Exhibit G.1
Attachment 1
March 2004

DRAFT

Mr. Robert Lohn
Regional Administrator
NOAA Fisheries, Northwest Division
7600 Sand Point Way NE
Seattle, WA 98115-0070

Dear Mr. Lohn,

The Pacific Fisheries Management Council (Council) is one of eight regional fishery management councils established by the Magnuson Fishery Conservation and Management Act (Magnuson Stevens Act) of 1976 for the purpose of managing fisheries 3-200 miles offshore of the United States of America coastline. The Pacific Council is responsible for fisheries off the coasts of California, Oregon, and Washington.

We are writing to offer guidance on the re-write of the 2000 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp). Council area salmon fisheries have suffered severe declines as a result of hydro development in the Columbia Basin. It is imperative that NOAA Fisheries produce a BiOp that provides more certainty of restoring listed salmon ESUs to sustainable, harvestable levels - even when ocean conditions change from favorable to adverse, as they inevitably will.

The Council's recommendations reflect broad agreement within its constituent base. The Habitat Subcommittee and Salmon Advisory Subpanel have reviewed this letter. Public testimony was taken at the March Council meeting with strong support from those testifying. The Council feels that these comments not only reflect the best interests of our constituents, but also those of the resource itself, e.g., the salmon of the Columbia River.

GENERAL COMMENTS

The Council recognizes that the 2000 BiOp was invalidated because it lacked reasonable certainty to result in the recovery of listed ESUs.[1] The 2000 BiOp, dubbed an "aggressive non-breach" strategy by federal agencies, attempted to compensate for the harm caused by the operation of federal dams by focusing primarily on "offsite" improvements to habitat, hatchery, and harvest practices. We believe it would be foolhardy, as well as a waste of time and resources, to pursue the same failed strategy and simply issue a slightly modified "aggressive non-breach" BiOp with only minor changes. Instead, the Council recommends that NOAA Fisheries rewrite the BiOp with actions that can be demonstrated with a high degree of certainty (through modeling or analysis as well as experimentation) to result in benefits to and eventual recovery of listed ESUs through the full range of ocean conditions.

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[1] National Wildlife Federation v National Marine Fisheries Service, 254 F. Supp 2d 1196 (D. Or. 2003).

The Council is also concerned about the degree to which state and tribal co-managers will be involved in the technical review discussions surrounding the BiOp rewrite. We are encouraged that NOAA Fisheries has agreed to engage the co-managers in the collaborative process described in a January 23, 2004 letter from the state of Oregon, et al., to U.S. Dept. of Justice.[2] We do not wish to find ourselves in the position of having to implement conservation measures that have not been subject to rigorous review and input from regional fishery experts.

The Council recognizes that while recent hatchery chinook returns are at high levels, wild chinook are still far from fully recovered. Wild runs that still require protection from fisheries harvest include Willamette Spring Chinook, Upper Columbia Spring and Summer Chinook, Winter Steelhead, Snake River Spring Chinook, Snake River Fall Chinook, Coweeman River Natural Tules, and Lewis River Wild Chinook. Each of these chinook stocks inhibits either Council fisheries, Southeast Alaska fisheries, or in-river, non-Council fisheries.[3] Updates to the status of these and other listed ESUs must be peer reviewed by the co-managers prior to adoption by NOAA Fisheries.

Council decisions are required by law to include social and economic impact statements for the managed fisheries and associated communities. Employment in North of Falcon commercial salmon fisheries has dropped from 47,600 days/year on the average from 1976-1980 to 2,400 days/year in 2002. Lows during this period include 200 days in 1994, and 300 days in 1998. In recreational fisheries, the drop is from 490,600 angler trips to 107,200 during the same time period. Lows during the period are ZERO angler trips in 1994, and 15,400 in 1998.[4]

Thus, the Council concludes that past recovery measures have had little effect on salmon populations under poor (El Nino) ocean conditions. Similarly, despite the opportunity to take advantage of good ocean conditions in recent years, federal salmon recovery agencies have largely failed to implement and fund the recently invalidated BiOp. Given that the loss of in-river habitat and the configuration and operations of the hydropower dams are far larger sources of Columbia River salmon mortality than already stringently constrained harvests, it is unlikely that additional fishery restrictions will provide much additional survival benefit. If substantial additional survival benefit is to be obtained, particularly improvements in juvenile survival, it must come from major improvements in mainstem habitat and within the FCRPS itself. The Council therefore recommends that stronger measures than those required in the past be included in a new BiOp to recover wild salmon to self-sustaining, harvestable levels.

SPECIFIC COMMENTS

We recommend that NOAA-Fisheries concentrate its Reasonable and Prudent Alternative (RPA) on the modification and rehabilitation of the FCRPS and mainstem habitat of the Snake and

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[2] Letter from David E. Leith, Assistant Attorney General, State of Oregon on behalf Columbia River Treaty Tribes, Washington Dept. of Fish and Wildlife, and the States of Oregon and Idaho to U.S. Dept. of Justice, January 23, 2003.

[3] Preseason Report III; *Analysis of Council Adopted Management Measures for 2003 Ocean Salmon Fisheries*; Prepared by the Salmon Technical Team and Council Staff.

[4] Pacific Fisheries Management Council, *2003 Review of Ocean Fisheries*, February 2003.

Columbia rivers. For eight salmon and steelhead ESUs, the 2000 BiOp concluded that the "…operation and configuration of the FCRPS…[is] likely to jeopardize the continued existence of [these ESUs] and to adversely modify [their] designated habitat."[5] However, the 2000 BiOp failed to address this concern.

The Council concurs with the key measures recommended recently by the Oregon Department of Fish and Wildlife (ODFW) to improve mainstem survival and production of anadromous fish as the minimum required of any new BiOp.[6] We include these key measures in Appendix 1.

The Council cannot remain silent on the issue of the four Lower Snake river dams. As stated in Idaho Department of Fish and Game's (IDFG) recent recommendations to Northwest Power and Conservation Council:[7] "Analytical risk assessments by PATH and by NMFS CRI (Critical Risk Initiative) indicate that mainstem options that include breaching of the four Lower Snake River dams are most likely to recover listed Snake River populations, and are least risky across a broad range of uncertainties (Budy 2001; State of Idaho 2000a; NMFS 2000).[8] Alternatively, the hydrosystem actions in the 2000 BiOp RPAs and the Northwest Power and Conservation Council's Program are less likely to lead to recovery and have higher risk (Budy 2001; State of Idaho 2000; NMFS 2000)." We concur with this assessment.

We note that in addition to IDFG, both ODFW and the Columbia River Inter-Tribal Fish Commission (CRITFC) recommend planning for or moving forward with the breaching of the four lower Snake River dams. Our recommendation is that NOAA-Fisheries acknowledge its own science and immediately begin the necessary planning and evaluations required for the breaching of the four lower Snake River dams as a component in the RPA.

The Council maintains a commitment to providing social and economic benefits to non-Council fisheries in the Columbia River. We strongly urge NOAA-Fisheries to pay attention to the interests of the treaty tribes of the Columbia Basin as expressed by CRITFC: "The tribes look forward to restoration of sustainable fisheries at all their usual and accustomed fishing stations, not simply rebuilding salmon populations to keep them at the brink of extinction for decades to come. For the Commission's member tribes and the United States, this obligation is over-arching. The responsibility of the United States is not simply to avoid jeopardizing the continued existence of salmon stocks listed under the ESA. Rather the United States has a higher duty. It

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[5] National Marine Fisheries Service, *2000 FCRPS Biological Opinion*, (December 21, 2000). Pp 8-1 to 8-26.

[6] Oregon Department of Fish and Wildlife, *Recommendations of the State of Oregon for the Mainstem Columbia and Snake Rivers to be Adopted as Amendments to the Northwest Power Planning Council's Fish and Wildlife Program*, June 15, 2001.

[7] Idaho Department of Fish and Game, Comments on NPCC Mainstem Amendments; http://www.nwppc.org/library/recommend/mainstem/14.htm

[8] See: Budy, P. 2001. Analytical approaches to assessing recovery options for Snake River chinook salmon. UTCFWRU 2001(1):1-86. Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah. Available at: www.r1.fws.gov/crfpo; State of Idaho. 2000a. Comments on Draft Biological Opinion of Operation of the Federal Columbia River Power System Including the Juvenile Fish Transportation Program and the Bureau of Reclamation's 31 Projects, Including the Entire Columbia Basin Project (Dated July 27,2000). Submitted September 29, 2000; and National Marine Fisheries Service. 2000. FCRPS Biological Opinion, December 2000.

must restore salmon runs to support its treaty commitments. Where the United States can not successfully assure the long term existence of the salmon, by meeting a jeopardy standard under the ESA, The United States will surely fail to restore salmon to support our treaty fisheries."[9]

SUMMARY

The Council is relieved that ocean conditions provide some relief from conditions experienced in the decade of the 1990s. Indeed, salmon harvest in council fisheries have risen dramatically since 1999.[10] The bulk of the returning salmon continue to be hatchery bred, however, and not entirely dependent on inriver conditions. The Council is wary of declaring success in recovery efforts based on four years of relatively strong hatchery runs, particularly when currently unusually favorable ocean conditions are inevitably going to end.

The Council believes a BiOP that protects wild salmonid populations against adverse ocean conditions such as occurred in the 1990s is required. Measures such as spill and minimum flow should be mandatory at a minimum, and not at the discretion of agencies such as the Bonneville Power Administration or the NPCC.

The Council recognizes the controversial nature of breaching the four lower Snake River Dams but is nevertheless clear in recommending preparation for breaching as a mandatory measure. In NOAA Fisheries own words from the 2000 BiOP, "…breaching the four lower Snake River Dams would provide more certainty of long-term survival than would other measures."[11] We could not have said it better ourselves.

Sincerely,

Donald K. Hansen
Chairman

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[9] Comments of CRITFC on Mainstem Amendments; http://www.nwppc.org/library/recommend/mainstem/01.htm
[10] Pacific Fisheries Management Council, *2003 Review of Ocean Fisheries*, February 2003.
[11] NMFS. *2000 FCRPS Biological Opinion*, December 2000. pg. 9-5.

APPENDIX 1

Oregon recommendations to Draft Mainstem Amendments:

1. Flow augmentation for juvenile migration and mainstem spawning - Improve inriver survival and production by implementing modified Biological Opinion and other operations to meet flow targets in the Snake and Columbia rivers; seek additional water to consistently meet flow objectives for all fish.

2. Spill - maximize fish passage efficiency and survival at all projects in the Snake and Columbia Rivers by implementing modified Biological Opinion spill including 24 hr. spill at all projects; conduct risk assessment of increasing spill in the short-term above 120% TDG waiver; modify projects to maximize spillway and project survival. ("Modified Biological Opinion spill" refers to Table 4, pp.33)

3. Juvenile fish transportation - implement "spread the risk" transport policy where no more than 50% of juvenile migrants are transported; improve in-river conditions by providing recommended flow and spill and improvements to bypass systems; bypass fish as needed to manage the proportion of fish transported.

4. Juvenile bypass improvements - continue to test and implement surface bypass and collection systems; evaluate and if necessary modify screen bypass and sampling systems and bypass outfalls to improve survival of bypassed fish.

5. Turbine improvements - operate turbines units at FCRPS dams for optimum fish passage survival; continue investigation and installation of minimum gap runners; implement Biological opinion actions to develop new turbine design and technologies to improve juvenile and adult survival.

6. Predator control - improve inriver survival by reducing predation losses to fish, avian and pinniped predators.

7. Planning for alternative actions if non-breach options fail to meet ESA requirements - conduct necessary planning and evaluations to ensure that alternative actions including breaching of Snake River dams can be implemented on a timely basis if non-breach alternatives fail to meet performance standards.

Exhibit G.1
Situation Summary
March 2004

CURRENT HABITAT ISSUES

Situation: The Habitat Committee (HC) will meet Monday and Tuesday, March 8-9, 2004, to develop recommendations on the following agenda items:

G.3 Artificial Reefs in Southern California
H.1 Scientific and Statistical Committee (SSC) Review of Marine Reserves Issues
H.2 Update on Other Marine Protected Area Activities

In addition, the HC will discuss the development of a briefing paper on salmon net pen aquaculture, as requested by the Council at the September 2003 meeting; Klamath/Trinity River issues; a letter to NMFS on the rewrite of the 2000 Federal Columbia River Power System Biological Opinion (Exhibit G.1, Attachment 1), and the function and purpose of the HC.

The HC's complete agenda is provided in Ancillary F.

Council Action:

1. **Consider comments and recommendations developed by the HC at the March meeting.**

Reference Materials:

1. Exhibit G.1, Attachment 1: Letter from Chairman Don Hansen to Mr. Robert Lohn, NMFS on the 2000 Federal Columbia River Power System Biological Opinion

Agenda Order:

a. Report of the HC — Stuart Ellis
b. Reports and Comments of Advisory Bodies
c. Public Comment
d. **Council Action:** Consider HC Recommendations

PFMC
02/24/04

Stuart Ellis

HABITAT COMMITTEE PROPOSED ACTION FORM

HC Sponsor: Mr. Stuart Ellis

Title of Issue: Columbia River Hydrosystem Summer Spill **Deadline (if any):** Late April

Proposed Action: Request the Council Submit a letter to NMFS in opposition of summer spill

Addressed To: Mr. Bob Lohn, Regional Administrator, NMFS

Description of Issue: The Bonneville Power Administration (BPA) has proposed reducing or eliminating its program of summer spill at the Federal Hydropower projects on the Columbia River. This will have negative effects on Council-managed species.

Description of Regional Significance: There will be fishery effects throughout much of the Council management area due declining abundance due to increased juvenile mortality.

Potential Adverse Impacts to EFH? X Yes ☐ No

For Which Species? Various Columbia River Salmon

Potential Benefits of Proposed Action: May assist NMFS in opposing BPA's proposed action.

PACIFIC FISHERY MANAGEMENT COUNCIL
7700 NE Ambassador Place, Suite 200
Portland, Oregon 97220-1384

CHAIRMAN
Donald Hansen

EXECUTIVE DIRECTOR
Donald O. McIsaac

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Draft

[Address]

Dear Mr. Lohn:

The Bonneville Power Administration (BPA) is proposing to eliminate its program of providing summer spill at the Columbia River Federal Hydropower Projects. This program was included in the reasonable and prudent alternatives (RPAs) for the 2000 Biological Opinion (BiOp). Spill has been shown to provide higher juvenile survival than other passage ~~routes~~. While BPA has claimed minimal impacts due to spill reduction, an analysis prepared for the Columbia Basin Fish and Wildlife Authority has suggested the no-spill option will result in a system-wide loss of ~~38,000 to 95,000 adult~~ chinook as compared to the BiOp spill program (Bouwes 2004).* BPA has suggested that additional mortality due to spill reduction can be offset by further harvest reductions and other mitigation actions. a signif. #

With the significant constraints again facing ocean fisheries in 2004 due to the need to minimize impacts to Snake River fall chinook, the Council ~~finds~~ must express grave concern the potential relaxation of current BiOp standards ~~to be unacceptable~~. until the remand BO has been updated.

The Pacific Fishery Management Council urges the National Marine Fisheries Service to take actions necessary to prevent the cessation of the summer spill program.

Sincerely,

Draft

Donald K. Hansen
Chairman

**Nick Bouwes, Eco Logical Research, "Review of the Bonneville Power Administration's Analysis of the Biological Impacts of Alternative Summer Spill Operations," prepared for Columbia Basin Fish & Wildlife Authority, 2004.*

Exhibit G.1.a
Supplemental HC Report
March 2004

HABITAT COMMITTEE REPORT

The Habitat Committee (HC) met on Monday and Tuesday to prepare comments on agenda item G.2 (Corals and Living Substrate); H.1 (Scientific and Statistical Committee Review of Marine Reserves); and G.3 (Artificial Reefs in Southern California). Those comments will be provided during their respective agenda items. The HC also discussed the following issues:

Summer Spills in the Columbia River Basin

The HC discussed the proposal by the Bonneville Power Administration (BPA) to reduce or eliminate summer spill in the Columbia River federal hydropower projects. The BPA has proposed this because they believe the revenues they could earn from the extra power generation without summer spill outweighs the survival benefits to fish from providing spill. Many juvenile salmon and steelhead, especially sub-yearling type chinook such as Snake River fall chinook, migrate through the federal hydro system during the proposed no-spill period. The BPA has done modeling and made estimates of costs and benefits, and has suggested that further cuts in harvest may be used to mitigate any effects of loss of summer spill. The states and tribes have provided comments critical of ending spill. The Columbia Basin Fish and Wildlife Authority has conducted an analysis (Bouwes 2004)* that indicates the BPA underestimated impacts to listed stocks and overstated benefits of mitigation.

The decision on summer spill is expected to be made in the next few weeks. The HC recommends the Council provide its input into this issue. The HC has drafted a letter (Exhibit G.1, Supplemental Attachment 2) for the Council to consider for action at this meeting.

**Nick Bouwes, Eco Logical Research, "Review of the Bonneville Power Administration's Analysis of the Biological Impacts of Alternative Summer Spill Operations," prepared for Columbia Basin Fish & Wildlife Authority, 2004.*

Klamath Flow Issues

The HC received a report regarding Klamath River hydroelectric project relicensing and river flow issues. On February 26, 2004, PacifiCorp, operator of six dams on the Klamath River, applied to the Federal Energy Regulatory Commission for a new 30-year to 50-year license to generate power; the present license expires on March 1, 2006. PacifiCorp seeks to continue operating most of the project under terms similar to present operations. The application does not address anadromous salmonid passage at the dams or evaluate dam decommissioning and removal as a project alternative. A number of stakeholders, agencies, and commissions believe threatened coho and depleted chinook salmon cannot be fully recovered within the Klamath River basin without providing access to several hundred miles of habitat found within and above PacifiCorp's project, and dam removal should be seriously considered as an option. For instance, the National Academy of Sciences National Research Council Final Report recommended removal of Iron Gate

Dam, and the California Energy Commission recommended PacifiCorp include decommissioning of all dams in their analysis. The HC concurs with this position. The deadline for commenting on the license application and for filing additional study requests is April 26, 2004. The HC will have a draft comment letter regarding the relicensing process for Council consideration at the April meeting.

Current Klamath River flows at Iron Gate Dam are being managed by the U.S. Bureau of Reclamation under the 2003 Klamath Project Operations Plan, which is effective for the April 1, 2003 to March 31, 2004 period and is based on inflow to upper Klamath Lake for the April 1 through September 2003 period (irrigation season). Currently, the water year is classified as below average, although precipitation in the upper basin is 97% of average, and the snowpack is 140% of average. In spite of this, flows at Iron Gate Dam have been below biological opinion levels for a below-average water year since December 2003. The HC is concerned the process for determining between irrigation season (October 1 - March 31) water year types is inappropriate and does not often represent true hydrologic conditions. We are further concerned that low 2004 spring flows, if implemented, may result in poor survival of brood year 2003 fall chinook and coho salmon. The HC will continue monitoring Klamath River flow conditions and give an update at the April meeting. If flow management does not improve, a draft comment letter addressing impacts of low flows on Council-managed species will be prepared for Council consideration.

Trinity River Flows

Under a federal District Court ruling, Trinity Record of Decision (ROD) flows are limited to a "dry year" water volume (452,600 acre-feet) until a court-required supplemental environmental impact statement (SEIS) is completed. In December 2003, the Department of the Interior (DOI) reported to the District Court that the July 9, 2004 deadline for SEIS completion might be delayed. The DOI will likely ask for more time to complete the SEIS.

All parties have appealed the District Court ruling on the Trinity ROD. The 9th Circuit Court of Appeals is expected to rule on oral arguments and briefs submitted. Meanwhile, the DOI has proposed a settlement offer relative to the pending litigation. However, the Hoopa Valley Tribe, defendant-intervenor and co-signer of the Record of Decision, has rejected DOI's proposal, citing its failure to meet the scientific standards maintained by the Central Project Improvement Act.

Resolution of permanent flows may be held up by the need to first resolve a number of outstanding Central Valley Project water initiatives, including the renewal of long-term water delivery contracts, completion of the Central Valley Project Biological Opinion for species listed under the Endangered Species Act, and other matters. State and federal legislators may be called upon to resolve these conflicts.

NMFS Columbia River Biological Opinion Remand

In 2000, NMFS issued a Biological Opinion (BiOp) on the federal hydropower system in the Columbia Basin. The BiOp found jeopardy with the hydropower system, and presented nearly 200 reasonable and prudent alternatives. In July 1999, the Council passed a resolution that found much, if not most, of the decline of Columbia Basin salmon is "due to cumulative impacts of the Federal Columbia River Hydroelectric System," and recommended the river be returned to more normative conditions as the option "most likely to avoid extinction and recover Snake River salmon and steelhead stocks." Five years later, the BiOp actions are not certain to be achieved, yet ocean fisheries continue to face deep constraints by Snake River fall chinook.

The HC discussed the draft letter in Exhibit G.1, Attachment 1, and considered whether and how the Council might comment on the current BiOp rewrite. The HC recommends the Council send a letter to NMFS that urges them to produce a BiOp that provides certainty of restoring listed salmon evolutionarily significant units to sustainable, harvestable levels. Because of the complexity of this issue, the HC believes a letter can be crafted that restates the Council's 1999 resolution (Exhibit G.1, Supplemental Attachment 2); articulates support for the collaborative process upon which participants will soon embark; and suggests the new BiOp address specific habitat-related concerns, such as flow augmentation, spill, and others as necessary.

We suggest the Council consider instructing the HC to draft a letter for review and potential approval at the April meeting. Instructions for the content of that letter could be based on our suggestions, above, or other topics identified through Council discussion.

Reopening of Rulemaking on Essential Fish Habitat

An advanced notice of proposed rulemaking on essential fish habitat was released last year by NMFS. NMFS is considering allowing revisions to the EFH rule. As several regional fishery management councils did not have a chance to comment on the rulemaking during the original comment period, NMFS has extended the comment period until April 26. The issue of EFH is important to the HC. The HC is interested in preparing a letter in advance of the April meeting for Council consideration in April.

HC Election

The HC held elections for Chair and Vice Chair. Mr. Stuart Ellis was re-elected as Chair, and Mr. Michael Osmond was elected as Vice Chair.

PFMC
03/10/04

PACIFIC FISHERY MANAGEMENT COUNCIL

2130 SW Fifth Avenue, Suite 224
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Telephone: (503) 326-6352

CHAIRMAN
Jerry Mallet

EXECUTIVE DIRECTOR
Lawrence D. Six

RESOLUTION

WHEREAS, fishing cultures, livelihoods, economies, and recreation along the Pacific Coast from Alaska to California, and east to Idaho and Montana, have been dramatically affected by the precipitous decline and subsequent listing under the Endangered Species Act of anadromous fish in the Snake River Basin;

WHEREAS, rigorous scientific review by the Plan for Analyzing and Testing Hypotheses (PATH), has demonstrated much, if not most, of this decline is due to cumulative impacts of the Federal Columbia River Hydroelectric System, and, that retiring Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams on the lower Snake River and returning this river reach to a normative river condition is most likely to avoid extinction and recover Snake River salmon and steelhead stocks;

WHEREAS, wild Snake River salmon and steelhead are an irreplaceable genetic resource that continue to play a vital ecological role even at their currently depressed levels. If these runs are allowed to vanish, the foundation of the interior northwest's ecosystems will be severely undermined.

WHEREAS, extinction will prove ever more costly, and recovery will restore these fish to their rightful place in the cultures, economies, and hearts of Pacific Northwest peoples;

THEREFORE LET IT BE RESOLVED, that the Pacific Fishery Management Council finds the extinction of wild Snake River salmon unacceptable, and recommends implementation of the measures deemed by scientific analysis to recover wild anadromous fish in the Snake River Basin to sustainable fisheries levels. The Council recommends consideration and mitigation of negative impacts of the selected recovery option on affected individuals and their communities.

