch reef of similar size near Pacific Reef Light to study the feasibility of increasing fish-carrying capacity and total biomass within a given area by augmenting natural reef habitat. Initially, we used an underwater habitat to gain some knowledge about how to effectively sample these reefs. We were fortunate enough to have this habitat for two sessions -- one immediately after we installed the reef in January of 1972 and again in April of 1972 as a followup. By using the habitat, we were able to develop sampling methods that we continued to use from small boats for the remaining two years of the study. After the artificial reef had been in place 7 months, our visual observations indicated that the artificial and natural reef were supporting about equal numbers of fishes and similar species composition. Although the artificial reef was less than 25 meters from the natural reef, it did not diminish the residence populations on the natural reef, but actually doubled the carrying capacity and fish biomass in the immediate vicinity of the two reefs. Most of the recruitment into the new reef was by juvenile fishes. Adults of the species which normally use more than one reef did start to use the shelter the reef offered as soon as it was constructed. These opportunistic feeders, such as the surgeon and parrot fishes and some of the larger snappers continued to use several reefs in the area during the course of the study. From August 1972 through the completion of the study in August 1974, the fish populations on both reefs showed similar seasonal fluctuations.

In summary, I would like to say that I am very optimistic about the future. I think there is a tremendous potential for the use of artificial reefs in fishery management, but I am a bit disappointed in the progress we have made since 1974. I think this will be echoed by several of the conference speakers who, I expect, will offer some provocative comments on the future use of reefs in the United States.
BIOLOGICAL ASPECTS OF ARTIFICIAL REEFS

J. Ananda Ranasinghe

The addition of relief or structure to relatively featureless floors of bodies of water has been shown to act as a focus for the concentration of fish. When man-made structures are placed on ocean, lake or estuarine floors for this purpose they are known as artificial reefs, which have come to be important centers of sport fishing activity.

Many different materials have been used in the construction of artificial reefs -- old street cars, automobile bodies, rubble, cement pipes, tires and the several Liberty Ships released by the Congress to the states under Public Law 92-402.

The biology of an artificial reef varies according to where it is situated -- in salt, brackish or fresh-water, on deep or shallow bottoms, inshore or offshore, in the open sea or in bays. The bottom on which the reef is placed may be sand, shell or mud or a mixture. Water temperature and how it varies from season to season is an important consideration. Finally the types and abundances of fishes that frequent an area before a reef is established plays an important part in deciding what the final population composition of the reef will be.

The clearest way in which the biological aspects of artificial reefs can be demonstrated is by posing questions:

1. We all know that many invertebrates settle and encrust on artificial reefs. Is there a general pattern in the way in which this happens? How long does it take before a stable state is reached -- if one is reached at all?

2. What changes occur in the animals living on the bottom around the reef, and the sediment that collects within the reef itself?

3. How and why do fishes come to the reef? How long does it take for populations to reach stability, and which reef fish reside in the reef while others merely visit in passing?

4. What do the different fishes eat? How much food comes from the sea bottom, how much from the encrusting organisms on the reef, and how much from the plankton?

5. What are the effects of the seasons?

6. What are the effects of heavy fishing pressure?

On student leave from University of Sierra Lanka; currently at Dauphin Island Sea Laboratory, University of South Alabama
We at the Dauphin Island Sea Laboratory have been investigating the faunal characteristics of reefs in the north Central Gulf since 1974. The studies were conducted in collaboration with the Gulf Coast Research Laboratory, Ocean Springs, Mississippi, and were initially sponsored by the Alabama-Mississippi Sea Grant Consortium. The reefs have consisted of Liberty ships that have been cut down, leaving just empty open topped shells divided into 5 or 6 compartments and positioned 5 to 15 miles offshore in open sea 50 to 100 feet below the surface. The main rationale for this study is the fact that natural gradients occur from the West to East in bottom type (mud to sand), and influence the run off, turbidity, productivity, and climate (warm temperate to sub tropical). The reefs were placed in position mainly as red snapper (Lutjanus campechenus) attractants.

The encrusting organisms showed a successional sequence. Barnacles were seen within a week, and tube building Serpulid Polychaetes followed soon after and achieved prominence within 2-3 months. Hydroids, Bryozoans, Algae and Ectoprocts settled shortly thereafter. These organisms made it possible for cryptic organisms to live in the spaces and crevices between their bases and thus errant Polychaetes and Amphipods were abundant after about 8 months to one year. Sea Urchins followed the Algae, and Tunicates and Oculinid corals appeared after about 2 years. The encrusting invertebrates have yet to reach a stable state.

The effects of the seasons are noticeable and apparently play an important role — tropical forms disappear during winter when diversity and abundance of all groups is reduced. Huge Bryozoan colonies which dominated the biota of one reef were wiped out after a harsh winter and never reappeared on any of the reefs again.

Little is known of changes in the animals living in and on these bottoms. But they obviously represent an important source of food for many of the fish.

Looking now at the fishes — within hours of establishing a reef, populations of planktivores such as cigar fish (Decapterus punctatus) and juvenile vermilion snapper (Rhomboptilus aurorubens) to the east and rough scad (Trachurus lathami) in the west arrive. Omnivores and generalized carnivores such as tom tate (Haemulon aurolineatus) and red snapper (Lutjanus campechenus) to the east, and rock sea bass (Centropristis spp.) to the west follow quickly. Soon after such top carnivores as grouper (Mycteroperca spp.) amberjack (Seriola dumerili) and barracude (Sphyraena barracuda) can be seen, their presence often correlated with schools of their preferred food — cigar fish, juvenile vermilion snapper and tom tate.

Thus, within days or weeks of establishing a reef large numbers of "desirable" fish are present. None of them derives any food directly off the reef at this stage. The attraction seems to be primarily for forage species which in turn are seeking shelter from either predators or strong currents, or thigmotaxis-attraction to relief which is probably used in orientation and navigation.
As the algae settle on the reef, algae eaters such as blennies and damselfish move in, and as sessile organisms increase in volume after 5-6 months the grazers (or pickers) such as sheepshead, spade fish, and trigger fish appear.

The more tropical fishes disappear in the winter. Butterfly fishes and damsels arrive as juveniles in late spring, reach adult size by late fall and are not seen on the reefs after December. This phenomenon is more marked on the shallow western reefs than on the deeper and more stable eastern ones.

How does heavy fishing pressure affect the reef? How fast and steady is recruitment? Our observations indicate that over holiday weekends and other periods of heavy fishing pressure, the snapper on the more accessible and better marked reefs become fewer in number and generally smaller in size than those on other reefs. Still, these reefs became repopulated with large snapper within days of reduced fishing pressure. In addition, our sampling program in areas adjacent to the reefs indicates that juvenile snapper frequent substrate with minimal relief and present an unaffected and extremely healthy recruitment resource.

The final question is largely academic -- do reefs stimulate increase in the total biomass and standing crop or do they serve only as centers of fish aggregation? Although no hard evidence is available, most authors and the team at Dauphin Island Sea Laboratory, feel that there is a substantial increase in production at least semi-locally due to the introduction of reefs.
ENGINEERING CONSIDERATIONS FOR ARTIFICIAL REEFS

Dr. Raymond F. McAllister

Twenty minutes is not much time to talk about an overview of oceanographic and engineering considerations, but many of these considerations of course, will already be familiar to many of you. I will be approaching this subject I am talking at the level of the layman who has come here with an interest in artificial reefs and doesn't have any extensive oceanographic or engineering, that is, ocean engineering background.

Also, I plan to gloss over the biological aspects pretty much, although when you deal with an all encompassing fluid medium like water, the most unique substance on the face of the earth, and one which is very close to, if not indeed, a universal solvent, there's no way you can separate the biological from the geological, physical, chemical, and even the engineering considerations. Therefore, from time to time biological matters will creep in.

Geological considerations: We must consider include first and probably foremost, the bottom -- whether it is rock, sand or mud and all of the characteristics of the bottom which are affected by the size of the sediment or by its stability and bearing strength. I can remember putting an artificial reef in an area where there was strong agitation by winter storms and seeing the artificial reef very slowly sink into what I thought was a good, firm sand bottom. It turned out that after a period of some twelve months, it has half buried and two or three years later only the very top of the original 6 ft. high reef was sticking out of the bottom. This was in the early days of experimentation with concrete jacks, a shaped form.

At this point let me suggest as the 2 previous speakers have, that you must hear Dr. Dan Sheehy's presentation at the Friday luncheon on concrete shaped forms in Japan. From my conversations with him thus far, it will probably turn out to be the high point of this conference, so please catch it if you possibly can.

To repeat, settling into the bottom is, of course, a very serious matter. Another serious matter involving bottom type is siltation. You must consider this when you emplace a reef on a bottom in an area where there are currents or wave action which can stir up the sediment. Siltation of the water may also restrict low life-chain growth and reduce light reaching the bottom. You also have a certain amount of sand blasting when moving sand is whipped against the reef. I have seen sand blasting almost completely destroy the life on a reef 40 feet underwater after a hurricane off our lower east coast of Florida, in an area which is normally very well protected against large wave action.
Fortunately, it has only happened twice in the 16 years I've been down there. There are places, for example the Gulf Coast, that receive these types of waves much more frequently, and off a place like Cape Hatteras on the U.S. east coast, the type of waves South Floridians get in a hurricane are standard day-to-day fare.

Visibility as a function of bottom type, and the types of creatures as the bottom affects them, must also be taken into consideration. Some creatures thrive on the turbid water, some do not. Some creatures forage on the bottom, others feed on the hard substratum that you place underwater, that is, the artificial reef itself. If they are foragers, you must have a type of bottom which contains a significant in-fauna. Consider this if you are trying, as the Japanese do for example, to be highly selective in the type of creature you want on your reef. Earlier, the desirability of the red snapper was mentioned. We know a significant amount about the red snapper, and we can, presumably, select what type of bottom they like, what type of visibility, what depth and temperature of water, and so forth and then place our artificial reef accordingly.

Reef depth: Depth is another very important characteristic which leads us into physical oceanographic considerations. Depth may probably turn out to be as important as any other construction consideration. Wave effects are greatly determined by depth. Many of you know that wave energy expenditure and either the orbital or the translatory motion of the water particles in the wave are functions of depth. I hope that very few reefs will be placed so shallow that the waves are translating rather than orbiting. Wave effects drop off very rapidly with depth. At a depth equal to half the wave length there is essentially no energy left, so that the depth is extremely important in determining wave effects. Also, there are major changes in temperature with depth. I was very surprised when our measurements showed that in the Gulf Stream, off southeast Florida, you only had to go a couple of hundred feet down to find extremely low temperatures. So, if you want low temperature forms, put the reef several hundred feet down. If you desire creatures who do not survive in low temperatures such as the tropical reef fauna, you certainly do not want to put your reef very deep.

Depth also is involved in the very practical way with navigational hazards, and that's a matter of considerable concern. It's one of the reasons why the artificial reefs made of Liberty ships are placed rather deep. I hope that the permitting people will continue to look at the depth requirement intelligently and not insist on throwing road blocks in front of us. When there is neutral reef, as along the southeast Florida coast, at a depth of 45 feet offshore, if you put a reef in the sandbowl inside of it, at 60 or 70 feet deep, you should not have to go through all sorts of permitting rigamaroll to keep a ship from hitting it. Any ship that gets in there is already in enormous difficulty. It probably has ripped its bottom out on the existing natural reef and I don't think an artificial reef is going to make much difference in this situation.
There are other physical oceanographic characteristics to be considered. Waves, as I've already said, feel bottom at a depth equal to about half of the wave length, i.e., the distance between two crests. During hurricanes, during the northeast storms of the East coast winters, during the great northers of the Texas coast, and so forth, the high winds develop high waves of longer wavelength and the waves often reach a lot deeper. The wave forces can be very, very large on the bottom and on structures emplaced on the bottom. It turns out that during this month's Hurricane David, we had fairly large waves off the southeast Florida coast. Nothing like what we would have received had we had a fully developed hurricane, not one offshore paralleling the coast but rather, one coming straight onshore, which would have caused a very severe disaster in our area, as ill prepared as we were for a hurricane. As it was, the waves tore up an artificial reef made up of some 100 to 125 thousand automobile tires bundled together and placed in about forty feet of water. The horrifying part of it was that considerably more than a thousand of these tires ended up on the beach, some of them in bundles and some of them single. It leaves you to wonder where the other 124 thousand tires are, but we have not been able to get out to see. The horrible suspicion exists that they are scattered very widely across the ocean bottom offshore from Boca Raton, Deerfield Beach, Hillsboro Beach, and so on. If so, this is going to present a clean up problem, an aesthetic problem. As a matter of fact, it may not provide a very serious problem in terms of the bottom organisms because they can thrive on an isolated single tire or a bundle of tires on a flat sand bottom. For other reasons, however, it's an undesirable situation and it brings to mind one of the arguments that constantly crops up, which is, "Why do we have the permitting agencies?"

Reef permits: I feel, more and more, that although there are some very good reasons for permits and very good reasons for some of the questions asked on the forms, there's also a very large bureaucratic component to the permitting. Much of the time of the permitting agencies is spent on worrying about questions 1-27, and whether or not you have ticked off this piece of paper or that piece of paper, or talked to this person or that person. Little consideration appears to be given to whether or not the proposed project is good for the environment; whether it is oceanographically sound to put the reef in at the depth and location you propose. I feel that the fault with this tire problem off Deerfield Beach should be laid at the door of the permitting agencies who did not consider the effect of hurricane waves or a very, very severe northeast storm in the winter on the materials being placed on the bottom. In this instance permitting the use of tires without concrete in them. This is definitely not a call for more restrictive permitting but for more technically competent and less political permitting.

Research: Research, of course is the key. We need more wave tank research and more current flume research on the effects of wave and current forces on the different materials and structures that we place underwater.
We are derelict in this area, which is a recurring theme at this and previous conferences, "more money from more agencies, and more good people for better and better research into the various aspects of artificial reefs."

Currents: Currents are another physical oceanographic parameter that we have to take into account. I've been told that the three ships, the "Amaryllis," the "Mizpa" and the "PC" that were placed on the Palm Beach Artificial Reef in relatively deep water have, under the influence of the very strong currents of that area, actually shifted position. Now, I find it a little hard to believe (unless there are still bubbles of air trapped in the ships) that, with as much negative weight as these ships have, they would have migrated. Yet, a 2 to 3 knot current, which is possible in this area, broadside on something like the hull of a Liberty ship might quite conceivably pivot it and move it somewhat. If there is anybody who knows more about the Palm Beach reef, during the question period I would very much appreciate a more factual account from somebody who has seen such movement. But certainly currents are important. They are important in bringing food to the fish that are going to be on your reef. They're important in terms of the light. Off southeast Florida coast, and I'm sure in many other places where you have inlets and rivers, the currents will sweep turbid material and the nutrients that are associated with it across artificial reefs, or away from them, as you place it in suspension or solution. Colonization is affected by the current. Larval forms in the plankton are carried by currents to reef sites in all phases of reef colonization, which is so important to reef success.

Reef substrate: Another consideration is the material of the substrate. Of the materials and shapes that I've seen in the United States, per unit of size, leaving cost out of it, I would place the concrete jack as probably among the best, if not the best. Very little attempt has been made in the United States to introduce structures with holes in them, simulating barges or ship hulls that have been ripped open so that they're full of passages for the creatures to get in and out of, basically high rise structures full of interlacing members that the thigmotrophic fish can get close to. When the funds are available a good deal more work on design of types of structures which specific fish are really attracted to would be very valuable. The Japanese apparently excel at this.

You would also have to concern yourself with the handling of these structures. Here again is where good engineering considerations come in. You certainly don't want a big square structure that, when picked up, becomes a long thin box, as it collapses due to insufficient strength and poor handling characteristics.

Corrosion: It is evident that the life of the structure is very important. You need to worry about the life of these structures in the ocean and that leads to a word about corrosion. You all know, as a general rule, that iron or steel is not a terribly desirable reef material, particularly in thin sections. We could use the ships because they have a long life underwater due to thick steel plate in the hull, but something
like an automobile body or a sheet metal structure, perhaps the shell of a washer or dryer, or something of that sort, typically is not a very desirable material for artificial reefs. These tend to corrode very rapidly, particularly in the presence of other metals which are not infrequently associated with them. We find that the depth of burial of concrete rebar in the reinforced concrete of the structure, and the density of your concrete, will make an enormous difference in the life of your structure. Dan Sheehy will probably talk a little about the Japanese corrosion research, or if he doesn't, you can ask him questions since he has the information.

Other metals that are put in the ocean typically fail. I don't care too much for them but there are some aluminum structures that are occasionally put in, such as wastes, debris etc., but very often the metals are in contact with different metals and they set up a battery, and corrosion then proceeds very rapidly. I'm reminded of an aluminum underwater archeological ship, or treasure hunting ship, that had one iron plate bolted to it on the wheel house. The ship is beautiful when you go see it today except for the one spot. There is an enormous corroded hole where the iron and aluminum got together, and of course the aluminum, being less noble, was corroded away. We must be careful of the materials we put in the ocean. Concrete is an excellent material. If properly made and the reinforcing steel is well enough buried, and the concrete is dense enough, it is probably unexcelled. If you put additives in the concrete to prevent salt water penetration to the rebar, or you protect the rebar with epoxy or zinc coatings, concrete is a very long lasting and effective material underwater.

Another engineering consideration is, of course, leaching. If you put fresh concrete in the water it takes a certain length of time for the surface "bloom" to leach away, the same as with most other materials you put in the ocean. Weathered materials, of course, are better than fresh material right out of the mold.

Materials transport: We need some innovative ideas in materials transport. Here's where the very great expense comes in for most reef projects. I would hope that there would be somebody in here who has solved the problem of transportation of materials commonly used in artificial reefs. If you have, we strongly urge you to participate by asking questions, by adding your comments and by coming up and talking to us. It is also an area of considerable difficulty in that you generally hire the lowest bidder to take a tug boat and a barge load of materials out to the site, and to save fuel they stop the engine on the tug boat when they reach the location, and start drifting. Unless you closely supervise the operation the whole time you end up by scattering the artificial reef over four square miles of bottom instead of on your permitted one square mile area. This does not make friends among the permitting agencies or among the environmentalists — and it makes for a poor reef. I strongly recommend that we talk a little more about transportation at some future conference. Anything that you can do on the surface, by the way, anything that does not require diver activity
underwater, even if the divers are volunteers, is extremely important. If your reef plan and permit calls for bundled units to be placed on the bottom, it's much more desirable to hire four people on the deck to tie them together and roll them over the side than it is to have four volunteer divers trying to do this work underwater. So if you're going to bundle things together with polypropylene lines or if you're going to stack them up, try to figure out a way to do it either on shore or on the barge going out, but on the surface, in air, not underwater! Diving is an enormous problem, at best.

Briefly summarizing, we need more information on the physical forces in the ocean and how they affect the reef. We certainly need more on the biological, probably some more on the chemical. I think a survey in advance is important and some tank tests and some current flume tests, and so forth, on the type of structure you are using. A model and even a prototype or two in the ocean for a few months on site is a good idea. We would have been a lot happier if we had put fifty bundles of tires offshore and had watched them in a hurricane, than we were after putting 125 thousand tires offshore and finding out, after the hurricane, that there were serious consequences almost impossible to correct.

Indeed engineering the reef in advance in terms of oceanographic parameters, materials and corrosion, materials handling, and human factors engineering as it applies to underwater work can save money and time and result in a long lived satisfactory artificial reef.
SOCIAL AND ECONOMIC CONSIDERATIONS FOR ARTIFICIAL REEF DEPLOYMENT AND MANAGEMENT

Dr. Robert B. Ditton

Introduction

A paper on social and economic considerations is long overdue with regard to artificial reefs. It is long overdue with regard to marine sanctuaries, wetlands and other marine areas as well. Many of the matters to be discussed here are generic to marine resources, or even terrestrial resources, that are used for recreation purposes. Unlike the landbased park and forest recreation research literature, most marine literature has a definite physical or natural science bent. This is evident in the artificial reef literature, which has been carefully reviewed in preparing this paper. Why have economic and, to an even greater degree, social considerations been ignored with regard to the utilization of various marine resources?

First and foremost, the physical and natural sciences have been around a lot longer than the social sciences. This was brought home when I reviewed a bibliography on the striped bass (Westin and Rogers, 1978) with citations dating back to 1792. Secondly, there appears to be a matter of "turf" involved — since few people live in the oceans, there appeared to be little need for a social science focus. However, the two-way impacts between people in coastal communities and marine resource uses cannot be denied and this has been the basis for social scientists becoming involved in marine affairs. Lastly, this "bias" has been perpetuated by many marine resources management agencies and their employees. Here, marine resources or fisheries management implies only a strong protective concern for the integrity of marine resources or fisheries. Man and his needs are often partially ignored. Worse yet, man is viewed solely as a threat to these natural resources and thus a problem. Hendee and Stankey (1973) identify two contrasting resource management philosophies — anthropocentric and biocentric — that are useful to understanding this kind of thinking. The term "anthropocentric" means that man's use of natural resources is the primary objective.

"The goal of maintaining the integrity of the natural environment, although important, is secondary to enhancing and providing opportunities for recreational and other human uses in a primitive setting. Management would seek to enhance these aspects of ... (natural resources) ... that are pleasing to man, with sociological and cultural definitions taking precedence over biological concepts." (Hendee and Stankey, 1973).
An example of this kind of thinking would be a "put and take" fishing pond or an artificial reef that was placed in an accessible location to provide a "hot spot" for local fishermen. Here, reefs mean more fish and more fish mean better fishing or more fishermen which leads to more spending in the local economy. The fishing constituency may be a great supporter of stocking programs but only if they can be assured they will be able to fish there later.

The biocentric philosophy would stress the natural integrity of marine ecosystems at the possible expense of recreation and other human uses. This approach could be viewed as preservation for its own sake. It can also be viewed as a case of when in doubt as to possible impacts of man's uses -- play it safe -- protect the resource! An example of this philosophy would be an artificial reef that is sited simply to provide cover for fish and to re-establish fishing populations. Depending on the purity of the views involved, there may be little or no room for a concern for potential users and how they may benefit from the fishery enhancement. These examples are partially clouded because it can be argued that by deploying artificial reefs, man has already by definition violated the integrity of the natural system. However, to make the analogy within the context of man-made reef deployment, we need to look less at what is provided and more at whether or not it is intended for a man's use (and to what degree this intent is considered important).

Because so many managers ably articulate and demonstrate the biocentric approach to management, I feel a need to make the alternative philosophy clear as well. It is unfortunate that they are viewed as alternatives. That is a good part of the problem! Fisheries management needs to take a more holistic approach -- one that recognizes the elements of both approaches. I am not advocating a compromise between man's needs and biological systems because more often than not such a compromise is an inappropriate solution. I am saying that we need to have a better appreciation of both approaches. For some time now, fisheries management has involved a great deal more than managing fish. Fisheries management means managing people as well. Beyond the problem orientation of too much fishing pressure, there are many other aspects of providing fishery benefits that need to be considered and understood. Again, these new demands on the fishery manager to be responsive and accountable are not in lieu of his biological responsibilities, they are in addition to them. With tight money, inflation, and concerns for cost effectiveness, fisheries and artificial reef decisionmaking will increasingly require that attention be paid to a growing number of social, economic, legal and political considerations as well. Matters like constituency support and producing economic benefits from fisheries resources will require a shift in focus from pure biocentrism in some quarters.

These changes will not come easily. There will be resistance! This was in evidence at a meeting held in Atlanta in January, 1979. The meeting was called by Centaur Associates, Inc. and Human Sciences Research, Inc. who were under contract with the National Marine Fisheries Service to assist in the improvement of the socioeconomic data base on marine
recreational fisheries. When the group was asked to rank social and economic data needs, several fisheries managers were quick to indicate that all they needed to manage fisheries was some idea of catch and effort. They felt that knowledge of age, education, income, race and fishing patterns of their fishing constituency, for example, were irrelevant to their efforts. They might well be irrelevant if fisheries management is viewed in traditional terms — heavy on fisheries and light on management. However, fisheries management can be (and needs to be) viewed as an extension of the management body of knowledge into the area of fisheries. Students who are interested in fisheries management in the future will need to complement their studies in fisheries science with an in-depth supporting background in management.

Two additional reasons to think about more than fish are the National Environmental Policy Act (NEPA) and the Fisheries Conservation and Management Act (FCMA). Language in NEPA implores federal officials to be interdisciplinary and to consider alternatives. The FCMA mandates comprehensive fisheries management in that social, political and economic considerations must be taken into account with biological concerns.

Sharpening Reef Feasibility Studies and Evaluating the Results

Artificial reefs have traditionally been the business of the public sector. If private enterprise had the opportunity to construct artificial reefs in marine waters and charge an admission fee (see Ditton et al., 1977, for a discussion of the arguments, constraints and opportunities involved), we would likely see a great deal more attention paid to social and economic considerations. For example, based on a demand curve of what fishermen would be willing to pay to fish an artificial reef and a supply curve of the number of reefs a reef builder would develop at various price levels, we would likely see considerable effort spent in finding a "good" reef location. There would be a market for reefs with "good" locations while the market for "poor" locations would not be great. Reefs would not be built in "poor" locations by developers who wished to maximize their profits. This analysis as used in the private sector is often referred to as a feasibility study.

The matter of profit or return on investment is one that differentiates the public and private sectors. Both sectors use information as a part of their planning activity. What may differentiate the sectors are the extent and quality of the information and the "stakes of the game." The private sector, for example, would be taking a sizeable risk in investing in an artificial reef project if it were now possible. The risk would be much less for the public sector because the agency would not be directly impacted if it selected a "poor" location and nobody came to fish.

Hellriegel and Slocum (1978) present us with an interesting view of the kinds of information sought by private sector planners as well as the sources from which it is obtained. They report research findings
from a study of managers of 41 chemical manufacturing firms which can be applied generally. The study showed the relative importance of each of four kinds of strategic external information (market, technical, broad issues and other information) as perceived by responding managers.

Market information was the dominant classification with 58% of first choice responses. The findings are especially significant because the chemical industry is usually regarded as very technologically oriented. How would reef planners and managers respond to the relative importance of each information classification? Based on a careful review of contemporary reef literature, we would suspect that technical information would receive the most attention with market concerns falling below even broad issues.

This apparent disparity in information needs and level of planning can be traced to the varying objectives of the private and public sectors -- the private sector must pay attention to people -- they are called customers -- while the public sector can choose to and often does ignore people in their management activities. This is not done willfully but often is the result of management objectives which are not clearly stated and operationalized. For example, the specific purpose and mission of artificial reefs is not clear -- are reefs to provide habitat, to improve fish populations, to improve people's fishing, to provide satisfying fishing experiences or all of the above (or some of the above)? If managers are only concerned with improving fish stocks, people may be (and often are) of little direct concern.

Public agencies must have better and more useful information if they are to evaluate the feasibility of artificial reefs prior to their deployment. For example, instead of assuming that all licensed fishermen in a particular region compose the market for some proposed reef, planners must have greater predictive understanding of who is likely to use the reef. Reefs and the benefits they produce cannot be justified without a more thorough understanding of the constituency to be served.

After deployment of an artificial reef, analysts, legislators and citizens are likely to ask the question, "Did we accomplish what we said we wanted to accomplish?" This question is being asked of coastal zone management programs today and will continue to be asked of public programs in the name of cost effectiveness. If more monies are to be committed to enable reef deployment, we should be prepared to demonstrate that past efforts have been beneficial. These matters will surely be raised prior to the passage of U.S. Senate Bill S.325 being sponsored by Senator Richard Stone (D-Florida).

Evaluation research or program analysis provides a framework for decisionmakers to answer this question. As Weiss (1972:44) puts it, "Let's remember that evaluation is designed to help with decisionmaking. Decisionmakers need to know what it was that worked or didn't work..." Evaluation research is cross disciplinary and involves numerous research methods like case study, survey research, and economic analysis. Hopefully, these will lead to informed decisionmaking instead of conclusions based on intuition, impressions, casual observation or conventional wisdom (Polster, 1978).
Although several studies have separately evaluated economic impacts, improved harvest and the recreational use of reefs (Daniel, 1974; Buchanan, 1972; Carlisle et al., 1964; Ditton and Graefe, 1978) or combinations of these topics (Stone, Buchanan and Parker, 1973; Liao, 1978) none have evaluated a reef or an entire reef program in terms of its total impact. Much of this total impact involves social, economic and political considerations. Schwartz (1979) is currently carrying out such a comprehensive evaluation of the Liberty Ship reef program for the Texas Coastal and Marine Council. Using a case study approach, Schwartz has developed a model which represents the process and forces that shaped the program. This procedure allows for the clarification of program goals and objectives. With the case complete, it is possible to identify the program’s intended and nonintended short term and long term effects. The program’s effects will be evaluated using criteria for effectiveness, efficiency, adequacy and appropriateness.

"The primary concern of the criterion of effectiveness is whether the program is producing the intended effects associated with the program’s goals. Is the program doing what it is supposed to? A secondary concern of effectiveness is how effectively is the program contributing other benefits to society. The criterion of efficiency refers to the costs and benefits derived by the program. Did the program cost more than the benefits obtained? Adequacy refers to the degree to which the program’s benefits eliminate the need for the program. Appropriateness refers to the equity and responsiveness of the program goals in the fair distribution of costs and benefits to meet the needs of the intended users and clients." (after Poister, 1978 in Schwartz, 1979).

Reef evaluation efforts like that being carried out by Schwartz should provide useful feedback to Texas decisionmakers and enable future reef feasibility efforts to be sharpened. Evaluation studies should help decisionmakers to make better decisions, drop current strategies that are not working, adopt new strategies that may be necessary and accept or reject current planning assumptions and theories in reef development. It is important that evaluation outcomes and causal relationships be related to future reef development efforts. Otherwise, the major purpose of evaluation research is defeated.

Some Social and Economic Considerations

Many are just now becoming concerned with questions that require social and economic understanding. I wish I could provide you with a set of generalizable social and economic guidelines but unfortunately much important research remains to be done. In the meantime, it is important that we discuss the questions and matters that remain so they can be considered in some fashion in reef planning efforts.
Reef Location: Although the topic of access or distance a reef should be from shore has received some attention in previous publications, treatment has been limited. Parker et al. (1974) note that:

Artificial reefs should be within easy and safe access of fishermen. If they are built for small boat fishermen, they should be located in protected waters, or within a few miles of a harbor or inlet. Only fishermen in large boats, such as head or charter boats, can safely use distant reefs. Most boat fishermen use small boats, and therefore fish more over nearshore than distant reefs.

This raises some rather obvious questions as to what constitutes "easy access" and "a few miles." In addition to safety standards that might be suggested by the U.S. Coast Guard, we need to know how far from shore boat fishermen actually travel to go fishing. Just as the location of a service station must consider traffic patterns, so too must reef planners take fishing patterns and distance traveled from shore into consideration. Unfortunately, there are not generalizable guidelines here as saltwater fishing patterns are likely to reflect the area's unique system of fishing opportunity, access and reef resources. Since these are likely to vary by coastal region so probably does distance actually traveled from shore. Also, energy implications need to be considered as the normal distance traveled from shore may decrease with added cost or reduction of available supplies in the future.

Instead of relying on such crude measures of reef "demand" as the number of fishing licenses sold in coastal counties (as is often done), greater effort needs to be expended in predicting "who is likely to use the reef." Hopefully, reef planners can make use of statewide fishing (or outdoor recreation) survey results that should allow them to have a profile of saltwater fishermen, their fishing patterns and preferences. Once the size of specific saltwater fishing constituencies (bay and offshore) are ascertained, relationships to boat length, number of trips, distance traveled from shore and other variables can be probed. These kinds of findings are essential to understanding the "market" for which a reef is being planned. The question of whether additional reefs should be deployed in bays or offshore can be better answered with some knowledge of the relative extent of fishing activity in these two areas.

Before more reefs are planned and deployed, we should have some knowledge of the extent to which the existing system of reefs are used. We should also know when and by whom they are used. Beyond a concern that reefs be used to some optimum capacity (biological or otherwise), there should be a concern for whether the reefs are accessible to the widest number of boaters rather than to some select group (unless this is by design in reef objectives). In our recent study on the Texas coast, we related distances fishermen travel offshore to various boat length categories (Ditton and Graefe, 1978). For example, we found that for our study area:
Boats in the 14 to 18 and 19 to 25 foot length categories comprise the two largest offshore fishing constituencies, accounting for 41 percent and 49 percent of all offshore fishing boats, respectively. Normal distance zones of 1 to 10 miles and greater than 20 miles are noticeably distinct in excluding certain boat length categories. That is, almost no boats longer than 18 feet normally stay within 10 miles, and very few 14 to 18 foot boats normally go beyond 20 miles. The 11 to 20 mile normal distance range, on the other hand, is the only range to attract a cross section of all boat lengths. This range thus attracts the broadest and largest constituency. Reefs could be sited in the 21-30 mile range and still have a sizeable constituency; however, most boaters with 14-18 foot boats would drop out.

These kinds of findings need to be considered in light of the objectives for a proposed reef. If it is important that a reef be a certain distance from shore for biological, legal or other reasons, the planners should be aware of the tradeoffs with regard to the size and diversity of the target constituency they expect to serve. Where these constraints do not exist, planners may have the opportunity to choose the size and diversity of constituency they desire. Even where these constraints do exist, an equitable distribution is of highest priority and political importance.

Because of these kinds of relationships between distance traveled offshore and boat length, reef planners should have a thorough knowledge of their state's recreational boating fleet. This knowledge can be derived from each state's boat registration system (Zapata and Ditton, 1979). From these systems, it is important to know how the fleet is distributed by boat length categories. Also, how does the boat length distribution in the coastal service area vary from the remaining area of the state? Over time, what kind of changes are taking place in the fleet that might have a bearing on reef location? With some predictive understanding of which boats are to be used in bays or offshore and for these, how far offshore, registration data can be extremely useful to understanding the constituency of a proposed reef.

In locating artificial reefs, it is also important that the shoreland access system be considered. Which launch sites are presently used and to what extent? Can the existing access system accommodate additional use likely to come as result of reef deployment or is additional shoreland access required as well? Similarly, is the necessary tourism infrastructure in place in the shoreland community to support the reef development (Gunn, 1972)? When fishermen visit the new reef attraction, can their needs be adequately taken care of (lodging, food, equipment, boat repairs, etc.)? It is conceivable that timing can be a problem here — a reef could be constructed with insufficient shoreland support which might act to restrict reef use until needed support can be provided by the private sector. Reef planners should take a systems approach when choosing a reef site (and adjacent community) on the coast.
A Concern for People's Fishing Experiences: For existing reefs, it is important that we have some understanding of what fishermen expect when they go to a reef. What species do they prefer? Do they expect unusually large catches? Are their expectations greater than the reality? Fishermen's expectations may need to be re-established or corrected through various communications if reef use is to be sustained. Similarly, we need to know if there is a disparity between species sought and species caught by fishermen. If the disparity continues, there is likely to be a behavioral response with economic impact implications -- people may go elsewhere to fish! Lastly, it is important that we know whether reef users are satisfied with their fishing experiences, and, if they are not satisfied, we need to probe the sources of dissatisfaction. Perhaps there is a problem with vandalism to cars and trailers at the launch site which makes people want to seek out other reef areas. These kinds of problems need to surface and be corrected if reef objectives are to be realized.

Economic Impact: Ultimately, the question will be asked, "How much are artificial reefs and their related fishing worth to a state's economy?" (existing dollars and value added). The question deserves an answer. Some economists (Daniel, 1974; Liao, 1978) have already tackled this most difficult question. Using survey findings, they have generally totalled direct expenditures, plugged in multiplier values and concluded that artificial reefs have significant economic importance to their respective states. Accepting this conclusion seems to force us to accept the underlying assumption that new reefs have led to fishing that previously didn't exist (with added value to the state's economy). However, there is also the attractive alternative explanation that artificial reefs not only attract fish but fishermen as well, with no sizable importation of new saltwater anglers (with no or little added value to the state's economy).

Survey research findings relative to artificial reef use fail to get at these questions. Perhaps what is required is an analysis of saltwater fishing before and after reefs are deployed. We need to know the extent to which reef users have been displaced from other inland locations (within-state fishermen as well as tourist), the extent to which reefs have displaced fishermen from one coastal community to another and the nature of costs incurred by communities in accommodating more fishermen (increased public services) if we are to come to grips with matters of economic impact. These are important details that are often lost in the desire to produce a number that demonstrates the total expenditure and impact of fishing associated with artificial reefs. If we are to avoid double and triple counting, simple linear projections and consider losses incurred by certain communities at the expense of gains elsewhere, these details must be considered more effectively in reef planning and evaluation.
REFERENCES


AN OVERVIEW OF STATE PROGRAMS

Charles R. Futch

Construction of artificial fishing reefs in marine waters is a widespread and increasingly popular concept. Development of substantial boats, reliable engines and accurate radiolocation electronics within the last twenty years has removed the offshore fishing trip from the exclusive province of the wealthy yachtsman, and occasional party boat "deep sea" fishermen. As the number of fishermen has increased, and their fishing range has expanded, natural reefal areas have received concentrated fishing effort. Concomitantly, recognition that World War II shipwrecks were effective in increasing fishing success resulted in individual and group actions to construct similar but smaller changes in bottom relief. Many such efforts were sporadic, loosely organized, and casually funded. State governmental responses to artificial reef construction have varied considerably in relation to the amount of interest, and to the degree of fragmentation of responsibilities among various agencies responsible for management of fisheries, sovereign lands, navigation, water quality, and environmental alteration. Too, sources of developmental funds have many, sometimes mutually exclusive, requirements for eligibility and constraints of usage. The following is a synopsis, as far as known, of state-sponsored programs of the southeastern United States.

Texas

The first constructions began in the mid-1950's with a program of depositing oyster shell reefs in selected bays. Later, car bodies were dumped off Port Aransas, Freeport and Port Isabel. These were subsequently added to, and marked with lighted buoys. Hurricane Carla in 1962 removed all traces of buoys and reefs. They were subsequently rebuilt by the Game and Fish Commission using clay and concrete pipe. A more formal program was initiated in 1972 with the passage of Public Law 92-402 which made Liberty ships available to states for use as fishing reefs. By 1976, 12 ships were sunk between 8 and 36 miles offshore. Shortly after completion of this program, a few tire reefs were built. Since then, there has been no formal program.

Subsea production of petroleum has played an important role in fish attraction and angler success. The manifold oil rigs and well jackets provide popular fishing sites for many fishermen. Continued oil exploration and production will doubtlessly result in additional productive fishing locations.

Florida Department of Natural Resources, Tallahassee, Florida
LOUISIANA

Short-lived efforts in the early 1970's resulted in construction of shell banks in shallow bay waters. No formal program has proceeded. The vast numbers of petroleum production sites apparently is sufficient to satisfy local fishing demands.

MISSISSIPPI

Mississippi received five Liberty ships, and placed them in two offshore locations. The efforts for reef programs remain with private organizations such as Gulf Fishing Banks, Inc., with no public program existing, or contemplated by State government. The relatively short coastline is possibly significant in Mississippi's lack of a formal program.

ALABAMA

In sharp contrast, Alabama's short coastline has not impeded public and private reef-building ventures. In 1955, the Orange Beach Fisherman's Association in concert with the Alabama Department of Conservation built a reef of 250 car bodies in the Gulf. In 1957, a line of car bodies was placed along Alabama's two county coastline. These gradually oxidized, or sunk in the soft substrate. Additional reefs were constructed with concrete pipes. Alabama has been largely dependent upon volunteer assistance to continue their efforts, but this year $30,000 (1979), from fishing license revenue will be designated for reef construction. The funds will be used for labor, buoys, materials and commercial barging.

VIRGINIA

From a humble beginning in 1961 with the lowering of eight car bodies into 15 feet of water at the mouth of Chesapeake Bay by the Tidewater Artificial Reef Development Association, Virginia now features a stable, and predictably-funded reef construction program. The program, began in 1974, draws funds from unfunded boat fuel taxes in amount of $50,000 per annum. Three major reefs have been established since 1974 by The Virginia Marine Resources Commission. Department of Corrections prison inmates prepare materials, a state-owned barge is used to haul materials, and a private company is hired for towing.

NORTH CAROLINA

North Carolina's program began in 1973 with a law designating unfunded boat fuel tax amounting to $250,000-$300,000 per year. The program was scheduled for six years, but was terminated after the fourth. It resumed in 1978 with a $100,000 appropriation. All aspects of material collection, preparation and barging are done under auspices of The North Carolina Department of Natural Resources and Community Affairs with a tug, barge, and 3 LCU's. Nine oceanic and two estuarine reefs have been constructed.
SOUTH CAROLINA

In 1967, $30,000 was appropriated for offshore reefs; the program continued through 1974. After discontinuance of state funding in 1974, the Coastal Plains Regional Commission made grants of over $160,000 to keep the program functional until 1978. Another state appropriation followed. As in Virginia, the transportation of materials is contracted to a private firm, but the rest of the work is done internally by the South Carolina Wildlife & Marine Resources Department.

GEORGIA

Georgia began its reef construction in a cooperative effort with the University System in 1972. The first formal program began with a 1973 grant from the Coastal Plains Regional Commission, with a state cash match. The current year budget is $10,000, with an anticipated $30,000 for next year's continuance of the construction program.

FLORIDA

Florida's early efforts were directed solely toward encouraging development of reefs, and advising and assisting local governments and fishing organizations in permitting procedures. This aspect was eventually transferred to the Department of Environmental Regulation. In 1972 funds became available within the Department of Natural Resources' Division of Recreation and Parks for artificial reef construction. Through 1977, $41,000 was spent on reef construction.

Florida also participated in the Liberty ship program. Four were sunk in 1976–77 off Miami, and the northwest Florida coast by the FDNR Marine Patrol.

Recently, FDNR expanded the scope of the Florida Boating Improvement Program to include funding of all aspects of reef construction. Inasmuch as these funds are proportional to the number of boats registered, it is expected to be a stable program. It is administered through our Division of Recreation and Parks.

In 1978, the DNR's Division of Marine Resources received a grant from the Coastal Plains Regional Commission of $100,000 for reef construction. The 1979 Legislature appropriated sums of $113,000 and $370,000 for the biennium. These funds are available for use in preconstruction engineering work, and transportation of materials to reef site. Local governmental sponsorship of volunteer labor from fishing or diving clubs is sought for these funds to be expended for such purposes.