PFMC
07//99

SALMON ADVISORY SUBPANEL RECOMMENDATIONS ON COLUMBIA RIVER SPILL

The Salmon Advisory Subpanel (SAS) supports the continuation of summer spill at curent Biological Opinion levels to facilitate and increase juvenile salmon survival in the Snake and Columbia River systems. The SAS recommends the Council submit a letter to that effect as drafted by the Habitat Committee (HC) (Exhibit G.1.a, Supplemental Attachment 2) prior to the decision point later this month.

The SAS also supports the HC Report (Exhibit G.1.a, Supplemental HC Report) in reference to Klamath River flow issues. The SAS notes that juvenile outmigrants affected by the poor water conditions have direct implications in this year's management of Council-area fisheries. We face the second lowest prediction on record of Klamath River age-3 fall chinook, which will impact this year's, and potentially next year's, management cycle.

PFMC
03/11/04

CORALS AND LIVING SUBSTRATE REPORT

Situation: There will be no report on West Coast corals and living substrate at this meeting.

Dr. Elizabeth Clark of the National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center will update the Council on the status of ongoing efforts by the National Oceanic and Atmospheric Administration (NOAA) in the area of research on West Coast corals and living substrates, and the potential of a progress report at some point in the future.

NOAA's Office of Protected Resources commissioned a report by the Marine Conservation Biology Institute on habitat-forming deep sea corals in the northeast Pacific Ocean. The report is included as Exhibit G.2.a, Attachment 1.

Legislation has been introduced to protect deep water corals and sponges (Exhibit B.2a, Attachment 4, S.1953).

Council Task:

1. Discussion.

Reference Materials:

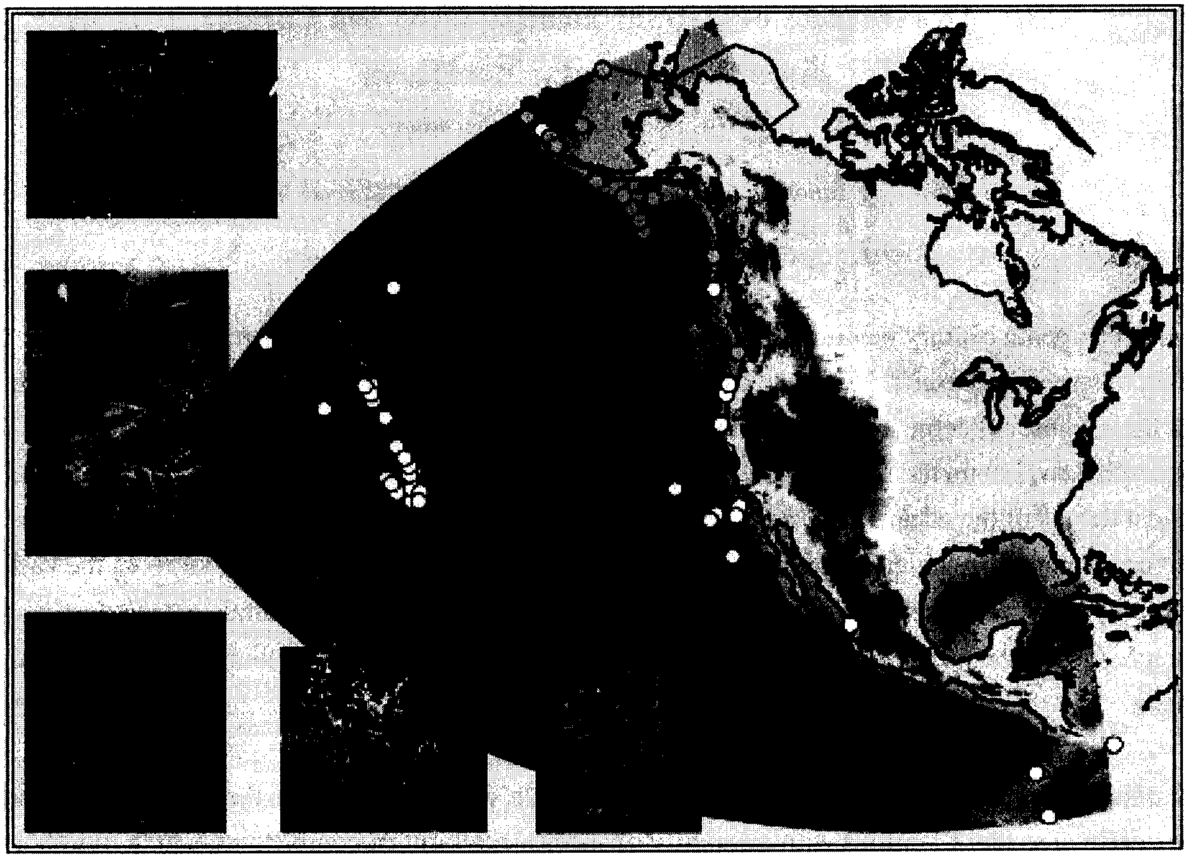
1. Exhibit G.2.a, Attachment 1: *Occurrences of Habitat-forming Deep Sea Corals in the Northeast Pacific Ocean.*
2. Exhibit B.2.a, Attachment 4: S. 1953.

Agenda Order:

a. Agendum Overview — Jennifer Gilden
b. NMFS Report — NMFS
c. Reports and Comments of Advisory Bodies
d. Public Comment
e. Council Discussion

PFMC
02/24/04

Exhibit G.2.a
Attachment 1
March 2004



Occurrences of Habitat-forming Deep Sea Corals in the Northeast Pacific Ocean

A Report to NOAA's Office of Habitat Conservation

Peter Etnoyer and Lance Morgan
Marine Conservation Biology Institute

MCBI
MARINE CONSERVATION BIOLOGY Institute

December 2003

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

Occurrences of Habitat-forming Deep Sea Corals in the Northeast Pacific Ocean

Peter Etnoyer and Lance Morgan

Marine Conservation Biology Institute, 15805 NE 47th Ct. Redmond, WA 98052

Abstract

Mid-nineteenth century naturalists once considered the abyssal seafloor a barren, lifeless plain akin to terrestrial deserts. However, in 1872, the H.M.S. Challenger began a four year expedition of the oceans, collecting specimens and revealing for the first time the extensive marine life found below 200 meters. Subsequent deep-sea exploration has discovered that life extends to the hadal depths of the oceans (greater than 10,000m), and that these profound waters are home to a diverse assemblage uniquely adapted to their extreme environment. Few people know of the vast extent of dep sea corals in temperate waters of the US when, in fact, these corals extend over a much greater area of the US exclusive economic zone than the much more familiar tropical coral reefs.

Habitat-forming deep-sea corals, octocorals, hexacorals, and hydrocorals in the Phylum Cnidaria, are defined as those families with a majority of species exhibiting a complex branching morphology and sufficient size to provide substrate or refuge to associated species. We gathered a total of 2,649 records (name, geoposition, depth, and data quality) from 10 institutions on 8 habitat-forming deep-sea coral families, including octocorals in the families Corallidae, Isididae, Paragorgiidae and Primnoidae, hexacorals in the families Antipathidae, Oculinidae and Caryophylliidae, and hydrocorals in the family Stylasteriidae. We use these records to investigate the range and distribution of these families in the Northeast Pacific Ocean and Bering Sea.

Acknowledgements

The authors wish to express their gratitude to Tom Hourigan for helping to initiate this study. Many individuals and organizations assisted in providing access to data: Noel Alfonso, Stephen Cairns, Jon Heifetz, Lawrence Lovell, Monterey Bay Aquarium Research Institute, Christine Pattengill-Semmens, Robert van Syoc, Waldo Wakefield and Gary Williams. We received invaluable assistance and advice from Frederick Bayer, Stephen Cairns, Edith Chave, Richard Grigg, Eric Hochberg, Andrew Lissner, Martin Willison and Les Watling. We thank Phillip Cola for his images of the Stylaster reef used on the back cover and on page 8. We also express our thanks to the NOAA Office of Exploration, Andy Bruckner, Robert George and Elliott Norse.

Photo Credits:

Lophelia	Dr. Andre Friewald
Antipathes	F. Cardigo copyright ImgDOP
Corallidae	Glasgow University Zoology Museum
Isididae	Monterey Bay Aquarium Research Institute
Paragorgiidae	NOAA Office of Ocean Exploration , GOASEX
Primnoidae	F.E. Moen
Stylaster (2)	Phillip Colla Photography, Oceanlight, Carlsbad, CA
Lingcod/hydrocoral	V. O’Connell ADF&G

Background on Deep-Sea Corals

The term "coral" refers to a vast array of organisms that are found throughout the world's seas from freezing polar regions to equatorial reefs, and at all depths from the intertidal zone to the bottoms of the deepest hadal trenches. The word "coral" is derived from the ancient Greek word "korallion," which referred to the precious red coral of theMediterranean, known today as *Corallium rubrum* (Linaeus 1758). Coral is a loosely defined paraphyletic assemblage of organisms belonging to the phylum Cnidaria. All corals are cnidarians, but some are more closely related to other coelenterates than to other "corals". For example, hydrocorals are more closely related to hydroids than they are to other corals, while hexacorals include sea anemones and stony-corals.

In this report, we use the term deep-sea coral to refer to the families of hexacorals, octocorals, and hydrocorals we know to exist beyond the traditional tropical boundaries commonly attributed to zooxanthellate shallow water tropical scleractinian corals. Cold water corals are also commonly referred to as deep-sea corals, even though some of these species are found in waters shallower than 200 meters. Similarly, deep-sea corals can be found in tropical waters, and this term is intended to reflect their latitudinal range rather than their habitat requirements.

Corals have a long fossil record dating back 450-500 million years to the Ordovician Period of the Paleozoic Era. Three groups of early corals- the heterocorals, the tabulate corals, and the rugose corals- were extinct by the end of the Paleozoic. Three other groups of corals, which developed during the Mesozoic and Cenozoic Eras, survive to the present day; the hydrocorals, hexacorals, and octocorals. All three of these types inhabit the Northeastern Pacific Ocean, and are documented in this report.

Following is a brief summary of those families of hexacorals, octocorals and hydrocorals considered to form complex bottom habitat for associated species in the Northeast Pacific Ocean. This appendix borrows form and content from a report on North Atlantic deep-sea corals by H. Breeze and M. Butler of the Ecology Action Center, and D. S. Davis of the Nova Scotia Museum of Natural History, but the list has been updated with facts relevant to the North Pacific.

Class Anthozoa

Members of the class Anthozoa (corals and sea anemones) are exclusively polypoid, having lost the medusoid stage, while most hydrozoans retain both polypoid and medusoid stages in their life cycles.

Subclass Zoantharia = Hexacorallia

Order Scleractinia "stony or hard corals"

These are the stony or hard corals and the species most often associated with the living coral reef. Hard corals have massive calcium carbonate skeletons with relatively large polyps (> 5mm in diameter), each containing internal radiating ribs called septa. Two families are known as deep-water structure-forming taxa in the Northeastern Pacific, the Caryophylliidae, represented by the genera *Lophelia*, and the Oculinidae, represented by the genera *Madrepora*, but there are many other non-structure forming scleractinians in the Northeastern Pacific.

Family Caryophylliidae

Lophelia pertusa (Linnaeus 1758) occurs throughout the North Atlantic, and has been well mapped by the British Geological Survey, in response to threats from bottom trawling. This is a highly branched, massive coral that occurs in large colonies on flat bottoms. These colonies are called bioherms. Bioherms are recorded with heights over 2m covering an area greater than 1500m (5000 ft) (Wilson 1979). The species occurs at suitable depths throughout the North Atlantic, and in the southern hemisphere, with very few records in the Northeast Pacific.

Family Oculinidae

This is a small family with only one genus *Madrepora* known from the Northeastern Pacific. At certain places along the Atlantic coast of North America, unique banks of *Oculina* are found that occur nowhere else on Earth. Two species of *Oculina* exist along the Atlantic coast and each inhabits a very restricted range. *Oculina arbuscula* is found off of Cape Hatteras in North Carolina while the ivory tree coral, *Oculina varicosa* (Lesueur 1821) is found on offshore banks and can form pinnacles of up to 30 m (100 ft) tall, growing below the Gulf Stream at depths of 60-90 m (200 to 300 ft). Like their shallow coral reef cousins, the reefs are critical habitat for a wide diversity of fish and invertebrates. Several species of snapper and grouper live and spawn on these reefs.

Order Antipatharia

Family Antipathidae

Antipatharians, or “black corals” are tree-like or stick-like cnidarians with a solid dark brown skeleton decorated with small spines or knobs. Colonies occur along current-swept drop-offs and under ledges. Live colonies may be rusty brown, orange, yellow, green, or white due to color of the polyps. They may also fluoresce. Several species are listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Appendix II (i.e., not threatened with extinction, but may become so without trade restrictions).

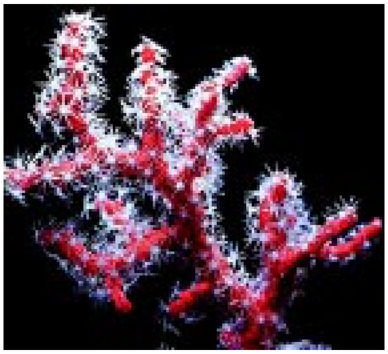
Two species of precious black coral are found at scuba diving depths in Hawaii. The largest of such trees in Hawaii reach about 6 feet tall, averaging 2 inches of growth per year. Both were collected extensively for the jewelry trade; a few large colonies may be still found in remote locations. Both are very similar to the untrained observer. *Antipathes dichotoma* (Pallas 1766) is more common, found as shallow as 4 m (15 feet). The stiff, vertically pointing branches may be as little as 0.6mm in diameter. *Antipathes grandis* (Verrill) was harvested extensively for the jewelry trade and is rare today. It normally occurs in water deeper than 45 m (150 feet). It has flexible branches as thin as 0.3mm in diameter, and 12 polyps per cm. Some rare fishes are associated with *Antipathes,* including the longnose hawkfish (G. Stender 2003).

Subclass Alcyonaria = Octocorallia

This group is comprised of the gorgonians and relatives, the soft corals, sea fans, sea whips and sea pens. All octocorals are easily identified by the eight feather–like (pinnate) tentacles that surround the mouth of each polyp. Soft corals are important members of deep Pacific benthic communities; their abundance, diversity and biomass rivals or exceeds that of the hard corals in some regions. Octocoral skeletons don’t form reef structures like some stony corals, although octocorals can have calcareous internal skeletons (sclerites). In addition to sclerites, the gorgonians also have internal axes composed of horn and/or calcium carbonate. The axis is always smooth, never horny as in black corals. The flexible internal skeleton of sea fans and sea whips allow them to bend and sway in the currents and bottom surges like the branches of a tree in gusty winds.

Order Gorgonacea "Gorgonians"

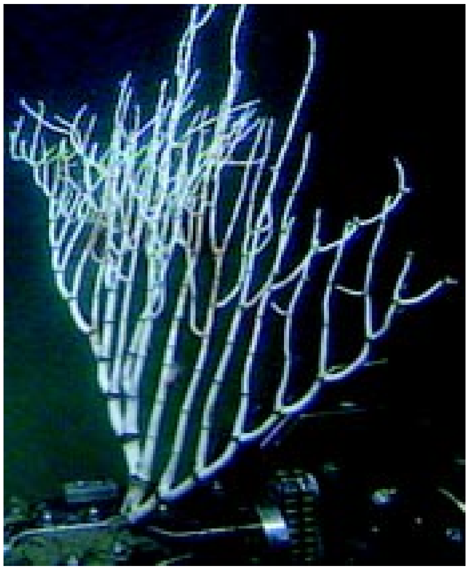
Family Corallidae



Also known as red coral or pink coral. These colonies are generally less than 0.3 m (12 in) with a loosely spaced, rigid branching morphology. In the Gulf of Alaska colonies of *Corallium* were found attached to small rocks of low relief.

These corals are prized in Japan for their decorative quality, and known to herbalists for their medicinal qualities. In Japanese traditional medicine, *Corallium rubrum* is thought to alleviate symptoms of bronchitis, tuberculosis, and gonorrhea.

Family Isididae



The bamboo corals are a species rich family within the octocorals. They have eight pinnate tentacles on each polyp that can be either retractile or non-retractile. The bony calcareous structures (internodes) are interspersed with proteinaceous gorgonin (nodes). This structure gives the skeletal remains of the organism an eerie fingerlike appearance.

Lepidisis colonies are unbranched, like sea whips, but they have an axis of proteinaceous nodes and calcareous internodes. *Lepidisis* is the only documented unbranched genus in the family Keratoisidinae. The are three unbranched genera. In *Keratoisis,* the branches arise from the nodes. In *Isidella,* the branches arise from the internodes, and the colonies are flat and spreading like candelabra. In *Acanella,* the branches also arise from the internodes, but the colonies are bushy, and branch in whorls.

Family Paragorgiidae

Paragorgia arborea (Linnaeus 1758) is a large and well known species that occurs in the North Atlantic and the North Pacific as well as the Southern Hemisphere. It is found off Greenland and in parts of the southern Grand Banks, Newfoundland. *Paragorgia* is found in submarine canyons off George's Bank between 200 and 900 meters and on seamounts in the Gulf of Alaska at similar depths. Large specimens exceeding 2.5 m (8 ft) have been reported. The GOASEX expedition recorded a specimen with a base of ~8cm harboring large numbers of individual galatheid crabs (pinchbugs), basket stars, and shrimps.

Family Primnoidae

Primnoa resedaeformis (Gunnerus 1763). This species occurs in the North Pacific and the North Atlantic. *Primnoa* is also well known to fishermen and trawlers from the Gulf of Maine. Dr. David Honeyman presented specimens of this and *Paragorgia arborea* to the Nova Scotian Institute of Science in 1880. Colonies are calcified and robust, and can grow to a height of one meter. They are often found attached to boulders between 100 and 500 m (330-1650 ft) (Deichmann, 1936).

Class Hydrozoa

Hydrocorals belong to the Class Hydrozoa. All other corals are anthozoans. Hydrocorals include both the stylasterine and milleporine corals. Stylasterine or lace corals include delicate colorful species belonging to the genera *Stylaster* and *Allopora*, both commonly found in the Pacific. All hydrocorals are characterized by a massive and relatively brittle calcium carbonate skeleton with numerous pinpoint - sized pores from which emanate two kinds of hydroid - like polyps, which are often finger-shaped with knob-like tentacles. The two kinds of polyps have a defensive function (dactylozoids) or a feeding function (gastrozooids).

Family Stylasteriidae

Stylasteriids are calcified and highly modified hydroids, occurring worldwide over a wide range of depth. Some stylasteriids resemble bryozoans and others colonial scleractinians, convergences that have caused confusion in recent and ancient faunas, and may also have limited our knowledge of their geological record. *Stylaster californicus* is an indicator of the strong currents. This species has low relief, but supports a number of associated species. It is common throughout the Channel Islands in California. Its presence in the deep-sea (depths >200m - 660ft) is documented in only a few cases.

Introduction

Deep-sea corals are a poorly known and poorly documented group of species that are becoming an increasing conservation concern because they are important habitat for commercially important fishes, as well as a wide variety of marine life. On the East Coast of the United States deep-sea corals occur from north of Georges Bank (*Paragorgia arborea)* to the mid-latitudes off of Florida (*Oculina*) (George 2002). Deep-sea coral records in Alaska and California date to the late 19th century (Dall 1884), but contemporary concerns about commercial fishery sustainability and the benthic impacts of commercial fishing gear have renewed interest in habitat forming deep-sea corals and areas of occurrence. In 1996, the United States Congress revised the Magnuson-Stevens Fishery Conservation and Management Act to include new habitat conservation provisions for U.S. marine fisheries. One candidate for a habitat area of particular concern (HAPC) under these provisions is “coral”. The *Oculina* Banks off Florida were destroyed by trawling over 25 years ago and are now designated as a Habitat Area of Particular Concern. These banks are important habitats and spawning areas for commercially important snappers and groupers. Proposals for similar HAPC designations are being developed for corals in the north Pacific.

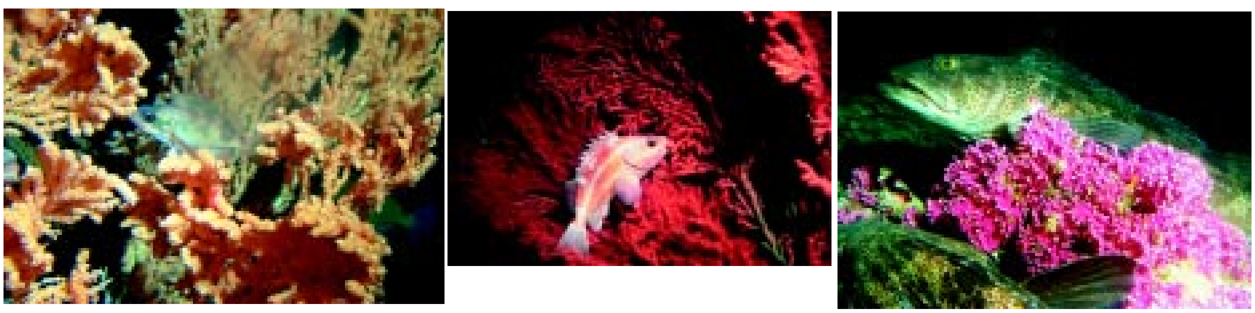


Figure 1. Juvenile rockfish in red-tree corals (*Primnoa* sp.) off southeast Alaska. Lingcod associated with hydrocal (*Stylaster* sp.). Photo credit V. O’Connell ADF&G.

In the tropics, reef fish species richness is less associated with coral species richness than it is with “rugosity”, a measure of three dimensional complexity (Connell and Jones 1991, Friedlander 1998). Complex habitats, such as seagrass beds and branching corals, are known to provide more refuge to prey species than less rugose habitats (Figure 1). Risk (1972) stated for tropical coral reefs, “there exists a striking positive correlation between fish species diversity and degree of substrate topographic complexity.” Complex habitats also provide more vertical relief, more surface area for settlement, and more microhabitat variability than simpler habitats. It is likely that the complex morphology of deep-sea corals similarly influence benthic communities in colder, deeper waters. Greater evidence of this relationship should result from increased exploration of these environments.

Deep-sea corals are known to occur on rocky habitats in deepwater (>200m) with strong water currents, similar to shallow-water gorgonians. These currents may facilitate settlement onto clean swept surfaces, or increase food availability and, therefore, growth rate and survivorship. Deepwater hard bottom biological communities of the California coast are commonly distinguished based on localized differences in relief height, although large-scale patterns are strongly influenced by depth and current regimes that influence productivity and sediment transport (e.g., Lissner and Benech 1993). Relief has been recognized for decades as a factor that influences the types of communities, although the origin of a relatively standardized definition appears to stem from early studies conducted for the Department of the Interior, Minerals Management Service (e.g., SAIC 1986). Changes in the species composition of seafloor communities are observed between areas with relief greater than 1m (3 ft) as compared to areas with less than 1 m relief. This distinction is not "razor" sharp, but 1m relief is a useful definition for habitat-forming species that has been applied to studies along the coast (e.g., Lissner 1989, Steinhauer and Imamura 1990, SAIC and MEC 1995).

A principal factor that appears to influence low- versus high-relief community differences is near-bottom sedimentation and particle loads. Many low-relief habitats can be subject to sediment encroachment and burial due to natural processes of sediment transport, and/or high near-bottom particle loads that can result in clogging and/or less effective filter/suspension feeding by many sessile species such as cnidarians and sponges (Lissner et al. 1991). In contrast, high-relief communities are relatively insulated from these factors and are often characterized by greater abundance, diversity, and size of many filter/suspension feeding organisms. Thus, low-relief habitats represent comparatively marginal habitat for some species as episodic events bury or uncover the substrate and associated organisms.