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It becomes evident to this observer that the single most important factor in insuring continuity of effort to build and maintain reefs is a reliable source of government funds. Although individual or group interest may be high, the likelihood of dependable commitment of time and funds cannot be assured.
As long as our marine waters serve a multiplicity of user groups, so shall there be overlapping and fragmented regulatory and/or management authority. I can only recommend persistence on the part of the applicant, and offer this Department's assistance and guidance through the Bureaucratic labyrinth toward successful completion and maintenance of the project.
RAPPORTEUR’S REPORT

Ronald L. Schmied

It is evident from the excellent presentations made this morning that much has been learned about the important functions that can be served by artificial reefs. As I listened to the speakers, it occurred to me that artificial reef construction could be referred to as an "ecological disposal service." "Ecologically," artificial reefs are important because they can provide habitat for a spectrum of marine life ranging from algae and encrusting organisms to top predators such as groupers and barracudas. Artificial reef construction may also provide an effective means to "dispose" and make productive use of selected surplus or discard materials. Lastly, artificial reefs are widely accepted as a "service" to saltwater anglers because they can enhance sport fishing opportunities.

While artificial reef programs can indeed produce multiple benefits, our speakers stressed the fact that successful reef programs involve far more than the arbitrary dumping of miscellaneous materials on the ocean floor. In my opinion, the advice given on how to derive maximum value from artificial reefs was the most important aspect of this mornings session.

Mr. Ananda Ranasinghe aptly pointed out that properly constructed artificial reefs provide habitat for marine life in much the same way as natural reefs. Research has shown that over time, artificial reefs attract and support similar types of marine organisms as do locally occurring natural reefs. More importantly, it was reported that, in spite of the absence of hard evidence, there is general consensus among researchers that artificial reefs can actually be used to substantially increase total biomass of marine organisms in a local area.

Two important messages were implicit in this discussion on the biological aspect of artificial reefs. First, based on research performed, it could be concluded that the term artificial reef is a misnomer. It strikes me that the only think artificial about artificial reefs is that they are man-made. Since semantics are often important in gaining public and legislative support for government programs, we should all be careful to specify the context in which the term artificial is used.

Secondly, we should remember that artificial reefs, like any other artificial object, function best when they most closely resemble the natural object after which they are modeled. In this regard, it was emphasized that we need to better understand the biological functions and

National Marine Fisheries Service, St. Petersburg, Florida
characteristics of natural reefs and to be ever mindful that reef biology is predominately controlled by local conditions. If we intend to use artificial reefs to enhance the marine resource base on which sport fishing depends, then artificial reefs should be constructed in a way that recognizes and builds upon the existing biological conditions of the area for which the reef is intended.

Dr. Ray McAllister discussed the difficulties of building artificial reefs in the harsh marine environment and expressed his belief that artificial reef programs can make productive use of surplus or discard materials. However, Dr. McAllister cautioned against indiscriminate dumping of materials as a method of artificial reef construction. He advised that a much different approach to reef construction needs to be used if we are truly serious about enhancing marine habitat and sport fishing opportunities. We must first formulate our reef construction objectives, choose an appropriate site for the reef through a comprehensive site evaluation process, and then select the construction materials that will best match prevailing local conditions and produce the most productive and stable reef. If discard or surplus materials meet the site specific construction criteria, then additional efficiencies are created through the availability of inexpensive (free) materials.

The Texas speaker, Dr. Robert Ditton, did an outstanding job of outlining the numerous ways in which artificial reefs can serve saltwater sport fishing interests, especially in the area of increasing sport fishing opportunities. We must all realize that the degree to which we improve sport fishing opportunities will ultimately depend on our ability to gather and utilize saltwater sport fishing information in reef deployment decisions. Most importantly, we need to better understand the fishing abilities, patterns and preferences of saltwater sport fishermen so that we can effectively predict who, if anyone, will benefit from artificial reef programs before precious time and resources are committed.

All of us involved with artificial reefs have been issued a challenge this morning. The speakers made it clear that multiple benefits may be derived from artificial reef programs. They also gave us sound advice on how to obtain these benefits. It is now up to us to develop artificial reef programs that will effectively capitalize on these potential benefits.
FIRST TECHNICAL SESSION

Planning: The Key to Successful Reef Programs

Chairman: Mr. Charles R. Futch, Florida Department of Natural Resources Tallahassee, Florida

Speakers:

"Planning Considerations for Reef Construction"
DeWitt D. Myatt
South Carolina Wildlife and Marine Resources Department
Charleston, South Carolina

"Artificial Reef Site: Selection and Evaluation"
Dr. Heyward Mathews, Jr.
St. Petersburg Junior College
St. Petersburg, Florida

"Understanding Artificial Reef Permit Requirements"
Bernard N. Goode
U.S. Army Corps of Engineers
Washington, D.C.

"Liabilities and Other Legal Aspects"
Robert G. Hayes
National Oceanographic and Atmospheric Administration
Washington, D.C.

"The Private Recreational Fisherman's Viewpoint"
Kenneth A. Himman
National Coalition for Marine Conservation
Savannah, Georgia

"The Charter and Headboat Operators Viewpoint"
Captain B. J. Putnam,
Panama City, Florida

"The Commercial Fishermen's Viewpoint"
Robert Jones
Southeastern Fisheries Association
Tallahassee, Florida

"Why Sport Divers Like Artificial Reefs and How You Can Use Them"
Steve Blount
Sport Diver Magazine
Miami, Florida
FIRST TECHNICAL SESSION - Continued

Speakers:  "Artificial Reefs and the FCMA"
William G. Gordon
National Marine Fisheries Service
Washington, D.C.

Rapporteurs
Report:  Willis Clark
Texas A & M University
College Station, Texas
PLANNING CONSIDERATIONS FOR REEF CONSTRUCTION

DeWitt D. Myatt

Introduction

Artificial reefs have been in use for at least 185 years. In 1794, the Japanese reportedly sank wooden frameworks filled with sandbags and tree trunks in the ocean near Kobe, to rejuvenate a declining fishery around a shipwreck (Ito, 1974). Fifty years later, coastal South Carolinians sank wooden structures filled with stones in estuaries around the sea islands to attract sheephead (Elliot, 1846). Since these early beginnings, artificial reefs have been widely used with varying degrees of success, but the past two decades have seen reef building become a budding science in itself. Technological advances, linked with increased biological knowledge and socio-economic changes have brought state and federal agencies, as well as private and municipal organizations, to the realization that artificial reefs can be effective tools for fishery management, solid waste management and the recreational industry.

Determining Objectives

An effective reef program should begin with long term planning. Goals and objectives must first be established, then strived for with the most efficient means of obtaining them.

One objective might be economic enhancement to an area. Anglers are naturally drawn to fishing areas that promise good catches, and they bring their dollars with them. Recent economic surveys show that the recreational fishery in South Carolina alone amounts to an astounding 47.03 million dollars a year, which is 3 times that of the commercial fishery in the state (Liao, 1979). Real estate values in areas near reefs are also enhanced because of the recreational opportunities they offer residents.

Economic benefits can also be achieved by harvest of fish from reefs by charter boats, headboats or commercial fishermen.

The sport diving industry also benefits from strategically placed artificial reefs. Careful planning is required to maximize benefits and to avoid conflicts between the foregoing factions.

South Carolina Wildlife and Marine Resources Department, Charleston, South Carolina
Solid waste disposal is another objective that is often incorporated into artificial reef programs. If reefs are to be effective means of solid waste management, careful plans must be made so that the reefs are actually serving as fishery enhancers rather than as offshore dumps. Once the preceding criteria are met, a logistical system should be established that will allow significant quantities of the waste material to be processed, transported and sunk at a competitive cost to other means of disposal.

Artificial reefs can also be effective in other areas of fisheries management. For example, many rivers, bays and sounds are off limits to trawling in the southeast and considerable sums are spent for law enforcement to prohibit this means of harvest. Illegal trawling could be eliminated while increasing fish habitat by the random placement of reef structures in non-trawling areas.

Artificial reefs have been documented as being effective spawning and nursery habitat. As more and more natural habitat is destroyed by development and neglect of our coastal waters this role of artificial reefs becomes more important and someday may prove to be the primary objective of many reef programs. Finally, artificial reefs are ideal workshops for research and education. Reefs function well in this mode because variables can be controlled and sites can be located near learning institutions. Careful planning is required to insure that compatible objectives are achieved with maximum results.

Implementation of a Reef Program

Once the objectives of a reef program are defined, more planning is required to implement it. The first step in implementing the program is to decide who can run it best. Artificial reefs represent a long term commitment and liability. All reef programs suffer when an individual or organization embarks on a reef program in an irresponsible or unenlightened manner. In many cases private or locally sponsored reef programs encounter problems because they lack the substance to follow through with long term maintenance and support after construction. Municipal, county, state and even federally sponsored reef programs can suffer because the administrations starting the programs failed to recognize the full responsibility of reef programs. The demise of the federal artificial reef program, which played an important role in getting many local and state reef programs started back in the late 1960's, is a classic example of how good programs can falter. Many state and local programs exist on the same tenuous grounds that the federal program did, and without a legal mandate they can end simply by the failure of a legislator to ask for another annual appropriation.

Financial Considerations

The funding requirements for reef programs are best considered on several levels. The first level is the most critical, even though the actual budget may be fairly small. This is, as the cemetery people call
it, "perpetual care" money. Funds need to be allocated for maintaining buoys or markers, paying insurance premiums, covering the cost of paper work, monitoring the condition of reef material, enforcing regulations, promotion, and user education. The best source of funding for this level would be by laws that clearly define who is responsible for reef maintenance and appropriate perennial funds for that maintenance. In the case of private reef programs, a trust fund would serve the same purpose.

A separate level of funding is needed for construction, which is usually the most expensive phase of a reef program. The most important requirement for construction funding is that it must match the nature of the project. A simple one shot grant or appropriation may prove to be adequate for sinking a load of rubble, a ship hull or a finite number of automobile tire units, but it is not adequate for a reef program that is intended to accommodate large numbers of anglers over many years or be a significant means of alleviating continuing solid waste problems.

An on-going construction program requires an on-going source of funds which would best come from licenses, special taxes or assessments clearly earmarked for that purpose. Annual appropriations for construction create problems for major reef construction efforts because annual start-up and shut-down costs are high and discourage mutually beneficial co-operation with industrial interests.

The third level of funding requirements for reef programs relates to research, development, pilot programs and other short term activities. These programs are served well by grants and donations that finance specific tasks with a predetermined termination point. If the work accomplished at the termination point merits further funding, the program can or should be incorporated into the "on-going program." If it doesn't, it should be dropped. Since not all research leads to a successful conclusion, short term funding encourages final assessment and prevents continuous funding of worthless effort but still allows us to learn from our mistakes.

If a program is to be funded by voluntary private donations it would be wise to limit your objective to specific short term accomplishments such as a "sink the liberty ship fund" rather than depending on them for continuous support of an ongoing program. An ongoing reef program funded by private donations needs a comprehensive system of solicitation. Fund-raising systems frequently require more effort than actual construction.

It is suggested that any major grant for artificial reef construction, whether from Federal, state or other sources, should be contingent upon the recipients' guarantee that they have provided for maintenance of the reef once construction is completed. Many programs are suffering serious setbacks and reefs are being lost and neglected today because this precaution was not taken in the past.

Considerations Relevant to Free Help.

Most reef programs have access to free materials, services, or equipment to some extent. Important factors to consider before accepting
any free materials offered to your program should include cost of preparation, transportation and the suitability of the material to the objectives of your particular program. If all the preceding criteria are positive, the abundance of the material should be considered. In many cases, otherwise excellent free material should be refused because the costs in establishing a system of handling it aren't justified by the supply. The motives of the donor should be examined closely. The more the donor stands to gain the better the chances that the reef program will also benefit. Donors simply interested in improving public relations or intrigued with making their own fishing a little better are not as dependable as those who can show a financial justification for their activity, especially in long term efforts. Donated services must pass the same tests as materials, as well as several others. Since services cannot be stockpiled for convenient use by reef programs, it is important to know how frequently the services will be available, how frequently you will need them, the cost to your program in terms of time, money, effect on other reef activities, the suitability to program objectives and whether the services offer a recreational value in themselves.

For instance, a group of people can derive substantial enjoyment from a weekend of building reef units and transporting them, but the activity quickly becomes work and volunteers evaporate after a few days. Several reef programs have benefited from free help from National Guard units which have successfully incorporated weekend training exercises into reef construction. Unfortunately, similar efforts in South Carolina resulted in two valuable summer months being expended to co-ordinate an effort that resulted in less than one thousand tires being delivered to a reef.

Generally speaking, as the number of different donated services and materials increase, so does difficulty in coordinating them. An example of how this can happen occurred in the early phases of South Carolina's tire reef program. A tire recapper in Charleston agreed to provide and bale tires for our program at no cost if we loaned him our tire baler and would haul away the tires. We also had an agreement with twelve truckers to haul two semi-tractor trailer loads of tires a month, each at no cost on a "dead head" basis. Since the bulk of our construction was taking place one hundred miles away in Garden City the service was quite valuable and the program looked great on paper. Unfortunately, we soon found ourselves in the middle of an awkward dilemma because we had to match a donated production schedule with donated transportation that could not be scheduled. It was soon evident that it was far more efficient to pay the truckers for their services and have the tires moved when we needed them moved rather than to constantly shift our baling schedule, which was the most valuable donated service.

Donated help from truckers of the South Carolina Motor Transportation Association is still requested occasionally for a specific hauling job but I doubt we would still be on good terms with them if we had pressed our original plan to the limit. Because of our experience and early successes in coordinating industrial tire disposal with our artificial reef program, the South Carolina Legislature has funded an engineering study of the feasibility of developing a statewide tire reef program.
An earlier study for three coastal South Carolina counties indicates that such a program may prove successful and competitive with existing methods of tire disposal (Weston, 1978).

Variables Affecting Reef Program Planning

The donated services covered in the preceding section represent one series of variables that may or may not be worth the effort to integrate into a reef program. Ideally, the fewer the variables that you must contend with, the better your program will be; in fact, if all your variables could be limited to weather changes you would still have your hands full. The wide number of variables associated with marine transportation make it the "Achilles Tendon" of most reef programs. Fluctuations in bids from marine contractors can wreck the best plans and destroy the most carefully organized budget.

The arbitrary doubling of marine transportation bids for the well organized Broward County reef program in Ft. Lauderdale contributed to the suspension of that program. Similar occurrences with other programs have caused their untimely demise. Do not be deceived! Piracy still exists and it is only partially concealed in many circumstances.

There are, of course, advantages in having offshore work performed by contractors. Many programs are not large enough to justify the acquisition of the heavy equipment and vessels necessary to accomplish program objectives on their own. Most established marine contractors have learned the hard way how best to accomplish a job and will have the insurance to cover their liabilities. Be prepared to pay for the contractors "education" as well as his insurance. Since the marine phase of a program involves the greatest risk, having it done by a contractor insulates the reef program from this liability to some extent. However, don't be complacent about your liability when having work contracted. You can still be stung badly if your aren't careful for the ultimate responsibility lies with the owner or permit holder. Marine contracting services should be kept as simple and consistent with existing practices in your area as possible.

A towing company will usually be able to bid competitively and perform competently on a simple towing job, but his risks and your costs increase drastically when other tasks are added with which he is unfamiliar. For instance, a reef program that owns or has easy access to a barge and dock is better off than one that has a tug or licensed captains to tow them offshore. Most programs benefit from contracting directly to have the work done rather than have a contractor subcontract a large portion of a job.

There are definite advantages in owning your own equipment if a reef program is big enough. Scheduling and quality is much easier to control when equipment and labor force are under your direct administration. Modifications to project equipment that would be impractical for most contractors who can't anticipate future work can be justified to facilitate your program. Budgetary planning is improved since costs
are most predictable for project owned equipment than when contracts are bid. Last, but not least, tangible assets and payrolls tend to give long term credibility to your program which aids in future funding and encourages the cooperation of industrial interests.

Planning Reef Construction to Achieve Objectives

Concurrent with planning for the implementation of a reef program, decisions should be made with respect to the location and design of the reef so that your objectives are best served.

An attractive aspect of artificial reefs is that several objectives can often be met simultaneously. In fact, most reefs in the southeast built primarily for recreational fishing also provide secondary benefits such as scuba diving and waste disposal sites. If the parties responsible for reef building have a clear picture of the groups who will use it then they can build it in a way that benefits those groups. For example, if the fishermen that you want to attract to your reef are primarily interested in trolling and casting for pelagic species, high profile material and possibly mid-water fish attractors should predominate at the site. The material should be distributed on the reef so that trolling patterns can be developed on the boats that will utilize the material effectively (Hammond, 1977). Since anglers equipped for trolling usually have boats designed for fairly extended trips, the reef sites for a pelagic fishery can usually be justified farther from shore than others.

Conversely, an artificial reef intended for a general recreational fishery usually comprised of bottom anglers would not necessarily require high profile material. Instead, the objective of a general purpose reef builder should be to create maximum coverage and as even a coverage as possible on the reef site. General purpose bottom fishing reefs, located as close to sheltered harbors as practical, encourage safe utilization by anglers in a wide variety of watercraft.

In some cases a system of multiple reefs can be justified. Inshore, or estuarine, reefs in the rivers, creeks and bays would augment the small boat fishery. A general purpose reef or reefs built in inshore waters would serve users with larger boats and better navigational ability. Farther offshore a deep water trolling alley comprised of ship hulls and mid-water fish attractors would be available for those equipped for the pelagic fishery.

If solid waste disposal is an important factor in your reef program, general purpose reefs located as close as possible to waterfront staging areas should be built with special consideration for gearing reef construction to the production schedules of your sources of material. Such a reef site should be free of strong currents or unstable bottom conditions that would require expensive preparation of reef material.

Artificial reefs are usually justified on the basis of economic enhancement to a coastal area. In many cases the tourist dollar is the intended source of economic return. Tourists are best attracted to a
reef built especially for them. The reef should usually be located close to shore facilities such as ramps, marinas, campgrounds, motels, tackle shops and charter services. The reef should be prominently buoyed and a promotional program should be planned to get people not only to use the reef in the first place, but also to educate them so that they will be able to fish the reef successfully. The best promotion for anything is word of mouth; not only will successful anglers return to fish the reef, but so will their friends and neighbors.

A survey at Murrells Inlet, South Carolina revealed that sixteen percent (16%) of the anglers visiting the area came to fish on the artificial reefs and would not have come if the reefs were not there (Buchannan, 1973). The recreational fishery has continued to boom in Murrells Inlet and, although catches cannot be guaranteed, it is evident that the reef program has been very effective there.

Not all reefs are built to attract tourists. For example, reefs built to improve the quality of life for residents. These reefs, like parks, playgrounds, tennis courts, swimming pools or golf courses, serve as "common" facilities.

Residents using a community reef usually have ample time to learn how to use it, thus the promotion and educational aspects required for a tourist reef are not as important and over-promotion may even detract from the desirability of the reef to residents. A decision should be made as to whether "out-siders" are encouraged to use the reef; then the appropriate policies and management techniques should be applied to support the decision.

Most artificial reefs in the southeast have been built primarily for recreational anglers who use their own boats. However, the success of these public recreational reefs indicates that reefs designed to augment charter boat, headboat or commercial fisheries would also prove successful. In fact, many public recreational reefs support commercial and charter boat fisheries although that was not the original intention of the builders. Charter boat and headboat use of recreational reefs seems to be compatible with the general intentions of most reef programs. Reefs built specifically for charter boats or headboats may prove to be even more effective for them.

The practice of commercial trapping for black sea bass on South Carolina reefs has stirred considerable controversy by recreational anglers. Regulations are needed to control harvest methods because the reefs were not built for commercial trapping operations. This problem was not foreseen when South Carolina's reef sites were selected and we can't resolve the problem by state legislation because our reefs are beyond the 3 mile jurisdictional limit. We hope to find a means of controlling the harvest on our reefs through provisions of the South Atlantic Fisheries Council. This is a cumbersome process because regulations needed to solve our problem might prove incompatible with programs in other locations.

The Japanese have built numerous sophisticated artificial reefs for the sole purpose of enhancing commercial harvests (Ino, 1974). There is
a good chance that similar commercial artificial reefs will be developed off our coast as natural stocks are depleted and the demand for fish products increases. Any regulations pertaining to the harvest of fish from recreational reefs should also include provisions for the eventual use of artificial reefs as a management tool for commercial fisheries.

Scuba divers are often treated as an afterthought by many reef builders but the diving associated with an artificial reef often has more economic impact on an area as far as bringing in new dollars than do anglers who were probably already fishing the area before the reef was installed. The successful development of a new diving industry in association with artificial reefs is demonstrated dramatically in South Carolina's Murrells Inlet area. Five dive shops thrive because of the three reefs in that vicinity whereas only one dive shop existed in the entire Myrtle Beach area before construction of the reefs. Diving activities on an artificial reef may include spear fishing, lobstering, training, exploring, shell collecting, photography and fish watching. Since conflicts often develop between anglers and divers over the use of an artificial reef those responsible for building and maintaining the reef should be prepared to take steps to control or minimize the conflicts through legislation, education and reef design. In some cases the consumptive activities of divers such as spear fishing or lobstering should be carefully controlled or prohibited on a reef. These steps are usually more effective in making the reef more attractive to divers than in benefiting anglers.

Artificial reefs attractive to divers are usually those that include sunken ships and other vessels which offer opportunities for exploration. Reefs built for divers may also be exceptions to the common practice of avoiding live bottom areas in site selection. Many live bottom areas, especially off Georgia and the Carolinas are relatively flat and unimpressive but could be improved substantially if high and medium profile habitat were added. The usual effect when this is done is that larger animals are accommodated and concentrated on the artificial structures while a rich diversity of small non-game fish on, or recruited from, the natural habitat provide the kind of experience that divers enjoy.

Conclusion

This conference is limited to general concepts associated with artificial reef programs. There is also an urgent need to assemble a forum of people involved in artificial reef research so that their discoveries will be made accessible. Artificial reefs represent a powerful tool in resource management and, like other powerful devices, there is a certain amount of risk associated with their use. The risk can be reduced and benefits increased when using reefs if careful plans are laid before application. Hopefully, this conference will help all potential artificial reef planners and users benefit from the successful, and not so successful, experiences of others.
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ARTIFICIAL REEF SITE: SELECTION AND EVALUATION

Dr. Hayward Mathews, Jr.

Introduction

One of the most exciting marine fishery management tools in the last few decades is the artificial reef. When properly built in optimum locations, these reefs can create an oasis of fish on what was formerly a biological desert.

In recent years coastal communities around the country have started artificial reef building projects. Unfortunately, some of these projects were failures or did not realize their full fish habitat potential due to improper site selection at the beginning of the project. With proper site selection an artificial reef can last indefinitely. Improperly sited it may last less than six months.

Physical Location

One of the main reasons for building an artificial reef is to attract food and game fish to a location easily accessible to fishermen and sport divers. With this in mind, planners should find a site that is easily located, with a minimum of travel time and fuel consumption.

Wherever possible, a reef should be located directly offshore from the channel or inlet where most fishermen will be departing. Many anglers utilizing an artificial reef will have small inexpensive compasses, seldom corrected or even checked. For this type of angler, a compass course such as 147° or 219° will decrease the likelihood of his finding the reef if it is more than a few miles offshore. A reef that is due south, east, or west from a sea buoy is usually best. However, a bearing like southwest or other major compass point is still much easier for small boaters than some odd number.

In locating an artificial reef directly offshore from the channel or inlet, care must be taken to avoid interference with navigation. If the area is frequented by large ocean-going vessels, there is the hazard of small boat anglers being run down by a large ship during fog or on a dark night. Such a location requires a lighted buoy greatly increasing the original cost and maintenance. Once the reef is constructed it probably will have many small boats anchored over it both day and night.

St. Petersburg Junior College, St. Petersburg, Florida
Another important consideration is the commercial fishing activity in the area. It is best to avoid an area used for purse seining, drift netting, or trawling to avoid conflict with commercial fishing interests and possible net damage. In most areas the local commercial fishing interests will cooperate and point out which areas they do not fish. Many areas will already have some existing obstructions that prevent net use anyway, and such obstruction areas make ideal reef locations (assuming the substrate is firm).

A final consideration is to avoid areas with strong tidal currents. A tidal current will cause erosion along alternate sides of the reef. This can cause reef materials to slowly work down into the substrate. A constant current from the same direction is usually not a serious problem. Since many of the benthic invertebrates on an artificial reef are filter feeders, a reef with its long axis running at right angles to the prevailing current would be more productive.

**Depth vs. Distance Offshore**

A very important consideration in reef site selection is water depth. In coastal areas water depth is normally a function of the distance offshore. Therefore, water depth and distance offshore must be considered together.

As a general rule, a shallow water reef in depths of 10 to 15 meters will not attract the large benthic species common to reefs in 20 to 40 meter depths. Shallow reefs will often support a larger total fish biomass, but most anglers are more interested in catching a single ten pound fish than ten one pounders.

An ideal site is one with 30 to 40 meter depths only a few miles offshore from the inlet or harbor. However, in areas with a wide continental shelf, 30 to 40 meters of depth is seldom found less than 75 to 100 miles offshore. For that reason, some type of compromise between depth and distance offshore is required. This is best solved by building several reefs to accommodate different user groups. Deeper reefs farther offshore provide larger individual fish for larger boats. Shallower reefs closer to shore attract smaller fish for smaller boats. Wherever possible the small boat reef should be in sight of land.

The depth of the reef site is also important in the choice of reef building materials. In this respect, however, the average wave energy as a function of water depth is of primary importance.

In the open ocean a wave travels free of the bottom when the depth of the water is greater than one half the wave length. Once a wave enters water less than ¼ the wave length it begins to interact with the bottom and any structure on the bottom. For example, a wave with a 20 meter length will begin to "drag" the bottom at a depth of approximately ten meters. This not only stirs up the bottom sediment around the reef but can actually shift low density reef materials about and even move them off the reef site entirely. Several artificial reefs have been
built, only to discover a year later that the entire reef was scattered out of the original drop site and, in one case part of the reef ended up on a public beach. This type of failure could seriously hamper future reef building projects in a given area and elsewhere.

Early in the project, planners should determine the average wave length for a range of storm waves, and some estimate should be made of what length waves probably would occur during a ten year storm cycle. This information can be obtained from the National Oceanic and Atmospheric Administration (NOAA) hydrographic offices. If the average wave length in such a storm is 50 meters, high density reef materials such as concrete and steel hulls should be used since the reef would be only 25 meters deep or less.

With high density reef materials, the wave energy problem is not as serious, and in most coastal areas, depths as shallow as ten meters are safe. An exception might be some exposed Pacific coastal areas like in California or Hawaii.

Auto bodies would normally be considered low density reef materials because the major portion of the car body is very thin metal. The auto frame itself is high density, but tends to separate from the body sections after a few years in sea water. P.V.C. tubing used in structures such as the "Prentiss" reef is also considered low density material as well as automobile tires and wooden hulls. One way to utilize a variety of reef materials is to build several reefs at varying depths simultaneously. On the deeper water reef (30-40 meters) use low density materials like auto tires, and on shallower reefs use high density materials like culvert and concrete rubble.

Substrate

Once the above factors have been considered the next step is to go out to the selected area and make an underwater survey of the bottom. A diver/biologist can make a general biological assessment of the benthic communities present, but if a biologist is not available, then an experienced diver would be the next best choice.

The types of substrate to avoid are mainly soft sediments (clay or silt size particles) and bottoms that are already biologically productive.

To determine the bearing capacity of the bottom a diver should probe the substrate either by hand or with a metal rod. As a general rule, a suitable bottom is one where the hand will not push down into the bottom past the wrist in a single push. If the hand penetrates beyond the wrist (with fingers extended) the bottom is probably too soft and will result in much of your reef effectiveness being lost soon after construction. In one case off the Florida east coast, a group built a reef in such a soft substrate that one year later no trace of the materials remained about the bottom. In most areas the bottom will be fairly firm for long distances with only an occasional soft spot. In other locations one may spend several days locating a suitably firm bottom.
The idea of selecting a site without existing productive benthic communities may seem strange. It would seem logical to try to improve on a productive area. However, while an artificial reef can provide more niches and habitat than a natural reef, the improvement will not be that significant in most locations. If a bottom area is already productive, then leave it alone, and select a barren sand or shell bottom where the improvement and additional habitat will add to the existing situation. A grass bed or rock outcrop already provides habitat, while a barren sand bottom has almost none at all. So the total habitat and, therefore, the total fish biomass of a given bottom area can be improved best by adding habitat where it does not exist or is scarce, rather that slightly improving an already productive location.

In many areas there may be rock or hardpan strata that will intersect the bottom surface at given points offshore. Where this occurs, a good practice is to move up slope from such an outcrop and locate a site with 10 to 30 centimeters of sand or shell over a rock foundation. This will assure that reef materials can sink no more than a short distance into the bottom, and often the current action around the reef materials will expose the rock itself, making additional habitat.

In one case of poor site selection in the Florida Keys, a tire reef was dropped on a grass bed adjacent to a coral reef. The unsecured tires not only damaged the grass beds, but some shifted and began to batter down the coral heads.

Firm sand or sand/shell combinations are the most suitable substrates for high and low density reef materials. Low density materials like car tires often only become relatively stable on the bottom when they become imbedded in the sand.

**Exact Location**

Once a suitable reef site has been selected it is vital that the spot be precisely fixed. All the careful steps in site selection can be totally negated by being a few hundred yards off when actual construction begins. In most states the necessary construction permits must show the exact location, as do permits from the U. S. Army Corps of Engineers and Coast Guard.

Time and distance runs from a known location are never accurate enough for reef site selection, nor are Loran A coordinates. If the reef site is within site of land with prominent landmarks, then horizontal sextant angles will give enough accuracy for site location. If the site is farther offshore, then Loran C is the only alternative. The same Loran C set should be used for the original site selection dives and the actual buoy placement prior to the first drop.

**Reef Permitting**

Permission must be received from both the U.S. Army Corps of Engineers and the appropriate state permitting agency to construct a marine reef. Regulations of each agency are available upon request.
Initial Biological Reports

Most permitting agencies will expect a biological report on the reef site as a part of the original permit application. This report also provides a good record of productivity of the site prior to reef construction for later comparison.

The initial survey should include a list of both invertebrates and fish species and some measure of abundance. If the above suggestions are followed, the initial biological report should be simple because the ideal reef site will have only a minimal plant and animal population prior to construction.

Once the reef is built, a series of fish counts should be conducted to evaluate the reef's effectiveness, and if personnel and funds are available, primary production and invertebrate populations should also be measured. If the reef is sited and built properly, the "before" and "after" comparisons should be so impressive as to warrant additional reef building projects.
UNDERSTANDING ARTIFICIAL REEF PERMIT REQUIREMENTS

Mr. Bernard N. Goode

Hearing some of the remarks this morning I come to you, perhaps, from the enemy camp for I am a regulator and have been a regulator for a number of years. I guess what keeps me interested in the business is trying to streamline and deregulate wherever feasible. Unfortunately it is true that there is still a lot of red tape. There is much too much in the way of delays. But there are a lot of laws that are applicable. We don't have the option of not applying some of these laws. Congress keeps coming out with new laws and the President comes out with new Executive Orders. Other agencies come out with new regulations, and revised regulations, and the beaureaucracy grows and grows. Furthermore, there are a lot of conflicting uses out there in the ocean. If you were a commercial fisherman eking out a living out in the ocean and you get your new net fouled up in a '58 volkswagen you would have a very different view on how quickly the Corps should issue permits for fishing reefs. So we act as the referee among these conflicting uses. We try to give the use that will serve the public the best. There are five laws that I want to particularly mention as I go through my presentation.

The primary authority of the Corps of Engineers comes from the River and Harbor Act of 1899, Section 10, which says you have to get permission from the Corps of Engineers before putting anything in the water. That law applied to the so-called "navigable waters of the United States" which, in the ocean, extends to the limit of the territorial seas. Recognizing the uses beyond the territorial seas, particularly for mineral uses, the Congress in 1953 enacted the Outer Continental Shelf Lands Act which extended the Corps' Section 10 authority to the outer limit of the continental shelf for the placement of fixed structures and artificial islands. Where is the outer limits of the continental shelf? I have been asked that question many times through the years. I gave up on trying to explain it's where the slope of the bottom or the ocean takes a rather dramatic change. Knowing that this drastic bottom contour change generally occurred around the 600-foot depth area, I started telling people that the outer limit of the continental shelf if the 100-fathom contour. If you say that with enough confidence that's the end of the conversation and they assume that you know what you're talking about. Or, if you really want to be sophisticated, you tell them it's at the 200-meter contour, for those who are interested in going metric. But, to my knowledge, it is not precise to define in terms of depth, it is a change in the slope.

The third Act I will mention is the Marine Protection Research and Sanctuaries Act of 1972, better known as the Ocean Dumping Act. That law says you cannot dump a pollutant in the ocean without getting a permit, either from the Corps or the Environmental Protection Agency.

U. S. Corps of Engineers, Washington, D.C.
The Corps' authority is only for the discharge or the dumping of dredged or fill material, whereas EPA's authority is for the dumping of any other type of pollutant. Which brings up something that you should be aware of for it is kind of important in terms or reducing the amount of red tape that might confront you. If you're going to apply for a fishing reef, make sure that's your main emphasis. If you try to camouflage your intentions so as to get rid of some old tires or old automobiles, and if that becomes the main purpose of your activity, a dumping operation, then EPA might come knocking at your door. As long as it is for a fishing reef the Ocean Dumping Act specifically excludes that type of activity from being regulated under the Ocean Dumping Act, provided it is being regulated by a state or another federal agency.

Then there's the Coastal Zone Management Act of 1972, which says to the states that designated federal agencies are empowered to help you in managing your coastal areas. You must develop a plan and get it approved by the Department of Commerce. Once it is approved, then activities that the federal Government has in association with it must be compatible with that coastal plan. This is not one of my strong suits but I'll mention it because it is one for the lawyers to wrestle with and that is whether or not a state could have some regulatory control over a reef beyond the territorial waters with respect to the fact that that reef might affect their coastal areas in terms of drifting. Whether that has come up before or has been answered, I don't know. But the reef within the state waters will have to be compatible with the Coastal Zone Management Plan if that state has such a plan approved. I don't believe Florida has theirs approved yet but somebody else could correct me on that.

The last one is the Clean Water Act, formerly known as the Federal Water Pollution Control Act, or as the Water Quality Act, and several other names back through the years. The two sections of interest are Section 401 and 404. Section 401 is the one that says that the state, in effect, has veto authority over EPA or Corps permits if the state finds that a discharge will be incompatible with the state water quality standards. The law is a little more complicated than that, but that's basically what it means. It does give the state a veto power over the federal government where discharge in state waters is involved. Section 404 is the one that says that you must have a Corps permit before you can discharge dredged or fill material into navigable waters. That law only applies to the three-mile limit. The complicating feature is the fact that Florida West Coast and Texas territorial waters extend out three marine leagues or nine plus nautical miles, whereas the law specifically only extends for three miles. In any event, where you are in this three-mile belt you'll be having your permit processed not only under Section 10 but under Section 404 as well. Section 404 brings with it state certification, application of EPA discharge guidelines under Section 404(b), EPA veto rights under Section 404(c) and some other things like that.

So then what is the permit process? Your first step is to contact the District Engineer who has jurisdiction in the area where you want to put the reef. You will be sent a booklet containing the laymen's version of what the permit program's all about, along with an application form
for your use. Fill out the form, prepare your drawings showing where it is, what it is and so on, and submit that, to the mailing Corps office. A little hint: ask for a ten-year construction period when you do submit your application. You might not get it, but if you don't ask for it, you'll likely get a standard three-year period during which you can place reef materials before you have to get a renewal. Go ahead and ask for ten years, you might be surprised and you might get the full ten years. Once everything is in order the Corps will then put out a thirty-day public notice. When comments come in they are sorted and if everything goes smoothly, we're looking at 60 - 90 days from the date of your application.

However, things don't always go smoothly. Some of the problems that do come up are conflicts with military operations. As you know there are a number of restricted areas, danger areas, prohibited areas that are out there in the ocean and gulf. These are set aside for some specific use by the Navy, Air Force, NASA. Likely you will not get a permit to put a reef in one of these areas and you certainly will not get it if it conflicts with the purpose for which that area has been set up in the Federal Register. Don't let this intimidate you! If that's an area that's particularly good for you to put a reef in, ask the District Engineer if you can get that restricted area changed. They can be changed. It's not easily done but it can be done but does involve your having to go through a rulemaking procedure.

Another problem can arise when reef materials drift. This has always been a source of complaint, not only from the standpoint of aesthetics when the tires come up on the beach but for navigation when a boater runs into something. I understand our District in Hawaii is prohibiting rubber tires now because they continually are washing up on the beach. I hear that California is making or considering a similar move. I was interested to hear that hopefully we can get these tires in deeper waters where they can continually be used because I think that is a good thing to do for society -- to find a public benefit use for these old tires. As you also might expect, navigation is a problem. If you come in with your application and you are, for example, on the edge of a navigable channel you will have your application denied within a matter of a day or two. But there are many traffic zones out there and the District Engineer, if you don't see them on the coast chart, can tell you where they are and you'll be asked to stay clear of these or within a reasonable clearance of them. Commercial fishing, as I mentioned earlier, is a continual complaint we get. There are the environmental problems that might not very sizeable, but there is the matter of cleanliness of the material to be dumped. Perhaps the dump site itself may be valuable and could be harmed by the placement of the material. For some of our interior fishing reef applications, we get involved in such things as conflicts with Indian fishing rights, but that to my knowledge does not occur in the ocean. Once we have sorted out all of these conflicts, and develop a position on it we are then ready to make our public interest decision and, if that decision be to issue, to give you your permit.
The last thing you have to do it pay us a fee. There is no fee for a municipality or federal/state local government. There is a $10 fee if we judge it to be a private type operation and a $100 fee if it's more of a commercial operation. I can publicly say that the Corps of Engineers does not like these fees and I personally have tried on many occasions to eliminate them. However, the Office of Management and Budget wants us to increase the fees rather than eliminate them, so we are trying to lay low and keep these rather nominal fees at their present level rather than risk the chance of them going up.

A word about reef criteria. Some districts do have established criteria. I know when I came into the business in the Jacksonville District in 1971, I saw a list of criteria for fishing reefs one of which said you can't use any metal. I asked one of the old timers why that was in there and she said that's because it made it difficult to find the German submarines and I asked if maybe that criterion hadn't served it's time. We did eliminate that criterion, in fact, that whole list of criteria and we now evaluate each application on its own merits. However, we still must report these to the defense mapping agency who files and maintains a current log of them, particularly those constructed with metal products.

Two years ago, the American Institute of Merchant Shipping, after receiving complaints about the increasing number of fishing reefs, asked us to establish some nation-wide guidelines that could be applied throughout the nation. We studied the ADMS complaints and in February of 1978, published some proposed guidelines in the Federal Register that we were considering to use in the evaluation of fishing reef applications. There was considerable opposition. For instance, our friends from the State of Washington spoke in opposition. They contended that the proposed guidelines just didn't work in given areas of the country and that there were too many exceptions. We have now decided that we will abandon that idea and not establish nation-wide criteria. Henceforth, each application will continue to be evaluated on an individual basis.

As I previously mentioned, state jurisdiction extends to the territorial waters, plus they have a certification right, under the Clean Water Act, which in effect gives the state a veto over our permit if it so chooses. The Corps permit is the only Federal permit that I'm aware of. EPA, as I mentioned, might knock on your door if it starts looking like an ocean dumping or disposal operation rather than a fishing reef. Our review process, involves the review by a number of Federal agencies; The Coast Guard, who is interested in standardization of markings and navigational safety; EPA, who is interested in water quality; Fish and Wildlife Service, and National Marine Fisheries Service who are interested in fishing and general environmental concerns; and the Air Force, Navy, NASA, who are also using the ocean waters for defense purposes or for the space program.

The last item I wanted to mention was general permits, which is sort of a new era that we got into about two years ago. This is where we are trying to permit certain activities on a regional or nation-wide basis to cut down on paperwork and delays. We have already issued
regional permits for fishing reef structures in a lot of waters -- in Kansas, Pennsylvania, Wisconsin, Alabama, New Mexico, and Texas. I noted that one ocean reef general permit has been issued. It is in our Los Angeles district for reefs off the coast of California. Although it does have quite a number of conditions that apply to it I understand it is working successfully, the main problem being the tires that occasionally wash up on the beach. They're considering modifying that general permit to prohibit the tires. That's not to say you couldn't put a tire down, but it would mean you'd have to go through an individual permit process rather than taking advantage of the general permit route.

One other item; after you do get your permit for your reef, make sure you let the Coast Guard know, particularly if it's of any magnitude. There are two reasons behind this. One is that the Coast Guard can issue a Notice to Mariners. The other is that it lets people know what's going on so that if you are talking about dropping a derelict vessel they won't come out there and try to rescue you as happened on at least one occasion in the past.

Well, I hope this wasn't too complex. Your best bet is to plug in with your friendly District Engineer and let him guide you through the maze and let him worry about all of the technicalities of the various laws.
LIABILITIES AND OTHER LEGAL ASPECTS

Robert G. Hayes

The construction of artificial reefs can provide local organizations and communities with a means to improve marine recreational fishing opportunities. At the same time, the reef siting plan and its execution can lead to long-term responsibilities and the potential for liability. This paper outlines the elements of a siting plan and provides advice, mostly in the form of cautions, on how to avoid potential pitfalls which can lead to the disruption of the successful siting of an artificial reef.

A number of the papers submitted outline each phase of the planning, financing, licensing and construction of the reef. Each of those phases presents different problems which can be avoided with careful planning.

The central issue in any determination of liability for an accident is whether there was negligence. Negligence is generally determined as a breach of some duty of care owed to a third party. This duty can be greater or lesser standard depending on the relative relationship of the parties. The responsibility owed by the person or group that constructs a submerged artificial reef is difficult to determine. There are no reported cases of damages resulting from an artificial reef. With this in mind one must analogize to other actions which may have similar relationships to artificial reefs. This is the kind of basis that will allow the planner to determine the potential for exposure and take a prophylactic response. The duty owed will depend on the complexity of the project, the phase at which damages occur and the law of the site of the damage.

Early in the development of a plan to site an artificial reef you should obtain legal counsel to assess the risks involved and the potential for long and short-term financial exposure. Once an assessment is made, your counsel can develop a package to insulate you from liability.

There are a number of things that can be considered. One of the oldest methods of insulating oneself from liability is to simply give someone else the problem. Traditional concepts of liability would suggest that those jointly engaged in a single effort can be held liable for each other's negligence. This is generally true of partnerships, joint ventures, etc. Prudence would suggest that in order to isolate oneself from the negligence of others you should disassociate yourself. Formation of a properly constituted and funded corporation, limited partnership or other legal entity should allow you to shift the risk to someone else. This is particularly effective in the early stages of your planning. Financing, shore-side transport and licensing are excellent examples of areas where an organization can be used to avoid short and long-term responsibility.

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For the long-term siting responsibility, another entity other than yourself should be left holding the bag. Remember that your objective is to put the reef in place so that you can obtain the enjoyment of fishing there. Your objective has little or nothing to do with maintaining the reef as a memorial to your efforts. Retention of the responsibility for the reef is not in your interest. Look to some organization or government body to accept the reef once it's put into place. Local, State and Federal Governments are in a far better position to accept and distribute the short-term risk of development and the long-term post implementation risk than you are. If it's possible to donate the reef to another organization or political body, take advantage of it. You can always donate the materials and services required to put it in place and at the same time shift the risk of damage to the recipient of your generosity.

In the event that you cannot shift the burden, there are still areas where you can insulate yourself. In the planning stages try to use the best technology and the best people available. Put together a team that provides you with biological, engineering and legal expertise. Develop a comprehensive plan for each phase of the reef, that takes into account risk shifting devices and insulators.

Once your team is together, try to obtain liability insurance to cover the land-side and water-born transport of the reef materials. It's unlikely that you'll be able to obtain insurance for any liability resulting from the long-term implementation of the reef, but insurance should be available at a nominal cost for transport of materials. You may be able to add an umbrella policy to an existing policy or carry an independent policy on the whole operation.

Investigate the type and number of permits you'll need and start the application process early. You obviously need a permit from the Corps of Engineers but you may need permits as well from local or State governments to transport heavy or oversized loads. You may need special access to the water which may require some form of permit. Look into all foreseeable possibilities and make sure you've got what you need.

The plan that you develop should address the orderly transport of materials to the proposed reef site. Because many artificial reef projects take on a public service air, you may find yourself swamped with volunteers. All of these public spirited citizens may have the best of intentions but may also turn the siting of your reef into an unmanageable circus. Large groups of people are important to the successful placement of the reef, but their actions could lead to disaster. As organizers of large events are discovering, they can be held liable for attracting large groups of people without providing for proper security and control. Two hundred or more small boats, skippered by well intentioned but highly charged seamen, loaded with bales of tires leaving a single marina headed for the same destination has the makings for trouble. The organizers of such a spectacle could be held totally or partially liable in the event of an injury. Try to avoid such a problem by controlling the participants and properly planning the siting of your reef.
If you've complied with the proper procedures, once the reef is in place, the risk of being held liable for its placement is negligible. An improperly placed reef could lead to actions by the Corps of Engineers to have it removed. In addition, you could be held responsible for beach cleanup in the event the reef breaks loose and is washed ashore. Although the occurrence of these events are unlikely, a good plan should take their possibility into account.

The fact that you personally may not be held liable for any of the damages suggested in this paper may not be much of relief in the event you are named as a defendant in a suit in which you are required to defend yourself. The cost of defending oneself in a protracted damages suit can be very high. For this reason alone you should find ways to insulate yourself or provide yourself with the type of coverage that you can obtain from legal counsel.

This paper has discussed some of the ways you might reduce the likelihood of being held liable for the placement of an artificial reef. The methods discussed are by no means exhaustive. Although these considerations may not previously have been part of your plan, they should not be overlooked. Careful, advanced consideration of the risks can save you thousands of dollars and months of time. Personal liability lawyers are becoming more inventive daily. Avoid the risk, plan ahead and use the services of a good counsel to protect yourself and your project. Before beginning a project consult an attorney, investigate ways to avoid responsibility and most of all put that lawyer on your planning team early.
THE PRIVATE RECREATIONAL FISHERMAN'S VIEWPOINT

Kenneth A. Hinman

When the private recreational angler goes out in his boat, he wants to feel that he has a reasonable chance of catching fish, and that his only handicap will be his skills as a fisherman. But as you know, that is not often the case. The scarcity of natural rough bottom in many increasingly popular fishing areas, the pollution and destruction of natural reefs, which are in some instances already bearing more fishing pressure than they can handle — all these things affect his fishing and point up the value of artificial reefs to the sport of recreational fishing.

In his many fine articles on artificial reefs, Dick Stone of the National Marine Fisheries Service speaks of their "potential" as a fisheries or resource management tool. This is, I think, the catchword — potential; particularly in this planning portion of our program. By increasing the amount of rough bottom habitat with the construction or sinking of an artificial reef, there is certainly the potential for enhancing the natural environment, increasing the fishing productivity, and in turn improving salt water fishing. It can be an effective means of dispersing the fishing effort in overcrowded areas, and of increasing the carrying capacity of natural habitat. But there are so many aspects for consideration in the planning, construction and management of a reef, and it is ultimately how we address each of these in a comprehensive program that will determine its success. That, of course, is the purpose of this conference.

From the standpoint of the sportfisherman, there are certain elements of a reef program that affect him more directly, and thus command more of his attention. These are: 1) location of the reef; 2) type and size of reef; 3) marking; and 4) the availability of reef information.

Location

The primary consideration in siting an artificial reef is to place it where it will serve the greatest need. New reefs can be used to create habitat in relatively barren areas, thereby increasing recreational fishing opportunity in areas that would otherwise be less productive; or they can supply additional habitat to natural "live-bottom" where fishing effort is very intense.

National Coalition for Marine Conservation, Savannah, Georgia
The area with the foremost need for new reefs, or expansion of existing ones, is within 20 or so nautical miles of shore. The majority of fishermen own small boats, 17 to 20 footers, and as a result utilize fishing grounds closer to shore. In most areas, however, there is not enough natural rough bottom nearshore, where the fishing pressure is heaviest. Most small boat fishermen use distant reefs only at greater personal risk and expense. Artificial reefs, then, should be located close to shore, in relatively protected waters, so small and even medium sized boats can reach them easily and safely.

The next consideration in siting a reef is the proximity to access areas. It really serves little purpose locating a reef nearshore if anglers must travel a considerable distance up or down the coast to reach it. For this reason, reefs are best located within several miles of harbors or inlets with established boat access points. A reef that is not readily accessible to sportfishermen will simply not be used.

**Type and Size**

Before a reef is set in a region, it should first be determined what are the anglers' preferences for certain species of fish. To attract anglers, the reefs must provide the kind of fishing they want. For example, if the major sportfishery is for bottom-dwelling fish, for snapper-grouper or sea bass for example, then we would want to construct a low-profile reef. On the other hand, if pelagic fish, such as bluefish and mackerel, make up the most desired species, the reef would need a high profile.

For any reef to achieve its purpose, it must be large enough to withstand the kind of fishing pressure it is expected to receive. Reefs that are successful in attracting and supporting large numbers of game fish are also going to attract large numbers of fishermen as well as divers. To avoid creating just another overcrowded fishing hole, the reef should be constructed of sufficient size initially, and periodically expanded as the need arises.

**Marking**

The best system of marking the location of a reef is with one large buoy in the center, and four perimeter buoys marking the extent of the reef in each direction. Perimeter buoys can be moved as the size and shape of the reef changes. But many of the problems experienced with man-made reefs have been due to inadequate marking. If marker buoys are not properly secured in the first place, or not inspected often enough to be sure they remain secured, they can come loose. Obviously, an unmarked reef is of no use to fishermen.

Further, if these buoys are not maintained, and any of them do come loose, sportfishermen, commercial trawlers and ships navigating in the area will not know the true boundary of the reef. Interference with shrimp trawlers, I might add, is largely responsible for most of the
opposition reef projects have encountered. This year in Brunswick County, Georgia, shrimpers were catching tires and complaining to the Department of Natural Resources for not properly marking the Yaupon Reef. The reef, it turned out, was marked by a single buoy, which was in place, but no peripheral buoys were employed. Consequently, shrimp boats were trawling the reef without knowing it. I understand that peripheral buoys have since been added, and that there should be no problem in the future. We don't need any more tension between commercial and recreational fishermen.

It is essential, therefore, that any reef program include adequate marking, and regular (probably monthly) inspections of the buoys and anchor lines.

Reef Information

A study by the Marine Resources Division of South Carolina indicated that, in 1977, expenditures in the coastal region of that state by recreational users of their artificial reefs totaled nearly $5,000,000. This is the return on a reef program that costs less than $100,000 annually to maintain. This success is directly attributable, in part at least, to the excellent job the state has done in publicizing its reefs.

The majority of South Carolina's private fishermen, it has been determined, are weekend or holiday anglers (Liao and Cupka, 1979). This is likely the case in other states as well. Along with the great number of tourists from out of state who arrive at the beaches to fish on weekends and holidays, they must, in order to have a successful trip, be made aware of the existence of the productive fishing over the reefs, and know how to get there.

Another area where anglers need information is on the use of the reef itself. New knowledge is required about anchoring over a reef, for example. There are hints for trolling and bottom-fishing a reef, too, that can assist the fisherman greatly. Too often, fishermen (and divers) are clustered around the buoys. As a result, these areas are overfished while there is relatively untouched but equally productive fishing 100 feet away. The knowledge that good fishing occurs over other portions of the reef, coupled with a knowledge of the reef's boundary, makes for a better use of the reef, and more satisfied anglers.

The dissemination of this information at tackle shops, marinas and known fishing resorts is crucial to the success of a reef program, and hence should be an integral part of any program. Every angler should know where his state's reefs are located, the easiest way to reach them, and how to get the best use of them.

As the situation exists in most states, the greatest obstacle to providing the kind of artificial reef program that can improve sport-fishing, boost coastal economies and assist in the management of marine

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resources, is funding. Some states have only enough funds and personnel for buoy maintenance, leaving little or no money available to develop new reefs, or for expansion of older ones.

Senator Richard Stone's (D-FL) reef bill (S.B. 325) would, I feel, provide a remedy for this problem in the form of initial financing to develop reefs, and perhaps more significantly, continuous support for their administration and maintenance, which is absolutely imperative. A reef project cannot be operated and planned for effectively with the annual threat of having its funds cut off by a fickle state legislature.

The funds have not always been there, but the potential for artificial reefs has. Some states have been involved in their own ambitious projects since the beginning of this decade, and while they have made mistakes, they've also gained an awful lot of experience. And this conference itself demonstrates the level of enthusiasm for the concept. The recreational fisherman, I'd say, is enthusiastic, too.
THE CHARTER AND HEADBOAT OPERATORS VIEWPOINT

Captain B. J. Putnam

I don't get the honor very often to speak for Captain Putnam. Hurricane Frederick, as you know, went in near Panama City and he is there with his business, his home, and his family and couldn't get away. You would have enjoyed him, far more than you're going to enjoy me -- he's just an outstanding speaker. B.J. did leave an abstract with the planners of this conference and I was able to talk to him on the telephone this morning for about ten minutes so I'm going to attempt to cover what he would have said had he been here.

If Captain Putnam were here he would have pointed out some of the non-planned artificial reefs that exist in the Panama City area. He would have told you about a mail ship called the Tarpon, that made 1,700 safe trips between Mobile, Alabama and Carrabelle, Florida. He would have told you it had a real salty captain, named Captain Barrow, who, when the ship was sinking in a storm in 1937, made the decision to take it back out to sea to sink in approximately ninety-two feet of water. Captain Barrow, the first mate and 15 crew members all went down with the ship. That was a non-planned artificial reef.

Captain Putnam would have also discussed the Empire Mictha. This 403 foot freighter was sunk by a German U-Boat near Panama City on its maiden voyage. Today it is a producer of millions of pounds of fish. The ship lies off Cape San Blas in 112 feet of water. The Leroy, a 290 foot ocean-going tug, sank in the late 1920's, 22 miles from Panama City Beach in 126 feet of water and became another non-planned artificial reef. The first catch that was made off of this particular ship, and it's still talked about widely in Panama City, was a catch of 10,000 pounds of red snapper.

As you can see, non-planned artificial fishing reefs do contribute quite heavily to recreational fishing in the Panama City, Florida area. B.J. feels that under the proper management, even non-planned reefs can contribute to the food supply and to recreational fishing experiences.

One point in Captain Putnam's abstract was entitled, "The present efforts in building artificial reefs around Panama City." He told me that the Panama City Marine Institute, this past year, with some help from the County and from the boatman's association, worked on 14 different reefs. This included construction of new reefs, as well as enlargement of existing reefs in the area. Most of the material being used is concrete rubble but approximately five tractor loads of tires were also used in this endeavor. The Marine Institute publishes a list of the coordinates of these reefs and makes these lists available to the general public.

Panama City, Florida
Note: Paper delivered by Mr. Robert Jones

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The use of the artificial reefs by party and charter boats was the next point on B.J.'s abstract. In the Panama City area, hire boats use the reefs for kingfishing and other pelagic fish as well as for bottom fishing. There was a liberty ship that was sunk recently in about 72 feet of water. The first year, the charter and party boat fleet alone reported 5,000 head of king mackerel landed. Captain Putnam also pointed out that divers are having a severe impact on this particular reef. Under Florida state law, fishermen must maintain a reasonable distance from a dive boat when the diving flag is displayed. He feels that the state should probably better define a "reasonable distance," and distribute this definition to reduce some of the user group conflicts that have occurred and probably will continue to occur in the future. I don't think there is any attempt on Captain Putnam's part to reserve the reefs for any one particular user group. He just wants to point out that user conflicts exist and that they must be addressed by someone before they get out of hand.

The fourth point in his abstract dealt with the optimum yield of artificial reefs. Captain Putnam feels that the optimum yield might be obtained by periodically closing either an entire reef or a portion of it to fishing if it were large enough. He thinks that many reefs are overfished. However, under a laissez faire or open access system it's very difficult to get people to voluntarily stay off a particular reef for a period of time for conservation purposes. I know that if you had your own private reef and you were the only one that knew how to get there, you would probably not fish it every day. You would let it rest before you would come back. By the same token, Captain Putnam thinks that if we don't get some type of management regime going for public reefs we are going to have an increasing number of biological and man-made problems. For example, Put told me that in 1971, a particular captain sunk a 104 foot tug in about 110 feet of water off Panama City. This particular boat captain sank it in 1971 and didn't fish it until the spring of 1973. He brought in 4,000 pounds of snapper and grouper. He didn't fish it again until the fall of the year and he brought in about the same number. The next time he went out with Al Pfleuger and Captain Putnam to attempt to set some world records for red snapper on a fly rod. Captain Putnam said on that particular day three world records for red snapper were set. He said they only brought in 50 head of snapper that day because they weren't meat fishing. The next time that this captain went to this reef another boat spotted and tracked him. This was in the summer of '74. Since that time there has been very little fish caught.

Captain Putnam's last point dealt with the future of artificial reefs from the standpoint of the charter and party boat industry. He feels strongly that Senator Stone's bill, or one like it, is a mandatory first step. He thinks that the establishment of a national concept and policy has to occur before you can move forward, and he supports it wholeheartedly. He feels that various organizations, local, state and regional, must raise funds and get these funds aside for the construction of artificial fishing reefs. Also, if you really want to protect yourself you ought to spend a few hundred dollars on a lawyer to make sure you're doing it right, as Mr. Hayes pointed out.
The main complaint that Captain Putnam mentioned, and if he'd heard Mr. Goode speak maybe he would have taken this back, is that it can get to be a full time job filling out the necessary papers in order to get a reef permit. Most working folks, including charterboat captains, can't take the time to tackle the mountains of paperwork involved. His one recommendation to the conference is to push to shorten the process for getting an artificial reef permit. Unless this is done, he feels that the future will be bleak for the charter and party boat industries.
THE COMMERCIAL FISHERMEN'S VIEWPOINT

Robert Jones

In 1975, the Southeastern Fisheries association decided that there were probably two or three recreational fishermen in Florida who really didn't think a whole lot of commercial fishermen. Accordingly, we thought that we probably should set up a program to develop a line of communication to try to get the last few people into the fold. We established a charter boat section and a recreational section within Southeastern Fisheries Association and we changed our organizational structure to set aside a seat on our board of directors for these two user groups. We've had quite a bit of success with this within the organization. The recreational people hadn't beat our doors down trying to join the association but we have made several 100s of new friends in the recreational sector and I think that as time goes by this number will grow because in about 90 or 95% of the marine world problems we should be together. There are a few instances on specific type gear or particular areas that we're always going to have a problem with because, in the final analysis, it boils down to who gets the fish.

One of the first actions that we took as an association was to develop an artificial fishing reef bill. This bill is in the handout on the back table and is the bill that Senator Stone introduced in Congress for us at our request. It didn't go anywhere the first session. There was some concern by the state people regarding the wording and there was a lot of concern with the $10 million appropriation. It may sound like it's a small amount but in our world, $10 million is something we thought was pretty significant and I don't know if we are going to be able to get that money the first year. I think if we can get a bill passed and set a national policy and a concept, even if you don't have any money, then that will be better than nothing at all. I think that if you have the bill in place you could develop methods for financing it. This will be a lot easier than trying to go through the Congress and do it all at one fell swoop. We are getting more people involved. Senator Hollings of South Carolina is behind the bill now, and he's one of the leading powers in the fishing world. Without his calibre of support, I don't think you're going to get a whole lot through Congress as far as saltwater fisheries are concerned. Congressman Ginn of Georgia also has filed a bill. Frankly, I'm optimistic that some type of bill will get through this particular session of Congress.

From a commercial fishermen's viewpoint, we think that this conference will have a considerable influence on the direction of the national artificial reef program. We feel that the information that is going to be generated and the data that will be collected will serve as the supporting background for implementing any kind of program. We

Southeastern Fisheries Association, Tallahassee, Florida

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salute the planners of this conference for their hard work. Our association
and our industry feels that artificial fishing reefs will play a vital
role in providing good recreational experience for fishermen in the coming
years. And while there is some difference of opinion on whether
artificial reefs actually increase the number of fish or just attract
them to the area, the fact remains that experiences by the fishermen
show that fishing over properly managed artificial reefs is excellent.
You can't deny that.

We think that consideration must be given in the management regime
to establish rules that will protect all recreational user groups.
Consideration must be given to time closures when the stock is declining.
Consideration must be given to bag limits for divers or rod and reel
fishermen if the stock is declining. It is our view that artificial
fishing reefs should be set aside for the recreational fishermen. This
will not be a commercial fishermen's haven for we think that the commercial
fishing industry's grounds are logically and basically further offshore.
We think he can still work those grounds and that the area that he works
is not stressed. We would not support bringing the commercial fisherman
in on the new artificial fishing reefs that would be constructed. We
might argue with you a little later about sport fishing selling their
catch but that could be the subject of another conference.

Placement of artificial reefs will be the most critical aspect of
this program as far as the commercial fishing industry is concerned. We
feel that there are hundreds of thousands of locations commercial and
recreational groups can agree on prior to the future placement of
artificial reef. I think that a formal review committee should be
established in each state for this purpose of determining jointly
agreeable locations. I think that such a committee could also work
together in finding suitable materials for the reef for the actual type
of material that will be placed on the bottom is also a concern to the
commercial fishermen. That's been touched on quite a bit during this
program. We've had numerous incidents where our trawlers have had to
pick car bodies and tires out of their nets. This is very costly to
the commercial fisherman and the destruction of the reef material makes
the reef builders upset. Therefore, selection of proper material must
receive a very high priority.

In conclusion, the commercial fisherman is supportive of the
artificial fishing reef program and their cooperation can be obtained
to assist in building artificial fishing reefs if they are invited to
be a part of the program.
WHY SPORT DIVERS LIKE ARTIFICIAL REEFS

Steve Blount

Sport divers like artificial reefs -- but not for the same reasons you do.

We look at these areas primarily as playgrounds, as recreational opportunities, but we also recognize their importance as ecological preserves and scientific workshops. They are also tangible expressions of scientific and governmental concern for the underwater environment in this time of constant funding cutbacks as program after program is resigned to the scrap heap.

The construction and study of artificial reefs is one of the few areas of marine research that has survived the oil-rig mentality that operates both in the public consciousness and at many levels of government. The oil-rig mentality looks at an oceans research program and figures if there is no direct, immediately foreseeable and demonstrable economic gain, the program should be scuttled. It was this type of thinking that made the ocean lab concept a helpless cripple and left it to be finished off by the budgetary insecurities of key researchers and organizations. It has resigned NULS-1, the Hydro-Lab project, to a position of frighteningly bare-boned austerity.

Not too many miles from here is the spaceport where we launched astronauts into outer space. Its landmarks, like the Vertical Assembly Building -- the world's largest structure -- are visible for miles, a clear symbol of our commitment to exploration. At the Hydro-Lab's Faile Marine Science Center where we launch aquanauts to innerspace, the launch arena is marked by a single buoy made of used tractor tire inner-tubes and a piece of plywood. It can hardly be seen 50 feet, and, like the Vertical Assembly Building, it appropriately symbolizes the level of our commitment to ocean exploration.

In this climate, progress in any area of marine science provides a psychological boost to the entire oceans community: researchers, program administrators and sport divers alike.

As a recreational asset, artificial reefs are quite popular with sport divers. In two years, our magazine has published a number of articles dealing with diving on artificial reefs. In April, 1978 a feature on South Carolina said, "The ocean bottom off South Carolina slopes gently toward the edge of the continental shelf; mile after mile of white sand with few marine inhabitants. In this underwater desert the South Carolina Marine Resources Commission has created nine man-made
oases: nine artificial reefs in a chain stretching from Little River to Hilton Head... a fair sampling of mid-Atlantic species inhabit the reefs. Triggerfish, blackfish and sheepshead dominate the reef structures. Mackerel and bluefish cruise among the tires. Divers have reported grouper in excess of 250 pounds on Capers Reef.... the largest sea trout on record in South Carolina was caught on the Fripp Island reef in 1971.

A feature on diving in Panama City, Florida appeared in October of 1978. It read, in part, "Another reef project, sponsored by the Florida Department of Natural Resources culminated in the sinking of a Liberty ship in September 1977. The football-field sized hull is now the playground of sea turtles, groupers, jacks and divers. The ship has just this summer put on its full coat of encrustation: a furry-looking growth that covers the bare metal. Thousands of silver minnows race the decks, parting to maneuver around bulkheads and divers. Their bodies flash alternately black and silver as they turn. They obscure the wreck, the sun, even the beam of a handlight; yet they never come closer than three or four inches -- a solid cloud that cannot be touched."

Even more widely known and appreciated by divers is the artificial reef formed by the hull of the Mispah and two patrol craft off West Palm Beach, Florida. The Mispah is famous literally worldwide and attracts thousands of divers each year.

Divers are attracted to, fascinated by and appreciative of artificial reefs, both in areas where there are no substantial natural reefs -- such as South Carolina and the northeast Gulf -- and in areas where there are plentiful coral formations -- such as South Florida.

The phrase artificial reef suggests that the reefs are a substitute, a second-best alternative to the real thing. But for sport divers they offer a different kind of experience: not a substitute but a unique, original type of diving.

From our point of view, reef building programs in the southeastern U.S. have been almost completely successful. The qualifier was added because the scientific community as a whole -- not just marine biologists but archaeologists and geologists as well -- have overlooked a tremendous source of enthusiastic, concerned volunteer labor: sport divers.

Sport divers are enthusiastic about anything that gives a purpose or direction to the time they spend underwater. This enthusiasm is normally displayed through a passion for underwater photography, shell collecting, for spearfishing or another activity. Divers will volunteer to do almost anything underwater; sport divers have built habitats and lived in them; some have organized annual cleanup/ecology dives; they are a force and an energy looking for an application.

We know sport divers are attracted to artificial reefs. Why not harness their enthusiasm, their search for direction and purpose to stretch your shrinking program dollars -- to expand the scope of your present operations?
After incorporating dive clubs, councils or individual sport divers, you may find your program has a greater range of water skills and level of experience than it had when only scientific workers were involved. When the construction is over and the reef is in place, you can be sure it will be visited regularly by divers -- often the same ones over and over. Is there a type of observation that can be carried out by semi-skilled workers with a minimum of training? Might you ask them to report fish species spotted, time of day, weather and temperature conditions?

Beyond these practical devices, using sport divers has another advantage: community involvement and public relations. Some of the congressional constituents who want to know what you do with that grant money are themselves divers. Many more are related to divers; thousands more know one or more divers personally. By involving sport divers in the construction, maintenance and supervision of artificial reefs you build both community awareness and community support for your program. And community support is what the bean counters in Washington and elsewhere listen to.

Scientific workers of all types tend to talk mainly to each other, intent on improving methodology, and ignore the public because they are too busy to seek out exposure in the media. The space program was successful partially because it gave every TV viewer a reason to want it to work. They shared in the adventure.

If the public wanted marine sciences to work, a way would be found. The public is not against marine science, it is against wasteful government spending. Give them a reason to want your project, make it understandable and real to them, and it moves out of the realm of wasteful spending and into the category of useful scientific exploration.

In the effort to change the attitude of an apathetic public and apathetic Congress, your first step is to communicate with and involve those people who are most sympathetic to your goals. Those people are the sport divers. Try some out on your next project. You'll be surprised how much those few extra bodies can do for you, in fact, for all of us.
ARTIFICIAL REEFS AND THE FCMA

William G. Gordon

The Fishery Conservation and Management Act of 1976 (FCMA) mandates that U.S. fishery resources be managed to provide the greatest benefits to the Nation while maintaining the stocks. With both recreational and commercial fishing pressure increasing, innovative management thrusts are needed to meet this mandate. The construction and wise use of artificial reefs are examples of some thrusts that can help to both conserve and enhance fishery resources.

In the United States, reef construction has been almost entirely oriented towards recreational fisheries. Usually, the reefs are built on relatively barren stretches of ocean bottom closer to inlets or other access areas than natural rough bottom existing in the area. This has been a useful practice and should be continued. However, we should also pursue the additional management potential available through the proper use of artificial reefs. Research and experience by scientists and reef builders in the United States and other countries have demonstrated the value of artificial reefs in enhancing habitat and reef fish stocks, providing additional opportunities for recreational and commercial fishermen, benefiting the economy of coastal communities and providing a means of resolving use conflicts.

The areas I just mentioned are all key concerns of the FCMA. While it is easy to see that artificial reefs can be instrumental in meeting the objectives of the FCMA, the realization of their full potential will require a dedicated, coordinated effort by the Federal Government, the States, the Councils, universities, industry and the general public with the support of Congress. It is possible, but it is not an easy task!

The Japanese have made great strides towards realizing the potential of artificial reefs. They have been using artificial reefs for many years to help manage their coastal fisheries. Their reefs take a variety of shapes and are specifically designed for a variety of purposes including shellfish culture, growing seaweed, providing nursery grounds for fish and shellfish and as shelter for both demersal and mid-water fishes. Other Asian countries are following their example. You will hear more detail on the progress in that part of the world tomorrow from Dan Sheehy.

In the U.S., coastal states have initiated numerous efforts over the last twenty plus years, but most of these efforts have been hampered by the lack of adequate and consistent funding. The Southeastern states have been particularly active and successful in reef construction efforts in spite of inadequate funding. Artificial reefs are providing improved rough bottom fisheries off all of the states in the Southeast Region with the possible exception of Louisiana where the numerous oil rigs and platforms provide similar fishing opportunities.
Studies by the National Marine Fisheries Service and the State of South Carolina indicate that artificial reefs not only provide improved fishing but also have a beneficial economic impact on coastal communities. In the National Marine Fisheries Service study, 16% of the small boat anglers that fished off Murrells Inlet, S.C. came to the area because of the artificial reefs. These fishermen accounted for about 10% of the gross economic impact in this area. In a more recent study by the South Carolina Wildlife Resources Department, they estimated that the economic impact of anglers fishing artificial reefs off that state amounted to over 10 million dollars out of a total of 47 million which was the total estimated economic impact of offshore recreational fishing to the state.

The Fishery Management Councils in this region recognize the value that improving rough bottom habitat can have on reeffish stock and have listed artificial reefs as a potential management measure that could be used in their reeffish management plans. While there is additional research that needs to be conducted to fine-tune the management potential, research by our scientists did confirm that habitat enhancement with artificial reefs can increase total number of reeffish. This stock enhancement potential, plus the possibility of resolving user conflicts are two aspects of reef use that may be particularly attractive to the Councils.

The competition for rough bottom resources has always been somewhat of a problem in heavily fished areas. The competition exists between foreign and domestic commercial fishermen, domestic commercial fishermen, recreational fishermen and sport divers. A thoughtful reef builder off St. Petersburg Beach, Florida in the early 1960's discovered a way to help alleviate the conflict between recreational fishermen and sport divers. He built four small reefs instead of one big reef and marked two of the reefs for divers only and two of the reefs for fishermen only. This concept may need to be pursued in the future.

While the states and local groups have been the reef builders over the years, U.S. industry has participated at times in these efforts and appears to be willing to continue support under certain conditions. Non-toxic waste and surplus materials are good examples of items that might be provided with benefit to both the agency building the reef and the industry disposing of the material. Scrap tires, surplus drain pipe, building and bridge rubble, old oil rigs, surplus vessels and even compressed flue wastes are examples of materials that have been used.

The tire and rubber industry has been extremely helpful in the past by providing scrap tires and in some cases equipment to help process them as reef material. Marine disposal firms have frequently provided building and bridge rubble and occasionally a scrap vessel. The list is quite long, but perhaps the most interesting contribution, which could have a positive impact on the energy crisis, has come from Pennsylvania's Duquesne Power and Light Company's Elkama Power Station. That company is providing blocks of chemically-stabilized flue gas desulfurization waste from coal burning power plants for construction of an artificial
reef off New York's Fire Island. This reef will be carefully monitored to see if there is any pollution of the environment or uptake of toxic materials by encrusting organisms or fishes. (Ed. note)

The use of artificial reefs is not without risk however. Many enthusiastic sport fishing clubs and other prospective reef building groups will confirm that reef construction is not an easy process. Poorly conceived reef efforts can incur a variety of problems and bad publicity. Some of the materials used in past efforts, without the benefit of technical assistance from knowledgeable agencies, moved onto commercial fishing grounds or washed ashore and littered beaches. Reefs must be placed where they will not conflict with other uses of the marine environment such as commercial fishing, shipping or mineral development. Habitat improvement with artificial reefs should be well organized, coordinated and monitored by agencies or groups with technical expertise and adequate financial support.

Most of the successful reefs built in the United States have been cooperative efforts. Liaison between federal and state governments, universities, industry and fishermen can reduce both the time required to build a reef and the cost involved. In most cases the states should coordinate the actual construction phase. Financial support still seems to be the big question mark. We have heard discussion of several bills that are now before Congress. If these become law then it appears that a giant step will have been taken towards solving the money problems.

We are committed at both the Washington and Regional levels to work with the States, the Councils, Sea Grant, and Congress to help safely develop the potential of artificial reefs as effective methods of maintaining or enhancing stocks of rough bottom fishes and improving catch-per-unit-of-effort for U.S. fishermen. I believe that artificial reefs, if properly constructed, maintained and monitored, can contribute significantly to meeting FCMA objectives by enhancing existing rough bottom habitat, allowing development of quality fishing grounds close to access areas, helping resolve user conflicts by providing additional rough bottom habitat and benefiting the economics of shore communities.

Ed. Note: See Appendix article "Coal Combustion Products – New Substrates for Artificial Reef Construction."
RAPPORTEUR'S REPORT

Willis Clark

We are now in an era in artificial reef activities where good, complete planning is absolutely essential. That is one reason we have been addressing ourselves to this important subject today. It certainly justifies the emphasis of a distinct section on this conference's agenda.

Back in 1973 a group of us got together in Washington, D.C. to talk about the possibility of holding an Artificial Reef Conference on a large scale. Again, we Texans volunteered to do it. And I inherited the task of setting up what eventually came out to be the 1974 International Artificial Reef Conference. That meeting in Houston has been referenced a number of times during this meeting. It did take quite a bit of homework on my part including visits with Dick Stone up at Beaufort, North Carolina where he was at that time, a number of days with Greg McIntosh down in Fort Lauderdale and another visit over to Marco Island. Also I spent some time with the Goodyear people in Ohio. I learned, in fact, that back in that era there was not much in the way of thorough planning. Some people on the program today have described their efforts. Some experiences in early times worked and were in the best interest of artificial reef concepts. But, in general, because there was a lack of planning the eventual results were not always what people had in mind when the project began.

The 1974 conference was, I feel, a real success but at that time the scientific and biological considerations were what people wanted to talk about. There were a lot of case histories, much speculation about reefs as a permanent attraction for various species. We did not talk very much about planning or about the gory path that people must follow before a reef becomes a reality. I think that was an omission. I say that but in saying it I am not disagreeing with a remark made earlier today about the fact that there is a need in these days and times for people to have a specific technical, scientific interest in various forms of artificial reefs, to get together and have their own workshop or small conference to iron out scientific details. A thing like that might make it possible for technical and scientific papers to eventually get into the literature. I think that is a good idea.

So we did not talk about planning back in Houston but today, some 5 ½ years later, I find the matter of planning to be woven into the remarks of practically all the speakers that we have heard from today and that includes the morning sessions. Drs. McCallister and Ditton frequently pre-empted the afternoon speakers with their comments on the need to know what had to be done to bring a reef on-line and to prepare for the long term effects of reef projects. Dr. Ditton spoke on the

Texas A & M University, College Station, Texas.

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social and economic factors and the need to consider things such as shore facilities and the tourist trade. I am sure some of these things were beyond the thoughts of people not too many years ago.

This afternoon we have heard more of this from our speakers in their comments about the competitive interests of people in recreational and commercial fishing groups and the off shore divers. Clearly I think artificial reefs serve a multiple audience and today, under these circumstances, planning that takes into consideration the interests of all these audiences is vital. We have also heard about the arduous task a real confident planner must follow. Site selection has been discussed and is so very important in the process. It includes not just the physical location but the social and economic factors involved. But that is only one step. An artificial reef may start out as a dream of one person or a small group. But before the construction actually begins the planner may find that those he must satisfy in local groups, state, regional, federal agencies, environmentalists, the press, financial groups, lawyers and so on, out number the potential direct beneficiaries in area. In a more recent study by the South Carolina Wildlife people they estimated the economic impact of anglers fishing on artificial reefs. The fishery management councils, particularly in the Gulf and the South Atlantic, recognize the value bottom conditions can have on fish stocks and have cited artificial reefs techniques to be considered in reef fish management plans.

Well there is additional research that needs to be conducted. Potential research by scientists on this panel and earlier today did confirm that habitat enhancement with artificial reefs can increase overall fish populations. This enhancement potential, plus the possibility of resolving user conflicts, are two aspects of reef use that may be particularly attractive to management councils. The competition for bottom resources has always been somewhat of a problem in heavily fished areas. Competition exists between foreign and domestic commercial fishermen, domestic commercial fishermen and recreational fishermen, recreational fishermen and divers. So, as laborious and frustrating as the task may seem, the planner has an obligation to take into account the overall public interest and act accordingly.

Now, although I have not quoted the speakers directly in any way in these brief remarks, I think the theme of what I have said represents the thought that was behind the creation of this particular session. So again, I want to commend my associates in the conference planning committee for their decision to set aside this time to address planning as the key to a successful reef program.
SECOND TECHNICAL SESSION

Artificial Reef Construction Considerations

Moderator: Dr. Robert E. Smith
Gulf Oceanographic Development Foundation
St. Petersburg, Florida

Speakers: "Organization for Reef Construction"
James T. Brown
North Carolina Division of Marine Fisheries
Morehead City, North Carolina

"Tires as Artificial Reef Material"
Howard A. Tolley
Goodyear Tire and Rubber Company
Akron, Ohio

"Concrete Rubble and Miscellaneous Materials as Artificial Reef Materials"
Lonnie L. Ryder
Florida Department of Natural Resources
Tallahassee, Florida

"Obsolete Ships as Artificial Reef Material"
William Demoran
Gulf Coast Research Laboratory
Ocean Springs, Mississippi

"Obsolete Petroleum Platforms as Artificial Reef Material"
Dr. Robert B. Dittson, Texas Experimental Research Station, The Texas A & M University System, College Station, Texas, and
James M. Falk
Sea Grant Advisory Service
University of Delaware
Lewes, Delaware

"Materials Placement Procedures - Surface to Bottom Transfer"
James Tyler
North Carolina Division of Marine Fisheries
Morehead City, North Carolina
SECOND TECHNICAL SESSION (Contd.)

Speakers: (Contd.)

"Coordination, Staging and Transportation of Materials for Artificial Reef Construction"
Grant R. Bieling
Pinellas County Government Artificial Reef Project
Clearwater, Florida

"Buoying and Marking of Artificial Reefs - A Club Experience"
Nicholas J. Delmedico
Jacksonville Offshore Sport Fishing Club
Jacksonville, Florida

"Buoying and Marking of Artificial Reefs - A State Experience"
Howard T. Lee
Texas Coastal and Marine Council
Austin, Texas

"The Electrodeposition of Minerals in Sea Water For the Construction and Maintenance of Artificial Reefs"
Dr. Wolf H. Hilbertz
The Marine Resources Company, Austin, Texas, and
The University of Texas at Austin
Austin, Texas

Rapporteur's Report:

Dr. Fred A. Kalber
Georgia Sea Grant Program
University of Georgia
Athens, Georgia
I am confident each of us here realizes that constructing artificial fishing reefs does not begin by shoving tires overboard – nor does it continue by merely adding more tires. Some type of organizational structure must precede the reef building, and most often that structure determines the project's future.

This particular topic – ORGANIZATION FOR REEF CONSTRUCTION – embodies some aspects of nearly every presentation of yesterday's sessions on "Planning." Even though not an aspect of construction in the literal sense, it is an appropriate lead-off topic for this morning's sessions.

Because there is a difference between organizing and managing a reef program, we should be sufficiently flexible to drop back and reorganize as our needs change. For example, we may have organized with an expectation of acquiring three surplus ships each year for four years, only to find out after obtaining three ships the first year, that there won't be any more. Our organization may remain nearly the same, but management emphasis must shift to some other reef building material. Or, we could wake up one morning and find that our funding has been cut in half (or even eliminated). Don't laugh. This can happen, and did in North Carolina!

In 1974, we received three liberty ships, and a fourth and last one in 1978. Our artificial reef program began in 1974, being amply funded by a small percentage of unclaimed gasoline road tax which had been paid by non-road users such as boaters. This funding source, which amounted to between $225,000 and $300,000 a year, was abruptly cut off in 1977. In response to considerable pressure from reef benefactors, partial funding was restored in 1978.

The ups and downs can come fast, and experience has taught us that with an artificial reef project, probably more than any other, there is ample reason to have organized a second team and to have developed alternative materials and sources. One type of alternative, if at all possible, would be to establish the reef building as a "sub-unit" of a larger and more stable program such as a recreational fisheries section. Loss of a sub-unit is certainly less devastating than loss of an entire program.

We all know from experience that there are as many organizational structures or frameworks as there are organizations housing them. Turning a sheet of paper lengthwise and drawing boxes and interconnecting lines may help, but "flow charts," as such, are a dime a dozen! Also, they usually include only the fulltime components of what is really a much larger team. The point here is that the incidental or second team components are very important.
Organization of the first, or in-house team is largely dependent upon: (1) the availability of funds and materials; (2) the goals of the agency head and of the project leader; (3) the extent to which a project leader is able to establish and fill positions, and (4) enabling legislation.

Who are some of the potential candidates we might consider for the second team? Obviously, we should look to those who also have something to gain. Quite often, they are not aware of any potential gain so we might even convince ourselves we have an obligation to help them develop an understanding of the mutual benefits.

Some groups such as organized fishing clubs are naturals. First of all, they can become the local sponsors of a reef - especially if their club is legally recognized (incorporated with the Secretary of State's office as a non-profit organization with one or more "registered process agents"). As a local sponsor, the permit(s) could preferably be in the club's name. Local governmental bodies such as cities or counties are also legitimate sponsors. In such projects, the state could be a co-sponsor and provide varying degrees of assistance from advisory to running the program - depending on how much is wanted.

If the original decision were mine, a local sponsor would be the first requisite to a reef project. Without requiring local sponsors, some groups that feel left out can argue that the state agency is obligated to spend equivalent funds and exert equivalent effort near each substantial community, port, inlet, etc. Perhaps some of you here have also been confronted with similar problems.

Where local sponsors are prerequisite, the extent of available state participation can easily be decided upon. If certain area residents complain that they are being left out, simply remind them that an active project requires sufficient local interest to produce a sponsor.

If it happens there is a sponsor, and the complaint is, "too little from the state," then explain that the project is still underfunded and indicate some of the ways citizens can help to secure additional funds. For instance, they can be encouraged to write, call, or visit their legislators and congressmen about Senator Stone's Artificial Reef Bill, or the Dingle-Johnson amendment bill - or, to support or initiate some local funding.

What otherwise would have required a strong defense, may thus have been turned into an offensive thrust. These particular individuals are reef proponents and are essential and effective when going before the legislature. Also, we will need their defensive efforts on our side if opposition is confronted.

In a hypothetical situation, let's pretend legal council for a group of shrimpers has notified your agency that reef construction units are in the trawling area and are damaging nets, decreasing fishing time, and ultimately causing substantial loss of income. Let's further hypothesize that either one or the other of two reefs are involved. One reef is solely state sponsored and constructed for recreational fishermen.
The other is a reef under permit to a well organized sportfishing club of 600 members which you assisted as a co-sponsor. In the event of legal action, and without having established "fault," don't you agree that it would be much more comfortable to have the 600 member club helping you represent recreational interests?

Are there others with vested interests who should be considered for this second team? Well, if we have a sizable ship to sink, we must obtain explosives experts. Our U.S. Marine Corps has and trains the best. Their recruits need training, and their seasoned experts need practice. What better training mission than a large ship to sink, particularly one which also involves ocean embarkation and debarkation exercises. Sometimes the commanding officers must be convinced of mission benefits. Too, there are preferred ways to request their assistance and many specific areas of joint responsibility which must be satisfied. Cooperative efforts with the North Carolina based Marine Corps stations have resulted in some 35 procedural recommendations and requirements which must be met. Some of these may involve additional costs while the ship is undergoing stripping and salvaging preparations and should be planned for in advance. Yes, I believe this too is part of "organization for reef construction."