As summarized by Lissner and Benech (1993), high relief habitats are typified by suspension feeders including sponges, a variety of anemones (e.g., *Metridium*, *Amphianthus*, *Actinostola*, and *Stomphia*) and zooanthids, corals (e.g., *Lophelia*, *Paracyathus*, *Desmophyllum*, and *Caryophyllia*), crinoids (*Florometra*), basket stars (*Gorgonocephalus*), and bryozoans. Many of these species, especially sponges, are also larger in size since higher relief is a generally more stable habitat allowing longer term survival and growth than many lower relief habitats that are subject to sediment encroachment and high particle loads. In contrast, low-relief habitats are usually characterized by relatively short-lived, smaller organisms including many hydroids, bryozoans, cup corals, and other opportunistic "turf" species, representing a complex low-growing matt of numerous invertebrate phyla. Other distinctions are evident based on depth, often with larger sponges observed at greater depths, perhaps influenced by reduced sediment transport in lower current regimes.

The strong currents that deep sea corals prefer can make survival particularly difficult for smaller marine life, such as juvenile fish. Coral outcrops and "forests" are also important habitat for adult fishes, crustaceans, sea stars, sea anemones and sponges because they provide protection from these currents and from predators. Clusters of biodiversity around deep sea corals were recently documented by submersible craft in missions to the Gulf of Alaska and the Gulf of Maine. A wide variety of fishes rely on coral areas for food, protection, and a place to lay their eggs (e.g. Fig. 2). *In situ* evidence of habitat functions for deep-sea corals is currently limited to video and photographic observations (e.g. a egg case attached to a *Paragorgia*, crabs perched atop *Isidella*, snail fish resting in the polyps of *Isidella*).With current research expanding into the deep-sea more quantifiable results are forthcoming.

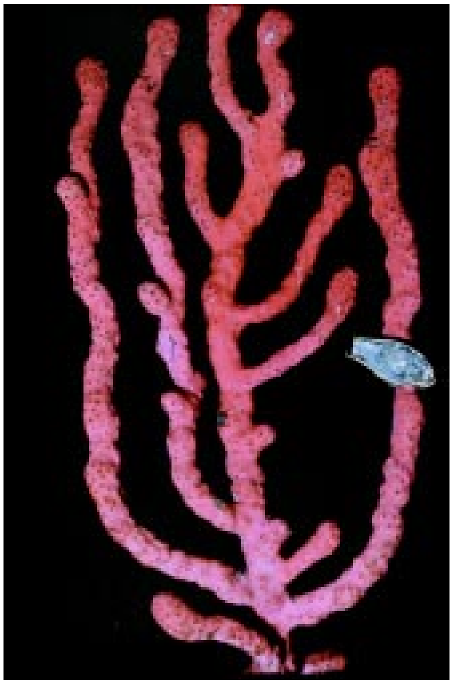


Fig 2. *Paragorgia* with an egg case attached, evidence of habitat function. Photo Credit: CAS.

Others findings suggest some commercially important fish species are found in association with these reefs, such as Atka mackerel, *Pleurogrammus monopterygius,* and shortspine thornyhead, *Sebastolobus alascanus,* in Alaska (Heifetz 2002). Krieger and Wing (2002) reported rockfish associated with *Primnoa* corals in the Gulf of Alaska. Fossa (2002) presented results at the *First International Symposium on Deep Sea Corals* indicating dense aggregation of *Sebastes sp.* associated with *Lophelia* corals off the coast of Norway. Elsewhere, Husebo et al. (2002) found that fish in coral habitats tended to be larger than in non-coral habitat.

Plans to commercially exploit precious coral beds in the Northwestern Hawaiian Islands recently raised concern about harmful impacts to endangered resident monk seal populations. In 1998, surveys withHawaii Undersea Research Laboratory (HURL) submersibles found coral beds at sites where seals fitted with satellite tags and dive recorders had repeatedly foraged in deep waters. One hypothesis is that colonies of deep sea corals tend to aggregate fish, and foraging monk seals may exploit this by frequently revisiting coral beds to improve their access to prey. This hypothesis is now being tested (Parrish 2001).

The most obvious threat to these complex habitats is the impact of commercial fishing activities. Bottom trawling is considered to be the most ecologically damaging method of fishing (Morgan and Chuenpagdee 2003), and is expanding globally especially to vulnerable seamounts (Roberts 2002). More than 5000 km^2 of the Northeast Pacific seabed is trawled more than once annually for Atka mackerel and other species (NRC 2002). Trawl nets and longline gear frequently remove coral trees from the rocks and boulders they grow upon. The benthic impacts of this mobile fishing gear is similar to clearcutting techniques in old growth forests (Watling and Norse 1998). Other anthropogenic activities, such as ocean dumping and seafloor mining also threaten deep-sea corals (Rogers 1999).

Based on limited knowledge of deep-sea corals and their growing conservation significance, the National Oceanic and Atmospheric Administration's, Office of Protected Resources commissioned Marine Conservation Biology Institute to document the known occurrences of habitat-forming deep-sea corals for the Northeast Pacific and the adjacent Bering Sea.

Methods

The goals of this project were to map occurrences of selected deep-sea corals suspected of being important formers of biogenic habitat, as well as to construct a database of the accumulated records that informed these maps. Our definition of deep-sea, habitat-forming coral includes hexacorallian, octocorallian, and hydrocorallian families with complex branching morphologies that grow large enough to provide substrate and/or shelter for associated species of fish and invertebrates. This definition excludes deep-sea scleractinian cup corals.

Our initial data gathering efforts focused on records of few well-documented species, e.g. *Paragorgia arborea and Primnoa resedaeformis,* in the Northeast Pacific. However, record reviews of database outputs from participating museums revealed that species-specific searching often resulted in record loss due to species name changes and spelling changes over time spans sometimes exceeding 100 years. For example, records from the Smithsonian Institution for the family Isididae revealed that the name *Ceratoisis* has been revised to *Keratoisis*. A database search for a single species name inevitably inadvertently excluded alternate spellings.

After consultation with Drs. Frederick Bayer and Stephen Cairns of the Smithsonian Institution, (leading taxonomic authorities on octocorals and deep-sea scleractinian corals respectively), it was suggested that searches should be conducted by family name rather than species name. This alleviated issues related to misspelling and synonymy, but also speeded search time, limited institutional effort, incorporated lesser-known species names with similar morphology and minimized the impacts of taxonomic misidentification at the species level. Drs. Bayer and Cairns identified 8 families as habitat-formers in the Northeast Pacific Ocean: hexacorals in the families Antipathidae, Oculinidae and Caryophylliidae; octocorals in the families Corallidae, Isididae, Paragorgiidae and Primnoidae; and hydrocorals in the family Stylasteriidae.

Based upon this list of families, we contacted all known deep-sea coral researchers through a series of networked contacts that resulted from the *First International Symposium on Deep-Sea Corals* held in Halifax, Canada, July 30- August 3, 2000. Of these contacts, a limited number maintained deep sea coral records, and of those, a further reduced number maintained geo-positional records and were willing or able to distribute these records due to staffing constraints or other institutional limitations. A total of 10 different organizations and institutions ultimately supplied range and distribution records, including the California Academy of Sciences (CAS), Canadian Museum of Nature and Department of Fisheries and Oceans (CMN-DFO), the Monterey Bay Aquarium Research Institute (MBARI), the National Museum of Natural History at the Smithsonian Institution (NMNH), National Oceanic and Atmospheric Administration (NOAA) Office of Ocean Exploration (NOAA-OE), the National Marine Fisheries Service RACEBASE (RACE), the Santa Barbara Museum of Natural History (SBMNH), the REEF Foundation (REEF), the Scripps Institution of Oceanography (SIO) and a study performed by the late Dr. Robert Cimberg for VTN Oregon (Cimberg). Contact lists are provided in appendices at the end of this report.

The record selection methodology varied only slightly between institutions. Generally, we selected only those records that included a field for taxonomic identification. RACE includes many records identified as “coral”, but these were not included in this effort. Records from NOAA-OE do not represent the extent of that office’s documentation of cold water corals. NOAA-OE records represent the results of a single expedition to the Gulf of Alaska.

Each database maintained different information, so all database records were subset to their common fields: latitude (“lat”), longitude (“lon”), family (“family”), species name (“sp_name”), and depth in meters (“depth”). Additional fields were added to these records in order to facilitate potential researcher follow up. These fields include an institution name (“inst”) as abbreviated above, an institution specific identification number (“inst_id”), a coordinate’s code (“coord_code”), and a rank (“rank”).

“Coord_code” is a measure of accuracy for the latitude and longitude information. If a given record included coordinate information, it was assigned a value of 1, if that record included a place name only it was assigned the value of 2, and we assigned approximate coordinates to that place name. If a record lacked either of these qualities, or if the place name was too general (e.g. Alaska) it was dropped from the database. Most often these records were duplicated by other more specific records (e.g. Alaska, Aleutian Islands, Unimak Pass).

“Rank” is a relative measure of record quality based upon two factors: 1) whether a physical sample is associated with that record and 2) the identifiers level of expertise.

The ranking system is as such:

1 = sample collected, expert identification
2 = sample collected, non-expert identification
3 = no sample collected, expert identification
4 = no sample collected, non-expert identification

This ranking system is consistent with ongoing efforts at HURL, where a fleet of manned submersibles makes frequent deep water dives, but takes few samples, relying instead on video and photo identification. This ranking is also consistent with a need to conserve slow growing cold water coral resources, and to limit the impact of scientific collections to sustainable levels.

Results

The table below summarizes those records made available to this analysis. A total of 2649 records on 8 habitat-forming deep-sea coral families were gathered from 10 participating organizations in the United States and Canada. The National Marine Fisheries Service’s RACEbase was the largest contributor with 1540 records on 5 families, followed by the Smithsonian Institution, the most comprehensive contributor, with 423 records in 7 of the 8 families. The Smithsonian is believed to have additional records in the family Stylasteriidae (unavailable at the time of this writing).

MBARI was a substantial contributor for a very specific locale, namely Monterey Bay, where "easy" access to deep water and remotely operated vehicles (ROVs) facilitates almost daily expeditions to the Monterey Canyon. Video archivists at MBARI meticulously document most of those species familiar to them. CAS also worked closely with this study to accommodate numerous data requests, and their high quality, very comprehensive information based on Gary Williams' identification was an important supplement to this study. Records from NOAA-OE are derived from the 2002 Gulf of Alaska Seamount expedition aboard the R/V Atlantis with the Alvin submersible. Though the NOAA-OE contribution was small in number, this remote expedition to seamounts in the Gulf documented several habitat-forming corals where none were known before, extending the known range of Isididae and Corallidae into the Gulf of Alaska.

Table 1. A total of 2649 records from 10 institutions on 8 habitat-forming deep-sea coral families contributed to the results from this report.

FamilyName	CAS	NMNH	SIO	SBMNH	NOAA-OE	CMN-DFO	MBARI	Cimberg	REEF	RACE	**Total**
Antipathidae	8	29			3		101			102	243
Oculinidae		2									2
Caryophylliidae		8	1	1							10
Corallidae		128			2						130
Isididae	17	60	5		4		237	2		19	344
Paragorgiidae	12	38			2	11	51	9		143	266
Primnoidae	53	158			5	15		73		1012	1316
Stylasteriidae	58								16	264	338
Total	148	423	6	1	16	26	389	84	16	1540	2649
Data rank	1			2		3			4		

Accessing institutional databases by family name resulted in a 13% increase in data records for Isididae across all institutions. For Paragorgiidae, searching by family increased CAS records from 6 to 18, and NMNH records from 16 to 39. *Primnoa* records increased from 1 record for *Primnoa willeyi* to 53 records for *Primnoa sp.*

A review of the taxonomic methods practiced by each of the participating institutions indicated that CAS, NMNH and SIO records ranked "1". CMN-DFO, NOAA-OE, and SBMNH ranked "2". Each of these institutions maintains physical samples associated with their records. MBARI and Cimberg's Report ranked "3", while REEF and RACE ranked "4", as these records failed to maintain a physical sample. RACE represents data gathered by fisheries observers with minimal training in taxonomic identification, and REEF records are gathered by volunteer scuba divers with a similar cursory training and background. As an example, in order to the identify octocorals to the species level, one often requires a scanning electron microscope (SEM) to identify sclerites in the preserved tissue. Thus, even a physical sample of a calcium carbonate skeleton may be insufficient to satisfy the highest level criterion.

The database documents 105 habitat forming deep sea coral species in the Northeast pacific. The species names associated with each family are detailed in Appendix 1. The family Primnoidae contains the greatest number of species in the Northeast Pacific according to the database, with 63 species names assigned to that family, compared to 14 species names for Isididae, 10 for Corallidae, 9 for Stylasteriidae, 4 for Paragorgiidae, 3 for Antipathidae, and one each for Caryophylliidae and Oculinidae. Maps are presented by family in Appendix 2, color coded by data rank. Database users may symbolize these records by species name, or any other field, using Geographic Information System (GIS) software.

Depth ranges for the families of interest are detailed in Table 2. Bamboo corals in the family Isididae have the deepest documented specimen from Scripps Institution at 3880 m (12,800 ft). Cimberg (1981) documents a specimen of *Keratoisis profunda* at 3532 m (11,650 ft) in the Aleutian Islands. Specimens of Primnoidae and Antipathidae are also documented at depth nearing 3000 m (10,000 ft). Paragorgiidae and Primnoidae have maximum depths of approximately 2000 m (6,600 ft). Each of these families is also represented by species records shallower than 220 m (660 ft), suggesting a wide vertical distribution. Alvin pilots and researchers aboard the GOASEX expedition consistently documented greater densities of deep sea corals at depths shallower than 700 m (2,300 ft), though there were exceptions to this rule, particularly for the Primnoidae (Etnoyer, *pers obs*.).

Table 2. Deep-sea coral families exhibit a range of species diversity and depth distributions. Bamboo corals (Isididae) are documented at the greatest depths. (In order of max depth recorded.)

	Species richness	Mean Depth	Min Depth	Max Depth
Isididae	**21**	-1262	-107	-3880
Antipathidae	**3**	-924	-9	-2957
Primnoidae	**63**	-324	-25.5	-2600
Corallidae	**8**	-539	-215	-2116
Paragorgiidae	**4**	-406	-19	-1925
Stylasteridae	**11**	-265	-79	-823
Oculinidae	**2**	-278	-40	-556
Caryophylliidae	**1**	-301	-115	-486

Discussion

The families Isididae, Paragorgiidae and Primnoidae all have ranges that encompass the greatest portion of Northeast Pacific from the Bering Sea south to the Equator and west to the Hawaiian Islands. Antipathidae appears equally ubiquitous, but is documented only as far south as Baja California. Families Corallidae, Caryophylliidae, and Stylasteriidae are not documented north of the Aleutian Islands chain. Upon review, the family list used in this study is likely a subset of those that satisfy the habitat forming criteria at this basin scale. Some genera in the families Zooanthidae, Gorgonidae, and Plexauridae should be considered for future study.

All families have records on one or more seamounts in the Gulf of Alaska, except Stylasteriidae which is best documented along the continental shelf, and Oculinidae and Caryophyllidae which are well documented in the Atlantic but poorly documented here. The depth ranges of these families include the shallowest maximum depths. *Stylaster californicus* of the family Stylasteriidae has a maximum recorded depth of 823m (2700 ft) (CAS). Several northeast Pacific seamounts reach above that depth, and may provide habitat for stylasteriids. Alternatively, stylasteriids may actually be restricted to the nearshore. They are widely distributed in nearshore habitats of California (Morgan, *pers. obs.)*, and most of the records reported here are from SCUBA surveys (REEF).

The southern extent of records along the mainland of North America for the family Stylasteriidae is the northern tip of Baja California. However since this family is present at lower latitudes in the Hawaiian Islands, its southern range limit along the North America margin might be an artifact of the geographic extent of our national databases. Similarly, the distribution map for Antipathidae suggests that any apparent geographic limit for deep-sea corals is most likely an artifact of sampling effort and expertise. *Antipathes sp.* is best documented in the islands of Hawaii, partly due to collaborations between scientists there and a manned submersible fishery (Grigg 1981). *Antipathes sp.* is likely to be present in seamounts off western Mexico at latitudes similar to those from Hawaii. Isididae, Paragorgiidae, and Primnoidae occur north and south of Pacific Mexico with an absence of records in Mexico, and west of Baja California.

Future data gathering might concentrate on building collaborations with Mexican benthic ecologists to test these southern range limits. This data gap could result from either a real lack of deep sea corals or, more likely, a lack of exploration and/or connections to researchers performing studies in these regions. Future submersible research might focus on the Islas Revillagigedo and the Mathematician Seamounts off the coast of western Mexico to better understand the southern extent of these deep-sea coral species in the Northeast Pacific. The volcanic origin of the Islas Revillagigedo and their proximity to the highly productive Gulf of California make these impressive seamounts prime candidates for thick coral forests.

In 2002, the R/V Atlantis and Alvin submersible conducted multi-beam bathymetric surveys of 7 seamounts in the Gulf of Alaska: Patton, Murray, Chirikof, Marchand, Campbell, Scott and Warwick Seamount (Fig. 3). The Alvin obtained physical samples of each of these deep-sea coral families from one or more of those seamounts, and those few data points represent a dramatic expansion of the known ranges of some of these families. GOASEX also documented the first occurrence of Corallidae north of the Hawaiian Islands.

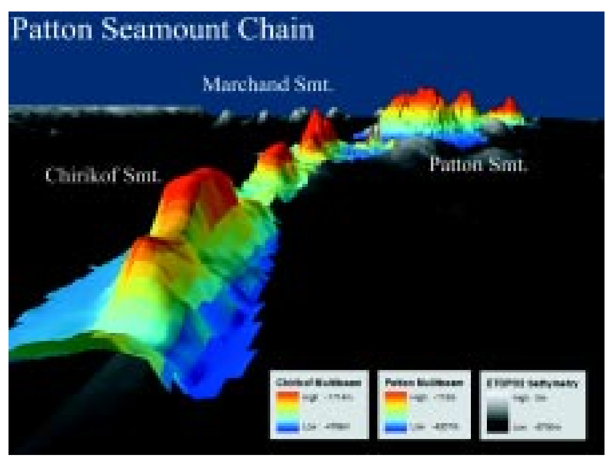


Fig. 3. Seamount “chains” consist of several peaks along a volcanic ridge, these seamounts are “home” to deep-sea corals.

It is important to note that this data ranking exercise is a relative one, and that a low data rank does not necessarily indicate poor quality. A low data rank in this case indicates that the researcher failed to preserve an intact sample, and that the researcher lacks scientific expertise in systematics. Neither of these conditions is surprising or rare. Research vessels may have limited human resources available, with few specialists dedicated to benthic invertebrates, limited quantities of ethanol preservative, and/or limited storage facilities. Also, the global number of researchers that can claim systematic expertise with deep-sea stony corals and gorgonians is less than a dozen (S. Cairns, *pers. comm.*). The number of researchers that may claim this expertise in the Northeast Pacific accounts for less than half that number.

The data ranking exercise suggests that the waters around Hawaii and Southern California have the largest numbers of high quality records. This is most likely due to the efforts of particular researchers in those regions to collect samples and submit them to the proper authorities for species level identification. However, Alaskan waters exhibit the greatest number of data points. This can be largely attributed to the RACEbase program, as evidenced by Table 1. The RACEbase program is the best candidate for data quality improvement in the near future. Capacity-building training in deep-sea coral systematics for these observers and record keepers should be a high priority.

Relatively little research has looked at deep-sea corals from a biogeographic standpoint. The 2002 seamount expedition by NOAA-Ocean Exploration to seamounts in the Gulf of Alaska (GOASEX) established additional Gulf of Alaska records for Isididae, extending the known range of the family there by 700 km. NOAA-OE records of Corallidae extended the known range of that family by more than 4000km to the north, a substantial increase in range from previous NMNH records.

The occurrences of the habitat-forming deep-sea coral families presented here suggest they have a large depth range throughout the Northeast Pacific. Dr. Bayer (*pers. comm.*) supports the conclusion that these families are widespread throughout their depth range (200-2000m) along the Pacific Rim. Too few data points and too little effort have been focused on seamounts in the Gulf of Alaska. Species occurrence appears directly related to sampling effort. Sampling effort in the Gulf of Alaska and the Bering Sea, however, is unfortunately defined as “bycatch” to the commercial bottom trawl industry. While some of these records represent first occurrences, most of these records are dated, and may represent deep sea coral forests that are no longer. With the expansion of trawl fleets into deeper waters and seamounts, deep-sea corals will be at greater risk in the future (Roberts 2002).

Studies suggesting deep-sea coral reefs may be decades to hundreds of years old further highlight the need for conservation. Retrospective analysis and isotope dating techniques for *Primnoa resdaeformis* suggest that a 5 cm diameter sample may be as old as 500 years (Risk et al. 1998). In another recent study conducted by Moss Landing Marine Laboratories, age and growth characteristics of *Primnoa resedeaformis* were described by counting growth rings in cross-sections of the coral skeleton. These estimates were validated using a radiometric aging technique. Andrews (2002) estimated growth rates of 1.74 cm per year in height, suggesting the largest limb studied took approximately 112 yrs to grow from its initial settlement to a total height of 197.5 cm (Andrews 2002).

At present there appears to be a great deal of variability in age estimates that likely reflects differences in the biology and ecology of the different corals, or laboratory methodologies. *In situ* measurements of corals belonging to 2 different orders, *Antipathes dichotoma* (Order: Antipatharia) and *Corallium secundum* (Order: Alcyonacea) yielded growth rates of 6.42 cm/yr and 0.9cm/yr, respectively (Grigg 1976), a 6 fold difference in growth rates under similar laboratory conditions. Andrew's (2002) study of *Primnoa resedeaformis* , 1.74 cm/yr, (Order: Alcyonacea) is more similar to the other Alcyonacea (*Corallium*) from Grigg's study (1976), suggesting variation in growth rate measurements might be due, in part, to different life histories.

Despite difficulties in documenting the age of deep-sea corals the importance of conserving coral communities cannot be overstressed. They are some of the world's most diverse deep-sea marine communities, representing banks of biological diversity and unique adaptations to life in extreme environments. Deep-sea corals are historical record keepers, and indicators of environmental stress such as pollution, sedimentation, and sea temperature fluctuations (Smith et al. 1997). Deep-sea corals are also sources of pharmaceutically important compounds such as prostaglandins and anti-cancer agents. Regardless of their research potential, however, these organisms perform important habitat functions for numerous associated species, and must be protected from fishing gears which destroy seafloor habitat (Watling and Norse 1998, Rogers 1999).

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Appendix 1: Scientific names associated with each family in this report.

CLASS HYDROZOA

ORDER STYLASTERINA

Family Stylasteriidae

Allopora

Allopora campyleca Fisher, 1938

Allopora petrograpta Fisher, 1938

Allopora porphyra Fisher, 1931

Distichopora

Errinopora pourtalesii Dall, 1885

Stylantheca porphyra Fisher, 1931

Stylaster

Stylaster californicus Verrill, 1866

Stylaster cancellatus Fisher, 1938

Stylaster venustus Verrill, 1868

CLASS ANTHOZOA

SUBCLASS HEXACORALLIA

ORDER ANTIPATHARIA

Family Antipathidae

Antipathes

Bathypathes

Parantipathes

SUBCLASS OCTOCORALLIA

ORDER GORGONACEA

Family Corallidae

Corallium regale

Corallium abyssale

Corallium ducale

Corallium imperiale

Corallium kishinouyei

Corallium laauense

Corallium niveum

Corallium regale

Corallium secundum

Corallium tortuosum

ORDER SCLERACTINIA

Family Caryophylliidae

Lophelia pertusa (*L. prolifera*)

Family Oculinidae

Madrepora oculata

SUBCLASS OCTOCORALLIA

ORDER GORGONACEA

Family Isididae

Acanella eburnea Pourtales

Acanella dispar Bayer, 1990

Ceratoisis flabellum Nutting, 1908

Isidella sp. 5

Keratoisis cf. *flabellum* Nutting

Keratoisis paucispinosa Wright & Studer

Keratoisis philippinensis Wright & Studer

Ceratoisis grandis Nutting, 1908

Isidella trichotoma Bayer, 1990

Isidella sp. 3

Keratoisis sp.