If we are using tires for constructing reef units, as most of us are, several other suggested candidates are available for the second team. For instance: tire retailers and service centers, tire manufacturers, solid waste disposal firms, health departments, and city and county administrators.

Tire dealers are finding it more and more difficult to dispose of old tires. The old method of burning them is illegal in most states because of air pollution problems. Most sanitary land fills accepting tires have experienced problems with the tires working their way to surface during periods of high ground-water levels, or tire-filled areas otherwise remaining spongy and being suitable for only limited use. If the dealer stockpiles the tires, he is usually cited by mosquito control officials due to the prime mosquito breeding areas being provided. If he pays some unknown trucker to haul tires off, he runs the risk of their being dumped along a public road and traced back—whereby the law too is "on his case."

New tire manufacturers produce large numbers of non-marketable rejects which must also be disposed of. That figure is like 2,000 tires per day in North Carolina alone. There is some clout available here also.

In our present tire site operations, manufacturers and dealers are considered contributors. They deliver tires and pay assessment fee of $1 per cubic yard of tires (about 8¢ per tire) to participate in the project. As all these dealers know, the assessments could be dropped if sufficient appropriations were otherwise available. Their voices should be helpful if the decision to seek additional funds is made.
Officials of coastal cities and counties have vested interests in several ways. Business firms such as tire dealers require waste disposal services, and the landfills used for solid wastes are most often contracted for by the city and county. Too, the health services involved in vector control are usually operated by one or the other or both these governmental units. On the plus side for a city or county, having nearby artificial reefs attracts fish and fishermen, and the fishermen add money to the local economy. Most cities and counties are willing cooperators and may contribute in the form of land area, facilities, labor, or sometimes funding.

It goes without saying that good public relations efforts are essential and, most often, rewarding. So, in some respects, the media becomes a second team member. If we have an evaluation program producing favorable information, share it with the press, radio, T.V. and other local publicity sources. Sometimes it is the best way to inform certain officials of the program's success and their need to support it. For instance, a statistical survey of two North Carolina reefs over a 14-month period during the 1976 to 1977 fishing seasons, revealed that 27,000 man-hours of effort resulted in a sport catch of 100,000 pounds. We estimate this catch to have contributed over twice that many dollars to the local economics of the two areas.

The usual organizational concepts change very little from one year to the next, or from one business to another. We all know organizational structure is important. However, for one reason or another, we seem to perpetuate old mistakes and continue to make new ones. It goes without saying that a large project, reef or some other type, needs a project leader. Yet one large and promising reef project I know of existed three of of its first four years with a chief of materials procurement and fabrication, and another chief of site selection, unit placement and evaluation, but no chief or project leader over the total components.

I have chosen to examine some routine contacts as a secondary, but decisive, part of a reef project organization. I personally believe such an analogy to have sufficient merit to warrant more deliberate development of these associations in the future.

I hasten to point out that these comments represent some personal thoughts as to a "second team" concept. Although I believe developing these outside components would strengthen anyone's project, our North Carolina program is still relatively small and just beginning to so develop. Also, discretion may suggest that some of the second team members may be more effective if they participate "out of uniform," so to speak.

With or without this topic on today's program, or with or without attending special courses in organization, the traditional personnel structures of most of our reef projects would change very little. On the other hand, I submit that more effort to develop a "second team" concept will substantially increase our project status.
TIRES AS ARTIFICIAL REEF MATERIAL

Howard A. Tolley

My subject may not have a very romantic title, nor does it stir intriguing scientific thoughts. The basic fact of the matter is simply that experience over the past decade or more shows that the round rubber doughnuts are an excellent reef-building material.

I can't claim that there was a major discovery by Goodyear. The fact of the matter is that Dick Stone of the National Marine Fisheries Service brought the concept to our attention back in 1970 when he made a presentation to our Research and Development staff. His work with scrap tires as reef materials -- and the fine results he achieved -- were intriguing. Scrap tires helping regenerate fish and marine life in an ecologically acceptable manner, that was quite a revealing discovery and it dovetailed with our corporate goals to recycle or find new uses for scrap tires. Our work has since been wide-ranging. In cooperation with the University of Rhode Island and the University of Michigan, two Goodyear concepts have been tested with positive results. Mats made of scrap tires lashed together have aided in erosion control in tests on Lake Michigan. However, one of the most promising approaches has been in the use of scrap tires as floating breakwaters to provide wave-action protection to marinas and other shore facilities. Floating breakwaters have been tested successfully in Lake Michigan, Lake Erie, Narragansett Bay and Lake Pontchartrain in Louisiana.

As an offshoot of breakwaters, Goodyear has experimented with floating fish reefs at the company's Wingfoot Lake Park near Akron. Incidentally, our scrap tire reefs in the lake are extremely productive. They are very popular spots with anglers.

Among our other recycling efforts have been the use of tires as a source of energy, as artificial turf, as highway impact point crash barriers, and a joint pilot plant study of the application of oil shale recovery technology to the recovery of oil and other materials from tires.

At this juncture, however, artificial reefs still remain as one of the leading practical uses for scrap tires. The same tire qualities that are advantageous to you as motorists, strength, durability and long life, are the keys to the basic advantage of tires as reef-building materials.

Rubber, both natural and synthetic is the basic ingredient of tires. It is specially blended with other materials to help it withstand wear, heat and aging. Fabric is used to give the tire body strength and resilience and steel is used in the bead that holds the tire on the rim. The inert ingredients are permanently locked in during the curing process. Our research studies as well as studies of others, reveal that tires simply are not harmful to the marine environment and, unlike many other reef-building materials, they will last indefinitely.
Another plus of scrap tires is their ready availability in most areas. More often than not, tire stores, dealers, retreaders and other accumulators are glad to make them available for reef projects. Annually, we generate in this country from 165 million to 200 million worn out tires annually.

The key to the use of tires for reefs is in their proper preparation and an intimate knowledge of the site. It is critical that holes be punched in them to prevent any air entrapment which would result in the tire becoming buoyant. We developed a special tire punch machine for the pilot programs in which Goodyear has been involved. It quickly enables the punching of three large holes in the circumference of the tire. However, while more tedious, this work also can be done with electric drills.

Our experience shows that compressed bundles of 10 to 12 tires make good, workable modules. Again, for the pilot programs, Goodyear utilized a special tire compacting machine to prepare and band the tires. As to bonding material we have worked primarily with nylon bands and stainless steel clips, materials which are relatively impervious to underwater deterioration. It would be prudent, however, to put down several test bundles and study their position and reaction to the site environment prior to full-scale launching of the project.

Incidentally, Goodyear is not in the tire reef machinery business. Machines were custom built for the pilot programs in which the company became directly involved. We will, however, be glad to provide detailed drawings of the punch-compacter equipment to responsible organizations with reef-building permits. The machinery can be built by a machine shop of the organization's choice.

To insure stability on reef sites with strong currents or in areas prone to severe weather, it is recommended that tire bundles be ballasted with cement, highway core samples, etc. The bundles can then be loaded on barges or other boats, taken to the reef site and unloaded. If the bundles land on top of one another, all the better. This provides more nooks and crannies for fish to breed and hide from predators while having access to life-sustaining marine and plant growth.

Tire reefs were tallied with considerable precision at Marco Island, Florida, by the Marco Applied Marine Ecology Station. Before a single tire was put down in April of 1972, the station's personnel fished the proposed reef area 1.2 miles offshore. Their hauls averaged .5 fish per hour. Several years later, a follow-up survey of the reef, comprised of over 100,000 tires, was teeming with some 90 species of fish. And the catch rate had increased by a factor of 12. Today, charter boat captains are taking their paying customers to the Marco Reefs and one off nearby Naples installed under the sponsorship of the Naples Cruise Club. The Fort Lauderdale reef also has been very productive.

Goodyear Tire and Rubber Company, Akron, Ohio
I would like to now put my presentation in graphic perspective with some underwater motion pictures taken about a year ago of Osborne Reef off Fort Lauderdale, probably the largest scrap tire reef in the world, with nearly two million tires on site. This short sequence speaks eloquently of the productivity of the reef that had its beginnings some seven years ago under the auspices of Broward Artificial Reef Inc. It also was Goodyear's first reef project involvement.

In conclusion, tires are an excellent reef-building material. Moreover, generally speaking, they are readily available. Recapping shops, service stations and tire dealers are always looking for ways to dispose of scrap tires. Also, municipal and private waste haulers must find acceptable ways to dispose of the tires that they collect.

But the prime advantage of reef building, in my opinion, is the opportunity it offers organizations in both the public and private sector to perform a real service. It gives people the chance to get involved and, as in the case of the Panama City, Florida, Marine Institute Reef -- a Goodyear assisted project -- enables delinquent youngsters to help reshape their lives in a meaningful, interesting, productive manner.

Goodyear is proud to have played a leading role in demonstrating that scrap tires can play an important role in artificial reef building -- to the benefit of people and the underwater ecosystems.
CONCRETE RUBBLE AND MISCELLANEOUS MATERIALS AS ARTIFICIAL REEF MATERIALS

Lonnie L. Ryder

Artificial fishing reefs can be and probably have been constructed of almost every material imaginable. Reefs have been constructed of automobile bodies, trucks, street cars, boats, ships, stoves, refrigerators, sinks, concrete, PVC pipe and a vast array of other material that could possibly be carried offshore and dumped.

Through many years of reef building much has been learned either by trial and error or, in more recent years, sophisticated research, about the importance of material for use in constructing artificial fishing reefs. Varying types of material have been used to construct a reef only to find the reef rendered totally ineffective after a few months or years or to find the reef no longer in existence due to environmental factors. If this type of situation is to be avoided it is particularly important that planners and builders take advantage of the many years of trial and error reef building and recent research pertaining to the best type of material to use for the type of artificial fishing reef desired.

Most of the many materials available for reef construction can be placed under specific categories. The type of material available for use and some of the many materials that may be categorized under each type are shown below:

<table>
<thead>
<tr>
<th>Reef Construction Materials</th>
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</thead>
<tbody>
<tr>
<td>By Category</td>
</tr>
<tr>
<td>Metal Material</td>
</tr>
<tr>
<td>Light Metal</td>
</tr>
<tr>
<td>Automobiles</td>
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<tr>
<td>Boats</td>
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<tr>
<td>Appliances</td>
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<tr>
<td>Heavy Metal</td>
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<tr>
<td>Oil Platforms</td>
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<tr>
<td>Steel Vessels</td>
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<tr>
<td>Concrete</td>
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<tr>
<td>Culverts</td>
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<tr>
<td>Manholes</td>
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<tr>
<td>Blocks &amp; Bricks</td>
</tr>
<tr>
<td>Rubble</td>
</tr>
<tr>
<td>Rock</td>
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<tr>
<td>Rubber</td>
</tr>
<tr>
<td>Automobile Tires</td>
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<tr>
<td>Truck-Heavy Equipment</td>
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<tr>
<td>Tires</td>
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<tr>
<td>Other</td>
</tr>
<tr>
<td>Fiber Glass</td>
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<tr>
<td>PVC</td>
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<tr>
<td>Wood</td>
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</tbody>
</table>

Florida Department of Natural Resources, Tallahassee, Florida

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The effective use of any of these materials for reef construction depends on several factors including the reef program objective, cost and availability. An understanding of the importance of material selection may be gained by comparing the various materials mentioned with these factors. Prior to making this comparison the full impact of each factor must be understood.

The overall reef program objective is to provide fish habitat that can yield a significant biomass of reef fish in sufficient amounts to increase potential success. A properly constructed fishing reef will meet three conditions; protection for fishes, availability of food and provision for suitable spawning area. Any material selected for reef construction must provide for these conditions and do so on a long-term basis. The first three conditions are self-explanatory however a fourth condition deserves further explanation. Longevity is defined by Webster as long-lived or long continuance. For purposes of reef construction the definition should be more broadly defined as material that is long in continuance and remains positioned at a specific site. Longevity of a reef assumes material stability in terms of the materials ability to withstand the effects of saltwater, current and wave action, covering by shifting sediment, or sinking.

The cost of reef material becomes significant especially on limited budgets. However, the cost of material is relative as cost is a function of longevity, in-as-much as a higher initial cost for use of a specific material that can last for many years may be a much more intelligent use of funds than using material that will last only a few years.

Material availability will of course dictate the type of reef to be constructed. In some instances deciding not to construct a reef may be much more intelligent than using readily available material that simply will not last or that may actually damage the surrounding environment.

Most of the materials previously identified provide good protection for fishes, food, spawning area and have, with the exception of light metals and wood, good longevity rates. However, this assumes that the material is properly placed according to accepted procedure for reef building. If materials such as rubber tires are improperly weighted and placed in relatively shallow water the reef longevity rate decreases significantly because of the potential for drifting or breaking apart and eventually being covered with sediment. As a general rule, tires should not be placed in water depths of less than 70 feet, unless substantially weighted.

Light metals are not recommended at all and heavy metals such as oil platforms and large vessels are used only for deep water reefs. A steel barge is probably the only heavy steel vessel that can be used in relatively shallow waters of 50 to 60 feet.

Probably the best material for shallow water reefs are the various concrete products available. Concrete makes excellent reef material in terms of protection, food, spawning and longevity. Both low or high
profile reefs may be constructed of concrete material and you don't have the problem of water depth as concrete is excellent for both shallow and deep water reefs. In addition, the availability of concrete products is excellent. There are very few coastal cities that are not growing in population. With such growth also comes growth in construction which means demolition of old buildings, culverts, bridges and streets to make way for new facilities. Obtaining these materials and storing, if necessary, will assure you of well built and effective artificial fishing reefs.

The cost involved in placing the various materials to some extent becomes a trade-off between materials. Light metals are expensive to prepare and place, as are most heavy metals. In terms of labor and material rubber tires are becoming expensive. Concrete products are the least costly in terms of preparation but costly to transport. The cost involved for transporting concrete, however, may be worth it not only in terms of longevity and but in knowing that concrete will stay on the bottom whereas other materials, at least in shallow water, may not.

Another factor to consider are regulations pertaining to various types of reef material. The Florida Department of Environmental Regulation will not allow light metals such as automobile bodies for reef construction and are beginning to be more careful about permitting a site if tires are used. Also, the Army Corps of Engineers is taking a second look at permit applications where there are requests for use of tires in shallow water.

In summary, agencies considering the construction of an artificial fishing reef should plan carefully for their reef project. The selection of a material for the reef should be made very early in the planning effort. In considering the project budget thought should be given to the longevity rates of various materials that seemingly cost more on an initial basis but actually cost less if the cost is amortized over the effective life of the material.
OBsolete ships as artificial reef material

William J. Demoran

The use of sunken ships and other large vessels as fish havens is really nothing new. Shortly after World War II, the growing sport fishing industry located and utilized merchant ships, sunk off the coast during the early years of the war as prime fishing locations.

Interest in purposely sinking vessels for use as fishing reefs in areas known to be inhabited by desirable species of fish has increased tremendously in the past twenty years. As more old, obsolete and aging vessels became available more interest in using such objects increased. Small fishing clubs, charter boat groups and other sport organizations attempted to sink old barges and fishing boats where they might serve to attract fish. The handling of such vessels from their acquisition to their sinking is an ambitious task, and each undertaking is almost entirely without some sort of problem or complication.

As interest in creating such fish havens grew, regulations regarding such operations grew proportionately, and for good reason. Some early attempts at building fishing reefs were done without regard for historical fishing grounds where trawl fishing is practiced, shipping and marine transport, and, last but not least, contaminants which might still be aboard the vessels.

In 1972, Congress passed Public Law 92-402, and Act which made World War II Liberty Ships from the National Defense Reserve Fleet available for the sole purpose of building artificial fishing reefs.

The use of World War II Liberty ships as artificial fishing reefs actually originated in Alabama. Shortly after the State of Alabama started it's reef program in the early 1970's, Mississippi followed suit, borrowing on her sister state's knowledge and experience in reef building. The State of Mississippi made formal application for five ships from the Reserve Fleet at Mobile, Alabama, and, in November, 1974, the U.S. Maritime Administration transferred five vessels to the State.

After all requirements were met which satisfied the Coast Guard, shipping interests, the U.S. Army Corps of Engineers and other agencies, the first ship hull was sunk on June 10, 1975. Between April 16, 1974 and May 25, 1976 the state of Mississippi started and completed its reef project.

The Mississippi Reef Program was a cooperative effort between the Mississippi Bureau of Marine Resources and Mississippi Gulf Fishing Banks, Inc.

Gulf Coast Research Laboratory, Ocean Springs, Mississippi
Careful planning and coordination did not preclude problems from occurring. The major problems encountered involved an uncooperative contractor who was reluctant to properly remove remaining bunker fuel from the double bottom fuel tanks of the ships and a sub-contractor who would not meet the towing and sinking schedule.

During the project, several innovations and changes were made in the usual sinking and buoys procedures. Several methods of actually scuttling the ship hulls were studied, and it was determined that the most effective way was to cut two 2 x 5 foot holes in the stern of each at the waterline after the hulls were on location. It was also found that anchoring the hulls both at the bow and at the stern prior to sinking facilitated maintaining the desired position of each hull.

While there are no longer any Liberty ships available in reserve fleets in the southwest, the methods of preparing and sinking hulls mentioned here would apply to almost any large, steel hulled vessel which might be available for use as an artificial fishing reef.

After a vessel has been acquired, the selection of a good contractor who will perform the necessary work to make it suitable as reef material, is of prime importance.

Too often where a state government is involved the lowest bid must be accepted; however, the lowest bid is not always the best. The contractors experience in dealing with such matters as salvaging and preparing a vessel, and his ability to perform the necessary work within a particular time frame are major considerations in making a selection; all others should be disqualified if at all possible. Undesirable contractors can usually be eliminated in the bid prospectus.

Secondly, a contract should be drawn up specifying exactly what work is to be performed by the contractor. Work such as cutting the hull down, equipment removal, removal of oil from fuel tanks, cleaning fuel tanks, cleaning oil from decks etc., should be spelled out and last but not least the contractor should be bonded.

The purpose of salvaging the superstructure is to reduce the height of the vessel so that it can meet minimum depth requirements. The depth of the water where a hull is to be sunk dictates the amount of material that can be left above the keel as there are minimum depth requirements set forth by the U.S. Coast Guard and other agencies.

The value of the salvaged steel, artifacts, machinery and other recyclable material usually pays for the costs involved in hull preparation, towing and sinking.

While all problems cannot be avoided, it was found during the project that they can be minimized by keeping in constant contact with the contractor through phone calls and frequent visits to the salvage yard. These procedures permit you to personally observe progress and to discuss the next phase or stage of the project as well as to see that all contractual agreements are met.
Most salvage contractors are reluctant to talk about schedules, however, firming up a sinking date is a must, if for no other reason than for publicity purposes.

Marking a proposed reef site with small, easily removable or expendable buoys prior to sinking a hull facilitates positioning the object so as to take advantage of currents or to create a desired reef configuration if more than one hull is used in a location. Buoying a site beforehand also eliminates the possibility of a contractor placing a hull in the wrong location.

It was found that wreck buoys placed at both the bow and the stern and attached with proper size chains and swivels, could be more easily accomplished before a hull was sunk rather than by divers after sinking.

Anchoring a large hull on site prior to sinking is important as it eliminates the possibility of a hull drifting away from the approved location. This can be accomplished by fastening anchors outside of the hull with cables while the hull is at the salvage yard. The cables can be cut with cutting torches allowing the anchors and chain to fall free when the vessel is on location at the reef site.

Large ship hulls have been successfully sunk by use of explosives placed at strategic spots on each hull. While this method works well, the use of explosives increases sinking costs and involves more people, particularly those trained in the use of explosives, adds to logistical problems and will most likely necessitate having to obtain an additional permit or two.

After studying the various methods of sinking large ship hulls like those of Liberty ships, which are 416 feet long and 50 feet wide, it was determined that a large hull can be safely and easily sunk by putting a small work crew of four people on board after the hull is on location.

Steel ladders salvaged from the ship and welded both inside and outside of the hull at the salvage yard facilitates getting a work crew aboard the hull and off again when work is completed. Cutting torches with long lines can be taken aboard, tanks and other equipment can be left aboard a work vessel which is secured alongside of the hull. After the cables holding the anchors are cut, the work crew then cuts two 2 x 5 foot holes in the stern, the bottom cut of each hole being made at the waterline. The crew can then proceed to open the ship's sea cocks, which are generally located amidship and are usually operable.

The water entering the hull from the open seacocks, along with the water entering the cuts made at the waterline, causes the hull to fill and gently settle to the bottom stern first.

Sinking a Liberty ship hull, usually takes between twenty to thirty minutes; therefore, the work crew has ample time in which to leave the sinking hull. The rapidity with which a hull sinks depends on the sea state; a two or three foot sea is very desirable as it allows for ideal working conditions and at the same time allows the hull to take on goodly amounts of water.
Sinking large hulls in the aforementioned manner certainly is not as dramatic as using explosives; however, during the Mississippi reef building project it proved to be a most efficient method in sinking the hulls of large vessels for use as fish havens.
Obsolete Petroleum Platforms as Artificial Reef Material

Dr. Robert B. Ditton

and

James M. Falk

Currently, there are approximately 3,350 petroleum platforms in the Gulf of Mexico. Of these, 3,000 are in state and federal waters off Louisiana. The remainder are off Texas (Exxon USA, 1979). Therefore, fishermen in Louisiana and Texas currently enjoy the fishery benefits produced by petroleum platforms while those in other Gulf states do not. This can change, however, since the Outer Continental Shelf Lands Act (OCSLA) and the BLM lease agreement require that platforms be removed when production ceases. Fishermen in Texas and Louisiana may lose their favorite fishing platforms to the scrapyard or their platforms may be used elsewhere for oil production purposes. Likewise, there is the opportunity for the oil companies to export their obsolete platforms to other current non-producing areas as artificial reefs.

Texas and Louisiana have a full range of platform reef alternatives to consider in addition to other reef materials like Liberty Ships, rubble, tires, etc. In addition to enjoying the fishing benefits currently produced by working oil platforms and considering the deployment of oil platforms as mid-level reefs, perhaps in conjunction with Liberty Ship reefs, planners in these two states also need to be sensitive to finding ways to legally allow some platforms to remain in place as fishing reefs when production ceases there. We should be especially concerned with those platform reef resources that are well sited and easily accessible to and used by sport and commercial fishermen. This latter alternative faces numerous hurdles at the federal and international level but it is nevertheless worth our continued attention for the future.

The other states in the Gulf and southeast have fewer oil platform alternatives since they are not yet active oil producers. Along with other reef materials they should give careful consideration to the future and the potential use of obsolete platforms as mid-level artificial reefs. Approximately 966 of the 3,350 platforms in the Gulf of Mexico are multi-well jackets. Because of their sufficient volume and surface area, they are prime candidates for future artificial reef material. Public officials need to monitor the status of these multi-well platforms through various public records and contacts with oil company officials so as to determine when the process of abandonment has begun and whether equipment is considered obsolete. If, after all other reef

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materials have been considered, obsolete platforms are desirable as reef material, public officials need to work closely with the companies to secure a platform.

The experience of the State of Florida and Exxon USA in deploying the first mid-level platform reef in the Gulf provides a valuable demonstration that the public and private sectors can cooperate to their mutual benefit. This paper will examine the topic of obsolete platforms as artificial reef material, some alternate applications and some of the tradeoffs involved with each.

Why Platforms Make Good Reefs

Like many other artificial reef materials, oil platforms provide two basic needs sought by all forms of marine life -- a safe, dark place to hide and abundant food (Treybig, 1971:64).

Additionally, petroleum platforms are effective reef material because: (1) they have a strong profile, (2) they do not significantly impede water flow, and (3) they are easily located (Shinn, 1974). Where many other materials are either unstable or uneconomical for offshore applications, problems with platform reefs are minimal and the finances are good. They also have good longevity.

Petroleum platforms, like other artificial reef materials, attract fish because of the availability of food. Algae, the basis of all life in the ocean, grow profusely on hard surfaces such as rock, steel, or concrete. Water depth is also important. Algae require sunlight to grow and therefore the amount of algae growth is greatest near the surface. Platforms that are in place and use the full water column allow for algae growth and many other organisms such as barnacles at depths where they could not exist in quantity under normal conditions (Duffy, 1975). This needs to be taken into account when platforms are deployed as mid-level reefs.

Studies conducted by the University of California have revealed additional information concerning the productivity of petroleum platforms. During an extensive examination of the biology of offshore platforms, researchers discovered that fish were present at all depths of existing structures. However, divers saw the greatest variety of fishes at water depths between 30 and 70 feet. In most cases, the number of species seen per visit ranged from 18 to 31 (Simpson, 1977). Depth, therefore, is an important consideration in deploying platforms as mid-level reefs.

Further examination of California platforms revealed that there were between 20 to 50 times more fish under the petroleum platforms than over a portion of the soft-bottom control area of the same size, and the platforms had 5 times as many fish as nearby natural reefs (Simpson, 1977). Every support member and oil conductor pipe underwater was coated with a fouling community 1 to 4 feet thick providing for an excellent fish habitat area. The abundance of organisms at the platforms appeared to increase significantly in the 17 years since the platforms
were installed. Biologists' estimates of fish abundance on the 1975 visit to a platform were in some cases 500 percent higher than estimates made in the late 1950's (Simpson, 1977). With careful planning, petroleum platforms deployed at new locations should continue to be valuable artificial reef resources.

Recreational Use of Oil Platforms

In addition to their potential as fisheries habitat the primary oil and gas purposes for which they were deployed, oil platforms currently support a considerable amount of recreational and commercial fishing and scuba diving activity. Besides casual observation, the extent of this activity has not been generally documented for the Gulf of Mexico. If we are to deploy platforms as artificial reefs, it is important that we know the extent to which reefs are used at varying distances from shore and for what purposes. Currently, we need this data on a Gulf-wide basis for the following activity classifications: 1) recreational fishing - private boat, 2) recreational fishing - charter boat, 3) scuba diving, 4) commercial hook and line fishermen (transient commercial trawlers or netters are excluded) and 5) other recreational pursuits. Some data have already been collected on the extent to which the offshore area adjacent to the Houston-Galveston region, albeit smaller than the entire Gulf, was used for sport fishing (Ditton and Graefe, 1978). Survey findings indicated that petroleum platforms were used for sport fishing by 87% of all offshore sport fishing boats registered in the adjacent area. Further, one-half of the total 66,924 offshore fishing trips taken by the population of resident boat owners in the adjacent 8-county study area were to oil platforms. Buccaneer Field and other oil platforms accounted for 21% and 29%, respectively, of the total number of offshore trips. In addition, charter and party boat operators in the Freeport - Galveston area indicated that of the 2,400 trips they took offshore, 545 (23%) were to platforms. Of all platform trips by charter and party boats in 1977, 146 (27%) were to Buccaneer Field.

When you look at the relative fishing use made of all possible types of offshore fishing attractions (as we did in our recent study), oil platforms as currently deployed indeed play a major role and produce considerable recreation benefits.

Perpetuating the Benefits of Obsolete Platforms in Place

As early as November, 1974, the Sport Fishing Institute recognized the recreational value of petroleum platforms, and urged the Secretaries of Interior and Commerce to work cooperatively to develop applicable policies, procedures, and guidelines for the purpose of converting non-active offshore oil platforms to use as permanent artificial reefs (Sport Fishing Institute, 1979).

The main problem in perpetuating the benefits of platforms as artificial reefs is the requirement that structures be removed once
petroleum production ceases. This is required not only by the Bureau of Land Management (BLM), but also through the Outer Continental Shelf Lands Act (OCSLA) and the Geneva Convention on the Continental Shelf. There are numerous costs involved in removing a platform.

Costs are incurred by both the private and public sector when a platform is required to be removed (Beardsley, 1977). Although the private sector must bear the cost of removal, the public sector is affected because a portion of its fisheries resource is lost. It should not be assumed that every platform offers and represents an equal value in terms of tangible and intangible benefits. Realistically, platforms closer to population centers represent more fishing opportunities than those in more remote seaward locations.

Another potential problem in perpetuating platform benefits is encountered when liability issues are raised. These issues might arise in the event that a public sector agency or a private business takes control of a platform to manage it as a recreational resource. This is especially critical if the platform is to remain standing. The question of liabilities arising from the operation of a platform as an artificial reef will generally follow the legal doctrines of tort and admiralty (Lawlor, 1975). Public or private sector costs and liabilities should be closely examined before management authority is transferred from an oil company.

In order to consider the management, maintenance, and development of platforms for recreational use, it is necessary to identify whether the public or private sector should handle these functions. An examination of sectoral strengths and weaknesses is necessary to determine which sector can best operate the structures for recreational uses (Swanson, Seymour and Ditton, 1978).

However, before sectoral alternatives can be considered, it is necessary to first address three important matters.

(1) An amendment to the OCSLA is needed to allow platforms to remain standing once production ceases.

(2) Modifications are needed in the Geneva Convention on the Continental Shelf, which includes petroleum platforms under its jurisdiction and requires them to be removed when production ceases.

(3) A new public law or an amendment of a previous law is needed that would allow a public or private sector agency to manage the water column and area adjacent to offshore platforms.

These three matters are not unresolvable. Agreement is necessary from all concerned parties and that likelihood is possible as secondary benefits are more widely recognized.

Three sectoral alternatives have been examined to provide some insight into perpetuating recreational benefits of obsolete petroleum
platform left in place. Assuming statutory problems can be alleviated, there is a possibility that one or more of the following alternatives can be considered at some time in the future.

**Public Sector:** Assuming the hurdles of national law, international law, and agency authority can be overcome, it is possible that some public agency, probably at the federal level, could manage obsolete platforms as artificial fishing reefs. Like other federally managed recreational resources, funds could be budgeted to acquire, develop, and maintain platforms for recreation. Although oil companies would probably be willing to donate the platforms to a federal agency to avoid removal costs, the agencies would likely not accept any such donation if they would have to bear maintenance and ultimate removal costs.

**Private Sector:** Private sector involvement in managing and operating platforms could occur in several ways. First, oil companies might decide to manage their own platforms as fishing reefs. This could be accomplished by charging fishermen who utilize the platforms a per-head fee to fish.

A second private sector involvement might be for the oil companies to relinquish the rights to their lease to an entity like a sportfishing club. The private club would then charge a user fee and use the accumulated funds for maintenance of the structure and removal when the platform is deemed structurally unsound.

Another private sector option might include the oil companies forming a cooperative where they would pool their funds and maintain and operate certain obsolete platforms as artificial reefs. The money the companies put into a general fund would be used for maintenance and eventual removal costs.

**Public/Private Sector:** This approach would allow oil companies to enter into an agreement with the Bureau of Land Management once oil production ceases. If BLM determines that certain platforms are desirable to the public, in a good location, and structurally sound, it could offer to release the company from its lease responsibilities and assume all responsibilities and liabilities. The oil companies, in return, would pay a certain amount to BLM to complete the transaction. The amount paid to BLM would be based on a standardized percentage of the assessed removal costs that the oil companies would incur if they were forced to remove the platforms themselves.

When BLM takes control of the platforms it would be understood that the platforms would never leave the water again. A platform would be operated initially as a high profile reef and a mid-level reef when deployed at a new site.

In summary, there are a number of inherent problems that arise when any of these alternatives are considered in addition to the preliminary legal hurdles: the liability by the new management authority and costs
of maintenance. If the problems associated with using obsolete platforms in place cannot be resolved, there is always the possibility of transproting the structures to alternate sites and deploying them as mid-level reefs. Either way, we need to recognize the benefits that the massive structures possess.

**Using Obsolete Platforms as Mid-Level Reefs**

The State of Florida and Exxon USA are currently cooperating in a pioneering effort. For the first time an obsolete platform (a Subsea Production System template to be exact) is being deployed at a new location in Florida offshore waters as a mid-level reef. Besides donating the template, Exxon is paying transportation costs and assuming all liability until the reef is in place. At that time, the State of Florida will accept title to the reef.

The template is "a maze of assorted pipes and tubing 125 feet long, 96 feet wide and 60 feet high. It weighs more than 3 million pounds." After capping the well and cleaning the production platform, it will be towed by Exxon to a site twenty five miles due south of the small community of Carrabelle, Florida. When deployed in about 100 feet of water, the strong profile of the reef will leave a 40 foot clearance for navigation purposes. Because this is short of the clearance required by the U.S. Coast Guard, a lighted buoy normally would have been required. Fortunately, it will be placed near a lighted and buoyed Air Force tower and therefore a separate buoy will not be required. This means that buoy maintenance costs are eliminated for the State of Florida. This example from Florida is an important demonstration of how industry and government can work together and it appears to be an "everyone wins" situation. Exxon saves approximately 5 million dollars, the cost of removal and dismantlement. Sport and commercial fishermen and divers have a new recreation attraction at apparently little or no cost. As long as removal costs increase and scrap metal prices remain low, it is in the best interests of the oil companies to participate in these public/private ventures. In addition to cost savings, they have the potential for acquiring considerable public good will.

Besides being the first platform to be deployed as a mid-level reef, it is significant that this activity is occurring in Florida, currently a non-offshore oil producing state. Currently, only fishermen in Louisiana and Texas enjoy the added fishing benefits which accompany oil platforms. Because of the many producing platforms in these two states, it may be difficult to generate support for mid-level platform reefs there. This is not the case in Florida where reef alternatives are more limited. If platform economics stay the same, the oil companies appear to have much to gain from spreading improved fishery benefits to other states where there are currently no off-shore oil production activities.
The Texas Coastal and Marine Council has plans to accept donated platforms to deploy at their existing Liberty Ship reef sites. They have already amended their Corps of Engineers permit for their Freeport Liberty Ship site so as to allow additional materials to be added (Lee, 1979). They chose the Freeport site over the other three Liberty Ship sites to the south because of the closer proximity to locations where oil platforms might become available.

There appear to be many similarities between oil platforms and Liberty Ships as reef materials. Both are large structures with considerable surface area and procedures for deployment would be essentially the same. Platforms deployed as mid-level reefs should be less susceptible to motion due to currents than the Liberty Ships.

The Texas Coastal and Marine Council is interested in platforms as reef materials because ships are no longer available at no charge and because other smaller reef materials would not stand up in offshore locations. Since no funds are currently budgeted by the State of Texas for transporting a donated platform to the deployment site and to pay insurance costs, these too would have to be paid by the oil company, a sportfishing club or some other non-state government sponsor. The goal of the TCMC is to accept title to the platform reefs once they were very carefully positioned between the existing Liberty Ship reefs (Lee, 1979). The TCMC has had offers for donated platforms but they would have had to take immediate possession at the platform site. This has been financially impossible.

Whether or not Texas eventually deploys any oil platforms as artificial reefs appears to rest with the oil companies. If their management decides that it is in the best interest of the company and its stockholders to donate platforms (and possibly bear the transportation and insurance costs) there will be platform reefs in Texas offshore waters. If management decides it is not in their best interest, the TCMC will need to find some alternative reef material. For now, in Texas, it is a waiting game!

The oil companies appear to be moving in a careful and prudent manner with regard to the disposition of oil platforms. It is unrealistic to expect that the industry will curtail its options by establishing any firm policy in this area. Rather, we can expect them to carefully evaluate each particular case in light of the Exxon experience in Florida, changing financial conditions and numerous other parameters that are subject to change.

Conclusions

Oil platform reefs appear to have a number of advantages with few identifiable disadvantages. Nearly everyone we spoke to in preparing this paper felt that oil platforms had more potential than nearly any other reef material. Planners need to be careful so as to not advocate any single category solution and need to be wary of any reef material that is put forward as a panacea. All alternative reef materials as
well as the alternative of no artificial reefs at all should be carefully considered for the particular situation at hand and the tradeoffs between alternatives should be understood to the greatest extent possible.

Table 1 was developed to help us to understand the tradeoffs between platform reef alternatives in Texas. Admittedly, non-offshore oil producing states do not now enjoy alternatives A and B. They must consider the advantages and disadvantages of mid-level platform reefs in relation to that of other reef materials for offshore deployment. As states develop artificial reef programs, there needs to be a commitment to developing a system of reefs and using the most appropriate material for each proposed reef. There is no room for "super solutions" or "fads" in the artificial reef business.
<table>
<thead>
<tr>
<th>CONSIDERATIONS</th>
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<th>B</th>
<th>C</th>
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<tr>
<td></td>
<td>USE EXISTING PLATFORMS FOR FISHING</td>
<td>WHEN PRODUCTION CEASES, LEAVE</td>
<td>REMOVE PLATFORMS TO ALTERNATE</td>
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<td></td>
<td>AS OIL PRODUCTION CONTINUES (COLLATERAL USE)</td>
<td>PLATFORMS IN PLACE AS VERTICAL ARTIFICIAL REEFS</td>
<td>LOCATION AND DEPLOY AS MID-LEVEL REEFS</td>
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<td>General</td>
<td>Only possible in Texas and Louisiana waters and other areas where there are platforms</td>
<td>Alternative now only operational in Texas and Louisiana waters</td>
<td>Alternative possible anywhere – particularly near oil production activity</td>
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<td>Prognosis for</td>
<td>Platforms are used now for fishing but benefits may be lost with removal</td>
<td>Not now legally possible – may be possible in future</td>
<td>Currently being implemented in Florida</td>
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<td>implementation</td>
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<td>Fishery potential</td>
<td>Opportunity to use full water column (pelagic to demersal species)</td>
<td>Opportunity to use full water column</td>
<td>Potential for demersal species and some (mid-level) species</td>
</tr>
<tr>
<td>Reef siting – optimum</td>
<td>Well sited platforms may be lost in the future when production ceases and platform is removed</td>
<td>Well sited platforms could be kept and poorly sited platforms would not</td>
<td>Reefs can be sited in a purposeful way so as to be accessible to fishermen</td>
</tr>
<tr>
<td>location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to be located by</td>
<td>Visual and/or charts – all fishermen can locate</td>
<td>Visual and/or charts – all offshore fishermen can locate</td>
<td>Must be buoyed or require Loran to locate – not all fishermen can find</td>
</tr>
<tr>
<td>fishermen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>Platform maintenance (private sector cost)</td>
<td>Platform maintenance (?)</td>
<td>Buoy maintenance (public sector cost)</td>
</tr>
<tr>
<td>Surface attachment sites</td>
<td>Fishermen tying up to platform is common practice but legally questionable</td>
<td>Tie up possible by design</td>
<td>Tie up only possible with added buoy cost and maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diving potential</td>
<td>More safe due to full water column</td>
<td>More safe due to full water column</td>
<td>More difficult to locate platform. Also, impact of muddy layer (Texas)</td>
</tr>
<tr>
<td>Life expectancy of</td>
<td>20-30 years or until declared a hazard to navigation</td>
<td>20-30 years or until declared a hazard to navigation</td>
<td>No limit – permanent facility</td>
</tr>
<tr>
<td>structure</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
References


Sport Fishing Institute. 1979. Fishing on Texas reefs. SFI bulletin, No. 307, August, p. 3.


North Carolina was active in artificial reef construction from 1974 through 1977 at a scale of some $3{1/2}$ million annually. Reef activity resumed again in late 1978, but at a much reduced scale of some $100,000 annually.

Four years construction and monitoring on nine oceanic reefs composed of a total of more than one-half million scrap tires, four liberty ships, and five scrapped boats have tested initial placement plans and modifications. Reefs were constructed in 35–72 feet depths, all within three miles of shore. Distance between the furthest reefs was 300 miles.

We began with a machine hydraulically compressed packets each containing 6–10 auto tires. The compressed pile was banded by three metal and one plastic bands. The unit then had to be vented. Hand held saws of the chain saw variety, but with a rotary blade, were used. We later purchased a hydraulic press that cut the tires during the compressing process. Truck tires were vented with hand held saws. More than 75 percent of the tires used were new rejects from the Kelly Springfield plant near Fayetteville and most were steel-belted. Processing new, heavy, steel-belted tires introduced many problems as opposed to handling worn-out scrap tires.

Offloads through January 1977 were comprised of compressed units strung together on 300 yard lengths of cable. Each bargeload contained three lengths of cable. Concrete anchors were attached at intervals along each strand. One strand would be laid along the bottom, then the other two would be offloaded over the first strand in a tic-tac-toe arrangement that would interlock the bargeload. At reef sites where a Liberty ship was located SCUBA divers would attach one end of the cable to the ship. The barge would back off and the units would topple into the water. We tried to arrange strands of tires some 20 feet apart. We sometimes accomplished this, sometimes not.

At sites with no permanent anchor on the bottom, a pull boat would supply the tension to offload the three strands of tires. This method worked well and fast except when cables broke or when the junctions within a strand were not fastened correctly. When loading the barge, it was not possible to string a 300 yard length of cable through the rows of units, so several shorter lengths were used and fastened with cable clamps.

While the cable method safeguarded the spread of tires from reef sites it did cause the units to bunch up too tight on the bottom. When the metal bands corroded and parted the units were unable to expand.

North Carolina Division of Marine Fisheries, Morehead City, North Carolina.
By July 1975 we began adding another layer to the two layers of compressed units loaded on the barge. The units were loaded by hand and laborers could not easily pile the 200 pound units three feet high. Our construction supervisor also believed the cables would tangle if we piled units three high. The third layer was a row of single truck tires. These were strung on short cables attached to the three long main cables. We called the single tire strands pigtails.

Beginning in January 1977 we started something new. By then we had a maze of cabled units at three sites - Atlantic Beach, Wrightsville Beach and Long Beach. We had a series of "tire fences" on the bottom. Truck and tractor tires were arranged in stacks of three. Two strands of 1/4" polyethylene rope and a strand of plastic strapping held the three tires together and these were offloaded by hand. When offloading by hand we could selectively place units in bare areas, either on Liberty ship reefs or non-Liberty ship sites.

On April 22, 1977, we made the first offload of a new 30-tire unit. The first step in building one of the units was to construct a barricade. Two rows of 10 tires were aligned in front of it side by side like a double-barreled shotgun. A third row was placed on top between the two bottom rows so the end view would be a pyramid shape. A 6' 8" piece was cut from a 20 foot length of 1/2" reinforcing rod. The remaining long piece was bent in the middle and placed through the bottom two rows. The short piece was placed in the top row. A torch was used to heat the short rod so it could be twisted around the long piece, thus attaching one end of the 30-tire unit. A tractor with forks was then aligned in front of the unit. The two forks were rammed through the bottom row and the 30 tires were compressed against the barricade. The tractor maintained this position while the rods jutting through spaces in the barricade maintained this position while the rods jutting through spaces in the barricade were heated and twisted together, thus sealing the 30 tires into a unit. The tractor then removed the unit from the barricade and 30 more tires were aligned to make another unit. When the tractor backed away from the barricade and released the pressure, the tires expanded so the finished unit was only partially compressed.

The units were then loaded on a barge and offloaded with a tractor with forks or a forklift. A buoy would mark a drop site. The barge captain would maneuver so the units would be placed around the buoy in an area approximately 200 feet square.

Proper placement of reef materials should be a continuing process of planning and consultation with staff and boat and tug captains before and during offloads.

The project leader needs to be aboard on each offload since the inclination of most captains and crew is to dump the stuff as fast as possible and get back inside the inlet. Their theme is "out of sight, out of mind." Weather conditions are bound to necessitate many compromises. But many shortcuts proposed by non-diving captains and crew members
would not be worth it. For example, take a few extra minutes and have
the captain of the tug towing the barge make a circle and come back on
station so as to prevent the units from being dropped 100 yards from
the designated area. Under certain conditions this might require that
the tug and barge make the circle again and again.

Location sketches of each offload need to be recorded. Each load
could represent thousands of dollars and proper placement should be
meaningful.

Materials placement procedures should include prior planning, the
operation itself, and then monitoring to see if everything went as
planned. Underwater SCUBA monitoring is essential.

Three major goals need to be evaluated separately and together before
placing materials on the bottom: arrange the best habitat for fishes;
maintain an acceptable cost/benefit factor, and provide for optimum
angler success and pleasure.

Habitat: Three placement techniques were used in a progression
scheme. The earlier offloads would be scattered, then saturation
offloads to create a nucleus, and then the creation of patch reefs
around the nucleus. We settled on this as a simulation of natural
rock outcrop areas within 50 feet depths along our coast.

Cost/Benefit: The economics of moving large quantities of tires
frequently eliminates the nice schematics drafted on shore. Sometimes
you have to go when the weather is marginal and maneuverability of barge
and tug is greatly reduced.

While placement procedures are important they are only one part of
construction. To obtain something an economist can appreciate, the
entire construction sequence has to run like a well-oiled assembly
line. You have to offload steadily to keep the men on shore working
steadily. Give as much concern and time to placement as possible, but
sometimes you have to compromise. If you have only one site you can
work on and a southeast wind makes it impossible to work that site,
a week long southeastern not only slows work on that particular site, it
backs up on down the line and throws the whole production schedule in
disarray. Even though you know the load should go to Reef A, go to
Reef B. Keep your assembly line running: have alternate sites, at least
one to chose from; have alternate plans so you can keep the show
running. One thing an economist or an auditor is keen on, is how
much did it cost to build that reef? If the costs come to $5 a tire
that economist or auditor will frown even though you assure him the
eventual benefits will be more than that. However, if the cost figures
out to $.50 a tire you will find him smiling. Strive to get the cost
per unit down, yet hit a conscientious compromise with quality.

Angler Pleasure: We believe the first placement goal is to spread
materials over as large an area as possible. This does not mean scatter
thinly. If we put down strands we would construct a series of overlapping
tic-tac-toe designs over a 20 acre or so area. We would then follow-up with quality by placing materials in bare areas. Fishermen usually do not choose to anchor bow to stern in a small area. If the reef is too small they have no choice. The result will be that those bottom fishing while anchored just a short distance away from the reef will do nothing, while the bottom-fishing angler anchored directly over the artificial reef will catch fish.
COORDINATION, STAGING AND TRANSPORTATION OF MATERIALS FOR ARTIFICIAL REEF CONSTRUCTION

Grant R. Bieling

This morning I would like to present to you a short discussion on coordination, staging and transportation of suitable materials used for Artificial Reef Construction.

Of primary importance in logistics is to plan, organize, and direct the work of skilled, semi-skilled, and unskilled employees engaged in these duties. The assigned co-ordinator should have a thorough knowledge of all phases of reef construction, and the ability to initiate programs and procedures and evaluate their effectiveness. He must establish and maintain an effective working relationship with all concerned.

Equally important is the proper use and maintenance of all heavy equipment utilized. Daily inspection and complete lubrication is an important factor in insuring that cranes and forklifts operate properly and safely. It would be most awkward to have a large truck arrive unannounced at a staging area loaded with heavy cement culvert only to discover that the forklift is inoperative. Equipment misuse, abuse, overloading, improper maintenance, alternation, or other cause can only have an end result of accidents, delays, repair bills, and total frustration. Consider your load ratings on your crane. Safe loads depend on boom length, radius of operation, and proper handling; all of which must be taken into consideration.

Once these policies have been established and your staging areas have been commissioned, you will be prepared to seek out and transport materials, and build artificial reefs. To assemble and stage materials for artificial reef construction, Pinellas County operates two (2) staging areas to service ten (10) reef sites — one in the northern part of the county and one in the southern area. Both areas are in excess of 75' X 250' and have mooring facilities for our motorized barge "Tortuga," which has the capability of carrying sixty-seven (67) tons. Additionally, each area is equipped with personnel and equipment sheds, telephones, forklifts and tire cutters.

We currently have three (3) tire splitters in operation, which are capable of cutting 150-180 tires per hour. Tires are cut around their circumference to within six inches (6"), and assembled into tire units, consisting of twenty-five (25) tires by placing the tire halves on the forklift forks and compacting the unit with the forklift against upright wooden pilings. While in this compacted position, the unit is then secured on each end and through the middle with half inch (½") Dynaric Polyester strapping and made fast with a heavy duty Signode self-locking

Pinellas County Government Artificial Reef Project, Clearwater, Florida
plastic buckle. The tire unit is then placed in storage until approximately 150-180 units are assembled. The units are then loaded aboard the motorized barge in units of four (4) by passing 5/8" nylon line (with an eye splice in each end) through them, to facilitate loading and unloading. Unballasted tire units are transported to an offshore reef and placed in 80-85 feet of water.

Concrete drainage pipe and other concrete rubble is generally available through various types of construction sites, and is available at no cost, provided that you can haul the material away. For our needs, we have established a continuing working relationship with local companies who manufacture cement culvert. Frequently, they have sections that fail testing and these are put aside for our reef project. The largest section of culvert that we handle is 7,480 pounds, which is the safe working load of our barge crane and forklift.

Another excellent source for cement culvert is with local contractors who remove old culvert when upgrading drainage and storm systems. Normally, the contractor is delighted to load your trucks upon arrival in that it relieves him of trucking and disposal costs. Materials of this type are transported by large lowboys from our County Highway Department to a designated staging area. Marine constructors have provided our reef system with many hundreds of tons of cement rubble at no cost. Rubble of this type is from seawalls that are rebuilt. The material is loaded on large barges and towed to a reef site by seagoing tugs. The only requirement on our part is to assign the Artificial Reef Construction Specialist to establish marker buoys where we want the material placed. Since June of 1974 to May of 1979, a total of 4,320,000 tons of material has been transported and placed on our artificial reef system.

Another desirable type of material for reef construction is old surveyed steel ships and barges because of the high profile and surface area that they offer. Approximately 4,000 tons of vessels have been placed. Preparation and co-ordination of placing large vessels on artificial reefs requires attention to detail. You must do your homework well. The policy that Pinellas County has implemented for accepting surveyed vessels appears to work very nicely. Upon receipt of an informal offer of a vessel, an inspection team is organized to determine just what the task will involve in placing the vessel, and what agreements are required. Generally, companies that offer large vessels will provide towing services. However, there are a number of other considerations that must be resolved before a formal acceptance is concluded. The United States Coast Guard Marine Inspection Office must certify the vessel safe for towing and pollution free. Frequently, hull patches are required to control flooding, as well as large dewatering pumps. It is recommended that vessels be accepted on site. This will relieve you of any responsibility of cleaning fuel tanks or the risk of the ship sinking in a main shipping channel. Determine the means that will be utilized to sink the vessel. We have been most fortunate in establishing a co-operative effort with the United States Naval Explosive Ordnance Disposal Team at Cecil Field, Jacksonville, Florida. The team's
professional handling of past sinkings has been an asset to our reef program. Holes are blown in the ship's hull with such precision, one would think a cutting torch was used. The use of explosives has created a great deal of media interest in our reef program. Television stations in the Tampa Bay area find these events particularly worthy of coverage. Our last sinking was featured in a 5-minute "Nautical News" segment on the NBC affiliate, WFLA-TV, Channel 8. The CBS and ABC affiliates carried reports on their regular newscast. Pinellas County Public Service and Information Department oversees all arrangement for invitations and publicity.

Our program utilizes a barge operator, three divers, a crane operator, and seven EJPs (Emergency Job Personnel) for the two (2) staging areas. The County's program is locally funded. It is estimated that our sitting, engineering, storage, transport, construction, and maintenance costs run about $104,000 per year, including all personnel and adjunct administration costs. The proposed budget for the fiscal year 1979-1980 is $143,110. This amount does not include a Capital Improvement project of $16,900 for fiscal year 1979-1980, and $77,000 for fiscal year 1980-1981. These funds have been requested for staging area improvements at a new proposed permanent site in our North area.

Pinellas County Artificial Reef brochures are available without charge to fishermen, divers, and other explorers. About 30,000 copies of the brochure have been mailed out since it was first published. This brochure outlines information on our 10 (10) reef sites and their location with compass courses.
BUOYING AND MARKING OF ARTIFICIAL REEFS - A CLUB EXPERIENCE

Nicholas J. Delmedico

This paper presents a cheap easy to build visible marker buoy which can be constructed from materials commonly found around the home, that is, if one happens to live in a hardware store. The price per buoy breaks down to about $17.00 in material costs, and with proper incentive when initiating the assembly, this could feasibly be the final net cost of each buoy. The Jacksonville Offshore Sports Fishing Club has been in the buoy business for twenty years and it is our pleasure to share the club's experience with interested parties.

Introduction

The first artificial reef built by the Jacksonville Offshore Sports Fishing Club was constructed in the fall of 1959 with over 200 auto bodies, 1200 junked appliances, and 7,000 auto tires (added one year later). Since then JOSFC has constructed new reefs and augmented existing natural reefs with over 100,000 passenger car tires, 5,000 large truck tires, 500 tons of culverts, 3,000 junk appliances, 1 ferryboat, 15 tugboats, 2 large drydocks, 1 LST (landing craft), 2 medium drydocks, and over 20 accessory boats (lifeboats, small yachts, etc.).

A scant year and a half after the club's inception, an ambitious project to buoy 17 natural and artificial reef areas offshore from the St. John's River jetties was put into operation. Two buoys were placed, one half mile apart and lying north and south over each reef or fish haven, and proved to be excellent aids to navigation in these waters.

An art work overlay was drawn to fit Coast and Geodetic Survey Chart No. 1242 giving distance in miles, compass course and reciprocal to each of the 17 numbered buoys. These charts were printed and made available to the membership and general public through sporting goods outlets, fish camps, and area marinas.

One year after this, the club chart was expanded to include reef areas off both Fernandina and St. Augustine to the north and south of the St. John's River inlet. The clubs of these communities were responsible for the construction and maintenance of their own buoys with the new chart available to both groups.

Basic Materials and Procedure

Buoys design and construction has varied little in the past twenty years, the current design undergoing slight modifications as experience...
showed. A list of needed materials may be found in Table 1. The following procedures are used by JOSFC in the construction of their buoys: A conical mold is filled with wet styrofoam and a piece of galvanized pipe (used in tops of chain link fence) passed through the center. When dry, this is removed from the mold and painted dayglo red. A 2'-3' piece of rebar is inserted in the pipe and allowed to rest on the very bottom as a counterweight. A 20' calcutta pole is inserted in the top of the pipe and secured with a galvanized bolt. A quarter of an inch chain is secured to the bottom of the buoy and an appropriate length of \( \frac{1}{2}'' \) polypropylene line fastened to a bottom weight of about 170 pounds. The line is eyespliced to a 46" length of 1" chain which in turn is secured to the bottom weight. It has been found that black line is best to use since lighter line seems to facilitate fouling by its increased ability to support growth. Weights have varied over the years, the best choice having settled upon scrap catapillar tread. I-beams were found to move too much and additionally corrode at a faster rate. A scope of 10 - 15' is well suited for the purpose, as no scope was found to facilitate "walking" along the bottom, even with shackles and \( 1\frac{1}{2}'' \) chain.

The weakest point in the whole buoy system is where the polypropylene line connects to the chain. Even with a strong metal eye, the constant movement and stress caused by marine forces will eventually wear away this section. Divers who use the reefs and respect these navigational markers will usually report worn buoy parts to club members or to the club's home base at Monty's Marine, Mayport, Florida. (Fig. 1).

**Buoy Assembly**

Once materials are accumulated, the assembly process can be initiated. JOSFC employs an effective method of putting the materials together. A club event, carefully headlined as a "Buoy Building Party" is used to attract club members to a large staging area where assembly is done. A large turnout is almost assured if the following conditions are met: 1) plan the event during a time of rough seas, foul weather, or similar conditions when the probability of successful offshore fishing is minimal; 2) copious amounts of mixed beverages have always been known to attract fishermen, and it would be wise to have this on hand in addition to buoy materials (cost not included in overall figure of $17.00 per buoy); 3) a club membership of over 1,000 (as JOSFC spouts) helps innumerably; 4) the use of food, prepared by wives, lovers, and acquaintances of club members, as an additional attractant may be employed.

At such an event, there is never a lack of duties to perform. Flags must be sewn, buoys painted, lines rigged, all in addition to the basic required assembly. A detailed breakdown of the buoy may be followed in figure 1 as a guideline for assembly. Minor changes may be required, but basically, buoy design has not varied over the twenty years in which the club has provided this community service. By following these guidelines, JOSFC has continued to effectively build and maintain buoys in the area offshore Jacksonville.
Figure 1.
Reef buoy used by Jacksonville Offshore Sport Fishing Club

- Naugahyde strip (doubled over)
- Calcutta Pole 10' - 20' length
- Nylon camper cloth
- Aluminum fencepost
- Reef designation sign secured with U bolt
- Styrofoam cast
- Rebar counterweight is inside lower shaft
- Galvanized bolt
- To bottom
Placement of Buoys

Once assembled, the buoy placement is sub-contracted to a local headboat operator for a reasonable sum of money. Alternative methods were explored, and this seemed the best possible mode of operations. Buoys placed in this manner are always exactly on the charted locations; headboat captains are usually quite familiar with the offshore bottom and can be depended upon for this aspect of a buoy program.

For years JOSFC club members were prevailed upon for placement of buoys, but this system has since been proven unreliable. With the advent of high fuel costs, it is almost impossible to get volunteer buoy placement. The services currently received for the set, fixed fee include an as-goes monitoring of buoys by the headboat captain in addition to an as needed replacement of buoys lost during adverse weather.

A buoy board is also maintained by the club at Monty's Marina which tells whether a reef's buoy is properly placed, missing, or off charted location. JOSFC now limits each reef to one buoy, rather than two as once was the original plan.

Conclusions

An effective, low cost buoying program can be successfully implemented provided one has the manpower, materials, and the means to oversee such an ambitious project. Proceeds from sales of charts marking these locations can be used to augment existing funds. As in all undertakings, time and energy are a premium, but JOSFC has shown that the task is far from impossible. Following this model, fishing clubs in Fernandina and St. Augustine have had similarly successful programs.
<table>
<thead>
<tr>
<th>Material</th>
<th>Dimensions</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naugahyde</td>
<td>36&quot; x 8&quot;</td>
<td>secure flag to pole</td>
</tr>
<tr>
<td>Nylon camper cloth</td>
<td>21&quot; x 36&quot;</td>
<td>flag material</td>
</tr>
<tr>
<td>2 galvanized bolts</td>
<td>¼&quot; x 2½&quot;</td>
<td>secure chain and flagstaff to buoy</td>
</tr>
<tr>
<td>Plywood</td>
<td>16&quot; x 8&quot;</td>
<td>small sign to designate reef</td>
</tr>
<tr>
<td>Calcutta pole</td>
<td>10' to 14' length</td>
<td>flag pole</td>
</tr>
<tr>
<td>U-bolt</td>
<td>1½&quot; center to center</td>
<td>secure sign to body shaft</td>
</tr>
<tr>
<td>Conical steel mold</td>
<td>12&quot; diameter tapering to 1½&quot; over 46&quot;</td>
<td>casting</td>
</tr>
<tr>
<td>Styrofoam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum fence top rail</td>
<td>1&quot; x 48&quot;</td>
<td></td>
</tr>
<tr>
<td>Polypropylene line</td>
<td>3/4&quot; x length as needed</td>
<td></td>
</tr>
<tr>
<td>Bottom chain</td>
<td>1¾&quot; x 42&quot;</td>
<td></td>
</tr>
<tr>
<td>Rebar</td>
<td>2' x 3'</td>
<td>counterweight</td>
</tr>
<tr>
<td>Paint</td>
<td>vinyl daglo</td>
<td></td>
</tr>
<tr>
<td>Bottom weight</td>
<td>150 pounds minimum</td>
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</table>
My personal experience in the marking of artificial reefs area is somewhat limited in that it only goes back to 1958. Rather than shatter your illusion that everything is done on a large scale in Texas, I'll tell you that in just under four years at five sites we've laid out over $103,000. Now let me attempt to explain why.

The sites I will describe are those where Liberty Ships were sunk in the Gulf off Texas. The funds I refer to were derived from the salvage contract we negotiated for reef construction and in no way can they be considered as taxes or license fees.

Texas asked for and was granted 12 of 18 surplus Liberty Ships from the Defense Reserve Fleet at Beaumont. Our application to MARAD indicated an intent to construct four reefs of three ships each. The application specified the locations and contained copies of Corps of Engineers permits as well as Coast Guard authorizations specifying the type of buoy to be used.

Several factors were considered in determining the buoy type. Water depths of 90 to 110 feet of course meant 130 to 150 feet of chain or cable. Daymark visibility -- radar reflector height of at least six or eight feet -- meant additional buoyant capacity. Nighttime shrimping operations dictated a lighted buoy, so extended time battery capacity was needed. Fishermen would much rather tie up to a buoy using a small deck rope than drop 150 feet of anchor line and maybe not be able to retrieve it, so a batter-resistant (metal) body seemed best.

Metal buoys present a hazard to small boats in fog, so a 1/2 mile fog signal -- and more batteries -- were added.

We're now really in the buoy business and Coast Guard experience indicated a buoy similar to their BLS-620 designation was called for. BLS means "buoy with light and sound" (Fig. 1). The 620 refers to diameter of body (6 ft.) and overall height (20 ft.). Now that is a Texas sized buoy. A corresponding anchor would be needed and transportation and placement could cost a good bit. But, the ships were going to the site and also going to the bottom, so we put the buoy on the deck and attached the chain to a special pad-eye welded in place for that purpose. We even provided a spare pad-eye, so that when the lower portion of the chain needed to be replaced due to chafing we could install a new short section sort of like a bridle to the extra eye. That should have provided a system better than the Coast Guards -- they lift a 5,000 pound block of concrete to the deck of a buoy tender to replace the bottom section of chain. They also have the resources of the Federal government behind them.

Texas Coastal and Marine Council, Austin, Texas
One thing the Coast Guard doesn't have with their concrete anchor is a 900 ton ground plate to speed up the galvanic action. After the third buoy got loose, we recovered enough chain to be able to pin that down as our biggest problem. So, we went back to the drawing boards of a diverse group of engineers and came up with an alternative that appeared to work pretty well.

In this, we replaced the single length of 1 1/8 inch stud-link chain with two lengths of 1 1/8 inch diameter polyethylene clad steel cable interrupted by two sunmerged spherical buoys to keep the lower section taut and erect. In all shackle joints, double-nutted safety shackles were used and stainless steel cotter pins held the second nut in place ... until somebody decided they didn't want the buoy on location at the offshore Freeport site. It's been on the beach of Matagorda Peninsula for over a year now. We replaced the buoy, but when the crew got back to the ship to attach it, they found that an enterprising crab, octopus, or maybe even a scuba diver had taken the entire mooring assembly for a souvenir.

That one finally went back with all new moorings with the shackle nuts welded in place. This time, a supertanker must have used it for a mooring because in just a couple of months, the buoy was found adrift with the cable pulled in two. A good bit of damage to the bottom of the buoy body was evident when removed from the water. As of the last week in July, it is still in intensive care.

I mentioned earlier our plans to sink 12 ships at four locations. We were 91.6 percent successful in that effort. The twelfth ship — the grand finale with all the media fan-fare we could muster — had to be the exception. Something called a low pressure system popped up and took that hulk for quite a ride before swamping it nearly 30 miles from the intended site. It's just about seven miles offshore in 60 feet of water — right in the center of one of the better white-shrimp grounds near Freeport.

Since marking is required and our experience with the buoys was not the best, we decided to put the light on a tripod tower mounted to the deck of the ship. About 30 feet of water above the deck wasn't all that much. A 45 ft. tower was installed with a light, fog signal, battery box and solar charging panel at a cost of $46,000. That included a rental of temporary buoy while the tower was being fabricated, and six spherical mooring buoys to reduce the temptation to tie up to the tower.

The mooring buoys lasted but a few months. Even an inexperienced diver could free one of them at a depth of only 30 to 35 feet. The tower lasted over a year; but in time, was laid over on the deck by unidentified forces. It has been extended to compensate for settling of the ship, with wider foot spacing to distribute forces better, and has been in operation for about eight months now.
Some of our buoy costs may be exceptional. Due to the currents in the western Gulf, the buoy from the Port O'Connor reef was carried into Mexican waters when it was detached. It was located in a Mexican Navy Yard at Vera Cruz. The telephone bill for calls to the Embassy in Mexico City was almost as much as the costs to have it trucked back across the river. Recovery of one buried in the sands of Padre Island was more expensive for us.

Let me then summarize the costs for the five locations in Texas. I'll not break down each item, but lump various costs by sites to get a comparison and some averages.

The attached table is accurate as of the end of July, but not as of 1 September. As shown, the original cost of a complete buoy was $11,500 in a lot of four. This included the five mile light with flasher and bulb changer, daylight switch, 1/2 mile sound signal, two packs of batteries calculated to power the light and horn for one year, identifying markers on the daymark, bridle, and full shot of 1 1/8 inch stud-link chain.

For reference purposes, a replacement lantern costs about $400. The battery packs run around $1,200. The sound signals are about $2,550 each. Bridle and chain (one "shot" or 15 fathoms) costs about $1,800. The largest item in buoy maintenance has been the service required to transport buoys and divers to reattach them on location.

Using professional hard hat divers necessitates tenders, decompression chambers, pumps, etc., and therefore, a larger vessel. In a couple of instances, we've had to rent a boat and a cherry picker to put aboard it in order to be able to pick up the fully equipped buoy. Weight of the buoy runs about three tons.

The question then arises as to why we did not enter into a service contract and turn all these problems over to someone else. We did, of course, consider this. In 1975, about the time the first buoy was put in service, we accepted proposals.

The best offer at that time was for a $1,600 per site per month charge to provide quarterly inspection and routine maintenance. Annual replacement of batteries and any repairs occasioned by damage or vandalism would have been additional. A $75 per hour plus travel expense for personnel and all replacement parts added to that just didn't seem appropriate. It now appears we made the right choice, since our problems have largely been in that last category anyway.

I guess I can best summarize by saying that, in deep ocean water, buoys are not cheap. After a period of time, they may not be necessary. Careful consideration of all factors should precede a commitment to install and maintain such buoys.
Table 1.
Marker Costs Per Month at Five Texas Sites

South Padre Island Site

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Buoy</td>
<td>$11,500</td>
</tr>
<tr>
<td>Repairs, etc.</td>
<td>7,951</td>
</tr>
<tr>
<td>Replacement Buoy</td>
<td>16,975</td>
</tr>
</tbody>
</table>

$36,426 ÷ 46 months = $791.87

Port Aransas Site

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Buoy</td>
<td>$11,500</td>
</tr>
<tr>
<td>Repairs, etc.</td>
<td>12,016</td>
</tr>
</tbody>
</table>

$23,516 ÷ 40 months = $587.90

Port O'Connor Site

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Buoy</td>
<td>$11,500</td>
</tr>
<tr>
<td>Repairs, etc.</td>
<td>21,219</td>
</tr>
</tbody>
</table>

$32,719 ÷ 39 months = $838.95

Freeport Site - offshore

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Buoy</td>
<td>$11,500</td>
</tr>
<tr>
<td>Repairs, etc.</td>
<td>44,519</td>
</tr>
<tr>
<td>Replacement, etc.</td>
<td>8,487</td>
</tr>
</tbody>
</table>

$64,506 ÷ 37 months = $1,743.40

Freeport Site - onshore

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary Buoys</td>
<td>$26,210</td>
</tr>
<tr>
<td>Original Tower, etc.</td>
<td>46,431</td>
</tr>
<tr>
<td>Rebuilt Tower, etc.</td>
<td>31,300</td>
</tr>
</tbody>
</table>

$103,941 ÷ 31 months = $3,352.94

Buoy only - 4 sites    | $157,167 ÷ 162 months = $970.17
Buoy & Tower           | $261,108 ÷ 193 months = $1,352.89

Note: Costs through July 1979. Freeport replacement includes recovery, reconditioning, resetting original buoy from South Padre Island site.
The BL-826, BL-620 and BL-717 buoys are excellent rugged markers for underwater obstructions and navigation channels. They can easily be equipped with sound signal apparatus.

The buoy bodies are made of ¼ inch steel plate. Eyes for the bridle moorings are welded to the buoy bodies. When properly moored, the buoys will withstand hurricane force winds and seas.

Note: Standard buoy does not include lantern, batteries or mooring. (Bridle is included)

Steel buoys standard finish: sandblast outside after fabrication, Dimetico type D-6 Coating; one coat primer, one coat vinyl color.

<table>
<thead>
<tr>
<th>Specifications:</th>
<th>BL-620</th>
<th>BL-826</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>19'7&quot;</td>
<td>26'0&quot;</td>
</tr>
<tr>
<td>B</td>
<td>9'0&quot;</td>
<td>10'9&quot;</td>
</tr>
<tr>
<td>C</td>
<td>10'7&quot;</td>
<td>15'3&quot;</td>
</tr>
<tr>
<td>D</td>
<td>1'11&quot;</td>
<td>2'5&quot;</td>
</tr>
<tr>
<td>E</td>
<td>7'7&quot;</td>
<td>11'11&quot;</td>
</tr>
<tr>
<td>F</td>
<td>6'0&quot;</td>
<td>8'0&quot;</td>
</tr>
<tr>
<td>G</td>
<td>2'4&quot;</td>
<td>3'7&quot;</td>
</tr>
<tr>
<td>H</td>
<td>1'10&quot;</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Bridle (size)</td>
<td>1¼&quot;</td>
<td>1¼&quot;</td>
</tr>
<tr>
<td>Recommended Moorings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anchor, concrete</td>
<td>5,000 lbs.</td>
<td>6,500 lbs.</td>
</tr>
<tr>
<td>Chain size</td>
<td>1¼&quot;</td>
<td>1¼&quot;</td>
</tr>
<tr>
<td>Chain length</td>
<td>2 -- 4 times water depth</td>
<td>2 -- 4 times water depth</td>
</tr>
<tr>
<td>Body Material</td>
<td>¼&quot; steel</td>
<td>¼&quot; steel</td>
</tr>
<tr>
<td>Pounds/Inch Immersion</td>
<td>150 lbs./in.</td>
<td>270 lbs./in.</td>
</tr>
<tr>
<td>Reserve Buoyancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight, less mooring</td>
<td>3,450 lbs.</td>
<td>7,600 lbs.</td>
</tr>
<tr>
<td>Day Mark height</td>
<td>8'0&quot;</td>
<td>11'10&quot;</td>
</tr>
<tr>
<td>Day Mark area</td>
<td>7 ft.²</td>
<td>17.5 ft.²</td>
</tr>
<tr>
<td>Recommended optional equipment</td>
<td>FA-249</td>
<td>FA-249</td>
</tr>
<tr>
<td>Lantern Batteries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry primary</td>
<td>12V, 2,000 ah</td>
<td>12V, 4,000 ah</td>
</tr>
<tr>
<td>Wet primary</td>
<td>12V, 6,000 ah</td>
<td>12V, 6,000 ah</td>
</tr>
<tr>
<td>Rechargeable</td>
<td>12V, 1,000 ah</td>
<td>12V, 2,000 ah</td>
</tr>
<tr>
<td>Sound Signal</td>
<td>SA-850/1A</td>
<td>SA-850/1A</td>
</tr>
</tbody>
</table>

Figure 1. Buoy used in Texas project.
THE ELECTRODEPOSITION OF MINERALS IN SEA WATER FOR THE CONSTRUCTION AND MAINTENANCE OF ARTIFICIAL REEFS

Dr. Wolf H. Hilbertz

Introduction

Sea water contains nine major elements: sodium, magnesium, calcium, potassium, strontium, chlorine, sulfur, bromine, and carbon. These elements comprise more than 99.9 percent of the total dissolved salts in the ocean [1]-[4]. The constancy of the ratios of the major elements throughout the oceans has long been well known [5]. In 1837, following the work of Davy on the protection of iron by zinc anodes, Mallet demonstrated that zinc so used became covered with a thick layer of zinc oxide and calciferous crystals which blocked the zinc surface [6], [7]. In 1940 and 1947, G. G. Cox was issued U.S. Patents No. 2 200 469 and No. 2 417 064, outlining methods of cathodic cleaning and protection of metallic surfaces submerged in sea water by means of a direct electrical current. During the cleaning process, a coating is also formed cathodically, consisting of magnesium and calcium salts [8]. If this coating is hard and continuous, it affords a considerable degree of corrosion protection to the enclosed metal [9], [10]. Lower marine organisms utilize the minerals in solution surrounding them to build structural formations. Mollusk shells, for instance are generally composed of calcium carbonate crystals enclosed in an organic matrix. A significant proportion of the soluble protein of the matrix is composed of a repeating sequence of aspartic acid, separated by either glycine or serine [11].

This sequence, comprising regular repeating negative charges, could bind Ca\(^{2+}\) ions and thus perform an important function in mineralization of the template [11].

Although impressed current produced CaCO\(_3\)/Mg(OH)\(_2\) formations were precipitated since the 1940's, these were never thought of as possible reef building components until recently. Consequently, only very few publications outline structural testing of these materials, describe experiments and techniques using the electrodeposited material for a wide variety of structural purposes, and report on the possible suitability of the material as a substrate for biological growth in mariculture facilities and as a primary construction material for same [12]-[22].

Large-scale studies with galvanized iron mesh cathodes and iron/lead anodes immersed in sea water have provided evidence for the role of electrochemical processes in the accretion of minerals [18]. A preliminary qualitative model for these processes has been proposed (Figs. 1, 2).

The Marine Resources Company, Austin, Texas and the University of Texas at Austin, Austin, Texas.
Artificial Reefs

It has long been evident that substrates to which marine organisms can attach themselves and/or find shelter within, attract fish populations.

The oldest recorded establishment of artificial reefs dates back to the early 1800's [23]. Since the early 1950's American marine fishery interests have been investigating the possibility of using artificial reefs as management tools for manipulation of fish populations [24], [25]. Calculations of fish populations or artificial reefs as compared with control areas or before reef placement showed increases of between 3 to 16 times [26]-[28]. Since the choice of material determines to a large extent transportation, construction, and maintenance cost of artificial reefs and their design, this factor becomes very important.

Preliminary investigations indicate that the mineral accretion process produces a very suitable substrate for marine growth and, at the same time, a strong primary building material [18], [19]. Accreted wire mesh components also present a reduced profile, compared to solid components which reduces resistance to water currents, thus increasing stability while offering open volumes and entrances for shelter to marine organisms.

Placement of steel mats or wire mesh as an artificial substrate in areas predominated by soft, fine-grained sediments has been suggested [29]. Accordingly, the use of accreted wire mesh may be particularly well suited for these areas.

Two artificial reefs were constructed and placed in Tague Bay, St. Croix, in August 1976. These constructions were built to determine the parameters of the electrodeposition process onto large surfaces as substrate for marine growth, and to support the hypothesis that wire mesh formations covered by electrodeposited minerals can support marine communities that are usually found inhabiting natural reef formations [18]. Both of these reef components were placed in shallow waters approximately 8' deep, on relatively barren and sandy substrate with small amounts of seagrass (Thalassia) present. Direct electric current was supplied intermittently to the reef components by an unregulated power supply in the range of 3-16V/10-40A.

Reef I consists of an assembly of regular and irregular shapes constructed with wire mesh of different gauges a total surface area of 253 ft.² (Fig. 3). Overall dimensions of the reef are 4' by 12.67' by 3'. Average accretion thickness on the wire mesh is 3/8" with thickness in some areas up to 3 in. Fish censuses preformed 42 months and 15 months after placement indicated 127 individuals (5 species), and 483 individuals (19 species), respectively. The most dominant fishes were medium-sized grunts, parrot fish, and damsel fish.

Twenty hours after submersion white accreted material was visible on all surfaces of the structure. Seventy-two hours after submersion diatomaceous and blue-green algae growth was observed on the outer
Figure 1
ELEVATION
1/2'-1'-0'

PLAN
1/2'-1'-0'

SURFACE AREA

1" x 2" MESH 141\(\frac{1}{4}\) SQ. F.
1/2" MESH 58\(\frac{3}{4}\) SQ. F.
1/4" MESH 33\(\frac{1}{3}\) SQ. F.
1/8" MESH 18\(\frac{3}{4}\) SQ. F.

Figure 3
surface of the structure, gradually covered all surfaces, and had reached a length of 8 cm, 280 h after inhabiting the structure. The first sample of the electrodeposited material was taken 437 h after the start of electrodeposition (Table I, Sample 33); the second sample was taken 1991 h after the start of electrodeposition and 1508 h after the power supply was disconnected (Table I, Sample 95). Mineral deposition thickness on 1" by 2" mesh measured 5.4 mm (diameter of metal wire = 1.75 mm) after 480 h of electrodeposition, consumption of electricity is shown in Fig. 4. The temperature of the electrolyte ranged between 82° and 88° F. The anode consisted of a cast iron 7' OD metal pipe with a length of 9' 2", and was placed parallel to the cathode at a distance of 4' 0" on sandy ground.

A moderate input of electrical power provided a mineral substrate that allowed rapid diatomaceous and blue-green algae growth which, possibly in connection with the availability of protected spaces, attracted various fish populations. The electric field between anode and cathode did not negatively affect algae growth, as was clearly established by the observation of an electrodeposited control sample without electric field under identical conditions.

Inhabiting fish populations visibly were not affected negatively by the electric field; individual animals moved freely in and around the structure.

Preliminary conclusions from X-ray diffraction analysis show, that, after a phasing sequence, the crystalline structure of the accretion matrix becomes more apparent. Peak intensities and breadths indicate more well-ordered crystals and less non-crystalline material.

Reef 2 consists of identically folded wire mesh, formations of two different gauges with a total surface area of 144 ft². Overall dimensions are 7.5' by 7.5' by 6'.

The anode consisted of a cast iron 6 3/4" OD pipe with a length of 7' 3" and was placed under the reef (Fig. 5).

Fifteen hours after submersion white accreted material was visible on all surfaces of the structure. Seventy-two hours after submersion the same growth as on Reef I was observed covering the entire structure and reaching a length of 8 cm, 190 h after submersion. Schools of small fish were observed grazing off the growth and inhabiting the structure.

Consumption of electricity is shown in Fig. 6. One material sample was taken 413 h after submersion (Table II, Sample 32). Mineral deposition thickness on the 1" by 2" wire mesh measured 6.2 mm (diameter of metal wire 1.75 mm) after 485.5 h of electrodeposition.

Fish censuses performed 4½ months and 16½ months after placement indicated 92 individuals (6 species) and 142 individuals (14 species), respectively. Again, the fish population was dominated by grunts, parrot fish, and damsel fish.
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Brucite</th>
<th>Aragonite</th>
<th>Calcite</th>
<th>Halite</th>
<th>Quartz</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>taken 437 hrs after power initialized</td>
<td>50%</td>
<td>10%</td>
<td>4%</td>
<td>-</td>
<td>1%</td>
<td>35%</td>
</tr>
<tr>
<td>95</td>
<td>1508 hrs after disconnect</td>
<td>98%</td>
<td>2%</td>
<td>trace</td>
<td>trace</td>
<td>trace</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table I

Figure 4
ELEVATION

$1/2^1 - 1/0^1$

CATHODE CONNECTION

$1/2^1$ MESH

$1'' \times 2''$ MESH

ANODE CONNECTION

$7'' - 6''$

PLAN

$1/2^1 = 1 - 0^1$

$6^{3/4''}$ O.D. METAL ANODE

Figure 5

ARTIFICIAL REEF 2
Artificial Reefs 3A and 3B were built to determine to what degree the electrodeposited minerals on wire mesh formations enhance the development of marine communities, and to what degree the wire mesh formation simply acts as an attractant. Two reef components were constructed and submerged in August 1977, in Tague Bay. Both components are identical in size and construction, each consisting of folded plate \( \frac{1}{2} \)" galvanized wire mesh formations on a wood frame, having a total mesh surface area of 192 ft\(^2\) and overall dimension of approximately 19.5' by 4.5' in height (Fig. 7).

Both components are situated in a water depth of about 15' on relatively barren, sandy bottom with small amount of seagrass (Thalassia) present. One component (Reef 3A) is supplied with dc from an unregulated power supply in the range of 6-12 V/10-20A; the other component (Reef 3B) is not under power, thus acting as a control since no electrodeposition occurs, and is situated 265' from Reef 3A. Floral and faunal censuses were taken every 6 weeks at both the accreting reef and the control reef. Fish counts taken 6½ months and 8 months after placement of Reef 3A indicated 17 individuals (8 species) and 33 individuals (8 species), respectively. Fish counts taken at the same time of Reef 3B indicated 33 individuals (10 species) and 16 individuals (7 species). More than 39 spiny lobsters (Panulirus argus) were seen in Reef 3A, while none were seen in Reef 3B, 8 months after placement.

Reefs 4 and 5, two larger artificial reefs, that utilize the mineral accretion process, were built and submerged in Corpus Christi Bay in water depth of about 12' on sandy bottom and 6 mi offshore Port Aransas in a water depth of about 60'. The two reef assemblies are supplied with dc each by a 600-W wind-driven alternator, facilitating the utilization of locally available energy (coastal winds). The wind-driven units are located on platforms near the reefs.

Each reef assembly consists of 10 folded plate \( \frac{1}{4} \)" galvanized hardware cloth components having overall dimensions of 3' 0" by 4' 0" by 10' 0". (Figs. 8, 9).

Total surface area of the hardware cloth used in each assembly is 2000 ft\(^2\). The components were arranged uniformly over an area measuring 46' by 18' on the sea floor (Fig. 10).

The reef sites with widely varying characteristics were selected on the Texas Gulf Coast. One criterion was the availability of platforms in close proximity to mount wind-driven DC generators. The other, that one reef site was representative of shallow bay waters and one reef site representative of deeper offshore waters.

**Sites for Reef 4 and Reef 5**

Site Reef 4: This site is located at latitude 27° 48' and longitude 97° 10' in Corpus Christi Bay, State tract 397, next to a platform owned and operated by Atlantic Richfield Co. The average depth of the mudline is 8 ft. (Fig. 11).
ARTIFICIAL REEF COMPONENT NO. 3

FOLDED HARDWARE CLOTH CONSTRUCTION

NOTE: CONTROL REEF 3B IS IDENTICAL EXCEPT FOR ANODES AND ANODE / CATHODE CABLES

WOODFRAME: 2\" x 4\" FIR NAILED, MESH FASTENED WITH NAILS

ELEVATION

1/4 = 1'-0"

1/16\" x 6\" x 9\" LEAD ANODE
2\" x 2\" WOOD STRUT
2\" x 4\" WOOD FRAME
ANODE CABLE AWG 14 COPPER
CATHODE CABLE AWG 14
1/2\" HARDWARE CLOTH (GALV.)
192 sq. feet
19'-6"

PLAN

1/4 = 1'-0"

1/16\" x 6\" x 9\" LEAD ANODE
2\" x 2\" WOOD STRUT
ANODE CABLE AWG 14 COPPER
CATHODE CABLE AWG 14 COPPER
1/2\" HARDWARE CLOTH (GALV.)
192 sq. feet
2\" x 4\" WOOD FRAME

Figure 7
ARTIFICIAL REEF 4 AND 5
TYPICAL COMPONENT 200 sq. ft.
1/2" GALV. HARDWARE CLOTH

FOLDING PLAN
ELEVATION
3/4" = 1' - 0"

ACCESS HOLE • NO SCALE

Figure 9
ARTIFICIAL REEF 4 AND 5
10 COMPONENTS 200 sq. ft. ea.
1/2" GALV. HARDWARE CLOTH

PLAN
1'8" = 1' - 0"
STAKE

ELEVATION 'A'

ELEVATION 'B'

Figure 10
NORTH ELEVATION
SCALE: \( \frac{3}{4} " = 1'-0" \)

PURPOSE: RESEARCH STUDY ON
ARTIFICIAL REEF MATERIAL

OWNER OF EXISTING PLATFORM:
ATLANTIC RICHFIELD COMPANY

PROPOSED ARTIFICIAL REEF
IN CORPUS CHRISTI BAY
IN "STATE TRACT" 397
NUECES COUNTY STATE: TEXAS
APPLICATION BY V.L.F. HILBERTZ
MAY 1, 1976

Figure II
Site Reef 5: This site is located at latitude 27° 45' 15" and longitude 96° 59' 28" off Mustang Island, State tract 747-L next to a platform owned and operated by Energy Reserves Group, Inc. The average depth of the mudline is 62 ft. (Fig. 12).

Arrangements with Atlantic Richfield Co. and Energy Reserves Group were made to use the platforms as a base for the wind-driven dc generator units.

**Design of Artificial Reefs 4 and 5**

The substrate material for mineral accretion reefs has to be conductive and fairly structural. For these reasons ½" galvanized hardware cloth was chosen.