Lepidisis evelinaea Bayer, 1986

Lepidisis longiflora Verrill

Lepidisis olapa Muzik, 1978

Lepidisis sp.

Keratoisis profunda Wright

SUBCLASS OCTOCORALLIA

ORDER GORGONACEA

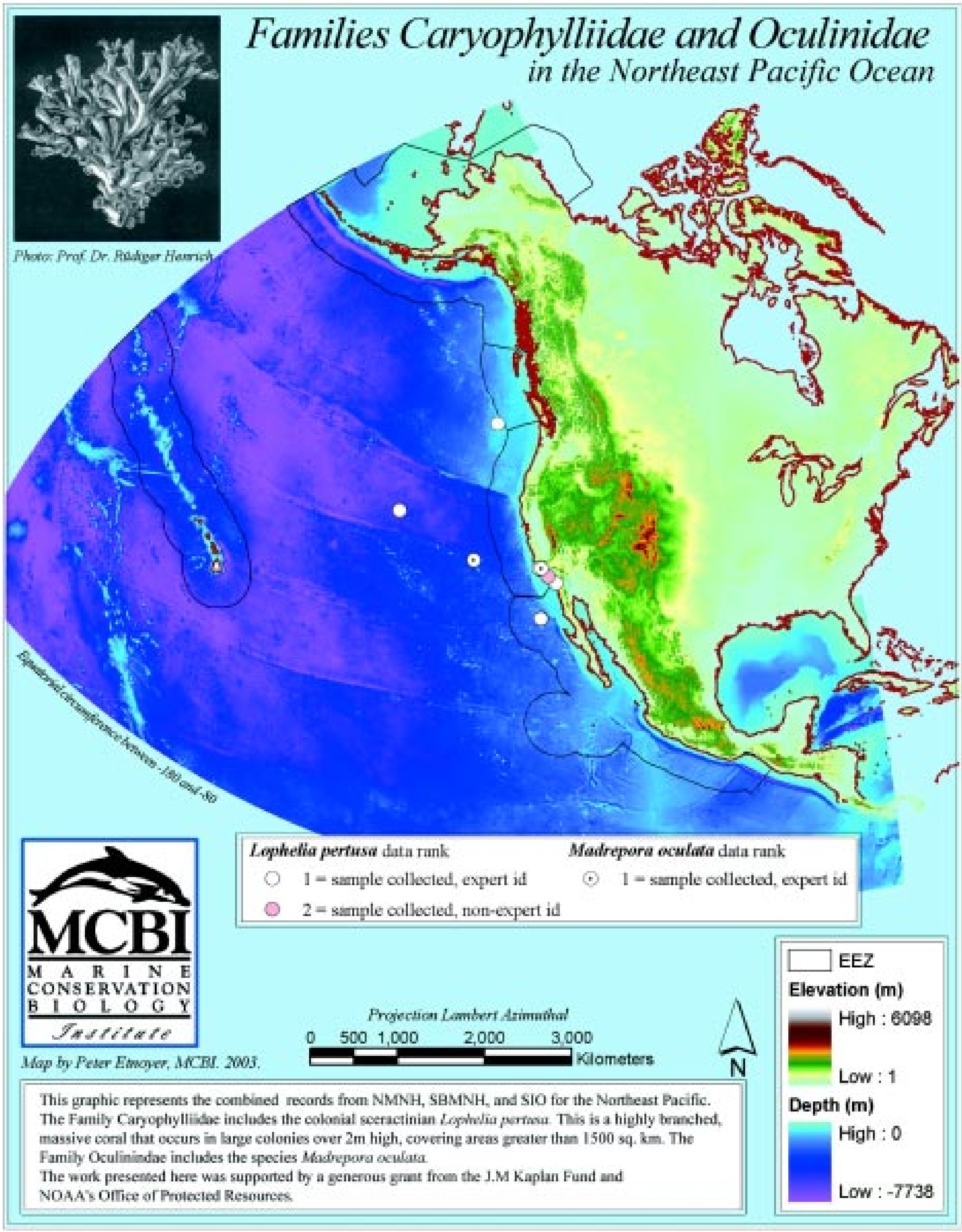
Family Paragorgiidae

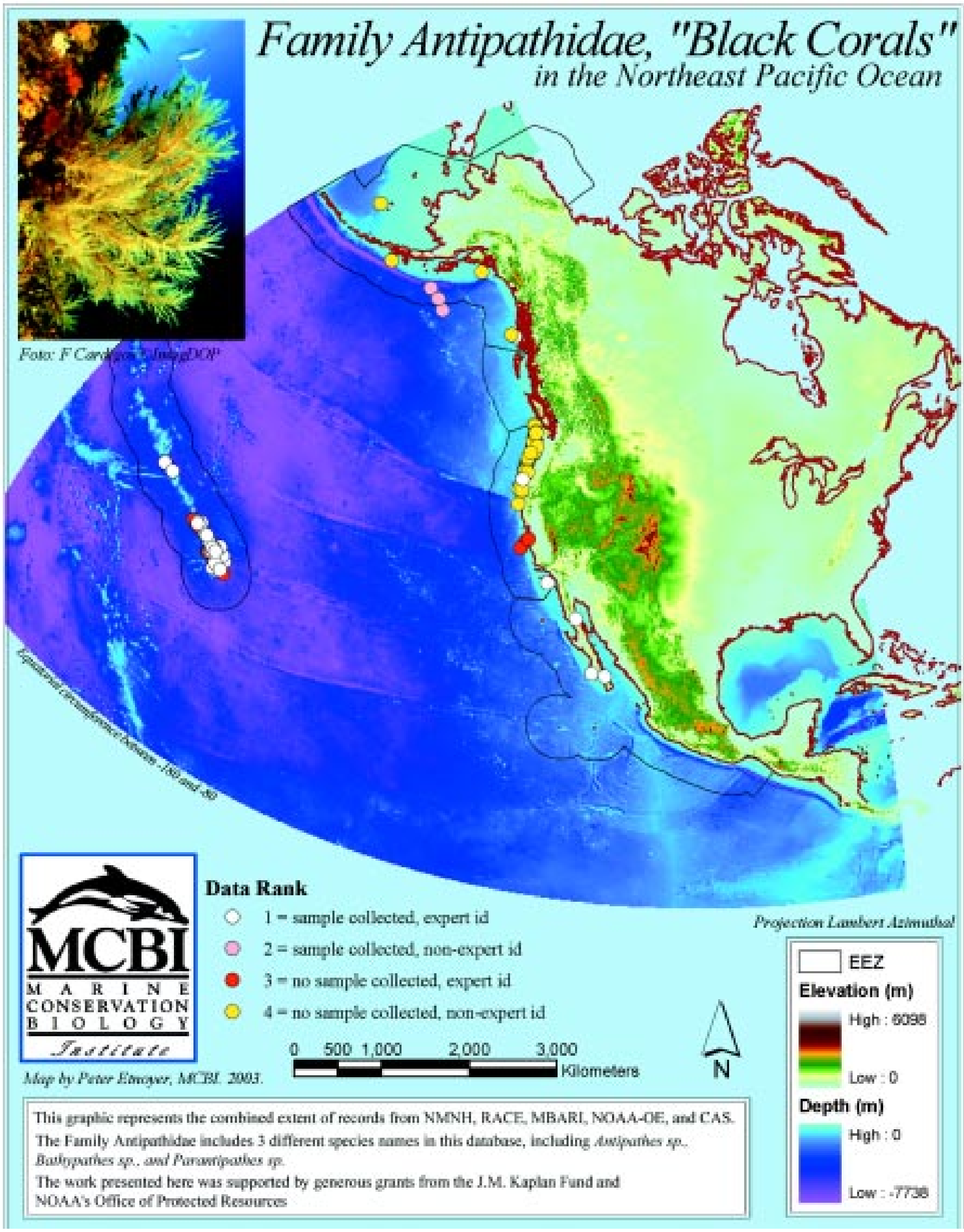
Paragorgia arborea Linnaeus, 1758
Paragorgia coralloides Bayer, 1993
Paragorgia dendroides Bayer, 1956
Paragorgia pacifica Verrill

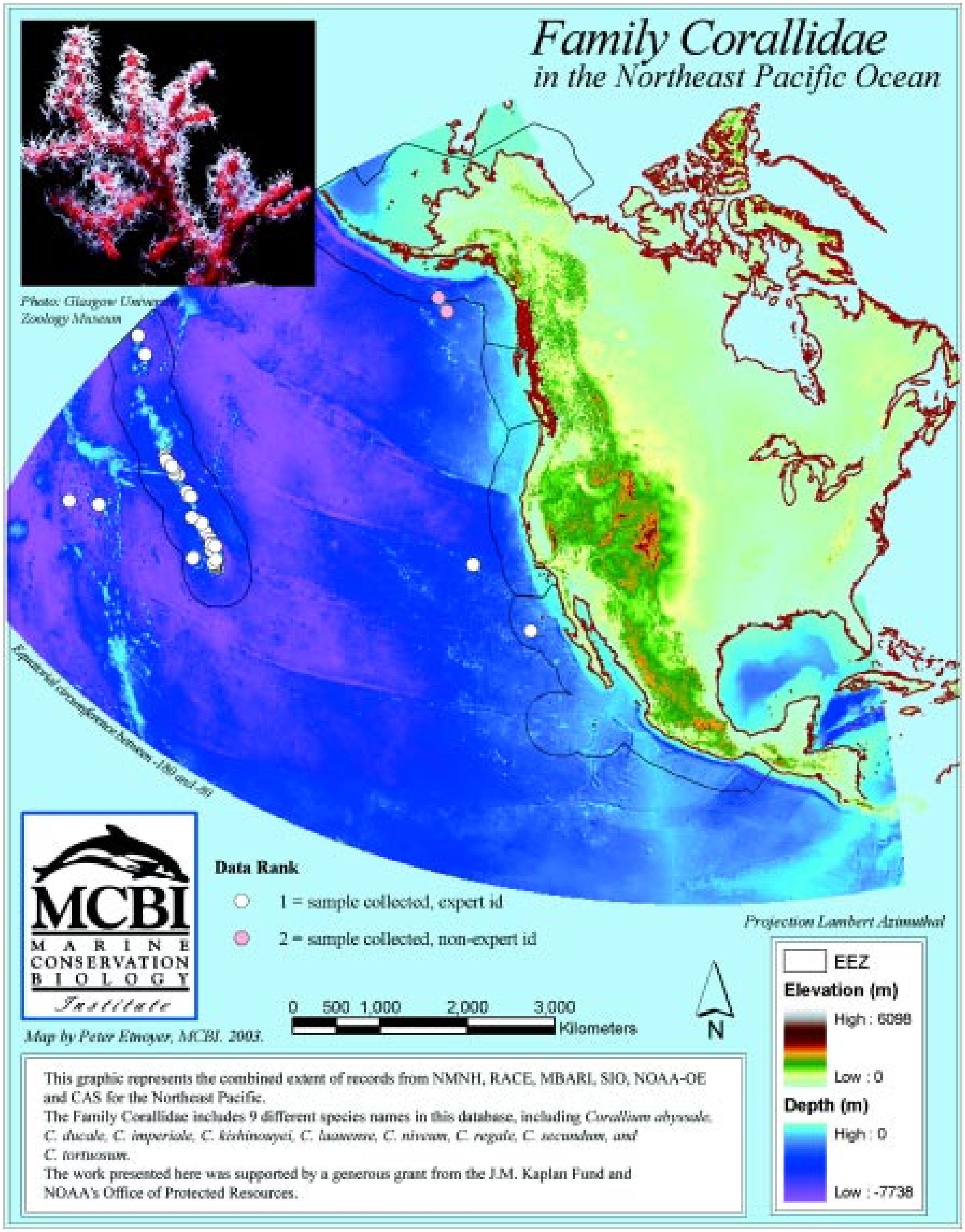
Family Primnoidae

Amphilaphis biserialis
Amphilaphis
Amphilaphis sp. 1
Amphilaphis sp. 2
Amphilaphis sp. 3
Arthrogorgia sp.
Arthrogorgia utinomii
Caligorgia cristata
Caligorgia gilberti
Callogorgia
Callogorgia flabellum
Callogorgia formosa
Callogorgia gilberti
Callogorgia gracilis
Callogorgia kinoshitae
Calyptrophora angularis
Calyptrophora cf. versluysi
Calyptrophora versluyi
Calyptrophora wyvillei
Candidella
Candidella helminthophora
Fanellia compressa
Fanellia fraseri
Fanellia compressa
Fanellia euthyeia
Fanellia sp.
Fanellia tuberculata
Narella
Narella allmani
Narella ambigua
Narella bowersi
Narella dichotoma
Narella ornata
Narellai bayer
Paracalyptrophora
Paracalyptrophora kerberti
Parastenella
Parastenella doederleini
Plumarella
Plumarella flabellata
Plumarella longispina
Plumarella sp. 1
Primnoa
Primnoa reseda
Primnoa resedaeformis
Primnoa willeyi
Stachyodes bowersi
Stenella helminthophora
Thouarella
Parathouarella striata
Thouarella regularis

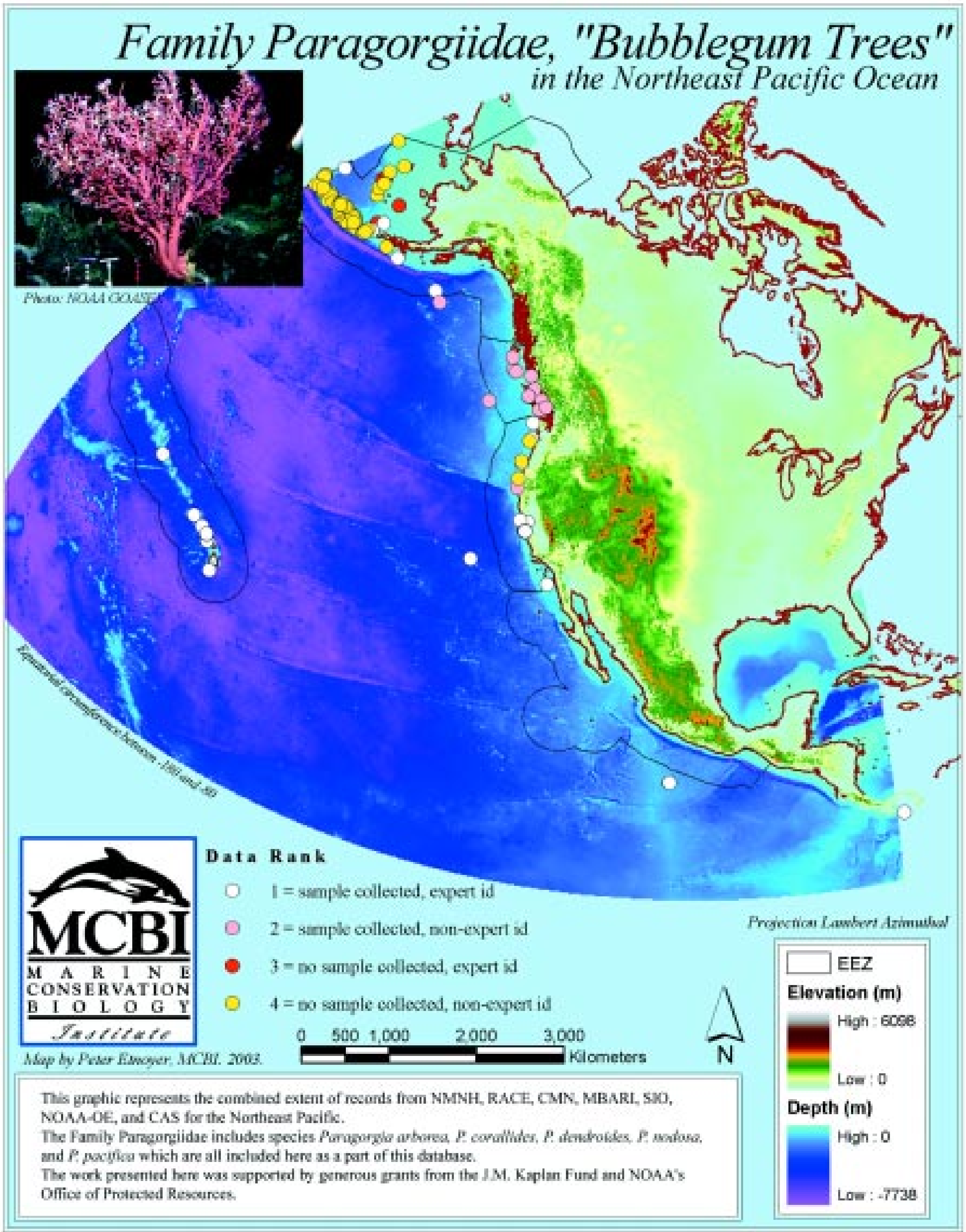
Appendix 2: Maps of range and distribution in the Northeast Pacific Ocean, by family

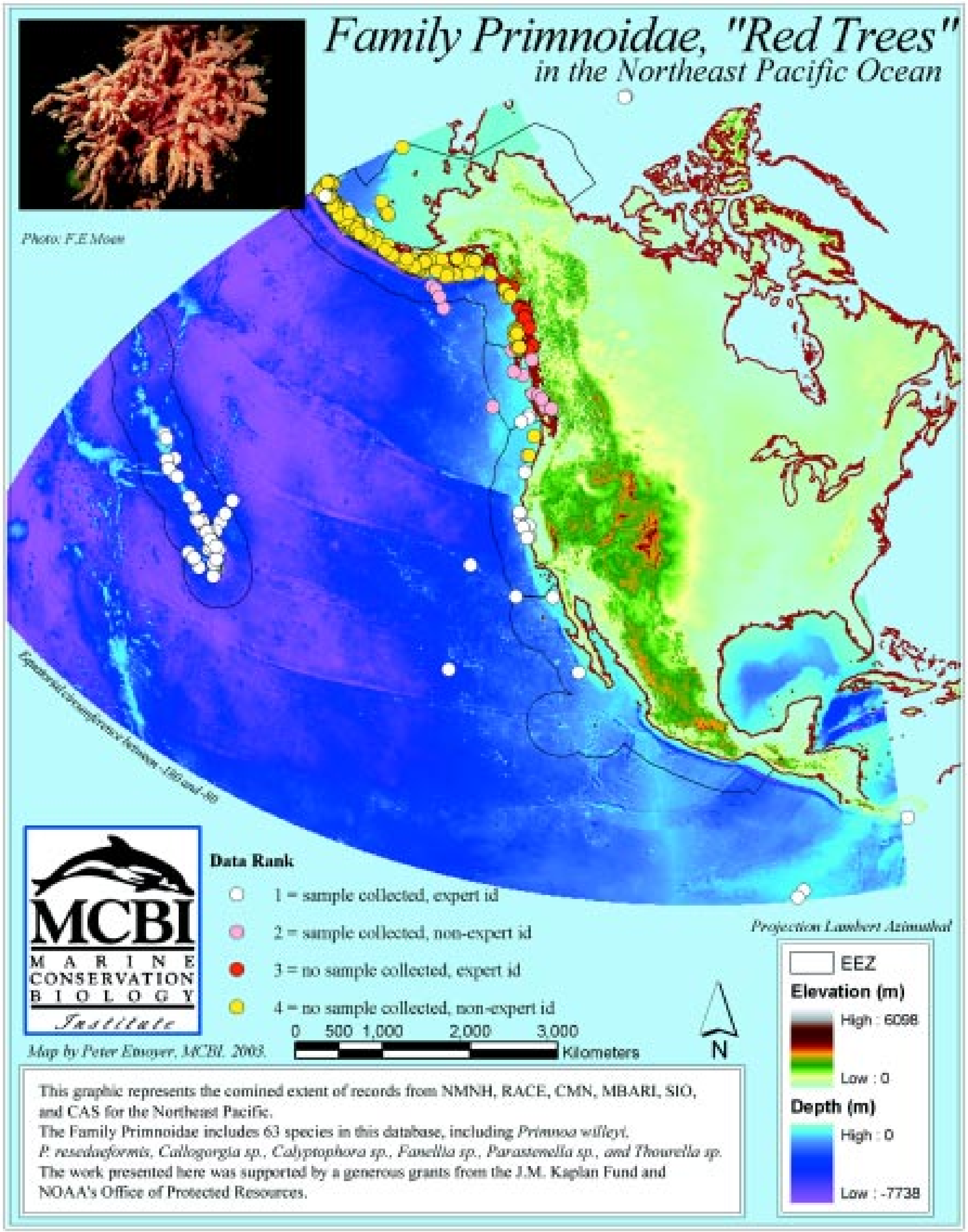



Family Antipathidae, "Black Corals"
in the Northeast Pacific Ocean
MCBI
MARINE
CONSERVATION
BIOLOGY
Institute
Data Rank
1 = sample collected, expert id
2 = sample collected, non-expert id
3 = no sample collected, expert id
4 = no sample collected, non-expert id
0 500 1,000 2,000 3,000
Kilometers
N
Map by Peter Etnoyer, MCBI. 2003.
Projection Lambert Azimuthal
EEZ
Elevation (m)
High : 6098
Low : 0
Depth (m)
High : 0
Low : -7736
This graphic represents the combined extent of records from NMNH, RACE, MBARI, NOAA-OE, and CAS.
The Family Antipathidae includes 3 different species names in this database, including Antipathes sp., Bathypathes sp., and Parantipathes sp.
The work presented here was supported by generous grants from the J.M. Kaplan Fund and NOAA's Office of Protected Resources