Design criteria included:

a. maximize surface area of substrate material used
b. use modular construction
c. use simple and effective joining techniques
d. provide sufficient structural strength of the components
e. develop a design that allows assembly of reef components on land, boat, or barge and submersion as an entity.
f. provide for the use of locally available power to facilitate the mineral accretion process
g. provide constant electrical power through the use of a specifically designed circuit and wind-driven generator
h. marinize all hardware

A relatively light artificial reef component resembling a folded plate beam was designed. This component, through modular coordination, can be handled by two workers. The total surface area of each component measures 200 sq. ft. All connections were designed to be made with tie wire or hog nose rings. The electric circuit was designed and tested (Fig. 13).

**Placement of Artificial Reefs 4 and 5**

Reef 4: The preassembled reef consisting of ten components described earlier was lowered into the water in scissor-like fashion from a barge and positioned on the sea floor on October 10, 1978. It was connected to a wind-driven generator plant located at the top of the neighboring platform at a height of about 50 ft. by two AWG 6 insulated multistrand copper cables with a length of 120 ft. each. The peak output of the wind-driven generator is 600W direct current, average output 120-360W at 12 V in winds ranging from 15-25 knots per hour.

Reef 5: The reef was preassembled on the boat and flotation devices were fitted. It was lowered into the water and positioned floating above the selected site. Two nylon ropes extending from the neighboring platform were fastened to the reef assembly. The flotation devices were deflated and the reef was positioned on the sea floor.
Figure 12

PURPOSE: RESEARCH STUDY ON ARTIFICIAL REEF MATERIAL

OWNER OF EXISTING PLATFORM: ENERGY RESERVES GROUP, INC.

PROPOSED ARTIFICIAL REEF

CSD: MUSTANG ISLANDS

IN MUSTANG ISLAND LEADING AREA

TRACT 747 L OFFSHORE TEXAS

APPLICATION BY WOLF HILBERT

SHEET 1 OF 1 DATE: 6/5/18
It was connected to a wind-driven generator plant identical in output to the one used for Artificial Reef 4 and erected on the middle deck of the neighboring platform with 150 ft. of AWG 6 insulated multistrand copper cable.

Two 8-lb. lead anodes were positioned approximately 30' from the reef in Corpus Christi Bay, and approximately 90' from the reef offshore.

These reef formations, once accreted, will represent a considerable reduction in transportation and material costs when compared to concrete block or tire reefs, as the bulk of the material (substrate for marine growth and shelter) is assimilated on the site. In addition, the initial layer of electrodeposited material presents corrosion of the wire mesh template.

Underwater Sculpture

An underwater sculpture, doubling as an artificial reef, was built and submerged during April, 1979, outside of Tague Reef, St. Croix, U.S.V.I. (Figs. 14, 15, 16).

The central shaft is of double-layer construction, consisting of 1" by 1" galvanized hardware cloth with 2 inch spacing. Twelve ballast tanks consisting of a single layer of 1 inch galvanized hardware cloth are fastened to the central shaft.

Direct electrical current is supplied by 20 photovoltaic panels with a peak output of 3.8V/2.5A each. These panels are mounted on a metal rack in the vicinity of the structure. No accretion data are available at the present time.

Testing of Mechanical Properties

Twenty samples of electrodeposited minerals obtained on 1/4" galvanized hardware cloth in Port Aransas and St. Croix, were prepared and tested at the University of Texas Structural Testing Laboratory. Following standard procedures for concrete testing, compression forces were recorded at the point of breakage [25]. For comparison, concrete that is typically used for stairs and steps, sidewalks, driveways, slabs on grade and basement wall construction (probably 28th day strength, normal Portland cement Type 1, 15 percent less than recommended by ACI Joint Committee) breaks at about 3500 psi [30].

Summary and Conclusions

Electrochemical accretion of minerals in sea water and other media appears to be as old as life itself and seems to have proven its worth during evolutionary time. Construction, maintenance, and destruction technologies as used at the present, are mainly brain children of the first industrial revolution with built-in limits [12]. Example given: A concrete or steel element in sea water, once broken or decayed, is
20 PHOTOVOLTAIC PANELS 1 FT. BY 2 FT. ON STEEL PROFILE RACK 11FT. BY 5FT. BY 10FT.

UNDERWATER SCULPTURE OFF TAGUE REEF ST. CROIX, U.S. V.I.

SITE PLAN 2 SHEET 2 OF 3
WOLF H. HILBERTZ

Figure 15
MATERIALS
Cylinder A consists of a double layer of 1\" hardware cloth with 1\" spacing.
All other cylinders consist of a single layer of 1\" hardware cloth.

PLAN

ELEVATION

UNDERWATER SCULPTURE
OFF TAGUE REEF
ST. CROIX, U.S.V.I.
SHEET 3 OF 3
WOLF H. HILBERTZ

Figure 16
Useless because it cannot meet its design specifications unless it is repaired. In most cases repair necessitates removal from the site and repositioning, thus incurring unreasonably high cost.

An element produced by electrodeposition, however, can be repaired or reconditioned in situ after failure. With renewed electrical power input the same conditions and resources which formed the element initially can be utilized again. This characteristic is not found in any commonly used construction method or material. Conversely, when, for instance, a reinforced concrete volume is cured and has left the form, its structural and formal characteristics can be altered only by major operations. Thus strict limits concerning the element's adaptability to changing conditions in situ are enforced.

Other applications for the electrochemical accretion process can be seen readily: floating habitats and industrial islands, settlements on banks, shoals, and the continental shelves, mariculture facilities, breakwaters, storage tanks, dams and jetties, pipelines, bridges, tunnels, airports, beach solidifications and accretions, current diverters, building components for use on land, sea walls, marinas, atoll closures, and power as well as sedimentation generating facilities.

Structures, while accreting, can double as artificial reefs. Thus a combination of aquaculture facilities and building component plants is envisioned.

Building components can be accreted at greater depths and be designed and calibrated in such a way, that, when surfaces are closed by the electrodeposited materials, accumulated hydrogen, oxygen, or chlorine gas provides uplift and "mature" components can be harvested at the water surface. In a similar way building processes can be designed that allow structures to "grow" out of the electrolyte.

Movable articulated form generators can be designed to produce a variety of configurations continuously by unspooling or weaving of cathodic material formations. These devices can "ride" on the generated profiles of pipes, anodes can be integrated in the generator or positioned independently in the vicinity of the form to be accreted. Energy requirements for the electrodeposition of minerals in sea water generally vary between 0.4 and 2 kW for 1 kg of accreted mass, depending on various parameters. Solar energy in its various forms can be harnessed everywhere to meet these requirements. The medium for construction, maintenance, repair, and reclamation of structures produced by the mineral accretion process covers 70.8 percent of the earth and thus represents a major resource for building in the oceans.

Furthermore, plasticity, a major principle in organic evolution, has to be maintained and augmented in order to ensure valid developments within the context of a continuously evolving world [13]. To this the process described above can contribute.
Summary and Conclusions

Electrochemical accretion of minerals in sea water and other media appears to be as old as life itself and seems to have proven its worth during evolutionary time. Construction, maintenance, and destruction technologies as used at the present, are mainly brain
REFERENCES


RAPPORTEUR'S REPORT

Dr. Fred A. Kalber

I had something running through my mind yesterday morning to the effect that I was going to stop agreeing to summarize. This assembly, however, changed my mind about that and a number of other things. I never felt I couldn't be further educated, and that conviction stood me in good stead during this meeting. More than anything else, it's given me some new perspectives about artificial reefs, as I'm sure it has you.

We at the Bayboro, Florida, Laboratory thought that an early engagement with artificial reefs was one of the first. But I found to the contrary in 1977, when we had a reef conference in St. Petersburg, that Corps of Engineers records show that artificial reefs have been constructed since 1896.

It's exceptionally difficult to easily put together an integrated summary of the extremely sophisticated and well-tuned technology that we heard about this morning. I usually try to avoid going 1, 2, 3, 4, however, I think it's going to be a better treatment for you of what we've heard this morning if I do a little bit of that.

We started with the air full of feathers and we ended with the water full of fish in some very meaningful ways. I think that what we heard from Jim Brown and several others today is an extremely important thing to keep in mind -- an echo from yesterday in effect -- and that is you are in a people business in a hurry if you get into artificial reefs. Environmentalists say it's done for the benefit of fish, but way down deep, we all know that it's folks you've got in mind. Jim Brown's program for example, has done an excellent job of bringing attention to that. Mr. Talley reminded us that Goodyear does more than photograph the Superbowl game from a blimp. They and other industries have, in fact, been heavily engaged in the artificial reef business for a long time. They see a great many multifold and integrated advantages in this. I think everyone should be happy to see that their interest is being carried with the kinds of research and technical development that they're putting into artificial reef engineering.

Sinking ships was made to seem deceptively easy by a number of people today. This procedure for creating productive reefs has reached a level of elegance, as you heard, in projects off Mississippi and Texas, and many other places. As I was making some mental comparisons between the incredible number of things that you can put under water to serve as reefs, sinking ships seems to be a very efficient way considering the enormous amount of surface area that you get with relatively high levels of cost effectiveness, and efficiencies of motion and engineering.

Georgia Sea Grant Program, Athens, Georgia
Lonnie Ryder brought up the issue again of public profile in reef building. I want to emphasize his remarks for you in a very careful way. I don't intend to repeat what Lonnie said, for I couldn't do it so well, but to tell you that there is a very delicate connection between selecting substance for your reef and good public relations. You have heard this several times today, I would like to emphasize it.

Innovation is important in a great many directions. For instance, big oil has gotten into the reef business. Dr. Ditton told us about how and why they're there by excellent examples of the use of industrial operational hardware and its offal, when pumping is through, toward human and ecological welfare. This is a thing that I think has been ignored by many people interested in ecological restitution. Not just in tire technology, but in many ways, the private sector is extremely interested in working with you. They need direction in many cases, and they are clearly getting it from people such as Ditton and others.

I think Dr. Hilbertz excited us all by showing that not only can you put another new thing in place for reefs that will be attractive to fish and people, but you can also gold-plate it if you like. The addition of Hilbertz's electrolysis technology, and I hasten to think of another word for it because it's as much art as it is engineering, I feel is a high point in the history of artificial reefs or environmental treatment. A procedure that uses all that energy blowing in the wind, and that coming from our nearest star, to help the underwater picture I think deserves a great deal of credit and attention. I'm going to get back to that a little bit later.

Mr. Delmonico gave you, I think, the first Mother Earth News approach to making artificial reefs that I've heard -- a do-it-yourself kit -- amaze your neighbors by doing it in your back yard! In fact, this brings a new dimension, in a very important sense, to artificial reefs by showing that it's not necessary to lose as much money as Howard Lee has. Reefs can be made on a shoestring, with those important ingredients of human involvement and interest.

Guidelines to be used in reef construction have become highly sophisticated and show what I'm calling elements of elegance. These now pay attention not only to matters of complex engineering and cost effectiveness, but also to human attitudes, involvements and needs. There is a very pervasive drive to do the best job possible to fulfill the aims of the guidelines, and so achieve goals that will satisfy a broad range of requirements that extend from effective operation to aesthetics. As a mark of this development, it seems that the time has come to write manuals that will tap the results of your experiences and hard work to aid others. I think that if the noted anthropologist Margaret Mead could have heard what I have today, she might say, as she did of some Pacific cultures, that artificial reefs have come of age. Thank you.
THIRD TECHNICAL SESSION

Reef Program Evaluation and Management

Moderator:  Mr. Jerry Sansom
Organized Fishermen of Florida
Melbourne, Florida

Speakers:    "Social and Economic Data Needs for Reef Program Assessment"
Mr. Alan R. Graefe
The Texas A & M University System
College Station, Texas

"Ecological Considerations Influencing the Management of Reef Fishes"
Dr. Gene R. Huntsman
National Marine Fisheries Service
Beaufort, North Carolina

"Artificial Reef Expansion and Use Issues"
Mr. Henry Ansley
Georgia Department of Natural Resources
Brunswick, Georgia

Rapporteur: Dr. John W. Merriner
Virginia Institute of Marine Science
Gloucester Point, Virginia
SOCIAL AND ECONOMIC DATA NEEDS FOR REEF PROGRAM ASSESSMENT

Alan R. Graefe

Introduction

From a socio-economic perspective, the evaluation of artificial reef programs is concerned with determining who uses the reefs and what benefits they receive, in relation to what costs have been incurred by the program. Most reef assessment studies have focused on identifying the amount of use a given reef site receives and the expenditures associated with this use. Underlying objectives for these reef assessments have typically included program justification through the establishment of positive economic impact and improved reef management as a result of better understanding of users and their use patterns. Ultimately, the real payoff from this type of research comes in the form of more efficient and equitable provision of opportunities in future reef deployments.

Several authors have noted the relative scarcity of socio-economic considerations in the technical literature on artificial reefs (Daniel, 1976; Ditton, 1979). However, the collection of social and economic data for marine recreational fisheries management has received considerable attention in recent years (Centaur Associates, Inc. 1979; Cato et al., 1978). Previous treatments of data needs in this area have tended to be quite general in nature, yielding data need priorities or rankings of importance. At the same time, recent methodological studies have sought to identify cost-effective approaches for collecting social and economic data from fishermen (Brown, 1977; Chandler, 1977; Hett and Ghosh, 1977; Metze, 1977).

Since artificial reef management can be viewed as a particular kind of fisheries management, we can apply much of this recent work to the subject of artificial reef assessments. This paper will attempt to summarize the general findings available from previous studies and focus them on the unique problems and situations associated with reef assessments. The first part of the paper identifies types of social and economic information that can provide useful inputs for reef deployment and management decision-making. Some findings of a recent study in Texas are presented to illustrate applications of the information. The second half of the paper deals with how this information can be collected and analyzed. Particular attention is devoted to issues involving sampling assumptions and problems, alternative data collection instruments, and the ability of fishermen to accurately estimate and recall pertinent information.

Social and Economic Data Needs

Participants in the recent workshop on social and economic data needs for marine recreational fishing found that socio-economic data can be helpful in making the following types of management decisions: policymaking,
resource allocation, defining marine recreational fishing, establishing budgets, selecting alternative regulations or management measures, and developing enforcement strategies (Centaur Associates, Inc., 1979). It should also be recognized that some social and economic information requirements are implied by law. The Fisheries Conservation and Management Act of 1976 mandates that allocation of fishing resources among user groups be equitable and efficient (Centaur Associates, Inc., 1979). Fisheries Management Councils created by this act are expected to select courses of action that will lead to the most good for the most people (Cato et al., 1978). Anderson (1975) adds that socially successful management provides a variety of recreational fisheries to create an opportunity for choice. The equity and efficiency criteria require that the economic value of fishing be understood and that fishermen and potential fishermen populations be identified and studied. Accordingly, data for estimating the economic value of and demand for recreational fishing was assigned the highest priority by participants at the data needs workshop (Centaur Associates, Inc., 1979).

Several previous studies have examined the economic impacts of marine recreational fishing (e.g., Daniel, 1974; Ditton et al., 1979; Hoffman and Yamauchi, 1973), although few have focused specifically on the economic influences of artificial reef fishing (Liao, 1978; Daniel and Seward, 1975). Considerable evidence exists documenting how much fishermen spend and how they spend it, but less attention has been directed at specifying what increment in expenditures should be attributed to artificial reefs and where that money would have been spent in the absence of the reefs.

Daniel (1976) pointed out that it is only prudent to try to establish the economic feasibility of reefs prior to the expenditure of additional public funds and further warned that benefits and costs are relative to the makeup, identity, and objectives of the groups involved. That is, benefits occur only if reefs are used, and benefits to one group may be costs to another group. The most direct beneficiaries of artificial reefs are fishermen and local merchants of fishing related services and equipment, although other sectors of the economy also benefit as a result of responinding effects. Net benefits to the local area are best measured by the increased local expenditures that can be attributed to the reef, but it should be recognized that local benefits are offset by negative effects in non-local areas where the money would otherwise have been spent (Daniel, 1976). The methodological implication of those observations is that any efforts to measure the economic development benefits of artificial reefs will require as a minimum a multi-year project with repeated surveys of reef fishermen and their spending habits.

Criteria of equity and diversity in fisheries management also require an understanding of the nature of reef use, in addition to amount of use. Knowledge concerning the type of use occurring at alternative reef locations can help decisionmakers select optimum locations for future reefs. As an illustration, a recent study on the Texas coast (Ditton and Graefe, 1978) identified the sizes of fishing constituencies
at various distances from shore and found that distance traveled offshore varied markedly by boat length (Figure 1). There appeared to be a major difference between the distances traveled by 14 to 18 foot boats and boats longer than 18 feet. Eighty-three percent of the offshore fishing boats 14 to 18 feet long did not travel beyond twenty miles during the study year. Conversely, a large majority of all remaining length categories did travel beyond twenty miles, as a maximum distance. Boats greater than 25 feet in length differed from those between 19 and 25 feet primarily by exhibiting an extended range. All categories above 25 feet showed a small number of fishermen traveling greater than ninety miles. Normal distances traveled offshore for fishing demonstrated the same general patterns but also exhibited a shift towards shorter distances overall.

The distance by boat length distributions shown in Figure 1 suggest that, to a considerable extent, different distance zones are attractive to distinct classes of boats. Almost no boats longer than 18 feet normally stayed within 10 miles of shore. This zone attracted a narrow class of small boats that is nonetheless substantial in numbers because these boats constitute forty percent of the offshore fishing fleet in this region. Similarly, distance zones above 20 miles largely excluded boats in the 14 to 18 foot class. The number of boats using the 20 to 30 and 30 to 40 miles zones was also large because 19 to 25 foot boats comprise about half of the boats used for offshore fishing. The 11 to 20 miles normal distance range was the only range to attract a cross section of all boat lengths. This range thus attracted the broadest, as well as the largest, fishing constituency. It should be remembered that these patterns were found to exist within the context of a particular offshore area on the Texas coast and should not be generalized directly to other areas without considering such situational factors as water depth and supply of fishing attractions. Nonetheless, this is the type of information that can be extremely valuable in attempts to forecast the amount of use and benefits likely to be associated with alternative reef locations.

This and other trip data barely scratch the surface of what can be obtained once the relevant population has been identified. Other types of social information which have been assigned relatively high data need priorities include: disposition of catch, sociodemographic data, and attitudinal data (Centaur Associates, Inc., 1979). Information on disposition of catch can help managers identify the benefits of food production from fishing of artificial reefs. Sociodemographic descriptions of reef users and non-users can provide valuable inputs related to equity of alternative reef locations.

Attitudinal data includes motivations for fishing, levels of fishing satisfaction, management preferences, and related concerns. McFadden (1969) was one of the earliest to explicitly recognize the social product of fishing as the aggregate of value which accrues to fishermen from an enriching use of their leisure time. Hendee's (1974) formal statement of the "multiple satisfaction approach" to fish and game management called attention to the need to develop an understanding of what constitutes a quality fishing experience. Many studies have shown that fishermen have numerous motives for fishing, some of which are totally unrelated to the catching of fish (Bryan, 1974; Knopf et al., 1973; Graefe and Ditton, 1976). Such studies have consistently found motives related to
### Figure 1: Distance Traveled Offshore by Fishermen in the Houston–Galveston Region of the Texas Coast, by Boat Length Categories

Percent of Boats Traveling Different Maximum Offshore Distances, by Boat Length Categories

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<thead>
<tr>
<th>Distance (miles)</th>
<th>Boat Length (feet)</th>
<th>14-18 (n=24)</th>
<th>19-25 (n=28)</th>
<th>26-29 (n=116)</th>
<th>30-34 (n=110)</th>
<th>35-39 (n=53)</th>
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Percent of Boats Traveling Different Normal Offshore Distances, by Boat Length Categories

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<th>Distance (miles)</th>
<th>Boat Length (feet)</th>
<th>14-18 (n=22)</th>
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*Some percentages do not add up to exactly 100% because of rounding.

temporary escape from stressful and ordinary situations to be among the most important reasons fishermen give for participating in fishing (Driver and Knopf, 1976). The full managerial implications of these types of studies have yet to be understood, but at the very least it should be recognized that fishermen are not a homogeneous lot seeking a common fishing experience. Modern analytical techniques allow fishing user groups to be segmented according to their motivations or preferences. Lessons learned in the management of other recreational activities suggest that more satisfactory experiences will result from providing a diversity of opportunities to meet the diverse expectations of user groups than from trying to deliver a standard type of fishing experience intended to please everyone all the time (Schreyer, 1976).

Identification of conflicts among user groups received an unjustified low priority ranking at the recent data need priorities workshop conducted by Centaur Associates. Since different people seek different experiences, conflicts are likely to occur between diverse user groups like divers and fishermen and even within single activity groups. Certain types of experiences at a given site can by their very nature preclude others from receiving the type of experiences they desire. As an example, large crowds of boats at reefs or access points may eliminate the possibilities for stress release and solitude that many fishermen seek. The managerial implication of such a situation is that, while reefs should be accessible to fishermen to provide benefits, reefs that are too accessible may produce less satisfactory fishing experiences for reasons in addition to the biological problems that could result from overfishing.

This is an area where management should realize its potential for influencing the situation. Again, experiences gained in managing other activities can provide some guidelines. Gilbert et al. (1972) describe a rough continuum of management tools that range from subtle and manipulative to authoritarian and regulatory. While studies have shown that recreationists tend to prefer manipulative over regulatory tools, they have also shown that managers tend to overestimate the opposition among users to the need for control and regulation (Hendee and Harris, 1970). Management preference studies could help managers formulate objectives concerning the types of experience to be provided and evaluate the tradeoffs between alternative management strategies aimed at meeting these objectives.

Data Collection for Artificial Reef Assessments

Since information must inevitably be obtained from recreational fishermen, the two most important considerations which must be addressed in formulating a data collection approach are: (1) What is the population that must be studied, and how can it be best represented? and (2) What alternative methods can be used to accurately and reliably obtain the necessary data? The first question refers mainly to matters of sampling while the second question leads to evaluation of various data collection procedures and instruments.
Sampling Considerations: Selection of the population to be studied may not be as simple as it appears on the surface. Should the study represent current users of artificial reefs or should it also include those who do not fish reefs? To what extent should divers and other possible reef user groups be represented in study designs? A great deal of managerially useful data could be obtained by focusing on people who would appear to be potential reef users but do not currently use reefs.

If the study is to focus on reef users, it must be determined whether the population can be represented better by on-site sampling or through an area-wide survey. Sampling problems which are inherent in on-site surveys include difficulties in representing and extrapolating to the total population of fishermen (Brown, 1977). These problems are minimized or avoided in small-scale studies in which representative coverage of a wide geographic area and numerous access points is not essential. However, in situations where information is desired on the total number of fishermen and their fishing activity in a large geographic area, Hiett and Ghosh (1977) recommend that on-site sampling be used only in conjunction with area-wide sampling to ensure accurate identification of the total number of fishermen and fishing trips.

Area-wide surveys can include reef users and non-users and can be most effective in cases where some information about reef use is available. For instance, selection of the geographic boundaries of the study area can be facilitated if the origins of fishermen in the area are known (for example, from local creel surveys). Area-wide surveys can provide accurate representation of fishing information for large, previously defined, populations and therefore are advantageous over on-site surveys in which the population remains unknown in large-scale studies. However, a suitable sampling frame must be found to provide access to reef fishermen or potential fishermen and screening procedures may be necessary to find adequate sample sizes. Household blocks, telephone exchanges, and boat registration files have all been used previously as sampling frames in area-wide surveys of recreational fishermen (Brown, 1977; Metze, 1977; Ditton and Graefe, 1978).

At present, it is difficult to identify the population of saltwater fishermen in general, much less artificial reef fishermen. A saltwater fishing license would afford access to a state's saltwater fishing population, but a separate saltwater license does not now exist in any state (Scogia, 1979). National studies (Deuel, 1973; U. S. Department of Interior, 1972) have used screening interviews of a probability sample of telephone households to identify saltwater fishermen, but little socio-economic or area-specific understanding is available from these studies.

State boat registration files may provide one of the most convenient means of gaining access to artificial reef fishermen since most reef fishing is done by boat fishermen and considerable understanding exists concerning boat use patterns. Many studies confirm that type of boat use is related to boat length (Rorholm, 1974; Brown and Noden, 1973). Thus, it is erroneous to assume that all boats in a coastal area are used for saltwater fishing, just as it is erroneous to assume that all
fishing license holders fish in saltwater or fish at all for that matter. As an illustration, Figure 2 represents a distribution of the boat-owning population in the Houston-Galveston region of the Texas coast (Ditton and Graefe, 1978). Data given in Figure 2 are not intended to represent the situation in all coastal regions but are presented to demonstrate fishing attrition rates from a particular full population of boatowners and to illustrate differences between small boats and large boats. It is interesting that, among all boats less than 26 feet in length, 33 percent were used for bay fishing and less than 5 percent were used for offshore fishing. Among all boats 26 feet or longer, 30 percent were used for bay fishing and 29 percent were used for offshore fishing. These portions of the boat-owning population represent potential users of bay and offshore artificial reefs.

Data Collection Procedures: Selection of data collection procedures and instruments is a separate issue, but it is related to sampling design. For an on-site sampling design, face-to-face interviews have been a traditional method for collecting data on recreational fishing. The creel census, in which questioning focuses on fish harvest and fishing effort, has constituted the dominant application of on-site interviewing in fisheries data collection, although it should be recognized that much additional data could be obtained through on-site interviews. Since creel surveys are likely to continue to be necessary for the collection of catch and effort data, they may provide a very cost effective vehicle for the collection of social and economic data as well. It would be wise not to waste the opportunity to gather the additional data, especially because studies have shown that recreationists are not as reluctant to be approached and interviewed as managers often think they are (Hendee and Harris, 1970; Chandler, 1977). In addition, collecting socio-economic and catch-effort data from the same respondents while they are a captive audience will enhance the explanatory and predictive capability of the studies (Centaur Associates, Inc., 1979).

For area-wide sampling designs, data collection instruments have included face-to-face interviews, telephone interviews, mail questionnaires and combinations of these procedures. Metze (1977) identified several refinements in procedures of the telephone interview method and concluded that it was a cost-effective method for screening and obtaining information from fishermen. Mail questionnaires can be even more cost effective when a convenient and suitable sampling frame like a boat registration file reduces the need for screening respondents and in cases where large amounts of social and economic data are sought from respondents.

A wealth of literature exists concerning the relative merits of various data collection procedures (see for example Dillman, 1978 and Potter et al., 1972). Findings of the methodological studies conducted by Human Sciences Research, Inc. reaffirm for recreational fishing studies specifically what social scientist have known for a long time in a more general sense, namely that the choice of the most suitable data collection method depends on the type of data needed and the type of statements to be made on the basis of the study results. Some types of information, including catch and effort, cannot be accurately provided
FIGURE 2: DISTRIBUTION OF GENERAL FISHING LOCATIONS FOR THE POPULATION OF BOAT OWNERS IN THE HOUSTON—GALVESTON REGION OF THE TEXAS COAST

by fishermen (Hiett and Worrall, 1977). Studies which obtain these types of data consequently must use on-site interviewing procedures in which trained biologists can verify the information obtained. Other types of information, including most social and economic variables, can be obtained equally well using a variety of procedures. Therefore, sampling considerations, which determine the types of inferences and generalizations that can be made from the findings, should usually be the final criterion in selecting an optimum approach for social and economic assessments.

If several methods seem equally appropriate, a further selection criterion may be the cost-effectiveness of the various alternatives. However, alternative methods are seldom equally appropriate so it is important to avoid a situation in which cost considerations override design considerations to produce a less than adequate approach.

Although the scope and nature of reef assessments will vary from study to study, one thing that will remain constant for even the smallest-scale study is the complexity of the data collection situation. Many questions will typically be under investigation in any given reef assessment, and each question will carry its own set of implications for data collection. It will be necessary to meet the data and sampling requirements for the most demanding questions. It may be necessary, as Hiett and Chosh (1977) found in the case of collecting marine recreational fishing data on the Pacific Coast, to use more than one method to simultaneously meet the methodological requirements for all questions under investigation.

The technology of all social survey methods is well developed and all can provide good results when used properly. Failure in social and economic reef assessments is most likely to occur in cases where the task is taken lightly and does not have input from trained and experienced social scientists. Past efforts, especially with mail questionnaires, have sometimes produced disappointing results which can only be attributed to less than careful questionnaire design and mailing procedures (Brown, 1977). It is beyond the scope of this paper to discuss in detail how questionnaires can be used successfully in fisheries assessments, but many sources are available as guides for questionnaire procedures (e.g. Dillman, 1978; Payne, 1951; Neberlein and Baumgartner, 1978). Two points need to be made, though, based on our experiences using questionnaires at Texas A & M University (Ditton and Graefe, 1978; Ditton et al., 1979). First, attention paid to detail at the design stage of a mail survey will yield dividends in terms of response rate and quality of responses. Secondly, although response rate is an important consideration, it is even more important to conduct a substantial follow-up telephone survey of non-respondents regardless of the response rate received. We have consistently found that fishing habits of respondents differed significantly from those of non-respondents and our non-respondent analysis has allowed us to correct study findings for this bias. The single greatest weakness of many previous mail surveys of fishermen has been either the complete omission or superficial treatment of the problem of non-response.
The Recall Problem: Certain data needs require fishermen to estimate and remember their past fishing activity. The ability of fishermen to recall various types of information has become one of the most troublesome issues in the collection of socio-economic data from recreational fishermen. Prior to the methodological studies carried out by Human Sciences Research, Inc., there was virtually no basis for determining an optimal recall period for surveys of fishermen (Brown, 1977). In their recommended approach to the collection of marine recreational fishing data, Hiett and Ghosh (1977) identified the estimation and recall problem as one of two over-riding issues which should be considered prior to selecting data collection procedures. This concern resulted in a separate report which dealt specifically with fishermen's ability to recall fishing information over time (Hiett and Worrall, 1977).

Figure 3 presents a proposed recall continuum indicating suitable recall periods for different types of information obtained in fishing surveys. Information categories shown for zero and two months are based on the findings of Hiett and Worrall (1977). Entries for zero months indicate that fishermen can neither recall this information nor accurately estimate it even at the time of the fishing occasion. Entries listed under two months include the types of information fishermen in the Hiett and Worrall (1977) study could accurately estimate and recall for at least 60 days. It is noteworthy that fishermen can recall some types of information better than other types of information. For example, fishermen could remember the total number of fishing trips within two months with reasonable accuracy, although their recall of specific fishing dates was poor (Hiett and Worrall, 1977).

<table>
<thead>
<tr>
<th>Figure 3: Proposed Recall Periods for Different Types of Information</th>
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<tr>
<td><strong>0 Months</strong></td>
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<tr>
<td><strong>Species Identification</strong></td>
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<tr>
<td><strong>Length and Weight of Catch</strong></td>
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<tr>
<td><strong>Fishing Effort (hours)</strong></td>
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<tr>
<td><strong>Date of Fishing Trips</strong></td>
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Types of information listed under the longer recall periods in Figure 3 include data on fishing and fishermen for which recall and estimation accuracy are not such a serious concern. General fishing patterns might include types of fishing participated in, seasons fished, species sought by fishing mode or season, and a variety of other variables that are not usually trip-specific and hence can be dealt with in a more general way. As an example of the utility of this type of data, our 1978 study of artificial reef fishermen in Texas used such variables to identify the number of participants in a wide variety of types of bay and offshore fishing (Ditton and Graefe, 1978).

The number of fishing trips is repeated in Figure 3 under recall periods of 2 months and 12 months for several reasons. First, this information is very valuable for determining economic values and as an input for allocation decisions. Secondly, evidence concerning recall accuracy for different periods of time is extremely limited. Hiett and Worrall (1977) suggest 2 months based on a test which compared a direct question on the number of trips with a question which asked fishermen to list the exact dates of their fishing trips. The inability of fishermen to recall dates of fishing trips produced the recommendation that the recall period be limited to 2 months. However, the equivalency of remembering dates of trips and numbers of trips has not been further documented. In contrast, two separate studies on the Gulf coast found nearly identical numbers of saltwater fishing trips reported for a 12 month period (Ditton et al., 1979; Environmental Research Group, 1974). While these two studies do not constitute a test of the 12 month recall period, the consistency of their findings provides some evidence of reliability of the measures. Finally, the desired precision of the estimated number of trips should be considered before selecting an appropriate recall period. Certainly, a 2 month period will yield better estimates than a 12 month period. But, given the lack of understanding of how much better the 2 month estimate is, certain data needs may be met by 12 month estimates. Comparisons of the relative degree of fishing activity in various geographic areas or across different modes of fishing or seasons, for example, can be made with reasonable accuracy using a 12 month recall period.

Recall periods indicated in Figure 3 should be viewed as suggested intervals on a continuum rather than absolute time limits. Under some circumstances it may be advisable to select a period between 2 and 12 months. For example, a 3 month recall period could be expected to yield estimates nearly as accurate as a 2 month period, and could have the advantage of corresponding to natural and commonly understood season lengths. In addition, a 3 month interval could be significantly more cost effective, since a full year could be represented with one-third fewer separate samples.

Although only one information category, socio-economic information is listed under no limit, this category actually includes a great many considerations. Most of the data needs discussed in this paper are unaffected by the recall problem since they do not deal with specific past fishing trips. The recall period is a serious consideration for certain data needs as discussed here, but one must be careful not to
overreact to the problem and attribute it indiscriminately to all types of information. In sum, the evidence available concerning the merits of alternative recall periods does not provide any clear decision rules on the selection of an optimum recall period. This selection should be made on the basis of the types of questions to be asked and the desired precision of the estimates obtained.

Conclusion

Artificial reefs represent a relatively new contribution to the realm of fishery management techniques, which has traditionally been dominated by introductions, stocking, and regulations. Artificial reefs can be useful in achieving management objectives related to efficiency, equity, and diversity. Future reef studies should focus on obtaining those types of social and economic information discussed in this paper which can provide the most valuable inputs to the management decisions which must be made. As socio-economic considerations become better understood, comprehensive evaluations of reef programs such as that by Schwartz (1979) should be better able to assess questions like: (1) whether to institute similar reef developments in the future, (2) whether to add or drop specific program strategies in future artificial reef developments, and (3) whether to accept or reject initial program assumptions. When questions like these can be answered through socio-economic research, artificial reef decisionmaking need no longer be based solely on intuition, impressions, casual observation or conventional wisdom (Foister, 1978).

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References


ECOLOGICAL CONSIDERATIONS INFLUENCING THE MANAGEMENT OF REEF FISHES

Dr. Gene R. Huntsman

Abstract

Sustained reefish yields are limited by meager water column productivity and by scarcity of reefs. Evolutionary impetus to retain and recycle energy and nutrients has fostered the development of extraordinarily complex reefish communities with many trophic levels. Complex reef communities contain many species, but the biomass and potential catch of any singles species is small. Most reefish biomass is contained in small herbivores and primary carnivores but man's interest is principally in the scarce, large, high-order carnivores.

Evolutionary adaptation to the low probability of larval encounter with reefs and survival to adulthood has resulted in four common characteristics of reefish life histories. Low mobility of reefishes allows their easy over-exploitation. Slow attainment of maximum size, low natural mortality rates and protogyny all suggest that fishing mortality be kept low and recruitment age high in order to achieve maximum yields.

Artificial reefs appear useful for increasing recreational fishing opportunities, but are not a practical way to increase commercial catches.

Introduction

The limit to the harvest of any renewable natural resource is set by the physical and biological characteristics of the system producing the resource. In this paper I discuss those factors which circumscribe production of reefishes.

I broadly define "reefs" to include not only true coral reefs but also other areas of firm substrate; rock outcroppings, wrecks, and artificial reefs, in warm subtropical and tropical marine waters. Although my experience has been in the western Atlantic, the concepts presented are applicable to reefs worldwide.

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1This article in most respects is identical to the author's paper "The Biological Bases of Reef Fishery Production," (Proceedings of the Gulf and Caribbean Fisheries Institute, Miami Beach, 1979) and is not to be considered as a separate publication.

National Marine Fisheries Service, Beaufort North Carolina
In this discussion I will first describe the relationship of reef systems to their physical, chemical, and biological environment and the resulting impacts on fisheries. Secondly, I will describe some common aspects of reef fish community structure and life histories and show how these result in severe limitations on use of reef stocks.

Chemical and Physical Characteristics of the Reef Environment

Typically, warm–water reef communities develop in clear nutrient–poor waters which support little primary productivity. For instance in outer (21 ft) Onslow Bay, North Carolina primary production is less than 100 g of carbon/m²/yr (Turner, Woo and Jitts, 1979; Personal communication Susan Huntsman, Duke University Laboratory, Beaufort, N.C.) whereas in the fertile waters of Long Island Sound (Smayda, 1973) and in Peru's upwelling area (Personal communication, Susan Huntsman) it is 400–500 g carbon/m²/yr. Thus while the solar energy necessary for primary production is abundant, little of it is captured and available for production of fish.

Another characteristic of reef communities which bears on fisheries production is that, in general, reefs are rare. Relatively little of the space within the geographic range of warm–water reefs is actually occupied by reef communities. For instance, on the U.S. Continental Shelf between Cape Hatteras and Cape Canaveral, reefs with greater than one meter of relief occupy only about 5% of the ocean floor between 15 and 55 fathoms. In the eastern Gulf of Mexico, natural reefs occupy only 1% of the zone between 10 and 55 fathoms. (R. O. Parker, personal communication, National Marine Fisheries Service, Beaufort, N.C.).

Reefs are not only rare, but they are also usually small, discontinuous and scattered. Many reefs occupy only a few hectares and are separated from other reefs by many kilometers of unproductive bottom, often unconsolidated sediments, or by deep basins. The areas between reefs support so little life per unit of area that they likely prove formidable barriers to reef fishes which have evolved in areas of concentrated energy. Natural reefs sustain fish stocks ranging from 270 to 5,279 kg/ha and averaging 1,384 kg/ha (R. O. Parker personal communication), whereas trawl surveys suggest non-reef open shelf habitats of the South Atlantic and Gulf of Mexico support only 6.3 to 46.3 kg/ha (Wenner et. al., 1979). Even if one assumes that some fish avoid trawls it is clear that reefs support immensely more life per unit area than the open shelf. Even relatively productive bottoms, for example seagrass and algal flats, appear to isolate reef and reef fish populations from one another. Reef fishes usually utilize only the flats within a relatively short distance of the high relief reef structure. In summary, reefs and reef communities are rare and scattered occurrences isolated from one another by a barren and unproductive environment.

The Reef Community and Its Structure

In contrast to the sterility of the surrounding environment, the reef community teems with life. Bio-energy, scarce and dispersed in
oceanic water and over most of the ocean floor, is abundant and highly concentrated on reefs. The disparity results from biological accumulation and retention of nutrients and energy at a small focus, the reef. The accumulation and retention appear to result from the firm substrate afforded by the rock outcrop, coral head, or sunken ship, whereon sessile invertebrates may attach and free swimming organisms may hide. The extraordinarily complex structure and function of reef communities results from several interrelated factors: (1) concentrated energy and materials are unusual over the ocean as a whole; (2) the existence of many life forms is possible only where energy and materials are concentrated; (3) evolutionary advantage has lain with those organisms which are able to capture energy and materials that would otherwise escape the reef system; and (4) evolution in reef systems has occurred over 50 million years (Newell 1971). Thus remarkably diverse reef communities have developed which capture and accumulate energy and nutrients from the surrounding water column and flats. Perhaps more than any other, reef communities continually recycle energy and nutrients through multitudes of pathways allowed by the existence of thousands of species of reef organisms.

Community Structure and Reeffish Harvest

Two interrelated characteristics, recycling and diversity, of the reef community have important implications to management of fisheries. Because reef biomass is divided into so many species, which is equivalent to saying because there are so many paths of energy flow, fisheries managers cannot expect large harvests of any single species. More than a thousand fish species exist on many tropical reefs and even the relatively depauperate live-bottom reefs of the Carolina Shelf support several hundred species. Complex multi-species fisheries pose problems in harvest technology and marketing. And they are extremely difficult to understand and model, and thus, their behavior is hard to predict. Although gross production in reef communities is high, net production is near zero (Odum, 1971). Much energy is recycled and little may be available for fisheries harvest without serious disruption of the community structure. Munro (1974) felt that imposition of a fishery on reef systems might rearrange the patterns of energy flow and allow a greater harvest than net productivity values indicate. However, sustained harvest must remain a function of meager water column productivity and of energy imported to the reef system from surrounding algal and grass flats.

The third effect of community structure on fisheries results from man's preference for the large high-order predators—snappers, groupers etc. (Huntsman 1976, Stevenson 1976) which constitute only a small fraction of the total reeffish biomass. Large predators represent only the energy left after four or five transfers in which each transfer resulted in loss as heat of 80 to 90% of the pretransfer energy. The bulk of reeffish biomass is composed of small herbivores and primary carnivores which are not readily taken on hook and line, and which are not highly valued as trophy or table fish. Capturing the greatest available poundage of reef catches calls for reflection of community structure in choice of gear.

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and in attitude about the acceptability of various species. Traps and other gears which take small and herbivorous fish are appropriate if the largest harvest of reef species are to be taken. Hook and line, the usual gear in the U.S., tends to select the large and relatively rare predators.

Reeffish Life History and Fishery Management

Life History Description—Abbreviated: the demands of the oceanic and reef environments have led to development of a life history pattern that in turn has important implications to management of reef fisheries.

A typical reeffish (such as grouper, snapper, porgy, or grunt) begins life as a fertilized planktonic egg resulting from the spawning of its parents on, or adjacent to, their home reef. The egg and resulting larva are usually planktonic for many days, and may drift hundreds or thousands of miles from the spawning site. The red porgy, *Pcaprus pagrus* may be planktonic for fifty days or more, long enough to cross the Atlantic in the Equatorial Current (Manooch et al., 1976). In the western Atlantic the Equatorial Current and its various branches, the Florida and Loop currents and the Gulf Stream may carry the egg and larva from the Caribbean to the Carolina Shelf. Only if this drift results in the larva settling on a reef will the life cycle be completed. And because reefs are rare and currents vagarious, only an infinitesimal proportion of spawned eggs result in successful recruitment to reef populations.

Reef Fish Life History, the Scarcity of Reefs and Management Implications: the interaction of the typical life history pattern with the pattern of the physical environment (that is, a system which is mostly hostile, and in which only a few scattered, acceptable habitats exist) produces three manifestations in the life history of the adult fish which have substantial implications to fishery management. These manifestations have to do with movements, growth and longevity, and reproduction.

Movements: an *a priori* judgement would suggest two ways to make a living in an environment wherein suitably concentrated energy supplies are situated far apart and are separated by a hostile environment. An organism could move rapidly enough to enable quick transit across the barren areas, or it could be sedentary which would ensure that it never strayed so far from a suitable feeding area as to perish. Reeffish have taken the latter course. Natural forces probably quickly eliminate reeffish which wander too far from their reef to find adequate food. Any wanderers that are lucky enough to return often find their territories usurped by less adventurous individuals. Tagging studies by the National Marine Fisheries Service, SEFC, Beaufort Laboratory (unpublished data) and others (Moe, 1966) show that reeffish move very little, usually less than a mile over a year or more. If reeffish do move it is most often only to an adjacent reef.

Low mobility has two implications to reeffish harvest. First, fish which are sedentary are more vulnerable to exploitation than pelagic fishes which move constantly. Once a reef is found, modern electronic
gear allows fishermen to relocate it easily and the resident fish may be subject to intense fishing pressure. The usual result is rapid reduction in the stocks. Snapper fishermen and headboat operators in the southeastern U.S. have observed this phenomenon many times. Artificial reefs especially are subject to overharvest because they are readily accessible and are usually well marked. (Buchanan et. al., 1974).

A second result of low adult mobility is that stock replenishment must result principally from juvenile immigration and growth. And while juvenile immigration is apparently rapid, growth is not.

Growth and longevity: natural selection will favor those genotypes which maximize the chances of having successful offspring. Because the probability that any larva will encounter a suitable reef site and grow to adulthood is low, reeffish must produce large numbers of zygotes to have successful offspring. A common way, exhibited by many reef species, of increasing fecundity, is to live a long time. Great longevity increases both the number of spawnsings and the possibility of spawning when conditions are favorable for larval survival. Groupers, especially, live many years, 26 years for the red grouper, Epinephelus morio, (Moe, 1969), 22 years for the speckled hind (E. drummondhayi) (Personal communication, R. Matheson, National Marine Fisheries Service, Beaufort, NC), 21 years for the scamp, Mycteroperca phenax, (Personal communication, Matheson) and 13 years for the gag, M. microlepis, (Manooch and Haimovici, 1978). Even smaller reef species are relatively long lived. The red porgy lives to 15 years (Manooch and Huntsman, 1977), the white grunt, Haemulon plumieri, to 13 years (Manooch, 1978) and the vermilion snapper, Rhomboplites aurorubens to 10 years (Grimes, 1978).

Great longevity has importance to fisheries management, first because it is a manifestation of a low natural mortality rate (M), and second because it is accompanied by slow attainment of maximum size (Huntsman and Manooch, 1978). Maximum harvest of fishes with these characteristics is achieved by fisheries of low intensity. The age (and thus size) at which fish are taken must be kept high (4-5 years for most species) and fishing mortality (F) should be kept low (F of 0.3 is adequate for many reef species and 0.1 is enough for red grouper, (Huntsman², et al. unpublished manuscript).

Reproduction: many reefishes, including species directly important to fisheries, display unusual patterns of reproduction. Many serranids and sparids are protogynous. Individuals of these families begin life as females and in midlife become males. This attribute, like those related to movements and growth, seems related to the ability to survive the ocean-reef life history pattern and to have important implications to management. While protogyny probably conveys adaptive value in

more than one way, I believe it is related to the population structure imposed by the wide scattering of reefs, many of small area, and to the low mobility of reefishes. The laws of probability indicate that when a normal bisexual population is separated into many small subpopulations, many of the subpopulations will have suboptimal sex ratios even though the overall sex ratio is optimal. And if, as with many reefishes, the subpopulations do not join for spawning, reproduction will be relatively unsuccessful. Protogyny, which has evolved with respect to the mean natural mortality rate for the species, will ensure that all subpopulations have a near optimal sex ratio as long as the mean mortality rate changes little and as long as recruitment is more or less uniform.

Protogyny affects the choice of management strategy. A fishing mortality rate \( F \) which does not allow survival of at least a few fish to the age at which they become males dooms the species to extinction, and because maleness is only attained at mid to late life, \( F \) cannot be very high. Probably any fishing pressure tends to disrupt reproduction, but natural compensatory factors will counteract small \( F \) and allow a fisheries harvest. Fortunately, the \( F \) necessary to take near-maximum yields is generally low so that low intensity fisheries protect reproduction without sacrificing yield.

**Summary of the Effects of Ecological and Biological Factors on Reef Fishery Harvests**

It is unreasonable to expect sustained high yields from reef fisheries because:

1. Reef communities typically develop in waters of low nutrient content and low productivity.

2. Reef habitats are relatively rare and reefish production is limited by the abundance of reefs.

3. Reefish communities are very diverse and large production of a single species is impossible.

4. Although reef communities exhibit large standing crops of fishes and gross productivity is high, most energy is recycled, net productivity is near zero and potential fishery harvests small.

5. Man is most interested in harvesting the rare high-order carnivores which represent only a small fraction of the energy in the reef system.

6. Because reefish move little, they lend themselves to over-exploitation and recovery of depleted stocks is slow.

7. Because of low natural mortality rates and slow attainment of maximum size, maximum harvests can only be attained with low fishing mortality rates and high recruitment ages.
8. Protogyny requires that fishing mortality be kept low so that sufficient males exist to allow good reproduction.

A review of the history of reef fisheries sustains the conclusions derived from this examination of biological and ecological factors. The red snapper fishery in the northern Gulf of Mexico was thought to be overfished by the early 1900's (Camberg, 1955) and the United States fishery has only been sustained through constant expansion of the grounds. Many nearshore fisheries of the Caribbean are considered overfished even though exploited only with primitive gear and vessels (Munro, 1974). Further, headboat operators and commercial snapper fishermen commonly acknowledge that good fishing sites must be kept secret and fished lightly if they are to continue to produce good catches.

**Reef Productivity and Artificial Reefs**

Theoretical and practical considerations suggest a bleak picture of reef fisheries but it must be recognized that, used with moderation, reef stocks can support important fisheries. Worldwide, reef fisheries produce an average of 2 mt per km² per year (Stevenson and Marshall, 1974). Moreover, many reef species are especially important as trophy and table fish and fisheries managers are interested in maintaining and increasing the production of these.

Artificial reefs have a role in this management program. Artificial reefs provide the firm substrate and relief necessary for establishment of a biological community which can concentrate energy and divert it into reef fish production. Quickly invaded by juvenile reef fishes (an occasional stray adult) artificial reefs within a few years sustain an abundance and diversity of fishes equal to that on natural reefs (Stone et. al., 1979).

Nonetheless, fisheries on artificial reefs are subject to the same ecological constraints as those on natural reefs. Artificial reefs are easily overfished and do not necessarily provide good fishing (Buchanan et al, 1974). Severe limitations on fishing effort and on the minimum size of fish taken are necessary to preserve high yields from artificial reefs. Artificial reefs can only be regarded as useful for increasing the accessible fish production but not overall production. Because artificial reefs are so expensive and time-consuming to build it is unlikely that we will ever build enough to materially change total production. For instance, despite an intensive and effective reef building program of several years duration, the State of South Carolina has constructed only 4 acres of artificial reefs, whereas natural reefs on the continental shelf (to 55 fathoms) off South Carolina occupy at least 2,469 acres. Thus artificial reefs are best used to support high-value fisheries like sport fisheries rather than commercial fisheries.

Management must be designed to recognize the limits of reef production, if artificial reef fisheries are to succeed in the long run.
References


ARTIFICIAL REEF EXPANSION AND USE ISSUES

Henry Ansley

The Georgia Department of Natural Resources has managed an offshore artificial reef system since the early 1970's, which is really not that old as far as reef programs go. Regardless, there was ample time within those years to allow for a multitude of wrong turns and mistakes. Georgia's learning experience was probably not unique.

Artificial reef programs have existed along the southeastern and Gulf coasts ever since the idea of creating manmade reefs was popularized in the early sixties. Since then program managers have accumulated, primarily through trial-and-error, a wealth of knowledge regarding the creation and management of successful artificial reef systems. Much of this knowledge, however, remains unavailable or in a form unsuitable for management purposes.

With this in mind, personnel involved in Georgia's artificial reef program felt that a general guide or flow chart useful to reef management in Georgia could be developed by conducting an informal brainstorming of existing city, county, and state programs from Texas to Maryland. Such an outline, it was conceded, could not be definitive, but might allow existing and beginning reef programs to anticipate and effectively deal with expansion and use issues.

From the responses and comments of reef program managers, the simplified "decision matrix" following was developed. Solid lines indicate what was perceived as preferred courses of action, while dashed lines indicate alternate choices. Separate channels were constructed for existing and non-existing programs.

Georgi Department of Natural Resources, Brunswick, Georgia
Survey

Basically reef program managers need to know just what's going on in order to obtain an effective solution to current and future problems. In this aspect creel and other surveys play a vital role by not only identifying problem areas, but also by providing justification for further action and funding. Surveys also allow quantification of three major problems that managers indicated affected their programs — the problems of access, pressure/demand, and conflict between user groups.

Access

For existing reef programs the problem of access is a matter of having artificial reefs already located in the wrong areas, while for non-existing programs it's a matter of locating suitable locations compatible with physical demands and navigational and commercial interests. For the recreational fisherman and diver the problem of access simply means that the reefs are either too far offshore or too far from the "beaten track."

Many small boat fishermen feel that traveling far offshore is too great a risk, even in the best of weather. Boats large enough to venture offshore have trouble finding the reefs because of the absence of landmarks, inexperience, and a general lack of sophisticated navigational devices such as LORAN.

Pressure/Demand

Growth in coastal areas is rapidly accelerating. The resulting pressure does not only increase the actual amount of fishing and diving effort on the existing reefs, but also creates a need for new reefs where previously the need did not exist. Sometimes the reefs are not large enough to provide increased catches; in other cases reefs may not meet the specific demand placed on them by user groups, such as affording better water visibility and/or attractive bottom material (wrecks) for divers.

Conflict

A third major problem mentioned by program managers were conflicts between groups utilizing the artificial reefs. Three were mentioned: recreational and SCUBA conflicts, SCUBA group conflicts, and recreational and commercial conflicts.

Conflicts between recreational fishermen and diving interests arises from competition for space over reef material, such as wrecks, that appeals to both groups. In Georgia conflicts of this nature occur mainly on the reefs situated in deeper water, where most of the system's sunken vessels and better water visibilities are located.
Problems between SCUBA groups occur usually as the result of clashes between consumptive (spearfishermen) and nonconsumptive (photographers and sport divers) diving interests. Because of various reasons, activities of these two parties don't always jibe. Intensive use of wrecks and other limited pieces of reef material by both groups only serves to aggravate the problem.

Pre-construction conflicts with commercial fishing interests generally deal with the problem of access mentioned above. Some post-construction conflicts between recreational and commercial factions were cited by some of the reef program managers contacted. Specific concerns dealt with the use of fish traps on the reefs and with commercial gill-netting operations being conducted on areas adjacent to existing reef sites.

If surveys do indicate either problems within the existing reef system or problems due to the absence of an artificial reef program, then obviously there is need for a solution. Something needs to be done.

Planning for Non-existent Programs

Evaluation: agencies without reef programs should consider if their organization has the time, the personnel, and the capabilities to successfully manage and maintain an artificial reef system before they actively engage in construction. Not only present, but also future abilities also need to be determined, as reef programs are usually accepted well and tend to grow, requiring increased management and regular maintenance.

Funding: once an agency has decided to undertake an artificial reef program, the primary concern centers around funding and funding sources. The reef program contacted utilized federal, state, county, and city funds whenever they were available. Other sources of revenue included special taxes, duties, and profits gained through the sale of scrap off large vessels that had been donated to the program.

Preplanned construction: if funding is available, new reef managers can use the knowledge gained by older programs to help them create a long term plan that will be flexible enough and broad enough to deal with the problems of access, pressure/demand, and user conflict. In other words, the new reef manager can "preplan" a scheme that allows controlled and effective growth according to constituent demand and agency capabilities.

Two of the programs contacted indicated that they had preplanned all their artificial reef activities before any construction had occurred. Special attention had been paid towards alternatives that would meet the demands of access, pressure, and conflict...inshore reefs were created for the small boat fisherman; reefs featuring better water visibilities were planned for SCUBA divers; other reefs were oriented towards the demands of recreational fishermen; sites near channels and population centers were obtained, if possible; and material specifically aimed at meeting the demands of various groups was acquired.
Existing Reef Programs

Evaluation: since the reefs have already been constructed, the manager of an existing artificial reef program does not enjoy the flexibility afforded to agencies starting anew in the reef-building business. Program leaders must obtain their solutions to the problems of access, pressure/demand, and conflict through modifications of the existing system, if modifications are indeed possible.

Again, before any action is taken, the agency responsible should re-evaluate its capability to deal with an expanded system. It must be decided whether the alternatives available are effective in providing solutions to reef use problems, or if further action will simply build upon existing mistakes.

Education: providing that the time and personnel are available, education sometimes represents the only viable solution for existing programs, especially for those managers whose programs either lack extensive funding or have overextended their agency's capabilities. The advantage of educational programs lies mainly in the fact that they can be aimed directly at specific problem areas. For instance, recreational fishermen and divers can be taught navigational skills to help them locate the reefs (access problems) and find underutilized portions on the reef site (pressure/demand, user conflict problems); they can be taught fishing and anchoring techniques (pressure/demand problems), boating safety (access problems), and courtesy (user conflict problems).

Program managers that responded apparently varied in their opinions regarding the effectiveness of their educational efforts. One program manager, however, mentioned the problem of public indifference towards his program, which resulted, as he perceived it, in a low rate of success.

Funding for expansion: if funding is available, the reef manager may directly attack the problems of access, pressure/demand, and user conflict through expansion of the existing reef system. This alternative is desirable in that expansion can conceivably eliminate the sources of the problems, and also because expansion solves problems by meeting public demands, rather than limiting public demands, as with regulation. Expansion can occur in two ways -- either through new reef construction of through the enlargement and diversification of existing reefs.

New reef construction: new reef construction allows managers of existing programs to start afresh, to create new reefs in light of past experiences. Through the construction of new reefs, the reef program manager can not only increase the amount of productive bottom, but can also locate this bottom in areas that are more accessible, that are closer to population centers, and that possess physical conditions more conducive to user group activities.

Negatively, new reefs do not constitute a viable alternative if barren areas with improved access and suitable substrate cannot be obtained. Permitting is usually more difficult when dealing with a new reef location than it is with existing reef locations. And perhaps most important of all the addition of a new reef to a system also means the addition of another buoy requiring regular maintenance.
Enlargement/diversification: existing reef programs can also increase the amount of productive bottom available to reef user groups by enlarging their artificial reefs. Enlargement can simply involve the addition of large quantities of suitable reef materials in an effort to intensify material already present and to increase coverage at an existing site; or it can involve the addition of user-specific materials (i.e., wrecks, trolling alleys, midwater reefs, etc.) in such a way as to provide for maximum spacing between conflicting groups. This alternative, unlike new reef construction, also may avoid the placement of an additional buoy, and permitting could be easier.

Enlargement and diversification, however, has little effect if the existing reefs are inaccessible or are located in areas featuring physical conditions that hinder utilization by user groups. Too, there may not be enough room at the existing reef sites to allow for significant enlargement; water depth and substrate limitations may prevent diversification of the area.

Regulation

A final solution to reef use problems is regulation, involving the imposition of limits, gear restrictions, and/or restricted entry. With increasing pressure and decreasing funds for reef construction, managers have to consider this tactic as a viable alternative when dealing with problems of pressure/demand and user group conflict.

At this point in time many programs choose to avoid the question of regulation because of its volatile and political nature. Several legal questions over the jurisdiction of artificial reefs located beyond state territorial still exist. Enforcement constitutes a very real practical problem.

As stated previously, the above "matrix" is very general, even incomplete. It points to three major categories of problems, although many other problems were indicated by the responses of reef program leaders. The diagram itself implies a straight line, step-by-step progression, utilizing one alternative before the other, when in fact the real solutions actually combine all three.

But the chart should represent more than an over-simplified view of a complex situation. Rather it should represent an effort at taking over twenty years of artificial reef experiences and putting the lessons learned down on paper where they can be studied and used — not just repeated — for more effective reef management.
CHAIRMAN'S COMMENTS

Jerry Sansom

As a postscript to the preceeding session, I would like to advise the participants that two entirely different situations govern the permitting and construction of artificial reefs.

Inshore reef construction continues to be the primary responsibility of the various state regulatory agencies plus such federal agencies as the Corps of Engineers, the National Marine Fisheries Service and such others as may have an interest in the proposed construction.

However, in the offshore waters, those waters, falling outside of the individual state's territorial waters the reefs may well be effected by one or more of the species management plans that the Fishery Management Councils may be considering or may have implemented. The Fisheries Conservation and Management Act of 1976 empowers the Councils to adopt such regulatory measures as are necessary for the adequate maintenance of the various fishery stocks. Artificial reef planners would do well to consult with the Council(s) with jurisdiction for those waters prior to proceeding with their planning to avoid Council adverse ruling. For instance, the Gulf of Mexico and the South Atlantic Councils both are in the final hearing stages of management plans for reeffishes and they might well effect plans by prospective builders as to location, depth and other specifications.
RAPPORTEUR'S COMMENTS

Dr. John W. Merriner

Artificial reef programs have developed rapidly in the coastal states, since the early 1970's from a combined impetus of state, local, and federal assistance. Today there are active reef programs from Maryland southward through Texas. All have had their problems, but, in their fashion, all are accomplishing their programmatic missions. Some programs are just getting underway, while others have been active for five years or more. In a similar vane these activities range from totally local efforts to fully state run activities.

There are some problems. Some of these include foggy programmatic goals, foggy direction, funding constraints, errant materials which were bound for the reef but found themselves elsewhere, what materials to use, how to conduct construction site evaluation, and the list goes on. The diversity of programs and experience, funding base and mission of the programs in the region provide examples of several approaches to management which may range from a laissez-faire attitude to one of a highly regulated system. Minimal regulation may well be the most effective way to go. Intensive regulation is surely a burden and it should not be an option we encourage. The most important element to reef program management success regardless of the program's maturity (longevity) is an integration of biological principles, social allocation questions and derivation of benefits from social and economic standpoints for both commercial and recreational users.

Unlike the biblical creation of the world, reefs are not built in a day. We have a longer time scale for reef evaluation as the life of a reef fish is considerably longer than that of a pelagic species. You don't just start and stop a program overnight.

Each reef project or program must bite the bullet of reality. To go along saying that it's a neat thing to do, just doesn't cut it anymore. Education, promotion of your programs, public acknowledgment of your successes and your failures have to be part of all ongoing programs. Stand up and say, we have made an objective decision: the reef program will provide either a biocentric benefit or an anthropocentric benefit.

A common thread is that management requires some forethought. The reef operations are scalar in nature depending in large part upon the amount of funds available to you. The people who may have it best, are those in the start-up phase since they can actually do a bit of planning. These smaller, marginally funded programs stand as monuments to the dedication of the project managers and are living examples of human ingenuity relative to getting the most from a dollar.

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Assume your program is well underway and has a consistent and stable funding base. You have suffered from overall fiscal constraints but the dollar is declining in purchasing power daily and are faced with level funding. Your concern is basically to keep your (program) alive. You’ve become entrenched in the "if it's broke, fix it" syndrome; trying to go along with nuts and bolts and bailing twine to keep the projects operational. At this point you have to take the time to plan activities. We don't have the view of planning as a luxury to be done in the future. Fiscal and administrative policy dictate that we know and state clearly what we want from the program and what mechanism will be used to tell where we are in the pursuit of our objectives, i.e., yearly programmatic goals, if not longer period goal setting. We must tell the administration, the funding agencies, and the public at large, where we are in our program and not get tied up in minor details. Too often we have to admit this human frailty! Budgetary constraints have hampered reef building activity but the amount of paper work and time lags involved in filing for permits and getting sites approved can also be disruptive. We have to be willing to accept constructive criticism, acknowledge our errors, and make the most of the positive program accomplishments.

Artificial reef project managers need to provide the fiscal and administrative overseers of the programs with quantitative and qualitative measures of project success or failure in terms of cost and benefit. All managers are aware that programmatic scrutiny is becoming more detailed and the law will probably require it as zero base budgeting becomes more widespread. We have to place the programs in perspective of other demands for the public resources and the tax dollars, as well as other demands for private funds and investments. We have to be able to compete effectively with agriculture, tourism, welfare and education at the local, state and federal levels in the budgetary cycle. We need an objectivity in evaluation and assessment of the reefs; to-date, this has been an off-shirked responsibility and often a belated activity in the presence of other "fires" to be put out. We have the tools of assessment, have identified data needs, have a developing base of methods for interpretation of these data as discussed in the panel sessions of yesterday and today. We have to come out into the real world, obtain the resource assessment and user data that we need and in the long-term detail the major reef program activities and their benefits.

In a few words, the reef program managers are held accountable for their programs in fiscal and biological terms. We have to provide information to the administrative decision makers in terms that they can understand. Too often, we have technical conferences and talk only to others of similar interests.

Assessment, evaluation, promotion and education are not luxuries in a reef program. We have to clearly tell the public, administrators, our fiscal and morale sponsors, our civic groups and our users what the program is to do, why and for whom it exists and how long will it take the program to accomplish its stated goals. We have to identify program accomplishments in terms of biological resources and dollars generated in the local or regional economy for both commercial and recreational users. We then identify the present and projected needs so that the reef program can generate greater public benefits and compete effectively for public funds. Then we recommend a program to accomplish these goals within the respective jurisdictions in which we work.
SPECIAL ADDRESS

"Artificial Reef Programs In Japan and Taiwan"

Dr. Daniel J. Sheehy

Aquaabio, Inc.,
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(Presented at Conference Luncheon. Actual presentation highlighted by slides)
ARTIFICIAL REEF PROGRAMS IN JAPAN AND TAIWAN

Dr. Daniel J. Sheehy

National programs to develop and use artificial reefs are currently underway in both Japan and Taiwan. The program in Japan is the most advanced in the world. Artificial reefs have been used to enhance fishing grounds in Japanese waters for more than 200 years, and the national government has helped sponsor reef programs for the past 50 years. Sophisticated, specialized reef designs give the Japanese a high degree of control over fisheries production and coastal resource management. By comparison, the Taiwanese program is less advanced but provides important information about a national reef project in an intermediate stage of development. Since the United States is now considering a national reef program, it is useful to review the reef experiences in both Japan and Taiwan in order to benefit from their research and development efforts, and to gain insight into the advantages of a national artificial reef program for the U.S.

The national artificial reef programs in Japan and Taiwan were initiated for the purpose of improving coastal fisheries production and recently have been stimulated by several factors. The 200 mile extended jurisdiction laws adopted by the U.S. and a number of other countries and the rising cost of petroleum products have significantly reduced the catches of the distant water fishing fleet in both countries. In addition, both have experienced expanding economies which have led to increasing demands for high quality seafood. At the same time, the availability of coastal stocks in both countries have been adversely affected by pollution, overfishing, and land reclamation. Although both Japan and Taiwan have substantial aquacultural industries, the limitations in available space and increasing costs of intensive culture techniques have influenced their decisions to move into habitat improvement as a means of increasing their seafood production.

The programs in both countries are designed to increase the abundance and accessability of commercially valuable species. The projects have devoted considerable effort to reef site selection, unit design, placement methods, and evaluation techniques. Some of the more recent studies have been directed toward evaluating the use of reefs or shelters in conjunction with stocking programs.

Taiwan

The national artificial reef program in Taiwan was begun in 1974. The program is funded by the Taiwan Fishery Bureau and is administered through the Joint Commission on Rural Reconstruction. The Institute of

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Zoology at Academia Sinica has been given the responsibility for reef site selection and evaluation of reef effectiveness. Dr. Chang, director of the Institute, is the coordinator of the technical program.

Small scale reef projects were begun in Taiwan around 1930 when local government agencies placed some concrete blocks off Pingtong in southern-most Taiwan. In 1970, several reefs were built by the Joint Commission on Rural Reconstruction in the waters off Miaoli in northwestern Taiwan. The latter project was quite successful in increasing area fish catches and served as a stimulus for the development of the current program.

Although the program is only five years old, it has made considerable progress. The work was divided into four basic stages: 1) site survey and selection, 2) material selection and reef design, 3) reef construction, and 4) evaluation of effectiveness.

Based on preliminary studies and earlier experiences dating back to 1930, initial sites were selected which 1) had level sand, gravel, or shell sediments, 2) were at a depth of 20-30 m, 3) avoided polluted or turbid waters and current velocities greater than 1.5 knots, 4) were not closer than \(\frac{1}{4}\) mile from the nearest natural reefs, and 5) were within reasonable distance from the local fishing ports.

In considering the selection of reef materials, factors pertaining to initial cost, fabrication or preparation, transportation, and durability were evaluated. Surface characteristics conducive to the development of marine communities were also considered desirable.

A number of scrap items such as tires, boats, and autos as well as several different types of specially fabricated concrete units were tested. Results indicated that old boats proved to be the most effective of the scrap items. However, wooden vessels were of limited durability and many of the vessels proved to be unstable on the bottom, especially during the storm or typhoon conditions common in many areas. The high scrap value of junked cars and used tires in Taiwan made them unsuitable as reef materials.

Of the concrete units, giant concrete shelter units proved to be the most effective. These units are 2.0 x 2.1 x 2.6 m in size and have been fabricated from several types of concrete for testing purposes. Other concrete units tested did not provide adequate shelter area or enough surface area for colonization.

More than 14 major reefs have been constructed along the coasts of Taiwan. Most of the recent construction has used the giant concrete blocks; more than 500 were placed in 1977. In general, most of the reefs have been quite successful and preliminary estimates of the annual value of the fish production at each reef (roughly 25,000 m\(^3\)) is approximately \(\frac{1}{4}\) million dollars.

During construction, concentrating material or shelter units on the selected site proved to be a major difficulty. The loss of marker buoys
and dumping techniques produced too much scatter in the drop to permit the development of reefs of the desired height.

Other problems have been caused by the impact of typhoons. Additionally the loss of markers has contributed to difficulties in fishing and monitoring some reefs. The use of dynamite by some fishermen has also damaged some of the reefs.

The Institute of Zoology has been monitoring the species composition on the reefs and making population estimates of the commercially valuable fish. They have also been observing the development of the communities on and around the reefs. Generally three types of reef surface communities have been observed: 1) a dominant autotrophic type composed of sessile algae, 2) a dominant heterotrophic type composed of sessile invertebrates, and 3) a mixed type of both algae and invertebrates.

The reef at Penghu is the dominant heterotrophic type, with a surface community consisting of barnacles, sponges, hydroids, sea fans, and soft coral which provide good shelter for many small crustaceans. More than 40 species of economically important fish, including grouper, snappers, sea grunts, and sea breams have been observed.

At Pingtong, the surface community is mainly autotrophic; however, the fish populations are similar to Penghu and also included grunts, surgeon fish, and caesiofish. Some pelagic species including mackerel, scads, and spade fish have also been observed at this site.

Examinations of the local catch records have clearly demonstrated that the local catch and catch-per-unit-effort have increased significantly after the construction of reefs. The level of catch has also become more stable. Fish communities have become more complex and stable with time; however, this progression is interrupted by strong environmental disturbances such as typhoons.

A number of basic investigations have also been conducted using model reef structures to assess the influence of environmental, site, and reef unit design factors on the development of reef communities. These studies have used multiple sampling units and have contributed to the refinement of site selection criteria, unit design, and the timing of construction to optimize surface community development.

Work now in progress is directed at expanding knowledge on the behavior-ecology of the commercially valuable species to provide improved harvesting methods and schedules. Additional studies are aimed at comparing the production and species composition on artificial and natural reefs.

An extension of this program which combines habitat improvement with coastal marine farming for shellfish is now being conducted at Haulein, in southeastern Taiwan. This project was developed jointly by a commercial fishing firm and the staff of the Institute of Zoology and is concerned with the harvesting of spiny lobster and abalone. The firm, which leases three small bays along the coast, began placing small
shelters of their own design in the bays to increase their catch. Initially juvenile abalone were stocked to supplement natural recruitment but there is now a sustaining population of both abalone and lobster.

The yield from this marine farm has increased dramatically during the past two years. Divers who harvest the shellfish have been able to increase their catch-per-unit effort by more than ten times. This project has recently been expanded with additional support from the Joint Commission for Rural Reconstruction. New shelter designs are being tested and behavioral and ecological studies are also being conducted in order to optimize placement and harvesting techniques.

Based on the results of the first five years of effort, the Institute of Zoology has made a number of recommendations to improve the efficiency and effectiveness of future reef projects. These include:

1) large concrete structures are the most suitable and cost-effective materials for fish reefs.

2) adequate temporary and permanent marker buoys are necessary to ensure proper reef placement, monitoring, and harvesting.

3) large crane-equipped barges should be used to obtain accurate reef placement and the necessary aspect ratio, as well as to minimize damage.

4) definitive pre- and post-construction surveys are required to provide the information necessary for accurate cost-benefit analysis. This should include the maintenance of detailed catch records and a combination of diving and acoustic observations.

Dr. Chang has particularly emphasized the necessity for a long term coordinated program to obtain the maximum benefits from reef development projects. A nationally coordinated and administered program with active local participation has contributed to the success of the efforts in Taiwan.

Japan

In Japan, artificial reefs have been used to enhance fisheries production for more than 200 years. Many of the early projects were conducted locally by individual fishermen using available materials such as stone, wood, and scrap boats. Dr. Ino gave an excellent review of the early progress in Japan during the International Artificial Reef Conference (1974) in Houston. Since then, the program in Japan has greatly expanded and has become a highly sophisticated and comprehensive undertaking designed to significantly increase Japan's nearshore fisheries resources.

The Japanese government has participated in reef building projects through subsidies since about 1930. In 1952, the Ministry of Agriculture and Forestry became directly involved and from 1952 to 1961 allocated
more than four million dollars to reef projects. From 1962 to 1970 the national government committed more than 27 million dollars to an expanded reef program. The amount of the subsidies was initially about 33%; the remainder was provided by the Prefectural (similar to our states), and Municipal governments and the fishermen’s cooperatives.

These expenditures were part of an integrated effort to enhance coastal fisheries development. Other projects within the scope of this effort included the construction of hatcheries, improvements to the culture grounds, and facilities to collect and transport shellfish juveniles and seaweed spores.

Much of the government reef support went to projects which used concrete block units to construct the reefs. Many of the first reefs were relatively small, but by 1958 larger scale reefs, greater than 25,000 m³ were being constructed. Prefectures and fishermen’s cooperative continued to use scrap materials such as tires, cars, pipe, and waste plastic to build local reefs.

A second series of projects involving even greater government support extended through 1975. During this period, new reef designs were tested and special shelter units designed for specific species of fish, shellfish, and seaweed and fabricated from a variety of materials were used.

The current national reef program, which began in 1976, was the result of the "Law for Coastal Fishing Grounds Consolidation and Development" enacted in 1974. This legislation allocated funding to promote the development of coastal fisheries through the construction of large fishing grounds and propagation areas. The program emphasizes habitat improvement as a means to enable Japan to meet its seafood demands in an era of 200 mile limits and increasing oil prices (Sheehy, 1979). The national government has committed more than a billion dollars to this seven year program. Matching funds from the Prefectures, Municipalities and cooperatives ranges from 30-50% of the projects total cost.

The program is made up of two basic sections. One is concerned with the improvement of bottom conditions for specific species of invertebrates, such as abalone, lobster, sea urchin, and sea cucumber, as well as a variety of seaweeds, while the other involves the construction of large scale artificial reefs and banks.

Small shallow water reefs used for shellfish and seaweeds are called "tsukiisso" in Japanese. These are used as part of the efforts to improve nearshore bottom conditions. Over 40% of the current large scale projects using this type of reef are designed for abalone, a popular and high priced item in Japan. Several of these projects are described below.

Ecological studies conducted near Tokushima indicated that the impact of storm waves on nearshore gravel habitat was responsible for heavy mortality in juvenile abalone. Wave action also caused the loss of attached seaweed which is the prime food source for the juveniles.
Shelter unit for spiny lobster used in Nagasaki. Photo credit: Mr. Inui.

Shelter unit for lobster in Miyazaki. Photo credit: Mr. Uchida.
Abalone shelter unit being placed in Hokkaido.
Photo credit: Dr. Sato.

Abalone shelter unit composed of FRP frame with rocks. Asahi Chemical International, Ltd.
Photo credit: Dr. Ogawa.
An effort to create an artificial nursery for abalone was undertaken as a joint operation by the Prefectural Fisheries Lab and the local fishermen's cooperative, with the support from the national government. Three types of concrete units were used to construct the nursery. In the nearshore zone (0.5 m) small jack units, with grooves to provide additional shelter for juveniles, were set into the gravel to stabilize the bottom. Just seaward of this, truncated pyramid-shaped units, with attached lines, were placed to promote seaweed growth. At the outer edge of the nursery, large hemispherical blocks weighing about 15 mt were set in two rows to break waves and provide shelter for adult abalone.

Preliminary studies indicated that the survival and growth of naturally spawned abalone has increased significantly in the nursery area.

In Hokkaido, two projects have gone one step further and include the stocking of abalone spat in conjunction with local reef projects, conducted under the supervision of the Hokkaido Institute of Mariculture, are designed to increase the survival of hatchery reared abalone by stocking them in prepared shelter units.

In Fukushima, 25 large concrete boxes (4 mt each) with open sides are filled with rock and placed in an intertidal site. The crevasses formed by the rocks provide excellent habitat for the juveniles which are stocked in PVC pipe sections. Special tidal channels which increase tidal flow were also constructed. These units have been very successful and marked seedlings experienced improved growth and survival.

At Taise, special units, some of which are covered with plastic coated wire to reduce predation and competition, are stocked with hatchery reared abalone spat. These units are placed in 3-5 m and are stocked and monitored by divers. Other units designed for larger abalone are also located in this area. Some have been fitted with plastic attachments to promote seaweed growth and thus provide both shelter and food. This project has clearly demonstrated the potential for a combined hatchery and habitat improvement program.

Artificial reefs, as we generally use the term in the U.S., are called "gyosho" in Japanese and are built either to expand natural reef areas or to create new fishing grounds in areas previously only sparsely or marginally productive commercially. These include bottom reefs as well as moored mid-water and surface structures. In addition to their use in concentrating fish, they are also used to alter normal migratory routes, to attract fish to unpolluted areas or water layers, and in the creation of nurseries.

Reef sites are carefully chosen based on detailed physical, chemical, geological, and biological studies, as well as practical considerations. Most bottom shelters are located at depths between 30-60 m, but some are placed as deep as 120 m. Generally the midwater and surface structures are moored between 60-100 m and some surface units are capable of being placed in water up to 200 m deep.
The National Agricultural Civil Engineering Laboratory has been studying the hydraulic factors important in reef design and site selection. This research has provided some new concepts about how reefs function. When currents impinge on reefs, instabilities occur between vertically stratified fluid layers which generate internal waves. Studies demonstrated that the presence of internal waves significantly influences fish distributions. Acoustical observations indicate that fish concentrations correlate with the presence of lee waves resulting from the interaction of currents with reefs. Results of these studies suggest that the aspect ratio (height of reef to water depth) should be between 1/20 and 1/5, depending on local conditions.

Large scale fish shelters are now commercially manufactured by more than 15 Japanese companies. These are fabricated from reinforced concrete, steel, iron, PVC, and FRP. The designs, many of which are patented, are based on extensive engineering efforts undertaken by corporations, national laboratories, and universities. Biological investigations are conducted by both regional and prefectural laboratories in cooperation with fishermen's groups. Almost all units are designed to last a minimum of 25 years.

Most of the larger reefs ("jumbo gyosho") are built to promote an upward current deflection, provide sheltered darkened areas, and permit good circulation within the units. Many of the shelters are constructed from prefabricated sections which are assembled at shore staging areas and transported by barges to the sites. With some notable exceptions, most are placed with large floating cranes. Some can be built in a variety of configurations from basic unit components.

A number of large scale units, which have undergone extensive testing, are now being placed in more than a hundred locations along the coast of Japan. Several of the types which are currently being mass produced are briefly described below to provide some idea of the scope of the work now in progress. All of the units described have a height adequate to attract fish without the necessity of being placed in piles.

Reef units produced by Ishidawajima-Harima Heavy Industries Co., Ltd. have been placed at over 40 sites. Each site is made up of between 10 to 50 units. Each unit weighs about 22 mt, has a volume of 139 m³, and is triangular in cross section with a height of 7 m. These structures are built from reinforced concrete sections which are coupled together into triangular panels.

"Dragon Reefs" manufactured by Onoda Cement Co., Ltd. have been placed at over 12 sites. The number of units per site ranges from 3 to 30, and each unit weighs about 34 mt and has a volume of 131 m³. These cube shaped units, roughly 5 m per side, are constructed from eight reinforced concrete panels which are bolted and mortared together.

Semicylindrical ferro-cement units produced by Ryowa Concrete Industries, Ltd. have been used at a number of sites off the northwest coast. These units can be built in several different versions. Although
Large scale prefabricated fish reef of reinforced concrete by Ishikawajima Kensai Kogyo Co., Ltd. Photo credit: IKK Co., Ltd.

"Dragon Reef" under construction at shore staging area. Photo credit: Onoda Cement Co., Ltd.
"Kamaboko Reefs," in two different configurations. Photo credit: Ryowa Concrete Industries, Inc.

Fiberglass reinforced plastic reefs manufactured by Asahi Chemical International, Ltd. Photo credit: Dr. Ogawa.
smaller types are available the units most commonly used are 6 m high, 151 m\(^3\), 22 mt, and 9.3 m high, 321 m\(^3\), 45 mt. Tests off Sado in Niigata Prefecture have demonstrated the effectiveness of these units.

Fiberglass reinforced plastic (FRP) units manufactured by Asahi Chemical International, Ltd. offer a variety of shapes and sizes. More than 25 of these reefs have been constructed using units which range in size up to 10.5 m high and 720 m\(^3\). These units have a large surface area which is rapidly colonized since there is no alkaline leaching. The weight per unit area of FRP units is less than half that of concrete and they can be used in areas unsuitable for more massive reef types. The reefs are generally weighted with concrete according to the local bottom type, wave, and current conditions. Installation of these fish reefs is less expensive since the units can be towed to the placement site with the aid of air bags.

Reef units made by Tokuyama Soda K.K. are being used in a large scale reef project off the north coast of Yamaguchi. These units are also constructed in a number of forms ranging up to 7.5 m high, 225 m\(^3\), and 44 mt and are made of reinforced concrete sections, generally box-shaped, and placed on top of one another at varying angles. Plans indicate that when complete, this reef will be more than 20 times larger than any currently existing reef in Japan and will cost almost two million dollars. It will be placed in 70-80 m and will include a seaweed bed of quarry rock. The project is intended to increase the stocks of yellowtail, jack mackerel, Pacific mackerel, and snapper.

**Conclusion**

As both the Japanese and Taiwanese have demonstrated, marine habitat improvement methods using artificial reefs and nursery areas have great potential for expanding coastal fisheries resources and rehabilitating areas adversely impacted by human activities such as pollution and overfishing. Similar reef structures could be used in the U.S. with considerable benefits to both recreational and commercial fisheries, as well as to the developing aquaculture industry. Three recent developments — the increasing U.S. consumption of seafood, the 200 mile extended jurisdiction statute, and the increasing cost and questionable supply of fuel have made the use of artificial reefs particularly appealing.

The U.S. currently has both a growing domestic demand for seafood and a rapidly expanding export market. A review of the U.S. fishery statistics for 1978 reveals that a number of new records were established: 1) per capita consumption (edible) -13.4 pounds, 2) value and volume of all U.S. commercial landings - $1.9 billion, 6.1 billion pounds, 3) value of all U.S. imports - $3,100 million (up 18% from 1977), and 4) value of all U.S. exports - $905 million (up 74% from 1977). As the activities of foreign fleets are reduced due to the 200 mile limit statute, opportunities for developing U.S. fisheries are expanding.
rapidly. However, the U.S. continues to import a substantial amount of the high-priced seafood it consumes. Habitat improvement technology offers a means for the U.S. to increase its production of high-valued species for both domestic consumption and export. Some of these species, such as spiny lobster, shrimp, and abalone have been shown to be adaptable to artificial reef and nursery techniques. By reducing our imports and expanding our exports, we can employ Americans and contribute to reducing the balance of payments.

The increasing price of fuel and the current potential for the reduction in supplies may also serve to enhance the advantages of artificial reefs as a passive means of concentrating fisheries resources (as compared to more energy-intensive means such as trawling). This consideration applies to recreational fisheries, which have accounted for almost half of the edible finfish landed, as well as to commercial fisheries and the possible development of ocean ranching ("extensive" aquaculture) techniques.

When comparing designed and manufactured reefs to those made from scrap items, as are most of those currently in use in the U.S., it is important to consider all of the costs involved (material, processing, transportation, and placement), as well as the expected life span and the productivity of the reefs. Many of the scrap materials used in the U.S. are either no longer available (surplus liberty ships), require extensive preparation and handling to meet current Environmental Protection Agency, Corps of Engineers, or state requirements, have a limited life span (cars and appliances), or do not provide the best aspect ratio for use in many areas (tires). Manufactured reefs offer design flexibility, extended life spans, and excellent bottom stability.

Specifically designed and manufactured reefs do require a sizable investment, but it is a one-time fixed cost, and the U.S. can benefit from the extensive research and development efforts already funded by Japan and Taiwan. Some of the other alternatives, such as hatcheries, which have been suggested to improve fisheries production require recurring expenditures subject to inflation and have not been shown to be effective with marine species in the U.S. However, hatcheries used in conjunction with habitat improvements and supplemental feeding have been shown to increase survival and growth of stocked juveniles, and may be cost-effective for some species.

Many of the current U.S. reef projects, which are administered by states, counties, or municipalities, lack the necessary funding to conduct research or expand their activities and a number have either been reduced to a maintenance status or are no longer active. A national program with active local support such as those now in practice in Japan and Taiwan may be the best approach to providing a coordinated U.S. artificial reef program.