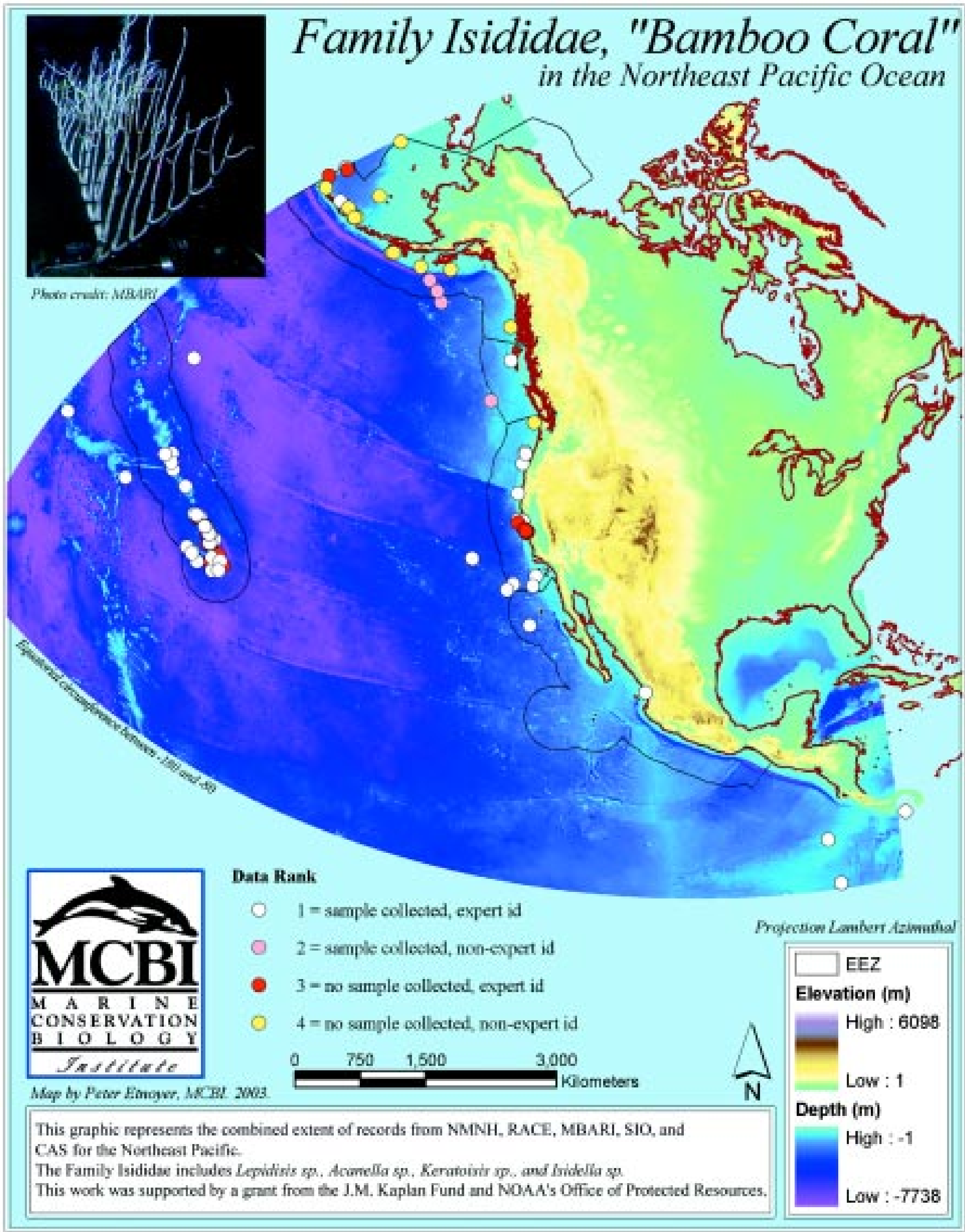


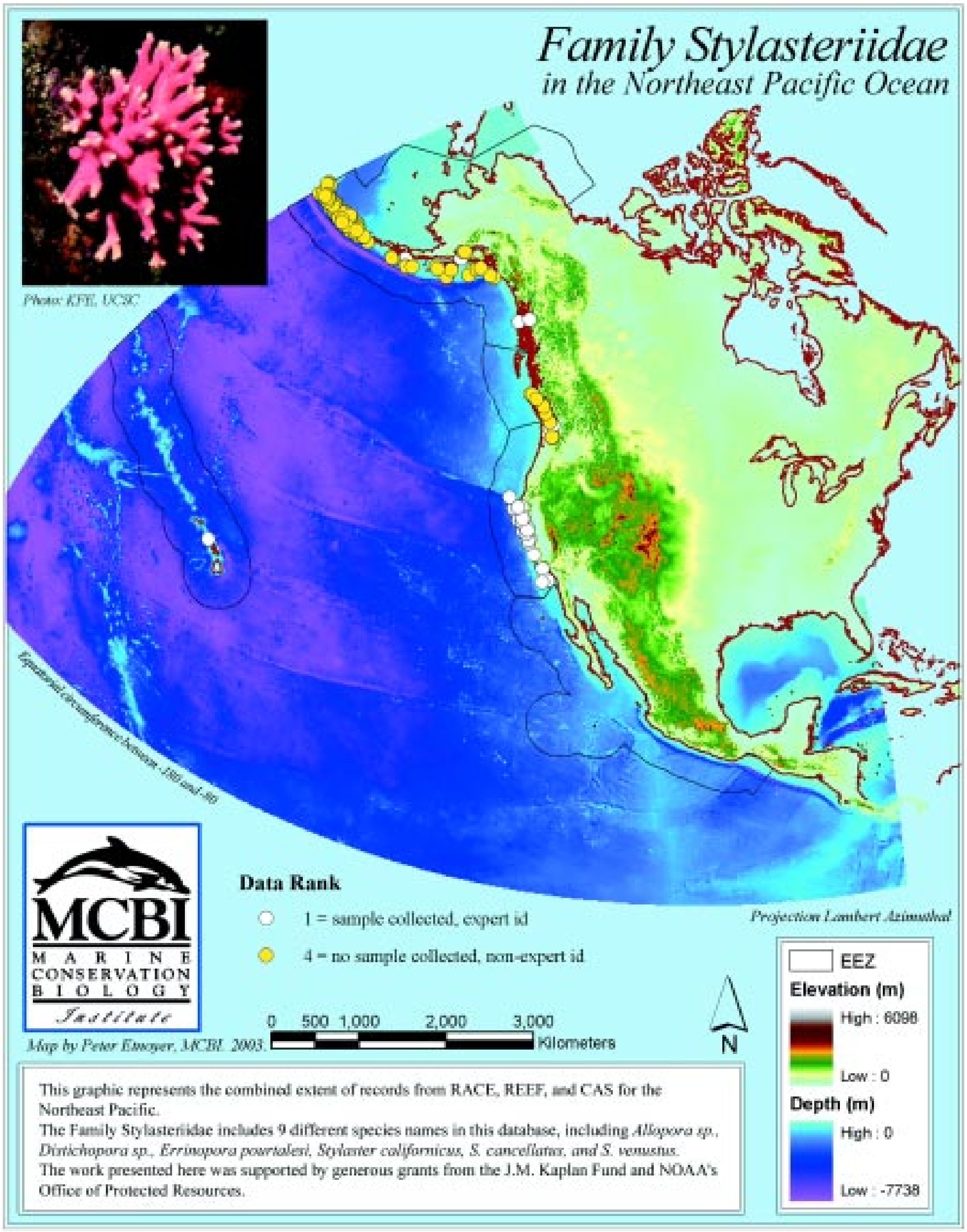
Family Corallidae
in the Northeast Pacific Ocean
Photo: Glasgow University
Zoology Museum
Equatorial circumference between -180 and -80
MCBI
MARINE
CONSERVATION
BIOLOGY
Institute
Data Rank
1 = sample collected, expert id
2 = sample collected, non-expert id
Projection Lambert Azimuthal
EEZ
Elevation (m)
High : 6098
Low : 0
Depth (m)
High : 0
Low : -7738
0 500 1,000 2,000 3,000
Kilometers
N
Map by Peter Etnoyer, MCBI. 2003.
This graphic represents the combined extent of records from NMNH, RACE, MBARI, SIO, NOAA-OE and CAS for the Northeast Pacific.
The Family Corallidae includes 9 different species names in this database, including Corallium abyssale, C. ducale, C. imperiale, C. kishinouyei, C. lauuense, C. niveum, C. regale, C. secundum, and C. tortuosum.
The work presented here was supported by a generous grant from the J.M. Kaplan Fund and NOAA's Office of Protected Resources.


Family Paragorgiidae, "Bubblegum Trees"
in the Northeast Pacific Ocean
Data Rank
1 = sample collected, expert id
2 = sample collected, non-expert id
3 = no sample collected, expert id
4 = no sample collected, non-expert id
MCBI
MARINE
CONSERVATION
BIOLOGY
Institute
0 500 1,000 2,000 3,000
Kilometers
N
Map by Peter Etnoyer, MCBI. 2003.
Projection Lambert Azimuthal
EEZ
Elevation (m)
High : 6098
Low : 0
Depth (m)
High : 0
Low : -7738
This graphic represents the combined extent of records from NMNH, RACE, CMN, MBARI, SIO, NOAA-OE, and CAS for the Northeast Pacific.
The Family Paragorgiidae includes species Paragorgia arborea, P. corallides, P. dendroides, P. nodosa, and P. pacifica which are all included here as a part of this database.
The work presented here was supported by generous grants from the J.M. Kaplan Fund and NOAA's Office of Protected Resources.



Family Primnoidae, "Red Trees"
in the Northeast Pacific Ocean
Photo: F.E.Moan
Data Rank
1 = sample collected, expert id
2 = sample collected, non-expert id
3 = no sample collected, expert id
4 = no sample collected, non-expert id
MCBI
MARINE
CONSERVATION
BIOLOGY
Institute
Map by Peter Etnoyer, MCBI. 2003.
0 500 1,000 2,000 3,000
Kilometers
N
Projection Lambert Azimuthal
EEZ
Elevation (m)
High : 6098
Low : 0
Depth (m)
High : 0
Low : -7738
This graphic represents the comined extent of records from NMNH, RACE, CMN, MBARI, SIO, and CAS for the Northeast Pacific.
The Family Primnoidae includes 63 species in this database, including Primnoa willeyi, P. resedaeformis, Callogorgia sp., Calyptophora sp., Fanellia sp., Parastenella sp., and Thourella sp.
The work presented here was supported by a generous grants from the J.M. Kaplan Fund and NOAA's Office of Protected Resources.


Family Isididae, "Bamboo Coral"
in the Northeast Pacific Ocean
Photo credit: MBARI
Data Rank
1 = sample collected, expert id
2 = sample collected, non-expert id
3 = no sample collected, expert id
4 = no sample collected, non-expert id
0 750 1,500 3,000
Kilometers
N
Projection Lambert Azimuthal
EEZ
Elevation (m)
High : 6098
Low : 1
Depth (m)
High : -1
Low : -7738
MCBI
MARINE CONSERVATION BIOLOGY Institute
Map by Peter Etnoyer, MCBI. 2003.
This graphic represents the combined extent of records from NMNH, RACE, MBARI, SIO, and CAS for the Northeast Pacific.
The Family Isididae includes *Lepidisis sp., Acanella sp., Keratoisis sp., and Isidella sp.*
This work was supported by a grant from the J.M. Kaplan Fund and NOAA's Office of Protected Resources.


Family Stylasteriidae
in the Northeast Pacific Ocean
Photo: KFH, UCSC
Data Rank
1 = sample collected, expert id
4 = no sample collected, non-expert id
Projection Lambert Azimuthal
MCBI
MARINE
CONSERVATION
BIOLOGY
Institute
0 500 1,000 2,000 3,000
Kilometers
N
Map by Peter Etnoyer, MCBI. 2003.
EEZ
Elevation (m)
High : 6098
Low : 0
Depth (m)
High : 0
Low : -7738
This graphic represents the combined extent of records from RACE, REEF, and CAS for the Northeast Pacific.
The Family Stylasteriidae includes 9 different species names in this database, including Allopora sp., Distichopora sp., Errinopora pourtalesi, Stylaster californicus, S. cancellatus, and S. venustus.
The work presented here was supported by generous grants from the J.M. Kaplan Fund and NOAA's Office of Protected Resources.

Appendix 3: Contact List of Institutions Able to Provide Data

California Academy of Sciences
Data rank: 1
Robert Van Syoc
Department of Invertebrate Zoology and Geology, CAS
Golden Gate Park, San Francisco CA 94118
email: bvansyoc@calacademy.org

Smithsonian Institution
Data rank: 1
Stephen D. Cairns
P. O. Box 37012
National Museum of Natural History, W-329, MRC-0163
Washington DC 20013
email: cairns.stephen@nmnh.si.edu

Scripps Institution of Oceanography
Data rank: 1
Lawrence L. Lovell
Benthic Invertebrate Collection, SIO
9500 Gilman Drive, Mailcode 0244
La Jolla CA 92093
email: llovell@ucsd.edu

National Oceanic and Atmospheric Administration
Office of Ocean Exploration
Data rank: 2
Catalina Martinez
NOAA Office of Ocean Exploration
1315 East West Highway, Office #10226
Silver Spring MD 20910
email: Catalina.Martinez@noaa.gov

Santa Barbara Museum of Natural History
Data rank: 2
F.G. Eric Hochberg
Department of Invertebrate Zoology, SBMNH
2559 Puesta del Sol Road
Santa Barbara CA 93105
email: fghochberg@sbnature2.org

Canadian Museum of Nature
Data rank: 2
Noel Alfonso
Research Services Division
Canadian Museum of Nature
P.O. Box 3443, Station D
Ottawa, ON K1P 6P4
Canada
email: nalfonso@mus-nature.ca

Hawaii Undersea Research Laboratory (data not included)
Data rank: 2
Edith H. Chave and Richard Grigg
University of Hawai'i at Mânoa
1000 Pope Rd, MSB 303
Honolulu HI 96822
email: chave@lava.net and rgrigg@soest.hawaii.edu

Monterey Bay Aquarium Research Institute
Data rank: 3
Judith L. Connor
Information and Technology Dissemination Division
Monterey Bay Aquarium Research Institute
7700 Sandholdt Rd
Moss Landing CA 95039
email: conn@mbari.org

Resource Assessment and Conservation Engineering (RACE) Division of the Alaska Fisheries Science Center
Data rank: 4
Mark E. Wilkins
Alaska Fisheries Science Center
7600 Sand Point Way NE, Bldg 4
Seattle WA 98115
email: mark.wilkins@noaa.gov

Reef Environmental Education Foundation
Data rank: 4
Christy Pattengill-Semmens
Reef Environmental Education Foundation
P.O. Box 246
Key Largo FL 33037
email: christy@reef.org

Appendix 4: Other potential data resources

American Museum of Natural History
Mark E. Siddall
Division of Invertebrate Zoology, AMNH
Central Park West at 79th St
New York NY 10024 email: siddall@amnh.org

Lawrence Livermore National Laboratory
Tom Guilderson
UC/Lawrence Livermore National Lab L-397
7000 East Ave
Livermore CA 94550 email: tguilderson@llnl.gov

Minerals Management Service
Janice Hall
MMS Pacific OCS Region, Mail Stop 7001
770 Paseo Camarillo
Camarillo CA 93010 email: janice.hall@mms.gov

Moss Landing Marine Laboratories
Jonathan Geller
Moss Landing Marine Laboratories
8272 Moss Landing Rd
Moss Landing CA 95039 email: geller@mlml.calstate.edu

National Marine Fisheries Service, NOAA
Waldo Wakefield
Northwest Fisheries Science Center
Hatfield Marine Science Center
2030 So. Marine Science Drive
Newport, OR 97365 email: waldo.wakefield@noaa.gov

Scientific Applications International Corporation
Andrew Lissner
Science Applications International Corporation
4242 Campus Point Court, Mail Stop D-4
San Diego CA 92121 email: lissnera@saic.com

University of Kansas
Daphne Fautin
Department of Ecology and Evolutionary Biology, UK
3002 Haworth Hall
1200 Sunnyside Ave
Lawrence KS 66045 email: fautin@ku.edu

Exhibit G.2.c
Supplemental HC Report
March 2004

HABITAT COMMITTEE COMMENTS ON CORALS AND LIVING SUBSTRATE

The Habitat Committee (HC) is concerned about the protection of deepwater corals as vulnerable habitat that may provide important fishery (and other) benefits. As noted during the agenda item on legislative issues (B.2.a, Attachment 4), a new coral protection act (SB 1953) has been proposed in Congress to close selected areas to “mobile bottom-tending gear.” The proposed coral protection areas would include specific areas known to harbor coldwater corals and sponges or areas that had not experienced bottom trawling during the three-year period ending November 1, 2003. The apparent objective of the legislation is to protect areas that likely contain corals. The areas closed to bottom trawling by the Council may or may not have significant corals. The HC recommends the Council review the wording of this legislation to make sure there are no unintended consequences related to the identified time period (2001, 2002, 2003).

PFMC
03/11/04

ARTIFICIAL REEFS IN SOUTHERN CALIFORNIA

Situation: The U.S. Department of Commerce (DOC) is considering creating a proposed rule regarding the creation of artificial reefs in Southern California from decommissioned offshore oil platforms. The general concept is to allow for a Federal Artificial Reef Program for the California outer-continental shelf. An offshore platform could be included in the program only if the applicant can demonstrate, on a case-by-case basis, net environmental benefit from leaving a platform, or a submerged portion of the platform, in place rather than removing it. The program will also require the donation from the applicant of 50% of the savings from including a platform in the program, compared to full decommissioning to the seabed floor. These funds are to be donated to an endowment organization charged with administering the program. Funds are to be used to cover costs for maintenance, monitoring, and insurance of platform remnants and to fund research, conservation, and management projects that will protect and enhance fishery and marine resources in outer-continental shelf waters adjacent to California and in California state waters. The National Marine Fisheries Service and the Pacific Council have been mentioned as candidates on a board of directors authorizing research, conservation, and management projects. There is also proposed national legislation on this issue (Exhibit B.2.a, Attachment 6: HR 2654.)

On January 30, 2004, the Council sent a letter to the DOC notifying it of the Council's intention to consider this issue and asking the DOC to coordinate input from the Pacific Council during the open comment period for the proposed rule (Exhibit G.3.a, Attachment 1.) Impacts to overfished groundfish stocks particularly bocaccio rockfish and cowcod, were cited as a primary concern.

At the time of the briefing book distribution, a proposed rule has not been noticed in the *Federal Register*.

During this meeting, the Council has the opportunity to consider the various scientific and technical reports that have been prepared on this issue and other relevant materials. (Exhibit G.3.a, Attachments 2-5). Mr. George Steinbach, Executive Director of the California Artificial Reef Endorsement Program, will provide a briefing as to process and schedule for this issue. After hearing the briefing, advisory body advice, and public comment, the Council should consider further activity on this issue.

Council Task:

1. Consider further activity of the Council on this issue.

Reference Materials:

1. Exhibit G.3.a, Attachment 1: Letter to Mr. Timothy Keeney, U.S. Department of Commerce, from the Pacific Council, January, 2004.
2. Exhibit G.3.a, Attachment 2: "Rigs-to-Reefs Policy, Progress and Perspective," by Les Dauterive, U.S. Department of the Interior, 2000.

3. Exhibit G.3.a, Attachment 3: General Report of the R2R Natural Sciences Committee, September 2003.
4. Exhibit G.3.a, Attachment 4: "An Economic Analysis of a Rigs to Reefs Program for the California Outer Continental Shelf," by Robert W. Hahn and Anne Layne-Farrar, National Economic Research Associates, October 2003.
6. Exhibit G.3.a, Attachment 5: Executive summary of "The Ecological Role of Oil and Gas Platforms and Natural Outcrops on Fishes in Southern and Central California," by Milton Love, Donna Schroeder and Mary Nishimoto, June 2003.
7. Exhibit G.3.a, Attachment 6: "The Role of Fishermen and Other Stakeholders in the North Sea Rigs-to-Reefs Debate," by Mark Baine and Jon Side, in *Fisheries, Reefs, and Offshore Development* (American Fisheries Society Symposium 36), 2003.

Agenda Order:

a. Agendum Overview — Jennifer Gilden
b. Status Report
c. Reports and Comments of Advisory Bodies
d. Public Comment
e. **Council Action:** Consider NOAA Proposed Rule

PFMC
02/23/04

PACIFIC FISHERY MANAGEMENT COUNCIL
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January 30, 2004

Mr. Timothy R.E. Keeney
Deputy Assistant Secretary for Oceans and Atmosphere
United States Department of Commerce
1401 Constitution Ave, NW
Washington, DC 20230

Dear Mr. Keeney:

The Pacific Fishery Management Council (Pacific Council) would like to take this opportunity to inform you of upcoming plans to consider the issue of creating artificial reefs in Southern California from decommissioned offshore oil platforms, under its authority as described in the Magnuson-Stevens Fishery Conservation and Management Act. We understand the National Oceanic and Atmospheric Administration (NOAA) is considering a proposed rule on this matter and would like to coordinate input from the Pacific Council during the open comment period.

The Pacific Council is very concerned about the overfished status of species of rockfish inhabiting Southern California marine areas, particularly cowcod and bocaccio rockfish. Rebuilding these stocks to healthy levels is of paramount importance to the various sport and commercial fisheries of the area, which have been substantially restricted to protect these stocks. Current estimates of rebuilding time frames are dramatic for these long-lived species; cowcod, for example, are projected to take 90 years to rebuild, even with a complete cessation on directed fishing, a closed area encompassing the bulk of their known habitat, and an incidental catch allowance in other fisheries of extremely minor amounts. The Pacific Council is interested in looking at anything that has potential in accelerating rebuilding of these stocks. Because there appears to be indications of concentrations of rockfish around existing offshore platforms, it seems appropriate to proceed with a proposed rule to appropriately deal with the question of an optimal decommissioning strategy that is best for the fish populations and the dependent fishery communities.

The Pacific Council is scheduled to meet twice in the upcoming spring months. We will meet the week of March 7-12, 2004 and April 4-9, 2004. We have scheduled consideration of this matter on the March agenda. At that time, the Pacific Council will consider reviews of the various NOAA scientific and technical reports that have been prepared on this issue, other relevant materials, and the anticipated proposed rule language. After hearing these reviews, the advice of formal Council advisory bodies, and public comment, the Council will consider taking a position on the proposed rule and submitting formal comment. In the instance further analysis is required, the Council may defer any decision making on this issue until the April Council meeting. It would be appreciated if you would consider these Council meeting dates in scheduling the open comment period.

Please send us a copy of the proposed rule when it becomes available.

Thank you for your consideration on this important matter.

Sincerely,

D. O. McIsaac, Ph.D.
Executive Director

DOM:dsh

c: Council Members
Dr. William Hogarth
Dr. Rebecca Lent
Mr. Jack Dunnigan
Mr. Rod McInnes
Ms. Linda Chavez
Mr. George Steinbach
Dr. Don Kent
Dr. John Coon
Mr. Mike Burner
Mr. John DeVore
Ms. Jennifer Gilden
Mr. Daniel Waldeck

Exhibit G.3.a
Attachment 2
March 2004

Rigs-to-Reefs Policy, Progress, and Perspective

Author

Les Dauterive

Published by

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

New Orleans
October 2000

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Abstract

The Minerals Management Service (MMS) has updated its policy affecting oil and gas platform abandonment and removal procedures that should facilitate efforts between coastal states and oil and gas companies in the development of better offshore Rigs-to-Reefs (RTR). Over the past 13 years oil and gas companies have donated 151 platforms for construction of reefs in the Gulf of Mexico (GOM). Through partial platform removals and the elimination of explosives in the RTR conversion process, companies can now conserve reefs with higher profiles and less trauma to platform-associated reef organisms. Providing the industry with more productive offshore disposal alternatives and options can lead to reduction of abandonment costs and preservation of environmental values, thereby generating more incentives to convert platforms to reefs. In addition to producing 98 percent of the gas and 91 percent of the oil on our Nation's Federal Outer Continental Shelf (OCS), GOM platforms provide the largest artificial reef complex in the world.

Introduction and Background

The U.S. Department of the Interior (USDOI), Minerals Management Service (MMS), is responsible for leasing submerged Federal lands on the U.S. Outer Continental Shelf (OCS) for minerals exploration, development, and production under the provisions of the OCS Lands Act Amendments of 1978 (92 Stat. 629). To meet this responsibility the MMS is charged with four priority goals.

1. Orderly minerals resource development on public land.
2. Protection of the human, marine, and coastal environments.
3. Receipt of fair market value from the development of mineral resources.
4. Preservation of free enterprise competition.

In 1980, the MMS Gulf of Mexico (GOM) Region initiated an effort to develop a database that would increase understanding of the scope and magnitude of recreational use of oil and gas platforms. The effort also provided a foundation for future decisions by government and industry concerning the role of platforms in fishery production. The MMS negotiated an interagency agreement with the National Marine Fisheries Service to carry out studies, with the active participation of the petroleum industry and Texas A&M University. This cooperative initiative had five objectives: (1) to develop a national policy that recognizes the artificial reef benefits of oil and gas platforms, (2) to prepare a Rigs-to-Reefs (RTR) program plan for the GOM, (3) to establish a standard procedure to ensure and facilitate timely conversion of obsolete platforms as reefs, (4) to identify research and studies necessary to optimize the use of platforms as reefs, and (5) to identify legal restrictions that may prevent use of obsolete platforms as artificial reefs.