References

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LOOKING AHEAD (Conference Summation)

Dr. Harris B. Stewart

I would first like to comment on the way this entire conference has been put together. I think to have a session on overview, one on planning, one on construction and, finally, one on evaluation and management is a magnificent way to have organized it. I have always been impressed with the manner in which the sponsoring organizations have cooperated together in efforts of mutual interest and I think that the Sea Grant and the state and federal agencies involved deserve a lot of credit for this cooperative endeavor. Also, I think if we can get the required funding to publish the Conference Proceedings we will have the only existing manual on artificial reefs. I urge each of you who have not yet submitted your paper to the conference coordinator and Proceedings editor, Don Aska, to do so because I think the Proceedings from this conference are, in fact, going to be the bible in the whole area of artificial reefs.

I have essentially 8 points that I would like to make; these revolve around these basic questions: OK, as a result of the last 2 days where are we today; where are we going; what should we be doing; what are the next steps we should take in order to accomplish the goals we have talked about so nebulously; where do we want to be and how do we get there? These 8 points are put together in part from my own listening to the papers and, in part, from the suggestions of both the moderators and rapporteurs of the technical sessions.

Point One, is in the area of research. There is a tremendous amount of research that needs to be done in the area of artificial reefs. A couple of these areas are; a critical need exists for tank studies, studies of the reaction of various reef building materials to the physical forces to which you can anticipate they will be subjected. This, it seems to me, is a very important step and one on which little has been done to date; then, we need research on reef building materials. I was very interested in the movie we saw yesterday of the work that had been done in Stonybrook, Long Island, New York, where materials residual to coal fueled power plant operations was being compacted and used as reef material with, apparently, quite effective results. Although he did not present a paper at this conference, as he so effectively did at the 1977 St. Petersburg, Florida, John Loudis, International Balers and Compactors, Jacksonville, Florida, reports that the machine he talked about is now a reality and in commercial production. That piece of equipment takes 100 automobile tires and compresses them into a block 45" x 40" x 60". They strap it and when the straps are removed it evidently has killed enough of the rubber aspect so that it does not
snap back and throw you into the next county — it seems to work extremely well. Another firm in New Jersey has come up with something they call "Bombjacks," which are concrete logs that you fit together like the Lincoln Logs we used to play with as kids. These are used for building reefs or, at least, building the outer structure into which other materials can be dumped to help put your reef together. I think these are some of the types of research that should be undertaken in the engineering area.

As an oceanographer who started out as an undergraduate in biology, I have always been fascinated by the biological aspects and I advocate much more research, or more funding to get the research done, in the area of succession on the reefs. For example, if you put a reef down at one point of the game you will have a group of organisms looking for a place to settle. They, perhaps, will colonize the whole thing so that subsequent fleets of organisms looking for a settlement place can't find it. Perhaps you wind up with a reef that is primarily Tunicate, or primarily barnacles, which then exclude subsequent organisms. I think this is an essential area of research that has to be done. I think more research on the succession of organisms working up through the trophic pyramid has to be done. I think research is badly needed in the economic aspects. I think I heard more about the economic and social implications in relation to artificial reefs than at any previous conference. I am delighted to see the people involved in economics and sociology participate so actively. We need more of them and their type of research.

Work needs to be done in the engineering economics of the whole thing. For example, there may be cheaper materials that are short-lived in contrast to somewhat more expensive building materials but which are longer-lived and the cost per year over 50 years is ultimately less per unit. I think these are the sorts of studies that have got to be done and have to be published for the benefit of all reef interested persons. So, Point One, was research.

Point Two has also been brought up. Dr. John Merriner of VIMS mentioned it quite recently, namely, that considerably more emphasis has to be placed on the matter of public awareness, the importance of getting through to the voters, if you will; bringing to them, the importance of reefs — the excitement of reefs — the benefits to them of reefs, because these are the people who are going to have to bang on the doors of the Congressmen and the Senators to see that things do, in fact, get accomplished. The newspapers like the idea of artificial reefs; underwater pictures are things that newspapers enjoy and use as much as anything scientific. Most of the ship sinkings have received very good publicity. The reef building activities in the Tampa Bay area off Panama City have received a tremendous amount of publicity, most of it good publicity. So, I would urge that in the future you see what can be done to increase the general public awareness of what we are doing or what we are trying to accomplish in the artificial reef area.

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Point Three relates to S.325, the Bill that Senator Stone and Congressman Stack, both of Florida, have introduced as companion Bills in the Senate and the House. At your session last evening you came up with some suggestions which our Dick Stone (NMFS) assures us he is going to relate to the Senator and the Congressman immediately upon his return to Washington to see that changes and improvements are made in the Bill. One change relates to including freshwater activities in the Bill, not only from the artificial reef point of view, per se, but from the purely practical point of view. Michigan and Ohio are just as interested in artificial reefs as the coastal states. I think that would be one definite improvement to see that freshwater reefs are included in the rewrite of the Bill.

Another point that I think should be reconsidered has to do with the $2.5 million originally called for which is not even a minidrop in the bucket when you think in terms of $10 billion for water resource projects in general in the United States. In many instances, it is easier to get a $40-50 million project through the Congressional system than it is to get a $2.5 million Bill through. This suggestion for an increased level of funding will also be forwarded to Washington. A third point relating to S.325 that I think we must do as individuals is to see that the appropriate level of your concern is adequately communicated -- that means pressure to your Congressional delegations. Bills like this seldom go through if there is just one Senator or one Congressman pushing it. You have to have strong support within both the House and the Senate and that support has got to be backed up by a strong level of constituency support. I would urge that if your own restrictions preclude your writing strong letters on your organizational or institutional letterhead that you don't be afraid to use your personal letterhead to the Congressmen and Senators and urge your friends to do the same.

Point Four is a matter I want to identify to you as a problem that needs resolution and one for which there are numerous solutions, no one of which everyone would agree to. That is the matter of focus, nationally, for the whole question of artificial reefs. One suggestion was made that there be a national focus in the National Marine Fisheries Service. Another suggestion was that we need focus at the state level since there is already too much center of control on local-federal matters now at the Washington level. Others suggested that the Sea Grant organization would be the obvious mechanism for providing a national focus for the whole artificial reef program. This drew considerable support as Sea Grant has a wholesome non-advocacy policy, is research-user oriented, is national in structure, has excellent professionals in the involved disciplines and has developed a well justified public posture. Perhaps you should consider an Artificial Reef Association made up of the sort of people who are here now with contributions which would support a newsletter and central mailing list. This would provide a means of communicating among yourselves. If a crisis came up in the legislature or some other organization in the state was having a problem with some aspect of artificial reef you know exactly who to call and who to talk
to get the help you need. If there were a national focus at the federal level it might be useful for obtaining funding, for example, or for finding out what other nations are doing and seeing that this information is effectively disseminated throughout the system. I will have to leave it to you, and others like you, to determine what might be the most appropriate mechanism for developing an expanded focus for artificial reef activity in this country. I am firmly convinced of the need and the merit for such a mechanism and pass it on to you as a point well worth considering.

Point Five is one that kept coming up over and over but in a disparate, hodge-podge, sort of way. That concerns the whole matter of cost-benefit studies. You heard mention during the past two days of cost versus benefit, some of the problems of trying to work these out, trying to sort out what might be a benefit to one state but a cost to another one. There are lots of recognizable problems in this, one being standardization of units of measure. One person refers to the fisherman-pleasure quotient, someone else mentions catch per unit of effort, another mentions number of snappers per cubic meter per week. All of these things are tried to be converted into dollar signs so that you have some significant numbers. What I would urge is this; if we are going to try to get the type of support we need at both the state and federal level for artificial reefs we have to be able to show the hard-nosed bureaucrat some very meaningful numbers as to why it is to his advantage, as a politician, the states advantage and the taxpayers' advantage to put their money in artificial reefs in contrast to something else. If we can show a $2 benefit in return for a $1 expenditure in artificial reefs, in contrast to a $1.05 return on a $1 investment in something else, then they will probably do it. However, we have to provide hard numbers, economically significant and statistically meaningful numbers, that the politicians can interpret and say "Yes, this needs to be done." So, in the whole are of cost benefit studies, evaluations of the worth of the project to the man-end of the system I would suggest that you try to find a key person, or a central group, to whom, when each of you who have looked at this could fire his or hers or their data. This one central person or organization would then try to put this all into some semblance of useable form whereby it would be available to all of us for our common use and need. I don't know who that would be, or where it could be, but you can approach this better than I. I am, however, firmly convinced of the need and thereby advocate that we get a much firmer handle on this whole cost-benefit dollar value to the man in the street if we are to make our case and if we are to obtain the funding levels that we require.

Point Six is a comment that came out of these meetings, and also one that I felt quite strongly on even before I came to this conference, and has to do with the idea of separate workshops, or if it is a large meeting like this, separate technical sessions devoted to fairly narrow disciplines within the artificial reef complexes. For example, one technical session, or one working group, or one workshop, on the legal aspects; another on the technical engineering aspects of constructing reefs; another on the scientific aspects; another on the sociological aspects, etc. I think it was not appropriate to do so at this current conference
but is worthy of consideration when planning future artificial reef conferences. I think this conference, as an overview conference, was strategically targeted to cover the state-of-the-art as we now stand. However, I think for subsequent meetings that matter of separate sessions, workshops, or even conferences, is worthy of strong consideration.

Point Seven has to do with the matter of "nudging" the National Ocean Survey to establish criteria for placing artificial reefs on the large-scale inshore nautical charts. They are already charged with putting bottom obstructions on the charts which is a problem since they have inadequate funding to do the job. I think that a real nudge from this group to NOS to see that the position of major reefs are placed on the nautical charts that the small boaters use would bear some fruit. Some logical criteria would have to be developed to sort out the small reefs, for instance the isolated piles of tires, from the major organizationally sponsored reefs.

Point Eight, and probably the most important of all, is the philosophy we develop as we go ahead into the next few years in artificial reefs. I think we should concentrate on quality rather than quantity. I'm not advocating any cessation or marked diminution of reef construction. I'm saying that we should take the lessons we have learned in these two days to heart; let's pay more attention to siting, to research, to planning, to construction materials, to alerting the public, to all of the things we have listened to, and let us see that the reefs we put down in the future and the management of the reefs we already have put down are, in fact of the highest possible quality. Unless we can achieve a high level of artificial reef quality we are in real trouble in the future.

My next point is really a comment and reflects on the United States vis-a-vis Japan. The Japanese have done a magnificent job as you learned this noon from Dr. Dan Sheehy. They have established a very fine system as to the things they do before they put a reef down and how they manage it. I do not believe the United States will achieve the same degree of sophistication or efficiency because of different motivations. The Japanese reefs are commercial reefs designed to feed a public with not very much land area. The United States has not yet reached the stage, and I repeat, not yet reached the stage, where we need reefs to feed our people. We are still thinking of reefs in terms of sport fishing or diving and other related recreational uses. While such motivation is undisputably important, I don't think it will generate the same degree of public and political support the Japanese have developed. However, this degree of support could visibly change if our reliance on artificial reefs as a substantial source of food for our population were to change and we should be ready to respond if that eventuality should develop. Yesterday similar comments were expressed by Florida's Congressman Chappell when both he and his representative commented on the future of aquaculture and artificial reefs as prime sources of protein food in the future. I simply reiterate what they stated.
These, then, are some, of my ideas generated through two days of attentive listening to all selected and qualified speakers, of corridor discussions with conference attendees and my own background as oceanographer, biologist and administrator. I hope they will spark some response from you on your return to your respective headquarters and that many meaningful improvements in all aspects of artificial reef research, management and management will evolve from your efforts.

(Ed. Note: Transcribed from tape of Dr. Stewart's oral summary, with limited editing to assure effective relay of Dr. Stewarts observations and emphasis.)
APPENDIX

(Ed. note: A number of excellent papers were volunteered by uniquely qualified authors but after the Conference Planning Committee had already received firm commitments to the originally structured agenda. Unfortunately, there was insufficient uncommitted time on the program to accommodate these several papers, each of which had topical and geographical application to the conference. Accordingly, it was mutually agreed that an Appendix would be added to the Conference Proceedings so that future readers would have access to these conference theme related papers. The Conference Planning Committee expresses its appreciation to the following authors for their contributions and only regrets that time limitation prevented actual presentation during the course of the conference.)

"Fishing Piers and Marine Habitat Enhancement in Washington State"
Raymond Buckley and Dr. James Walton
Washington State Department of Fisheries
Olympia, Washington

"Artificial Reefs As Strategic Nursery Grounds"
Mike Calinski
Florida Keys Community College
Key West, Florida

"Underwater Photogrammetric Survey of a Tire Reef"
Bill Raymond
Ocean Research & Survey, Inc.
Ft. Lauderdale, Florida

"Coal Combustion Products - New Substrates for Artificial Reef Construction"
P. M. J. Woodhead, J. H. Parker and I. W. Duedall
Marine Sciences Research Center
State University of New York
Stony Brook, New York
An active program to establish fishing piers and marine habitat enhancement in the Pacific Northwest was undertaken by the Washington Department of Fisheries early in 1974. The impetus for this program was a recognition of the need to provide shore-bound anglers with access to productive marine recreational fishing, especially in metropolitan areas. Large fishing pier facilities are now being used to provide centralized access locations and, in order to maintain good fishing under intense angling pressure, the adjacent bottomlands are being enhanced with introduced habitats to increase local productivity.

The design of this fishing pier/habitat enhancement program was influenced significantly by information obtained at the International Conference on Artificial Reefs in Texas in March 1974, and on a subsequent examination of fishing pier facilities on the Texas Gulf Coast. The organization of a Puget Sound Fishing Pier Workshop by the Northwest Fisheries Center of the National Marine Fisheries Service, in April 1974, aided considerably in establishing the need and the mechanisms for using these enhancement techniques to solve local fishery problems.

To implement this concept and respond to other developmental research needs, the Marine Fish Enhancement Unit was established in mid-1975. The Unit began with a staff of two biologists, an operational budget of $102,000, and a capital appropriation of $455,000 to construct a habitat enhanced public fishing pier at Edmonds and some additional habitat enhancement of an existing underwater park. To increase the research capabilities of the Unit, some operational funds were used to contract with the Washington Cooperative Fishery Research Unit at the University of Washington, College of Fisheries, for a graduate student to use the design and analysis of the introduced habitat enhancing the Edmonds Pier as his Doctoral dissertation topic. This expertise in habitat enhancement was retained within the Unit through subsequent employment of the student.

In four years, the Marine Fish Enhancement Unit has expanded to four biologists and two scientific aides, and the operational budget has increased to $266,000, which includes funding for four graduate students. An additional $2.9 million in capital funds has been appropriated to construct five additional fishing pier/habitat enhancement complexes, 12 habitat enhancement areas for boat anglers, and one SCUBA divers' facility. The source of these capital appropriations has been

Washington State Department of Fisheries, Olympia, Washington
50% State/50% Federal matching funds administered through the State’s Interagency Committee for Outdoor Recreation. The State’s share was obtained from referendum bonds for recreation. The Land and Water Conservation Fund, administered by the Heritage, Conservation and Recreation Service of the Department of Interior, has supplied the Federal matching funds.

The rapid success of the fishing pier/habitat enhancement concept in Washington was due primarily to its well planned application to a clearly visible need, and to the "enhancement" directive of the program. It was determined early in the design of the program that marine habitat enhancement was the primary biological tool available to solve a number of fishery problems, but the habitat enhancement concept by itself was not sufficiently "visible" to gain the broad base of public support necessary to generate the funds required to build an extensive program. Therefore, it was decided that the initial local application of anglers in a "high profile" situation. This would firmly establish the concept with the Department and the funding sources, and would facilitate rapid expansion into areas that are equally justified for biological and management reasons, but that may not have the immediate high public demand factor needed to compete for funding.

The association of the benefits of habitat enhancement with the first public fishing piers fulfilled this need. The piers were virtually guaranteed to be successful because they were the first quality access for local shore-bound anglers, and their barrier-free design provided an excellent fishing experience for all anglers, regardless of age or physical ability. The habitat enhancement structures dramatically increased the number of fish available to pier anglers, so their value was easily related to the quality of fishing. Harvest regulations and related research were implemented to maintain good fishing on a sustained basis and to demonstrate that intense recreational fisheries on introduced habitats could be properly managed.

The second phase of the habitat enhancement program was to expand their application to include the boat angler recreational fisheries adjacent to metropolitan areas. These intense fisheries and the limited productive habitat in these areas, have resulted in depressed recreational catches. Strategically located and properly designed introduced habitats would enhance local catches and reduce the distance to productive fishing grounds, and important factor considering the current energy consumption constraints.

The information gained from these specially designed offshore projects will allow further expansion of habitat enhancement into oceanic waters. Recent targeting of ocean charter boat recreational fisheries on rocky bottom species has created the demand for more productive fishing locations in proximity to major harbors. The habitat enhancement projects in these areas, and many of those on inside waters, will also be equally adaptive to enhancing commercial fisheries employing gear that can be fished productively around introduced structures. This will require, however, the development of introduced habitat management policies that will sustain fish production, under concurrent or allocated use, by dramatically different fisheries.
ARTIFICIAL REEF AS STRATEGIC NURSERY GROUNDS

Mike Calinski

Our present artificial reefs have been shown to improve normally poor fishing grounds, but biologically speaking, they only fulfill the needs of the later life stages of the species involved, i.e., reefs have been traditionally placed in deeper water so as to attract larger fish.

All fisheries depend entirely upon the strength of their recruitment stock, and the survival rates of its early life stages. The nursery grounds of these early life stages are a major factor which determines the strength of the future seed stock. With the nearshore nursery environment comprising a great deal of all nursery grounds, man's encroachment upon these shallow waters is of vital concern to the existence of many fisheries. Habitat availability probably plays a key role in the survival rates of the young that utilize these shallow water environments.

If fishery standing stocks are to be maintained under an ever increasing pressure, an offset must be made available to insure adequate seed stock survival, and to eventually develop the full potential of the fishery by "sowing" all available seeds.

One strong possibility would be the development of an "artificial reef system" designed exclusively to meet the early survival needs (food and habitat) of the species involved. A system that could be incorporated into strategic nursery grounds, and would, in essence, make the very best of larval and postlarval recruits -- a presently wasted and non-utilized resource.

Artificial habitats which have been designed and developed to protect the early life stages (postlarval through 6th to 8th stage) of the Florida spiny lobster, Panulirus argus, have been shown to dramatically avail the survival rates (nearly 100% for the first month after postlarval settlement) of the animals, and theoretically, a total one square mile of habitats could double the total spiny lobster landings in the state of Florida (Calinski, in script). These habitats (¼ m²) had to undergo several developmental changes, with the most functional design (which floats on the surface in shallow water) being focused at and used almost exclusively by spiny lobsters.

Present research strongly indicates that such habitats could be developed for the early life stages of other commercially important species (such as shrimp, snappers, stone crabs, and blue crabs) to step up their early survival rates, and thus provide an additional imput

Florida Keys Community College, Key West, Florida
into the fishery. Rates of highest animal mortality in the marine environment are incurred during their early life stages. Therefore, it would stand to reason that if these early stages were protected (from predation) that the adult populations would be benefited.

Japan has long since realized the possibilities of such a system and, although built out of necessity, their combined reef system has increased their total fishery landings tenfold in the past 5 years (Dr. Daniel Sheehy, Conf. Proceed.). Each species is unique in this respect, and each species has different habitat and nutritional requirements. Much research is needed to identify these requirements so that they may be secured upon and improved upon. In doing so, we would not only be better managing our future fisheries (along with making the very best of what we have), but we would greatly aid nature in her own management scheme.
UNDERWATER PHOTOGRAMMETRIC SURVEY OF A TIRE REEF

Bill Raymond

Background

In 1972, Broward Artificial Reef, Inc., began dropping tires in a permit area east of Sunrise Blvd., Ft. Lauderdale, in an effort to build an artificial reef for attracting fish. The permit area was located on a sand terrace between the second and third reefs, 65 feet deep. The potential for attracting fish at that depth was demonstrated by the success of a ring of 300 concrete hexapod "erojacks" at the same locality in 1970. By the end of 1973, over a million tires had been dropped in the permit area.

At first the tires were bundled and weighted with concrete, forming free-standing upright modules on the sea floor, which were separated by several feet of open space. The sand bottom would scour around each module due to the hydraulic action of currents passing around the cylinder-shaped modules. The procedure was subsequently modified to punching, compacting and bundling the tires to form a low density, cylindrical module for easier handling. A decomposable steel clip was placed on three of the bands used in bundling and a stainless steel clip on one, so that the bundles would soon spring open into a fan-shaped module. The practice of dropping cylindrical modules continued until 1979. In June 1979, less than 30% of all bundled tire modules were fan shaped (Table 1). The remainder were cylindrical modules which are easily rolled by wave or current action. Concern was expressed that perhaps therollable modules would eventually wash up on the beach or damage live corals on the reefs.

In 1978, Broward County contracted with D. E. Britt Associates, Inc., to conduct a survey of the tire reef, using side-scan sonar, photogrammetry and biological diver inspections, in order to document the location of tire modules on the permit area at the time of the survey. A future comparative survey would enable a determination of the extent of tire movement during the interim. The present study, subcontracted to Ocean Research & Survey, Inc., was conducted in June 1979 to complete the photogrammetric field work for the first phase of that study.

The results of the photogrammetric survey consist of a photomosaic strip 500 inches long, representing a linear distance of 1500 feet of the sea floor. The area photographed in the survey runs east-west from the second reef (50 feet) across the sand terrace (65 feet) to the crest of the third reef (55 feet) and varies in width from 15 feet to 25 feet.

Ocean Research & Survey, Inc., Ft. Lauderdale, Florida
The purpose was to provide a reproducible photographic cross-section of the main body of the tire reef. The tire reef covers an area of roughly 1000 feet by 1000 feet. The photogrammetric survey would supplement the side scan sonar map by providing a detailed analysis of a representative area.

The photogrammetric survey was considered extremely successful in providing a representative quantity of detailed information on the tire reef. The information includes (for the area photographed) the distribution of tire units, orientation, condition, proportion of each type of unit, and, to a limited degree, the type and amount of organic growth covering them. Because of observable "landmarks" within the photomosaic, it will be possible to re-photograph the same strip to determine the subsequent movement of these tires from events such as Hurricane David in September 1979.

The results of the data acquired from the photomosaic strip are summarized in Tables 1 and 2. One of the 40-inch-long photomosaic strips is reproduced on Figure 1. Reproductions of the entire survey are available from D. E. Britt Associates, Inc., Ft. Lauderdale, Florida.

Underwater Photogrammetry

A modification of the principal of aerial photogrammetry, underwater photogrammetry simply consists of mounting a pair of underwater cameras vertically on a stabilizing platform and taking sequentially overlapping pictures of the sea floor at consistent heights above the bottom. Depth perception and scale are achieved through parallax, similar to how our eyes perceive visual objects. A variation of this technique is often preferred, where only one camera is used. Stereo pairs are taken from sequential photos, require more ground truthing data than with twin cameras. The technique varies with theographer and the availability of specialized equipment.

The majority of published underwater photogrammetric surveys have been conducted on marine archaeological projects (Bass, 1968; Rebikoff and Cherney, 1965; Newton, 1975) although a few underwater photogrammetric surveys have been biologically oriented (Lundalv, 1971; Torlegard & Lundalv, 1974; Bohnsack, 1979). Recently the technique has been utilized for surveying reef damage from dredging for beach restoration projects (Raymond, 1978), preliminary underwater surveys for oil transfer/storage facilities in the Cayman Islands (Raymond, 1978), surveying an ocean outfall (Parnell, 1979) and surveying coral reefs adjacent to a Navy bombing range (Raymond, 1980).

The technique used in this study was described in detail by Pollio (1969) and modified in the following areas:

(1) scale was derived by photographing along a one-meter-interval tagged cable;

(2) no attempt was made to produce stereobathymetric contour maps; and,

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### TABLE 1

Tire Unit Distribution Data From Photogrammetry

<table>
<thead>
<tr>
<th>Photomosaic Board #</th>
<th>Length</th>
<th>Single Tire Units</th>
<th>Fan Modules</th>
<th>Upright Cyl. Mod.</th>
<th>Horizon. Cyl. Mod.</th>
<th>Total Units</th>
<th>Density Units/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>30m</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>.09</td>
</tr>
<tr>
<td>2.</td>
<td>40m</td>
<td>2</td>
<td>12</td>
<td>8</td>
<td>19</td>
<td>41</td>
<td>.18</td>
</tr>
<tr>
<td>3.</td>
<td>40m</td>
<td>6</td>
<td>30</td>
<td>11</td>
<td>41</td>
<td>88</td>
<td>.39</td>
</tr>
<tr>
<td>(65% barge)</td>
<td>40m</td>
<td>0</td>
<td>10</td>
<td>9</td>
<td>41</td>
<td>60</td>
<td>.27</td>
</tr>
<tr>
<td>5.</td>
<td>45m</td>
<td>5</td>
<td>19</td>
<td>17</td>
<td>85</td>
<td>98</td>
<td>.39</td>
</tr>
<tr>
<td>6.</td>
<td>50m</td>
<td>2</td>
<td>11</td>
<td>11</td>
<td>83</td>
<td>107</td>
<td>.34</td>
</tr>
<tr>
<td>7.</td>
<td>50m</td>
<td>2</td>
<td>34</td>
<td>3</td>
<td>64</td>
<td>103</td>
<td>.33</td>
</tr>
<tr>
<td>8.</td>
<td>60m</td>
<td>10</td>
<td>9</td>
<td>0</td>
<td>12</td>
<td>31</td>
<td>.07</td>
</tr>
<tr>
<td>9.</td>
<td>45m</td>
<td>31</td>
<td>6</td>
<td>1</td>
<td>11</td>
<td>49</td>
<td>.19</td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td>63</td>
<td>11</td>
<td>0</td>
<td>3</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>400m</td>
<td>126</td>
<td>145</td>
<td>53</td>
<td>340</td>
<td>664</td>
<td>2.25</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>44m</td>
<td>13</td>
<td>15</td>
<td>5</td>
<td>34</td>
<td>66</td>
<td>.25</td>
</tr>
</tbody>
</table>

### TABLE 2

Horizontal Cylindrical Tire Module Orientations

<table>
<thead>
<tr>
<th>Photomosaic Board #</th>
<th># Modules</th>
<th>North-South</th>
<th>East-West</th>
<th>NE-SW</th>
<th>NW-SE</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>2</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>2.</td>
<td>19</td>
<td>26%</td>
<td>37%</td>
<td>16%</td>
<td>21%</td>
<td>100%</td>
</tr>
<tr>
<td>3.</td>
<td>41</td>
<td>26%</td>
<td>26%</td>
<td>24%</td>
<td>24%</td>
<td>100%</td>
</tr>
<tr>
<td>4.</td>
<td>41</td>
<td>37%</td>
<td>20%</td>
<td>13%</td>
<td>30%</td>
<td>100%</td>
</tr>
<tr>
<td>5.</td>
<td>64</td>
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<td>East-West</td>
<td>NE-SW</td>
<td>NW-SE</td>
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Average: 35% 25% 18% 21%
FIGURE 1

PHOTOMOSAIC TRANSECT
ACROSS TIRE REEF -
Board #5 of 10

F  =  Fan module
U  =  Upright module
S  =  Single tire
\( \theta \)  =  Orientation

Survey Area

Ocean Research
& Survey, Inc.
(3) A 35 mm camera was used instead of a 70 mm camera

A Rebikoff "REMORA" (modified Pegasus with remote power supply) was used to propel the camera, a Rebikoff M-184 Flight Research underwater photogrammetric camera, equipped with a 92 corrective lens, intervalometer and 400-foot film magazine (3200 frames). Approximately 750 frames of black-and-white Kodak #5231 35 mm film were shot in the survey.

The Remora was first used to lay a one-eighth-inch galvanized steel cable from the crest of the third reef to the crest of the second reef. The cable was pulled from a reel mounted on the bow of a whaler containing the Remora's power supply, fed down through a swivel snatch block on the tail of the Remora and attached to the reef. As the Remora advanced along a compass course the cable was laid straight behind it. A second run with the Remora was required to straighten the cable. A ten-foot-high barge was crossed by the cable part way along the transect.

The diver-driven Remora then "flew" the survey in one continuous run at a speed of one knot, towing the whaler and power supply behind it. Then the tagged cable was wound back onto the spool with the aid of the Remora. The entire operation took less than four hours, including launching and recovering the Remora.

The resulting photo overlap was 85%. Approximately 500 3 1/2" x 5" prints were used in the photomosaic, by cutting and gluing them onto ten 30" x 40" illustration boards.

Analysis

A number of informative data analyses can be performed on the photogrammetric survey. Perhaps the most significant will be the results of future comparative surveys, in which net motion of tire modules will become apparent. Some indications of recent motion are visible in the present photomosaic, indicated by orientations of cylindrical module axes. The photomosaics allow a quantitative measurement of these orientations, yielding useful information on current and wave transport.

The ten mosaic boards were carefully examined by placing onion skin paper over the 40-inch long photostrips and designating each tire module with a symbol. Upright cylindrical modules were designated with a U, single tires with an S, fan-shaped modules with an F and horizontal cylindrical modules with a line oriented in the direction of the axis of the cylinder. The axes were then measured to the nearest ten degrees with a protractor and so marked. The orientations were lumped into four groups: 337°-224°=North-South; 224°-67°=NE-SE; 67°-112°=East-West; 112°-157°=NW-SE. The data is summarized per board on Table 1.

The results indicate movement of the tire bundles has occurred since more of the bundles are aligned north-south and east-west than in the other quadrants, NE-SW and NW-SE. It is presumed that bottom currents, which are strongest north-south (Raymond, 1972; Raymond, 1974) in this
vicinity, would align mobile bundles with their axes east-west, and that shoaling waves would align their axes north-south. Predominance of orientation in one of these directions may, therefore, indicate a predominance of one of these modes of transport. The predominance of north-south orientations of tire bundle axes (Table 2) suggests wave transport is the predominant transport mode, although there are three significant areas of exception in the transect, where current transport appears to dominate. It should be kept in mind that tire bundle orientations probably reflect only the most recent mode of transport, and that each of the two modes may dominate at different periods of time. That the bundles have moved is demonstrated not only by their tendency to orient themselves, but also by their appearing to have coalesced into small and large groups, rather than remaining spaced apart with a random spacing. This movement has been observed by divers during periods of high wave activity, and their net movements from one area to another has been observed by periodic inspections.

It is hoped that funds will be appropriated to re-photograph this transect in 1980 for a comparative tire distribution and transport study.
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A multidisciplinary team at the Marine Sciences Research Center (MSRC), and the Materials Science Laboratory (MSL) of State University of New York at Stony Brook, is investigating the long term interactions in the ocean of solid blocks made of combustion wastes from coal-fired power plants. The objective is to assess the feasibility of using blocks of the coal waste materials for underwater construction of artificial fishing reefs. Results of a variety of experiments conducted over the past three years, first in the laboratory and later in the sea, have suggested that coal waste blocks are environmentally acceptable in the ocean. The program will build a demonstration pilot reef of waste blocks in the Atlantic ocean in the spring of 1980 for three to four years of in situ studies.

There is urgency to convert from oil to coal burning in northeastern power plants and conversion has now begun. An important obstacle to utilizing coal for generating electricity is the large volume of combustion products produced which require disposal. Eastern coal contains about 3 percent sulfur but air pollution problems associated with burning high sulfur coal have been greatly reduced by the use of lime/limestone flue-gas scrubbers. In the scrubber process, sulfur oxides are removed before the flue gases are emitted. The voluminous by-product of the scrubber system is a white filtercake of calcium sulfate-sulfite with the consistency of toothpaste. Another waste of coal combustion which is produced in large quantities is ash, which occurs both as fine fly ash and as coarser bottom ash. To understand the magnitude of the problem, consider that a modern coal burning power plant requires a train with one hundred rail cars of coal each day. The wastes generated from this plant, consisting of scrubber sludge, fly ash and bottom ash, would fill 30 of these cars each day. The problem is especially critical in coastal urban areas where disposal sites, even for municipal wastes, are rapidly disappearing.

The dumping of either the untreated scrubber sludge or fly ash in the sea would be unacceptable, probably having deleterious environmental effects. In the water column, the fine particulates in both untreated sludge and fly ash would elevate levels of suspended sediments and possibly clog or mechanically damage gills of midwater organisms. Sulfite-rich sludge may also have consequences: first, because sulfite solutions of high concentrations have toxic effects and second, sulfite may react with dissolved oxygen to deplete oxygen levels. At the sea bed, the dumping of large quantities of sludge and fly ash could smother the benthic faunas which are also improtant to the feeding of many fishes.
An industrial company, IU Conversion Systems, Inc., has developed a marketable stabilized coal waste by combining the scrubber filtercake with the fly ash. Basically this system treats sludge and fly ash with lime additives and cementitious reactions convert the mix into the stable material that can range from a clay-like substance to hard blocks. The bottom ash can be included as an aggregate. This stabilized mixture is being used to fabricate blocks for artificial reef building. The stabilization reactions in the formation of the blocks are very similar to the basic pozzolanic reactions which occur in the forming of concrete. The research conducted as part of this project has been directed at determining the physical and chemical characteristics of such solid stabilized blocks in sea water systems and what, if any, environmental effects the blocks would have. In particular, we are looking at how well the blocks serve as substrates for settlement and colonization by the plants and animals which associate with reefs.

Laboratory Investigations

The initial work started three years ago with laboratory studies funded by the New York State Energy Research and Development Authority, New York State Sea Grant and the Link Foundation and performed by Marine Sciences Research Center at Stony Brook and IU Conversion Systems, Inc. in Philadelphia. Coal combustion products from power stations in both Pennsylvania and Ohio producing scrubber sludges high in calcium sulfate have been used. The mixes tested are representative of sludge produced by flue gas scrubbing equipment and reactive agents currently in use. Several ratios of fly ash to scrubber sludge have been stabilized into blocks over the range of 1:1 to 5:1 and different lime additives and curing procedures have been evaluated.

In the early phases of the investigation, small stabilized test blocks were studied in the laboratory to characterize chemical properties especially as they compared to concrete, which has commonly been used in constructing artificial reefs. Sample blocks of concrete were prepared using methods given by American Society of Testing and Materials (ASTM).

As to their physical properties, coal waste blocks have considerable similarities to concrete but do not have the yield strength of concrete and are more porous and permeable. Their porosity results in part from less calcium being available to form calcium alumino-silicates in the cementation process, precipitation of such compounds causes a general reduction in porosity and permeability. The bulk density of the blocks is about 80% that of concrete, due to the lighter fly ash used and the absence of high density aggregate materials. Compressive strength values of coal waste blocks are only 25 to 50% that of concrete, but in seawater some of the blocks continued to cure and increase in strength up to 50% in four months.

Changes in physical properties with time immersed in water are also being studied using ultrasonic techniques. Ultrasonics provide non-destructive methods to sense internal physical changes occurring
within the blocks and they reveal that the blocks continue to increase in density and develop greater strength after being placed in seawater. These changes are not due to the penetration of water into the pores of the blocks. Instead, slow changes in chemical composition appear to be taking place, associated with the formation of a new chemical phase within the material. The changes in density and strength revealed by ultrasonic testing of immersed blocks appear to be directly correlated with the increases in yield strength found by the destructive compressive strength tests subsequently made on the same material.

Considerable research has been conducted to characterize the coal waste blocks and also the fly ash and scrubber sludge used in the fabrication of the blocks. Knowledge of the elemental composition, mineralogy, and seawater dissolution of coal waste is fundamentally important to the assessment of the environmental acceptability of the coal waste blocks in the ocean, to the materials science of the stabilization process, and to the longevity of the blocks in the sea.

The chemical composition of the blocks has been analyzed by total acid digestion and atomic absorption spectrometry and neutron activation. We are particularly interested in the concentrations of potentially toxic trace elements. Generally, we have found that the heavy metal concentrations in coal wastes and concrete are similar; some elements are higher, others lower in their concentrations but none exceeded the Environmental Protection Agency’s permissible standards. Blocks high in calcium sulfate generally had slightly lower concentrations of heavy metals than those in sulfite. However, the heavy metal concentrations will change according to the type of coal being burned and the lime or limestone used in scrubbing.

The mineralogy of the blocks has been determined by x-ray diffraction. A principal aim was to determine the sulfate and sulfite phases present in the coal waste blocks. Block strength and leaching characteristics are dependent, in part, on relative amounts of calcium sulfate and calcium sulfite. Several studies have been carried out to determine the long term leaching characteristics of coal waste blocks. Calcium and sulfate at first leach fairly rapidly from small test blocks newly suspended in tanks of seawater. As the leaching waters are renewed, the rate of release of these major components decreases as the concentrations of the more soluble phases in the block decrease.

Tank waters are also analyzed for trace elements such as iron, nickel, copper and mercury. Some elements showed an initial increase in the seawater in the first days of exposure but were again taken up into the blocks; other elements did not dissolve at all. The behavior of dissolved trace elements was probably due to desorption-adsorption processes, the trace elements remaining associated with the fine materials such as fly ash in the blocks.

Bioassays were performed on elutriates from several different coal waste mixtures using procedures recommended by the U.S. Environmental Protection Agency. These assays provide information on material toxicity in seawater. Using sand shrimp, developing fish eggs, and
newly hatched fish larvae (sensitive early life stages) in 4 and 6 day acute assays, none of the elutriates appeared to have effects upon viability, although their concentrations exceeded any that might occur in the open sea. Other assays were made with a unicellular plant, the marine diatom, *Thalassiosira pseudonana*. The daily growth, or rate of reproduction, of the plant cells was measured in elutriate solutions from different coal wastes but analysis of the assays indicated that the elutriates did not inhibit the growth of the plant.

Habitats in Shallow Water

The first investigations of coal waste blocks in the sea were made in a small estuarine bay off Long Island Sound in about 18 feet of water. Several 1 ft³ blocks were stacked into separate small habitats, on "mini-reef" formations; one reef consisted of coal waste blocks high in calcium sulfate, one reef of blocks high in calcium sulfite, a third reef of concrete blocks as a control formation, and a number of large natural rocks were stacked nearby (P. Roethel, Ph.D. thesis research in progress). The "mini-reefs" have been periodically examined for biological colonization and photographed by SCUBA divers in a series of field experiments over a span of two years. At intervals, test-blocks and encrusting organisms have been removed for laboratory analyses.

In the sea, the blocks have retained their physical integrity and, although the blocks were placed in a bay with strong tidal flows, their edges remain sharp without notable erosion. Test blocks were removed from the site and tested for compressive strength. As had occurred in laboratory studies, the strength of the blocks was maintained over extended periods. The blocks high in calcium sulfite increased progressively in compressive strength from 320 to 720 psi during one year on the sea-bed.

We have found no adverse environmental effects resulting from the placement of the waste blocks. After only 3 weeks, toadfish used the blocks as a spawning substrate, attaching their newly fertilized eggs. Seaweeds and animals have attached themselves and grown on the coal waste blocks, as they have also on the concrete and the rocks at the site. Some calcium sulfate blocks showed evidence of boring by pholid clams. There appears to have developed a diverse productive community of reef organisms on all of the blocks. At first, there were some differences in settlement on the materials. While hydroids and seaweeds were early colonizers on all blocks, encrusting colonies of bryozoans developed preferentially on the coal waste blocks and slipper limpets were found only on concrete blocks. But, as the blocks became more heavily overgrown, and finally encapsulated, by plants and encrusting animals, the initial differences in colonization between the coal waste blocks and concrete began to disappear. After a year in the sea, differences were no longer evident and the colonizing organisms appeared to form a stable community.

Because the coal waste materials contain trace amounts of potentially toxic elements, representative samples of organisms growing on the blocks were removed by divers for trace element microchemical analysis.
Samples were analyzed for Cu, Cr, Zn, Pb, Cd, Hg, Ag, Se and As using atomic absorption spectrophotometry and other methods. The collections and analyses were repeated on five occasions over two years. In no instance was there evidence of elevated levels for any of the trace metals in the biomass collected from the coal waste blocks when compared with the trace element concentrations in biomass collected from the control concrete blocks and the natural rocks (F. Roethel, Ph.D. thesis research in progress).

The continuing laboratory experiments have suggested that blocks of stabilized coal combustion wastes are environmentally acceptable in the sea as the two years of studies of blocks in a shallow embayment of Long Island Sound appear to confirm. The research has now advanced to a new stage, moving to establish a pilot project artificial fishing reef in the Atlantic.

Pilot Reef in Atlantic

The program has now initiated a larger demonstration project, to build a pilot reef from approximately 500 tons of coal waste blocks, prepared by IU Conversion Systems, Inc. The blocks will be placed south of Long Island at a depth of about 70 feet in the New York Bight. The program is being funded by U.S. Environmental Protection Agency, U.S. Department of Energy, the Electric Power Research Institute, New York State Energy Research and Development Authority and the Power Authority of the State of New York.

In preparation for fabrication of the 500 tons of reef blocks, a combination of different coal waste mixes, stabilization additives, and curing procedures were screened to develop candidate mix designs. Large scale experiments in block manufacture were carried out in Ohio where 1 yd³ blocks, weighing about 1 ton, were built. Subsequently assessment of these experiments suggested that it would be cheaper and faster to produce smaller blocks (weighing 50 lbs) using conventional concrete block-making machines. This was confirmed in another large scale experiment made at the research facilities of the Besser Company in Alpena, Michigan where coal wastes were successfully formed into blocks by block machines. This technology will be used to fabricate the 500 tons of blocks for the demonstration reef. Additionally, reef blocks made from fly ash with fluidized bed combustion residues (produced by coal furnaces employing an alternative method of removing sulphur oxides from coal gases), will be made by these methods and simultaneously tested in the sea.

The pilot reef is planned for spring 1980 and will be monitored for three or four years to assess environmental impacts which may occur and to measure the development of the biological communities which will be associated with the reef. The pilot reef site is in an area selected for reef-building by New York agencies and is near an existing artificial reef, which will provide a basis for some comparisons. Prior to placing the reef, a series of baseline oceanographic cruises have been made by
the MSRC Research Vessel, MV. OVRUST, to characterize the project site and surrounding areas and to describe the seasonal cycle of changes occurring there.

Extensive testing will be performed on blocks periodically removed from the demonstration reef throughout the study to evaluate their acceptability as materials for artificial construction from physical, chemical, and biological perspectives. Other tests, including ultrasonic sensing of internal structural change, will be made by divers on blocks remaining in the sea. We hope that if this extended program of testing and oceanographic monitoring finds the blocks to be environmentally acceptable in the ocean, and without adverse effects, we may have demonstrated an acceptable alternative for the disposal of coal wastes which also carries benefits for man and the marine environment.
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