In addition to this cooperative effort, the Secretary of the USDOI joined with the president of the National Ocean Industries Association to form the Recreational Environmental Enhancement for Fishing in the Seas task force. The task force was composed of fishery representatives from coastal states and private and public officials. The goal of the task force was to develop a strategy that would lead to the creation of a national RTR policy, plan, and program in the United States (Reggio, 1987). This goal was realized when The National Fishing Enhancement Act (NFEA) was signed into law (Public Law 98-623, Title II) in 1984. The Act includes the following: (1) recognition of social and economic values in developing artificial reefs, (2) establishment of national standards for artificial reef development, (3) creation of a National Artificial Reef Plan (NARP) under leadership of the U.S. Department of Commerce, and (4) establishment of a reef-permitting system under the U.S. Army Corps of Engineers (USACOE).

Increasing interest and participation in fishing at offshore oil and gas platforms, along with widespread support for effective artificial reef development by coastal states, led Congress to enact the NFEA. The NARP, written in 1985, allowed for the planning, siting, permitting, constructing, installing, monitoring, managing, and maintaining of artificial reefs within and seaward of state jurisdictions.

The removal of platforms from the GOM has resulted in the loss of valuable reef and fishery habitat. Researchers report fish densities to be 20 to 50 times higher at oil and gas platforms than in nearby open water. Each standing platform seasonally serves as critical habitat for 10,000 to 20,000 fishes, many of which are of recreational and commercial importance (Stanley and Wilson, 1997). Reggio (1987) estimated that 70 percent of all saltwater fishing trips offshore Louisiana were destined for one or more oil and gas platforms. Avanti Corporation, Inc. (1991) estimated that 30 percent of the recreational fisheries catch, a total of approximately 15 million fish, was caught near platforms offshore Louisiana and Texas.

Policy

At the end of 1999, 5,862 platforms had been installed and 1,879 platforms had been retired from the GOM. The total number of platforms installed and removed per year is presented in Figure 1. At the end of 1999, 3,983 oil and gas platforms existed in the GOM. Platform distribution across the GOM is presented in Figure 2. Rigs-to-reefs locations across the Gulf of Mexico are presented in Figure 3.

Abandonment and removal of offshore oil and gas platforms are regulated and required by the MMS in Federal waters and by the USACOE in state waters.

The MMS requirements for platform abandonment are the following:

1. remove all platforms from the lease within one year after lease termination;
2. sever all well conductors and pilings at -15 feet below the mudline; and
3. verify the location is clear of any bottom obstructions after platform removal.

Recognizing the benefits oil and gas platforms contribute to the enhancement of marine fisheries habitat, the MMS announced in 1983, and again in 1993, its support for the conversion of selected obsolete oil and gas platforms for permanent use as artificial reefs (i.e., RTR) on the OCS.

In 1998 the MMS policy on RTR was revised to reflect the progress made through the artificial reef permitting requirements of the USACOE and artificial reef criteria of the NARP. The MMS policy is as follows.

> The MMS supports and encourages the reuse of obsolete offshore petroleum structures as artificial reefs in U.S. waters. The structure must not pose an unreasonable impediment to future mineral development. The reuse RTR plan must comply with the artificial reef permitting requirements of the U.S. Army Corps of Engineers and the criteria in the National Artificial Reef Plan. The state agency responsible for managing marine fisheries resources must accept liability for the structure before MMS will release the Federal lessee from obligations in the lease instrument.

Progress

Three methods of platform removal and reefing have been used in the RTR process (Figures 4, 5, and 6).

1. Tow-and-Place Platform
2. Topple-in-Place Platform
3. Partial Removal in Place Platform

The first use of an oil and gas structure for a reef occurred in 1979 with the relocation of an Exxon experimental subsea production system from offshore Louisiana to a permitted artificial reef site offshore Apalachicola, Florida. In 1982 the first platform jacket was donated. Owned by Tenneco, it was towed from offshore Louisiana to a location offshore Pensacola, Florida. The first platform toppled in place for a reef occurred in 1987 with the Oxy USA, Inc. donation of their platform "A" in South Marsh Island Block 146 to the Louisiana Artificial Reef Program.

Since the first RTR project, progress has been made in the RTR conversion process. In 1995 Union Pacific Resource Company used the first non-explosive partial platform removal method offshore south Texas at their North Padre Island A-58 platform reef site. At the end of 1999, 16 partial platform removals had been used as the method of conversion from platform to reef. This progress in the RTR process has resulted in economic savings to the industry and monetary reward to the state. Equally important are the higher reef profile and minimal trauma to and loss of platform-associated reef organisms.

The RTR donations and methods of removal and reefing by state are presented in Table 1.

Table 1. Rigs-to-Reefs Donations and Methods of Removal and Reefing by State at the End of 1999

State	Rigs-to-Reefs Donations	Tow-and-Place Platforms	Topple-in-Place Platforms	Partial Removal Platforms
Louisiana	94	59	31	04
Texas	50	24	14	12
Florida	03	03	00	00
Alabama	04	04	00	00
Mississippi	00	00	00	00
Totals	151	90	45	16

Recognizing the preservation of environmental values associated with the method of partial removal of the platform, the MMS in 1997 established a policy to allow the industry the option to partially remove the well conductors at the same depth below the water line (BWL) at which the industry had proposed to remove the platform jacket.

During the MMS review of the initial application by the industry for partial platform removal, a concern came up about the failure of the well conductor(s) associated with a partial removal. The concern was what effect does the eventual toppling of the well conductor have on the wellbore's integrity and surface plug? Consequently, the MMS conducted a structural failure analysis of a typical well conductor and found that failure would occur around -16 feet below the mud line (BML), whether or not the top of the conductor was above or -85 feet BWL. This was also in agreement with experience of well abandonments caused by Hurricane Andrew (a category 4 storm that traversed the Central GOM in 1992), which found that, when toppled, wells were vertical around -15 feet BML. Since wellbore surface plugs are required to be set per MMS regulation at -150 feet BML, loss of surface plug integrity should not occur because of the eventual toppling of a platform that has become a reef in place. Thus, the MMS adopted the policy that allows for the retention of well conductors at the same depth at which industry proposed to remove the platform jacket. This policy eliminates the need for explosives in the removal process and minimizes the impacts on the platforms' fish and reef communities.

Perspective

The use of obsolete oil and gas platforms for reefs has proved to be highly successful. Their large numbers and availability, particularly in the Central and Western GOM, their stability and durability, and their function as the world's largest artificial reef complex, are surely a success story.

As previously stated, 3,983 active oil and gas production platforms existed within the GOM's Federal OCS by the end of 1999. Also, 1,879 platforms were retired from oil and gas production, and 1,728 platforms were removed from the GOM and disposed of onshore for scrap metal. Alternatively, 151 of the retired platforms have been permanently dedicated as RTR for fisheries enhancement. The addition of oil and gas platforms in the GOM has positively affected fish populations and has been an important component of the Gulf's recreational and commercial fishing industries.

The oil and gas industry has demonstrated its interest in productive reuse of obsolete platforms by its participation in the states' RTR programs. Oil and gas companies that donate platforms to the states' artificial reef programs are asked to contribute half the disposal savings realized by not having to remove the platform to shore, to the state's artificial reef program fund.

In addition to structure, participating companies have donated nearly $20 million in disposal savings to sponsoring state RTR programs for fisheries conservation, research, and management. Presumably, these companies saved a comparable amount in structure disposal costs. Clearly, it is to the economic benefit of the company if a productive use were found for oil and gas platforms, a use that can mitigate the cost of platform removal and disposal as scrap onshore.

So, at the beginning of the 21st century, several questions need addressing by RTR stakeholders in the Gulf of Mexico:

1. Should we strive harder to retain and use oil and gas platforms for fisheries enhancement and development, considering that the majority of current removals are going to shore for scrap metal?

2. Should we be even more selective and conservative in encouraging artificial reef development with obsolete platforms?

3. Just how important are these platforms to ecological productivity and diversity, fisheries sustainability, or the development, use, and enjoyment of marine fisheries in the GOM?

4. What are the biological, legal, social, economic, technological, and regulatory limits to using oil and gas platforms for artificial reef development in the GOM?

5. What can we do to avoid problems and conflicts with other users of the marine environment?

Conclusion

Federal and state governments, the oil and gas industry, as well as commercial and recreational fishermen, have all been beneficiaries of the RTR development in the GOM. However, it will take the continued cooperation and support of these stakeholders and user groups to ensure that the RTR program will enjoy continued successes through the 21st century.

References

Avanti Corporation, Inc. 1991. Environmental assessment for the regulatory impact analysis of the offshore oil and gas extraction industry proposed effluent guidelines. Volume 1 - Modeled impacts. U.S. EPA Contract No. 68-C8-0015. 225 pp.

Reggio, V.C., Jr. 1987. Rigs-to-Reefs: The use of obsolete petroleum structures as artificial reefs. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, La. OCS Report MMS 87-0015. 17 pp.

Stanley, D.R. and C.A. Wilson. 1997. Seasonal and spatial variation in abundance and size distribution of fishes associated with a petroleum platform. International Council on the Exploration of the Sea, Journal of Marine Science 202:473-475.

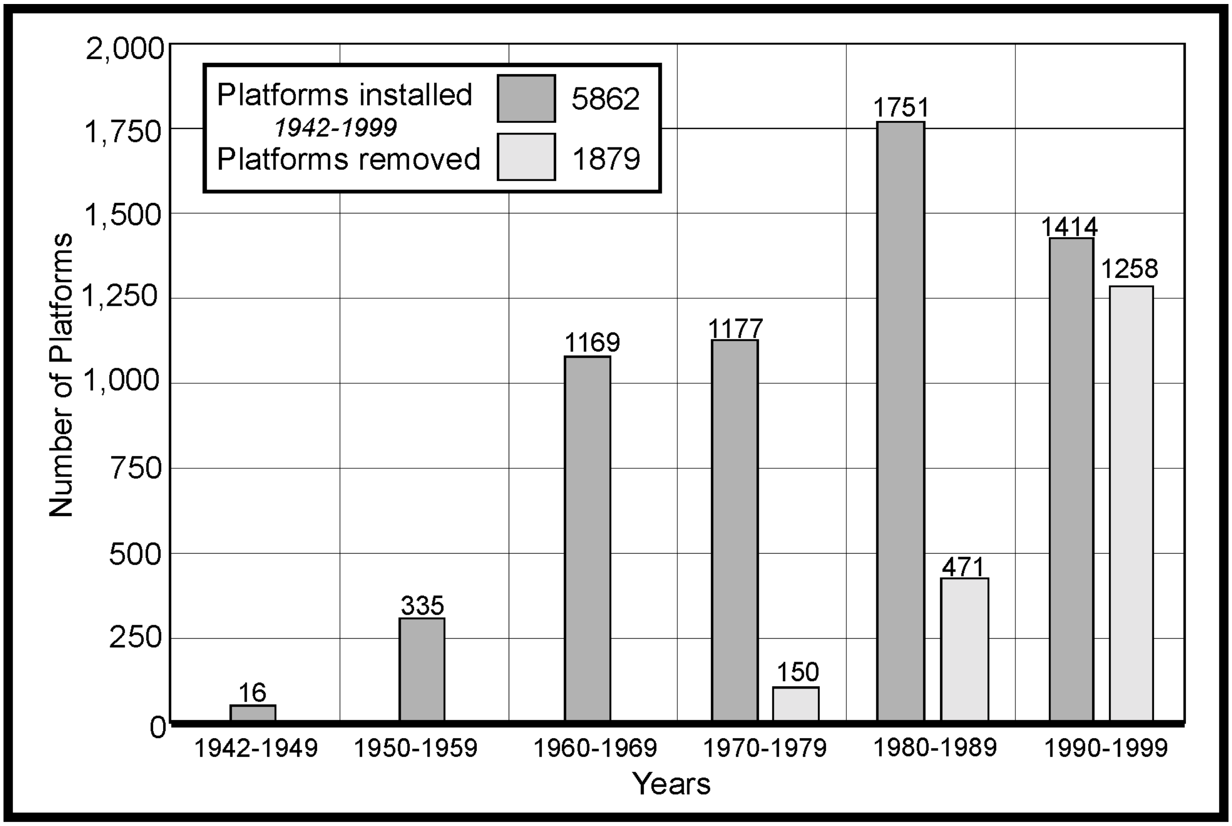

Figure 1.-Platforms installed and removed by year

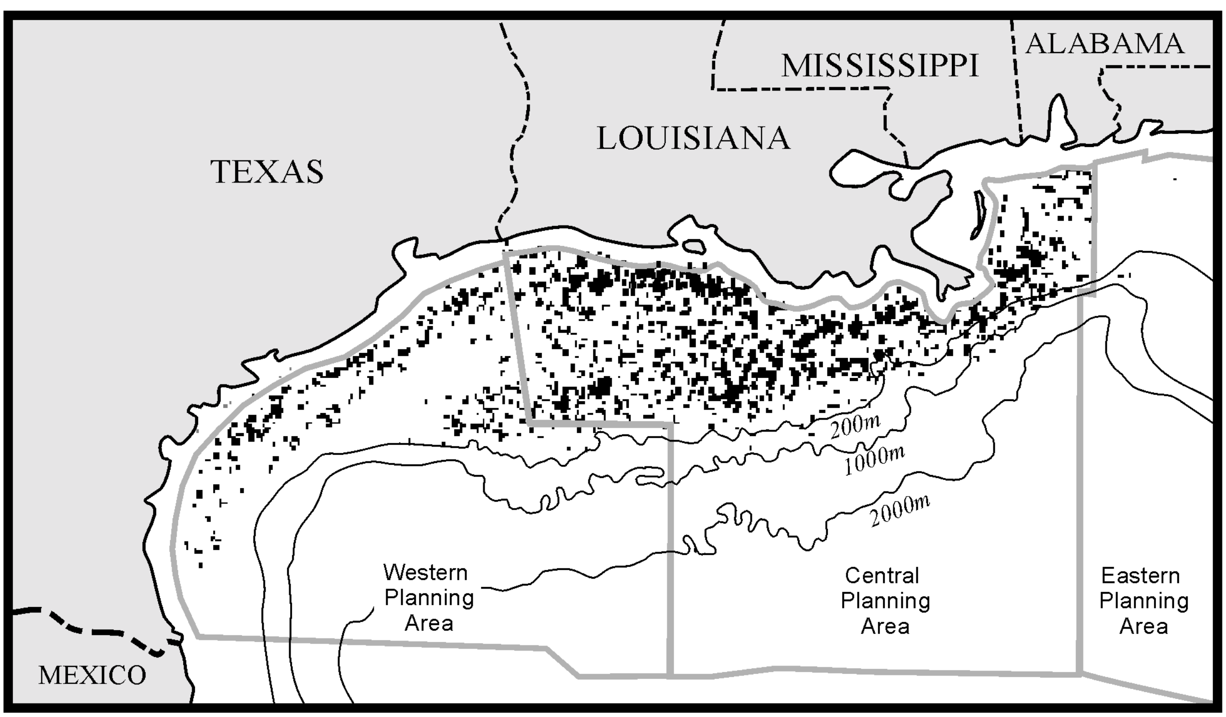

Figure 2.-Platform distribution across the Gulf of Mexico

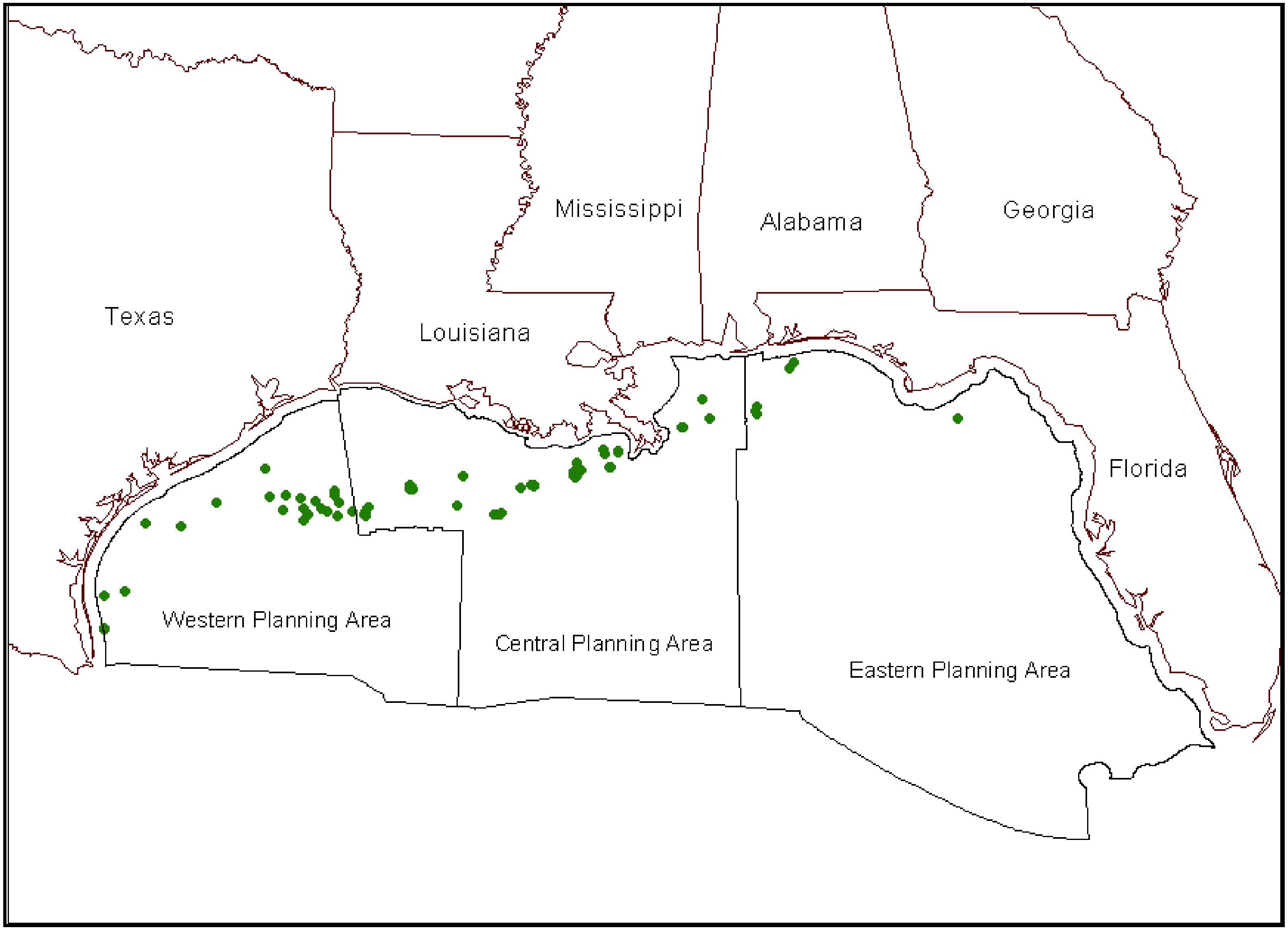

Figure 3. -Gulf of Mexico Rigs-to-Reefs Locations

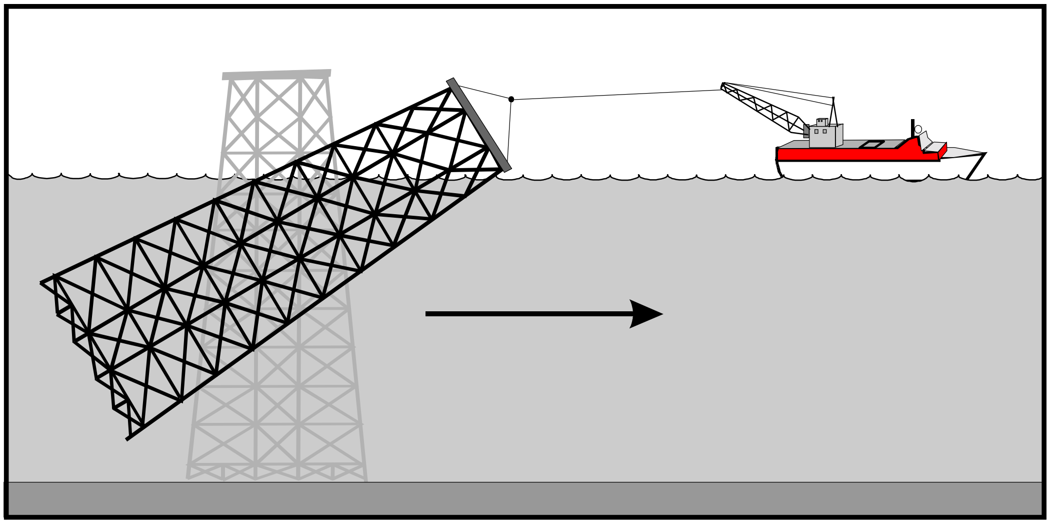

Figure 4.-The tow-and-place platform reefing method

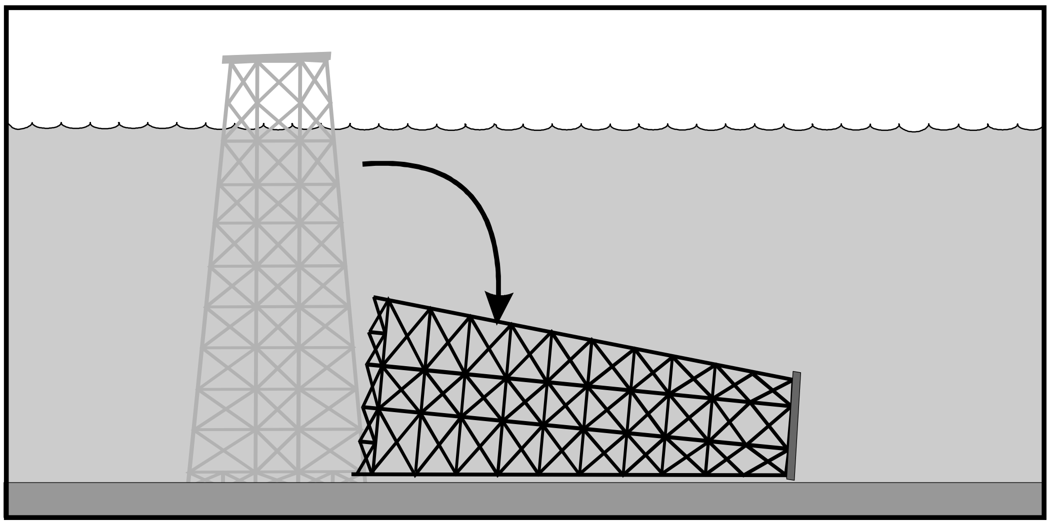

Figure 5.-The topple-in-place platform reefing method

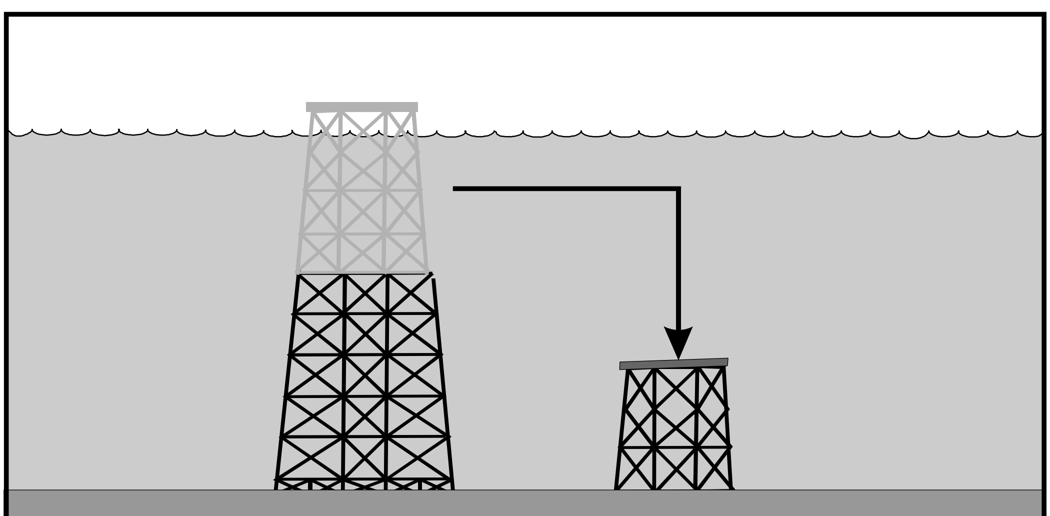

Figure 6.-The partial removal platform reefing method

General Report of R2R Natural Sciences Committee

September 10, 2003

The Committee

Our committee included representatives from artificial reef research, fisheries research, resource management, and other programs with mandates related to artificial reefs, essential fish habitat, or offshore oil and gas production. This government committee received basic support from several private-sector representatives.

The following people participated in at least one of the three committee meetings (in alphabetical order):

> Tom Bigford (NOAA Fisheries/Habitat Conservation, Silver Spring, MD), Greg Boland (MMS/Gulf of Mexico OCS Region, New Orleans, LA), Suzanne Bolton (NOAA Fisheries/Science and Technology, Silver Spring, MD), Kay Briggs (MMS, Herndon, VA), Ann Bull (MMS/Pacific OCS Region, Camarillo, CA), Linda Chaves (NOAA Fisheries/Constituent Services, Silver Spring, MD), Rebecca Cooper (formerly with NOAA Fisheries/Habitat Conservation, Silver Spring, MD), Barry Crowell (DOI Office of the Solicitor, Washington, DC; Chair of Legal Committee), Gregg Gitschlag (NOAA Fisheries/Southeast Fisheries Science Center, Galveston, TX), Churchill Grimes (NOAA Fisheries/Southwest Fisheries Science Center, Santa Cruz, CA), Melanie Harris (NOAA Fisheries/Habitat Conservation, Silver Spring, MD), Don Kent (Hubbs-SeaWorld Research Institute, San Diego, CA), Herb Leady (MMS/Gulf of Mexico OCS Region, New Orleans, LA), Andy LoSchiavo (NOAA Fisheries/Habitat Conservation, Silver Spring, MD), Milton Love (University of California at Santa Barbara/Marine Science Institute, Santa Barbara, CA), Conrad Mahnken (NOAA Fisheries/Northwest Fisheries Science Center, Manchester, WA), Larry Maloney (MMS, Washington, DC), Donna Schroeder (University of California at Santa Barbara/Marine Science Institute, Santa Barbara, CA), George Steinbach (California Artificial Reef Enhancement Program, Sacramento, CA), Jim Sullivan (formerly California Sea Grant College Program), Russ Vetter (NOAA Fisheries/Southwest Fisheries Science Center, La Jolla, CA), John Ward (NOAA Fisheries/Science and Technology, Silver Spring, MD; Chair of Social Science Committee), Mary Yoklavich (NOAA Fisheries/Southwest Fisheries Science Center, Santa Cruz, CA).

Our Charge

At our initial meeting on April 2, 2003, the Natural Science Committee working on the rigs-to-reefs issue agreed that our charge is to:

> 1. Review the best available scientific information (with an emphasis on ecological issues) associated with offshore oil and gas platforms related to various decommissioning alternatives that could convert platforms into artificial reefs.

2. Provide our perspectives and summarize our discussions on the pros and cons of various decommissioning options ranging from leaving platforms in place to total removal from the water.

3. Determine if the habitats provided by natural reefs are limited with respect to the organisms that inhabit them, and if artificial reefs can make a significant contribution to meeting any habitat deficits.

4. Estimate the resources needed to establish a monitoring program and to answer key research questions. MMS is holding a Decommissioning Workshop on October 26-28, 2003, which will help identify key research questions.

5. Identify any ecological "deal breakers" that could block further consideration of this idea in either the Gulf of Mexico or Pacific. Summarize our discussions about whether these platforms as artificial reefs are good for the marine environment, benign, or bad.

Key Accomplishments

Meetings – The Natural Science Committee was established in mid-March 2003 based on a direct request from NOAA leadership. Committee membership was expanded to include representatives from the DOI/Minerals Management Service and the private sector who have worked on issues related to artificial reefs, essential fish habitat, or offshore platforms. The committee met three times (April 2, May 19, and June 20). The discussions during those meetings formed the basis for this summary. Discussions were intended to provide insights to decision makers, but expressly not to suggest specific actions or to support decisions. The vast majority of input was generated from federal representatives.

Best available information – In direct response to Charges #1 and #2 above, committee members debated whether there was sufficient natural science information available to provide the types of scientific review requested by NOAA leadership and needed by all involved in rigs-to-reefs discussions. After much deliberation, all committee members individually decided that the existing body of natural science information could support our efforts to address Charges #3 through # 5.

With support from NOAA Fisheries' Office of Constituent Services, the committee established an intranet site and posted key reports and sources for individual use:

www.noaar2r.intranets.com

Postings at that website, coupled with other references, support the following conclusions.

Our Approach

1. Comfort level with natural science information – Committee members agreed that while we will never achieve perfect knowledge on science issues associated with the various options of decommissioning the platforms (see Conclusions section), we do have sufficient information to proceed. Caveats were provided wherever appropriate to clarify information. There are potential benefits from the retention of the habitat and the fishes living on and around the platforms. These benefits include the retention of sites for fish recruitment and larval production, and the retention of the existing marine biomass of both fishes and invertebrates. There is not enough information to determine if these benefits are regional in nature or are realized locally. It is also recognized that there are many social, economic, legal, and regulatory issues associated with any policy recommendation. These areas were considered by this Committee to be outside our basic charge. Other committees will offer their input, and agency leadership will make any final decisions.

2. Overall framework – Site-specific data from the platforms and their surrounding environments should be taken into account when making decisions about the fate of individual platforms. A case-by-case evaluation would confirm the specific benefits attributed to each structure and help to weigh other factors that could impact the decision to retain it. This would likely be done under NEPA. The evaluations should also form a basis for determining the optimal configuration for any retained platform. This would include location where the platform is to be retained, the depth at which a platform jacket is to be severed below the waterline, the appropriate remediation for any contamination found, and any alternate uses that may be appropriate.

Our Committee developed a set of general statements and some specific thoughts, where appropriate, for the Gulf of Mexico and Pacific coasts. This approach was chosen for the following reasons:

- Habitat availability differs – Benthic habitats in the Gulf of Mexico are mostly soft bottom (i.e. unconsolidated sediments such as sand and mud), while the Pacific coast has extensive hard substratum habitat (including complex structures of rock outcrop and cobble and boulder fields). Thus, it is likely that biological communities associated with complex structures in the Gulf are limited compared to the Pacific coast. Both systems can be limited by the supply of new recruits. Differences in habitat availability could lead to different goals and purposes for converting a platform for some alternate use.
- General interest differs – Committee members have greater professional expertise and involvement in issues related to habitats and associated organisms off the Pacific coast than with those in the Gulf of Mexico. Hence, we were more prepared to discuss issues related to decommissioning platforms off the Pacific coast.
- R2R program maturities differ – Texas and Louisiana have well-established rigs-to-reefs programs while the Pacific states do not currently have rigs-to-reefs programs, although several attempts have been made in the last seven years to establish a program in California. Decommissioning of California platforms will begin in five years. Combined with the lack of a California state rigs-to-reefs program, this placed greater emphasis on focusing our discussions on the Pacific.

- Structural differences – There are approximately 4000 platforms in the Gulf of Mexico and only 26 off California. Although the Gulf of Mexico has deep-water platforms, the vast majority are small structures in relatively shallow water (less than 200 m). Most of the Pacific platforms are large, North Sea-type structures, up to 10x the height of the majority of Gulf facilities, and located in deep water (maximum depth of 363 m).

3. Presenting our conclusions– We agreed to summarize our discussions as a series of statements related to the primary choices for decommissioning platforms, i.e., leaving the platform in place as an artificial reef, moving it to a designated reef location, or removing it from the ocean.

4. Issues addressed – Our discussions focused on possible dispositions for the platform. Committee members decided not to discuss secondary and tertiary uses (aquaculture, wind power, prisons, Navy Seal training facilities, and others) of decommissioned platforms because those are societal issues outside our natural science charge. We understand that those are issues that should be addressed by both the Legal and Social Sciences Committees.

Primary Conclusions/Synthesis of Current Knowledge

The Committee's discussions focused on the six topics listed below. The following statements apply to decommissioned platforms in the Gulf of Mexico and off California unless otherwise stated.

1. Reasons to leave a decommissioned platform in place as an artificial reef, i.e., reasons not to remove:

- Existing platforms represent established high vertical relief habitats supporting a diverse assemblage of fishes. Removing platforms would cause the removal of these habitats with the attendant loss of the diverse biological communities associated with them. The hard substratum habitats would revert to pre-platform sandy bottom habitats and the associated community.
- Because total removal in deep Pacific waters will most likely include the use of explosives, a high percentage of resident finfish, particularly those with swim bladders, would be killed. Those not killed will be displaced and will need to find alternate habitat in order to survive. The potential to harm marine mammals and sea turtles, particularly with the use of explosives exists in both the Gulf of Mexico and off the Pacific coast.
- Resident finfish on platforms may contribute recruits to local populations that have been dramatically reduced in recent years. These declines are due both to overfishing of adults and subadults and to changing ocean conditions that have been adverse to survivorship of young stages of these fishes. While recruits associated with platforms may contribute to local populations, the overall effect at the population level would probably be small, given the large availability of natural habitat off California and relatively small size of platforms. It is possible that platforms could have more of an effect on populations of certain key species (i.e. over-exploited, threatened, or endangered) than those of abundant species.

- If platforms are removed, both the mussel beds associated with the platforms and their fisheries will be lost. We understand that the shoreside implications of that loss will be addressed by the Social Sciences Committee.
- If contaminants are present and associated with soft sediments, platform removal would create disturbance that may worsen the contamination problems.

2. Reasons to move a decommissioned platform to another marine location to create or expand an artificial reef:

- Platforms in deep waters that are very large could be cut into pieces and used to create more than one reef in various seafloor habitats and depths.
- If there are contaminant issues, they may be dealt with more completely during removal when the site is more available and accessible.
- If the current platform site is not suitable as a reef due to other uses, another reef location could provide more habitat benefits for individual reefs or several reefs that could be coalesced into a larger area with increased diversity and abundance.

3. Reasons to remove a decommissioned platform from the water:

- Platform removal could reduce the numbers of fish potentially exposed to any contaminants (e.g., barium, zinc, PCB, and VOC have been detected in elevated concentrations at the 4H Shell Mounds). This would apply only if the contaminants were a hazard to marine life (i.e., leaching and bio-available) and if the contaminants could not be adequately remediated.
- Platform removal would restore soft demersal habitats (and potentially EFH).
- Platform removal would reopen potential trawl fishing grounds. Several members felt that this issue should be addressed in greater detail by the Social Sciences Committee, as trawling is an activity that has socio-economic value. Note that almost no trawling is allowed within state waters off California, and trawling is currently greatly restricted on much of the continental shelf off the west coast inside the new Rockfish Conservation Areas.

4. Other points worth noting:

- While not a natural science issue, Committee members noted that, in California, there is no existing State Rigs-to-Reefs Program, and complete removal is the only current decommissioning alternative contemplated by MMS Decommissioning Regulations.
- There are no designated areas along the Pacific coast to move platform pieces to create a reef; there are several designated reef sites in the Gulf of Mexico. The California Department of Fish and Game's permit for existing reef sites excludes oil platform legs, but does not prohibit the use of some portions of offshore oil platforms. The permit does state that the use of oil platform parts is not requested though, and would require future modification of the permit. The California reef sites of Bolsa Chica (offshore Long Beach) and Big Sycamore Canyon Ecological Reserve (Ventura County) are south of Point Conception and could accept some portion of platform material, which would probably need to be augmented with quarry rock to meet the California artificial reef requirements.

- There are designated reefing areas in the Gulf of Mexico. Louisiana has issued a policy (and Texas is considering one) that it will allow *in-situ* reefing on a case-by-case basis of platforms which are in 400 feet of water or greater and at least 2 miles from a shipping lane. Currently there are about 72 platforms offshore Louisiana in these depths. Fifty-four of the 72 platforms are within 2 miles of shipping lanes. Louisiana is currently working on the shipping lane issue with the U.S. Coast Guard (i.e. establishing a depth to top platforms within 2 miles of shipping lanes). Such platforms would be left in place in federal waters yet included in the state program. Some platforms offshore California are within 2-3 miles of shipping lanes.
- If platforms are left intact, this would allow for secondary uses, such as aquaculture, which could be beneficial. Responsible agencies would need to review all potential future uses to ensure that they would not compromise the reproductive success of species that prompted the primary decision to leave the platform intact.
- A fundamental policy issue is whether reefs created from platforms should be open or closed to fishing. Individual members felt that this issue should be decided on a case-by-case basis, keeping in mind that if fishing is allowed, it should not interfere with the primary benefits identified with the reef. Reefs created from platforms could be open to fishing for some gear or species and banned for others, although this would be difficult from an ecological and also enforcement standpoint. For example, Lingcod are the only non-airbladder fish common at the California platforms, and thus can be hauled to the surface and released alive. Rockfish, *Sebastes* spp., are predominant at the platforms, and not many would survive being brought to the surface and released, even if their swimbladders are deflated at the surface. California SB.1 would have closed reefs created from platforms to fishing, but the bill was vetoed by the Governor.
- Fishing is currently discouraged in 500m safety zones around most California platforms. After decommissioning, fishing may be allowed. That means that potential contributions by resident fish to nearby populations could be short-lived unless the areas are designated as no-fishing refugia. By default, refugia could become sanctuaries with improved reproductive success. However, if fishing is allowed on those platforms, this could help balance public opinion about the creation of new marine protected areas that may not allow fishing.
- Several individual members felt it would be helpful to our leaders if we gave thought to a list of prioritized additional research needed in the decommissioning process (see section below).
- Platforms will corrode after decommissioning, but even without cathodic protection might last about 300 years, shorter if infrastructure is compromised and salt water infiltrates steel supports.

5. Preliminary criteria for grouping platforms as artificial reefs off California (for management or research):

- Depth
- Geographic location (west of Santa Barbara Channel, east of Santa Barbara Channel, Pt. Conception, off Long Beach) as related by currents.
- Species composition on platforms.

6. Key research question: What benefits to the marine environment are provided by the offshore oil and gas platforms in the Pacific outer continental shelf?

Areas of investigation prior to each decommissioning decision:

1. What fishes live around platforms and near-by natural reefs? What is the availability of natural reef habitat in surrounding area?
2. How do platforms compare to natural reefs with regard to:
    a) Fish growth rates?
    b) Mortality rates?
    c) Reproductive output?
    d) Recruitment?
3. What is the relative contribution of platforms in supplying hard substrate and fishes to the region?
4. How long do fishes reside at platforms?
5. What are the effects of platform retention or removal on fish populations within a region?
6. How does structural modification of the platform and surrounding sea floor change associated assemblages of marine life (invertebrates and fishes)?

Areas of investigation after platform decommissioning:

1. How do platforms perform as artificial reefs compared to estimates?
2. How can platform performance be enhanced?

Other research questions:

1. Would reefs that are created from platforms and then closed to fishing have a significant positive effect on managed species at the population level (given large availability of natural habitat off California and relatively small size of platforms)? What about on a local scale?
2. What is the carrying capacity of a platform (juveniles and adults)?
3. What is the connectivity among local populations (i.e. among platforms, and among platforms and natural reefs)?
4. How does the value and function of a reef that is produced from a platform differ from a natural reef based on its position and size in the water column (i.e. do platforms serve same ecological functions after they are toppled or topped versus left intact)?
5. How are platforms used by protected species? How large is the area of potential impact of platform removal for protected sea turtle and marine mammal species?
6. Monitoring/research:
    - Monitor effects of decommissioning method so that future decisions could be adapted to respond to the ecological consequences.
    - Conduct intra- and interannual surveys to assess the seasonal abundance/species composition of protected species in the vicinity of platforms approaching decommissioning.

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Exhibit G.3.a
Attachment 4
March 2004

AN ECONOMIC ANALYSIS OF A RIGS TO REEFS PROGRAM FOR THE CALIFORNIA OUTER CONTINENTAL SHELF

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October 1, 2003

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EXECUTIVE SUMMARY

This paper compares the economic costs and benefits of converting obsolete oil and gas platforms into artificial reefs with the alternative of full rig removal. Advocates claim that "rigs-to-reefs" programs provide important habitats for fish, crustaceans, and marine mammals as well as direct economic benefits. Opponents argue, among other things, that artificial reefs can hinder commercial fishing and may pose liability risks.

Using data from California, we construct an economic framework that assesses benefits and costs of a rigs-to-reefs program. Our principal finding is that a well-designed rigs-to-reefs program for California would likely result in direct and indirect benefits far in excess of costs. Based on our analysis, we recommend that a state and/or federal program be established that would enable the citizens of California and elsewhere to reap these benefits.

AN ECONOMIC ANALYSIS OF A RIGS TO REEFS PROGRAM FOR THE CALIFORNIA OUTER CONTINENTAL SHELF

Robert W. Hahn and Anne Layne-Farrar

I. INTRODUCTION

With over twenty oil and gas platforms off its shores due for removal within the next few years, California stands at an important policy crossroads. Federal law requires oil and gas companies to remove their offshore platforms within one year of terminating an outer-continental shelf land lease.[1] The Minerals Management Service (MMS), the federal agency overseeing removal or "decommissioning," can waive the full removal requirement in order to accommodate converting a platform to an artificial reef.[2] In brief, conversion involves modifying a rig so that it can continue to support marine life while not posing any undue threat to other ocean users; ownership and maintenance of the structure is passed from the oil and gas company to a governmental agency. Policy makers must decide whether an artificial reef program serves ecological and economic goals better than the status quo of complete rig removal.

In 2001, State Senator Dede Alpert (D-San Diego) sponsored a bill that would have established a rigs-to-reefs program in California.[3] The bill passed the state legislature, but was vetoed by Governor Gray Davis. The main concern Governor Davis raised in his veto was the lack, at the time, of "conclusive evidence that converted platforms enhance marine species or

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[1] *See generally*, 30 C.F.R. Part 250, subpart Q, §250.1700 *et seq.* Removal guidelines specify that platforms must be cut down to fifteen feet below the ocean mud line.

[2] Waiving is subject to certain restrictions, such as approval by the Army Corp of Engineers and acceptance of liability by a responsible state agency. MMS policy states "The MMS supports and encourages the reuse of obsolete offshore petroleum structures as artificial reefs in U.S. waters." (As quoted by Milton S. Love, Donna M. Schroeder & Mary M. Nishimoto, "The Ecological Role of Oil and Gas Production Platforms and Natural Outcrops of Fishes in Southern and Central California: A Synthesis of Information," U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, Seattle Washington (2003), at 4.5.) Any artificial reef must conform to the National Artificial Reef Plan (NARP).

[3] For information on the bill and its legislative history, see the California State Senate website (visited Aug. 4, 2003) <http://info.sen.ca.gov/cgi-bin/postquery?bill_number=sb_1&sess=PREV&house=S&site=sen>.

produce net benefits to the environment."[4] If California does not reverse this decision on establishing a state program, the Federal Government may consider such a program for platforms within its jurisdiction in the California Outer Continental Shelf. As a matter of necessity, any program would need to designate an entity to assume ownership and maintenance of the structures once they are reefed. A designated state or federal agency or a responsible third party could fill this role.

This paper compares the economic costs and benefits of converting obsolete oil and gas platforms into artificial reefs with the alternative of full rig removal.[5] Advocates claim that rigs-to-reefs programs provide important habitats for fish, crustaceans, and marine mammals as well as direct economic benefits. Opponents argue, among other things, that artificial reefs can hinder commercial fishing and may pose liability risks.

We use an economic framework to compare these two opposing points of view. In Section II, we describe the key operational details of an artificial reef program, including how the oil companies' monetary savings might be divided. We assume that either a state or federal program is enacted to cover the 23 platforms due for decommissioning in federal waters offshore California. In Section III, we identify the potential costs and benefits of establishing a rigs-to-reefs program in California, providing quantification where possible. Section IV concludes the paper with our recommendation that a rigs-to-reefs program would be economically beneficial for California.

II. HOW A RIGS-TO-REEFS PROGRAM WOULD WORK

Rigs-to-reefs programs are already well established in the Gulf of Mexico, where the first large-scale offshore oil and gas drilling took place.[6] Both Texas and Louisiana passed laws

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[4] *See* the "Veto Message" link at the California State Senate Website (visited Aug. 4, 2003) <http://info.sen.ca.gov/cgi-bin/postquery?bill_number=sb_1&sess=PREV&house=S&site=sen>.

[5] For a description of cost-benefit analysis, see Edith Stokey & Richard Zeckhauser, *A Primer for Policy Analysis* (1978).

[6] As of 2001, there were more than 150 permitted artificial reefs off Alabama, Florida, Mississippi, and Texas. *See* Michael McGinnis, Linda Fernandez & Caroline Pomeroy, "The Politics, Economics, and Ecology of Decommissioning Offshore Oil and Gas Structures," Final Technical Summary and Study Report, U.S.

(continued...)

in the late 1980s that established state trusts to oversee oil and gas offshore platform decommissioning and conversion to artificial reefs.[7] To date, over 188 platforms have been converted to artificial reefs in the Gulf.[8] This figure represents around 8 percent of all decommissioned platforms. The primary reason for the low take-up rate rests on the economics of the obsolete Gulf platforms: most were in shallow water where the cost of complete removal (with subsequent salvage and scrap sales) was less than the cost of artificial reef conversion.[9]

Converting a rig to an artificial reef can take one of several forms. Most simply, the platform can be left entirely in place. In this scenario, the wells are abandoned and the upper portion of the structure is cleaned and stripped and navigational aids, such as lights and signals, are installed for the benefit of any ocean traffic.[10] Thus far, none of the Gulf rig conversions have chosen this option, due to the high maintenance costs.[11]

Another conversion alternative is "toppling." Here, the wells are abandoned, the upper portions of the rig are removed, the platform connections are severed at the base, and the resulting structure is pulled to a horizontal position on the ocean floor. Depending on the depth of the water, toppling may require navigational aids, as well. Related to toppling, another decommissioning option involves towing the rig to another site for reefing. This option has been exercised on a majority of the rig conversions in the Gulf, most notably when two

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Department of the Interior, Minerals Management Service, Pacific OCS Region, OCS Study MMS 2001-006, (Mar. 2001), at 11.

[7] For example, the Louisiana Fishing Enhancement Act of 1986 (LA. Rev. Stat. § 56:639.1 *et seq.*; Act 100) creates a process by which ownership and liability pass from the oil and gas companies to the state for obsolete platforms that meet the Act's criteria. The Texas Artificial Reef Act of 1989 (Tex. Parks & Wildlife Code § 89.001 *et seq.*) is similar.

[8] Love et al., *supra* note 2, at 4.9.

[9] *Id.*

[10] For a description of each decommissioning option described here, see *Id*, at 4.1-4.4.

[11] *Id*, at 4.4.

platforms were removed from offshore Louisiana and hauled to waters off Dade County Florida, some 920 miles away from the original site.[12]

Finally, a platform can be partially removed and the remaining structure converted into an artificial reef in place. In this scenario, the wells are abandoned and the upper portion of the platform is removed. The amount of removal varies, but the remaining platform could be over 100 feet below the ocean surface, just beneath the surface, or anywhere in-between. The ultimate depth of the artificial reef is determined by a Coast Guard assessment and by the willingness of the liability holder to pay for any required navigational aids. Around 10 percent of the decommissioned rigs taking advantage of artificial reef programs in the Gulf of Mexico have been partial removals.[13]

The artificial reef programs established by Louisiana and Texas do not receive state or federal funding.[14] Instead, they are funded by lump-sum oil and gas company contributions and the interest paid on those donations. In particular, companies decommissioning platforms donate one half of the cost savings from reefing the rigs as opposed to completely removing them. In turn, the state assumes liability for the artificial reef and the fund handles any maintenance. Currently, the Louisiana artificial reef fund has a balance of $18 million and earns approximately $1 million in interest annually; the Texas fund has at least $4 million.[15]

We assume that an artificial reef conversion program in California would be largely based on programs already operating in the Gulf of Mexico states. In particular, we assume that oil and gas companies would apply for rigs-to-reefs status when a platform was due for decommissioning. The rigs then would be evaluated on a case-by-case basis, with the company supplying cost savings estimates (likely to be independently verified) and the appropriate state

[12] C.A. Wilson, V.R. Van Sickle & D.L. Pope, "Louisiana Artificial Reef Plan," Louisiana Department of Wildlife and Fisheries Technical Bulletin No. 41, Louisiana Sea Grant College Program (1987).

[13] Les Dauterive, "Rigs-to-Reefs Policy, Progress, and Perspective," Minerals Management Service, OCS Report MMS 2000-073 (2000).

[14] Love et al., *supra* note 2, at 4.9.

[15] The Louisiana balance was obtained from authors' interview with Rick Kasprzak, Artificial Reef Coordinator for Louisiana's Department of Wildlife and Fisheries, Aug. 11, 2003. The Texas balance is cited in Love et al., *supra* note 2, at 4.9.

or federal agencies determining whether an individual platform was eligible for the program. Once eligibility is determined, the offshore platform would be partially removed to a depth determined by the appropriate agencies. The reef conversion project would be subject to review under the National Environmental Policy Act.

For each rig accepted in the rigs-to-reefs program, we assume that the oil and gas company would remove the upper portions of the rig to some depth below the ocean surface. The company would donate fifty percent of the cost savings resulting from partial rig removal (as compared to full rig removal) to a trust fund.[16] The money would be invested by the fund and the interest used as needed for reef maintenance and liability costs.[17] Interest remaining after covering necessary expenses could be available for marine research and conservation projects.

III. THE ECONOMICS OF PARTIAL RIG REMOVAL

In this section we present the potential costs and benefits of converting an offshore platform into an artificial reef. We start with the costs, reviewing the relevant literature for a rigs-to-reefs program in California and quantifying costs where data are available. We then turn to the benefits, again reviewing the available documents relevant for measuring the gains an artificial reef program could bring.

A. Potential Costs

California has been deliberating on a rigs-to-reefs program for well over five years, and a number of concerns have been raised in that time. For example, certain commercial fishermen's groups oppose the program,[18] due primarily to concerns over equipment damage. In testimony before the California State Lands Commission in December of 1999, a representative of one of California's trawlers associations noted that trawlers do not want reefs

[16] Alpert's bill proposed that the California Department of Fish and Game be responsible for managing the rigs-to-reefs program, although some critics of the bill suggested others, such as adjacent county governments.

[17] In Louisiana, company donations are made to the general fund, but artificial reef dollars are tracked separately.

[18] Other commercial fishermen appear to support the program, as we discuss below.

of any kind, and instead prefer a "clean ocean bottom" to reduce the risk of snagged nets and damaged gear.[19] It is our understanding, however, that in the Gulf of Mexico only one incident of trawler equipment damage has been reported in over 15 years of artificial reef operation.[20] While damage of this nature may go unreported, it is likely that any significant problems would be reported. Moreover, with the proper navigational aids installed around the reef, trawlers would be able to avoid gear damage by maintaining an appropriate distance. Shrimp trawlers in the Gulf evidently drag their nets within a quarter mile of reefed platforms and report that these areas tend to be more productive than others.[21] As a result, we view trawler gear damage as a problem that is unlikely to generate economically significant losses.[22]

Other concerns revolved around the expense of creating and maintaining an artificial reef. The bill proposed by Senator Alpert in 2001 provides an estimate for the cost of creating a rigs-to-reefs program. For instance, the agency responsible for coordinating the program would need to establish operational guidelines for evaluating and accepting rigs into the program and for maintaining them once converted to reefs. Alpert's bill estimated the one-time cost of creating guidelines at $250,000.[23] As for ongoing maintenance and operations for the program as a whole, Louisiana spends approximately $250,000 each year to monitor and maintain the 111 converted platforms remaining off its coast.[24]

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[19] *See* the testimony of Mike McCorkle, Senior Representative of the Southern California Trawlers Association, before the California State Lands Commission, Dec. 3, 1999 (visited Aug. 4, 2003) <http://www.slc.ca.gov/Division_Pages/MRM/RigsToReefs.htm>.

[20] The shrimper filing the claim failed to heed the warning placed on buoy markers around the artificial reef, and as a result, his claim was thrown out. Authors' interview with Rick Kasprzak, Artificial Reef Coordinator for Louisiana's Department of Wildlife and Fisheries, on Aug. 12, 2003.

[21] Wilson et al., *supra* note 12. *See also*, Love et al., *supra* note 2, at 4.6.

[22] Removing the platforms completely would increase the fishable area for trawlers by clearing current obstructions from the ocean. However, the scientific evidence discussed in the next section suggests that trawlers would incur costs from platform removal in that fish stocks would be depleted, both from the immediate damage caused by explosives used to sever the platform base, as well as long-term effects from loss of habitat and spawning grounds. As neither of these effects is easy to quantify, the net impact on trawlers is unclear.

[23] *See* the bill text (visited Aug. 4, 2003) <http://info.sen.ca.gov/pub/01-02/bill/sen/sb_0001-0050/sb_1_bill_20010914_enrolled.pdf>.

[24] Louisiana has 34 artificial reef sites, with a total of 111 converted oilrigs. As noted earlier, many of the reefed Louisiana rigs were hauled to other sites. The rigs are a minimum of 85 feet from the ocean surface. Costs

(continued...)

Some opponents have expressed concern over liability issues as well.[25] Any structure in the ocean extending relatively close to the surface, whether man-made or natural, poses a potential hazard for ocean vessels. Under a rigs-to-reefs program, ownership and liability would pass from the original lease owner to a state or federal agency, although the original owner would provide indemnification. Critics worried that up-front indemnification may prove to be inadequate.[26] Note that as part of artificial reef maintenance, a rigs-to-reefs program (following the Gulf model) would include the installation and upkeep of navigational devices. While this would reduce accidents, some liability issues may remain.[27] Insurance broker and risk management advisor Marsh & McLennan estimates that annual insurance premiums, per rig, would run around $25,000, although they anticipate that the premiums would decline as more rigs are added to the program.[28]

A few opponents have voiced concerns that the structures would corrode, and thus, cause pollution or prove unstable. Generally, offshore platforms are made of steel, which over time corrodes into iron oxide (rust). However, if the steel is covered with crustaceans, it is

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relayed in authors' interview with Rick Kasprzak, Artificial Reef Coordinator for Louisiana's Department of Wildlife and Fisheries, Aug. 11, 2003.

[25] A report by MMS prepared in 2001 expressed concern over liability issues. *See* McGinnis et al., *supra* note 6, at 57. The assumptions made by MMS—that rigs would be left in place and not partially removed—differ from the assumptions we make here. As a result, liability issues differ between the two reports. More importantly, MMS did not examine the liability experience of the Gulf of Mexico, nor did it attempt to estimate liability costs for California.

[26] *See, e.g.*, the testimony of Warner Chabot, Director of the Pacific Region of the Center for Marine Conservation, before the California State Lands Commission, Dec. 3, 1999 (visited Aug. 4, 2003) <http://www.slc.ca.gov/Division Pages/MRM/RigsToReefs.htm>. *See also*, Christopher Chatto, Program Director for Citizens Planning Association of Santa Barbara, Inc, "Letter to Chairperson Kuehl and Members of the Senate Natural Resources Committee," Mar. 20, 2001.

[27] As the NARP observes "when a reef has been properly located, marked on navigational charts if necessary, and any required surface markers are affixed, there should be very little potential for liability." R.B. Stone, "National Artificial Reef Plan," NOAA Technical Memorandum NMFS-OF-6, U.S. Department of Commerce, *cited in* Love et al., *supra* note 2, at 4.5.

[28] Correspondence between Mary R. Berry of Marsh & McLennan and George Steinbach, Executive Director of the California Artificial Reef Enhancement program, July 23, 2003. Berry notes that Marsh does not have off-the-shelf policies or pricing guidelines for insurance of this type, so the estimate is a rough one.

sealed off from oxygen and will corrode more slowly.[29] Moreover, the rate of corrosion in the ocean is low and most experts believe that oil platforms would last upwards of two to three hundred years without maintenance before collapsing.[30] Corrosion does not appear to be a problem in the Gulf of Mexico, where platform reefs have lasted over 15 years thus far. For instance, the Louisiana Department of Wildlife and Fisheries notes that, "The use of obsolete oil and gas platforms in Louisiana has proved to be highly successful. Their large numbers, design, longevity and stability have provided a number of advantages."[31]

Finally, some of the early complaints made concerning a California rigs-to-reefs program centered on the uncertainty of the scientific research. Many worried that artificial reefs had unproven benefits, and thus may not warrant maintenance and liability costs. This was, in fact, one apparent reason for Governor Davis's veto of Senator Alpert's bill. Since 2001, however, additional studies have yielded new scientific evidence. In the next section, we discuss the most recent study of oil platforms as marine habitats and note that there now appears to be evidence that rigs acting as artificial reefs produce environmental benefits.

B. Potential Benefits

While difficult to quantify, the impact of converted rigs on marine life is likely to be one of the most pivotal benefits. Without at least some suggestion that decommissioned offshore platforms can act to benefit the marine environment, contributing to fish stocks and providing suitable habitat, there is likely to be far less support for establishing a rigs-to-reefs program.[32] At the time of Senator Alpert's bill, the scientific research on this question was

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[29] *See* the Aug. 23, 1998 talk by James Wiseman, a deepwater engineer with Winmar consulting (visited Aug. 25, 2003) <http://www.reefs.org/library/talklog/j_wiseman_082398.html>.

[30] *See* the discussion of reefed platform life span in Love et al., *supra* note 2, at 4.11.

[31] *See* Louisiana Department of Wildlife and Fisheries website (visited Aug. 25, 2003) <www.wlf.state.la.us>. Jon Dodrill, a representative from the Florida Wildlife Commission, echoes this confidence: "We consider the obsolete energy jacket units safe, and environmentally sound." Correspondence between Jon Dodrill and George Steinbach, Executive Director of the California Artificial Reef Enhancement program, Feb. 24, 2003.

[32] The Gulf of Mexico and California coastal habitats are sufficiently different that the clear success in increased marine life in the Gulf was not enough to establish environmental benefits in California. *See* Linda Krop, Chief Counsel, Environmental Defense Center, "Letter to Senator Alpert and the Senate Appropriations Committee," May 11, 2001.

evidently incomplete and mixed. As a result, some parties felt that a state law allowing for rig conversion was premature.[33]

In the last two years, additional research studying offshore platforms as artificial reefs has been completed. The detailed six-year study prepared by Milton Love, Donna Schroeder, and Mary Nishimoto (released June 2003) supports the hypothesis that "platforms act as de facto marine refuges."[34] In particular, oil platforms appear to be "functionally more important as nurseries" than natural rock outcrops.[35] Some juvenile rockfish, several species of which are officially "over-fished" in California,[36] were found in higher densities at several of the platforms as compared to nearby natural reefs.[37] The Texas rigs-to-reefs program supports this finding: "By providing food and shelter, artificial reefs can enhance over-fished populations of resident reef fish... rigs make ideal artificial reefs because they are environmentally safe, are constructed of highly durable and stable materials that withstands displacement or breakup, and already support a thriving reef ecosystem."[38] Thus, while research questions remain,[39] it appears that sufficient evidence now exists to move forward with a rigs-to-reefs program.[40]

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[33] *See, e.g.*, Joni Gray, Board of Supervisors for Santa Barbara County, "Letter to Chairperson Kuehl and Committee Members," Mar. 26, 2001.

[34] Love et al., *supra* note 2, at vii.

[35] *Id.*

[36] Of the approximately 60 species of rockfish, at present 16 have been fully assessed by government biologists and nine have been found to be over-fished. *See* Glen Martin, "West Coast Rockfish Stocks: U.S. Likely to Impose Bottom-Fishing Ban," *San Francisco Chronicle*, June 3, 2002.

[37] The authors suggest three reasons for the finding: first, platforms physically occupy more of the "water column" than most natural outcrops; second, because there are fewer large fish in the midwater habitat where the platforms are located, predation is likely lower; and third, the offshore location and extreme height of the platforms "provide greater delivery rates of planktonic food for young fishes." *See*, Love et al., *supra* note 2, at vii.

[38] *See* Texas Parks and Wildlife Department website (visited Aug. 25, 2003) <www.tpwd.state.tx.us>.

[39] Love and his colleagues list several, in fact. *See, e.g.*, Love et al., *supra* note 2, at ix-x.

[40] Note also that full rig removal would require the use of explosives, killing any surrounding fish and potentially damaging the auditory systems of nearby marine mammals. Complete removal would kill all the invertebrate life attached to the platform legs as well. *See* Love et al., *supra* note 2, at ix. The MMS reported that on average 850 dead fish were observed floating at the surface after each reviewed platform removal in the Gulf of Mexico during 1986-1998. Not all of the killed fish float, however, so these counts underestimate the total impact (note they also represent samples, not complete censuses). The MMS also estimated annual mortality of red snapper, the species most acutely affected by the explosives, based on their above and below surface samples. The estimates ranged from 29,046 to 82,400 dead fish per year due to explosives used in platform removal. These

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The research on offshore platforms improving fish populations, apart from its environmental importance, is also relevant to certain commercial interests in California. Commercial fishing in the state has been on the decline since 1970. In that year, California's share of the U.S. harvest, based on the dollar value of commercial landings, was 14 percent; by 1990 the state's share had dropped to 4 percent; and by 2001 it had further declined to 3 percent.[41] The declining catch in California is especially clear for certain species, including several species of rockfish. As Figure 1 illustrates, both the pounds caught and the economic value of the total rockfish catch (in 2002 dollars) has declined steadily from 1982 to 2001.[42]

In 2002, federal fishery authorities instituted an offshore rockfish closure along the continental shelf off California's coast.[43] Intended to head off the "plummeting rockfish populations," the closure will push the rockfish catch to zero in the short term, but will improve the rockfish catch in the long term after populations are reestablished and restrictions lifted.

The Love report suggests that oil platforms could contribute to an increase in rockfish populations. As the authors note, "In some locations, platforms may provide much or all of the adult fishes of some heavily-fished species and thus contribute disproportionately to those species larval production."[44] And, as noted earlier, the Love report found that "Platforms usually harbored higher densities of young-of-the-year rockfishes than natural outcrops and thus may be functionally more important as nurseries."[45] Observations on oil structures acting

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counts do not cover marine mammals or invertebrates. *See* Gregg R. Gitschlag, Michael J. Schirripa & Joseph E. Powers, "Estimation of Fisheries Impacts Due to Underwater Explosives Used to Sever and Salvage Oil and Gas Platforms in the U.S. Gulf of Mexico, Final Report," OCS Study MMS 2000-087 (2001), at 23 and 13-14, respectively.

[41] Based on the pounds of commercial landings, the state's share had declined from 19 percent in 1970 to 7 percent in 1990 to 5.5 percent in 2001. Annual Commercial Landing Statistics, National Oceanic and Atmospheric Administration (visited Aug. 25, 2003) <http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html>.

[42] *California Statistical Abstract* (various years). Similar declines are evident for tuna and crab catches, as well.

[43] NOAA Fisheries Notices, 67 Federal Register 44778 (July 5, 2002) and 68 Federal Register 23901 (May 6, 2003).

[44] Love et al., *supra* note 2, at vii.

[45] *Id.*

to replenish some species are also echoed in the support for a rigs-to-reefs program from certain commercial fisherman, such as lobster trawlers.[46] Combined with the severely over-fished and depleted state of these fish species, the platforms could be making economic contributions to the rockfish fishery that would be lost if the platforms were completely removed upon decommissioning.[47] The full impact of platform removal would be to slow the recovery versus what is estimated and therefore to lengthen the time during which fishing restrictions would be imposed.

It is worth highlighting that the offshore platform structures are already in place. Other forms of artificial reefs that could be used to enhance over-fished species population growth must be designed and installed, and thus funded. Existing platforms, however, are already in the ocean, providing marine habitats and contributing to fish stocks.

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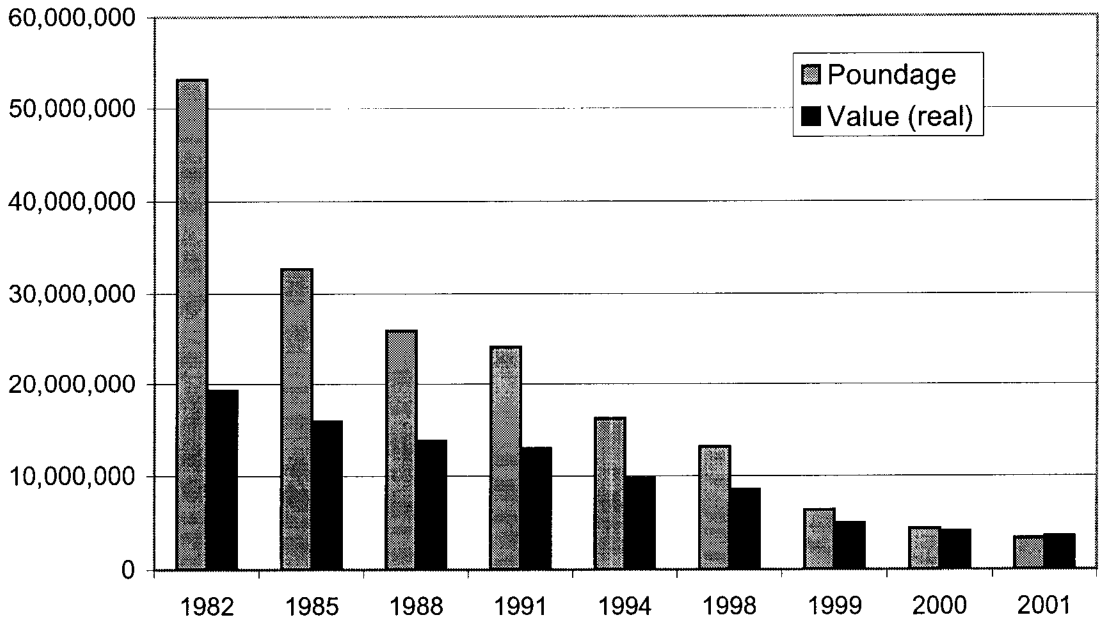
[46] Chris Miller, Vice President of the California Lobster and Trawling Fisherman's Association and the Vice President of Commercial Fisherman of Santa Barbara, observed that Rincon Oil Island provides excellent lobster fishing grounds and that pipelines and rigs provide spawning and producing habitats for abalone. *See* testimony of Chris Miller, before the California State Lands Commission, Dec. 3, 1999 (visited Aug. 4, 2003) <http://www.slc.ca.gov/Division_Pages/MRM/RigsToReefs.htm>.

[47] McGinnis et al. attempt to calculate the habitat value attributable to platforms. Their assumption of $5 per species as the value of species diversity is unsubstantiated and appears to be simply a guess. As a result, their estimate of a habitat value of $83,000 for nine platforms seems to be little more than speculation. *See* McGinnis et al., *supra* note 6, at 52.



Note: Value of landings were converted to constant 2002 U.S. dollars using the GDP implicit price deflator available from the U.S. Department of Commerce, Bureau of Economic Analysis (http://www.bea.doc.gov).

Source: *California Statistical Abstract* (various years).

Figure 1. Poundage and Value of Landings of Rockfish in California

A related economic benefit of platform reef conversions could come through certain tourism effects.[48] While the dollar value is likely to be small for California, recreational scuba divers favor rigs-to-reefs programs because they offer dense marine life and provide underwater photography opportunities.[49] Sport fishermen, another source of tourism dollars,[50] also tend to support artificial reef programs.[51]

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[48] In total, ocean and coastal tourism contributed almost $10 billion to the California's economy in 1992. *See*, "California's Ocean Resources: Tourism and Recreation (Chapter 5)," California Research Bureau (Mar. 1997), at 5G-1.

[49] In Florida, artificial reefs offshore Miami are estimated to contribute around $20 million each year to the local economy. Statistics cited by testimony of Kristin Valette, Professional Association of Diving Instructors (PADI), before the California State Lands Commission, Dec. 3, 1999 (visited Aug. 4, 2003) <http://www.slc.ca.gov/Division_Pages/MRM/RigsToReefs.htm>. Note that California's waters are not as hospitable for diving as southern Florida's so the economic impact is likely to be considerably lower. A study

(continued...)

While the tourism effects may be important to some narrowly defined communities, the largest dollar benefit would come from the cost savings contributed by oil companies to the designated responsible agency. Winmar, a consulting company that managed the decommissioning of over 250 platforms in the Gulf of Mexico, prepared estimates of the decommissioning costs for California's oil and gas platforms located in federal waters.[52] Table 1 below reports their main findings.

Table 1. Estimated One-Time Cost Savings From Partial Rig Removal*

Decommissioning Method	Low Cost	Median Cost	High Cost
Complete Removal	$875M	$1,200M	$1,600M
Rigs-to-Reef In-Place Partial Removal**	$375M	$540M	$600M
Potential Savings	$500M	$660M	$1,000M

Source: Winmar CA POCS Decommissioning Costs Final.
Notes: * Assumes 23 rigs are decommissioned. ** Assumes the remaining rig would extend from the seafloor up to a depth of 85 to 100 feet below the waterline.

(...continued)

conducted by MMS in 2001 estimates that converted oil platforms near Channel Islands Harbor could provide $10,000 a year in scuba diving value, based on a travel cost estimate (that is, based on willingness to pay). *See* McGinnis et al., *supra* note 6, at 51.

[50] The United Anglers of Southern California estimate that recreational fishermen contribute tens of millions of dollars (or more) to the state economy each year. *See* Robert Southwick, "The Economic Effects of Sportfishing Closures in Marine Protected Areas, The Channel Islands Example," Prepared for the American Sportfishing Association, United Anglers of Southern California (Mar. 2002).

[51] *See, e.g.*, testimony of Tom Raftican, United Anglers of Southern California, before the California State Lands Commission, Dec. 3, 1999 (visited Aug. 3, 2003) <http://www.slc.ca.gov/Division_Pages/MRM/RigsToReefs.htm>. *See also*, Love et al., *supra* note 2, at 4.7. Bear in mind that if the rigs were designated as "no take" zones, fishermen would incur the cost of avoiding these areas in the short term. However, in the long term as over-fished species' populations' rebound and fishing restrictions are lifted, fishermen would benefit from improved fisheries.

[52] Winmar Consulting Services, Inc., "Removal Cost Estimate, Pacific OCS Platforms," (May 2003).

A striking feature of the table is that estimated savings could range from one half to one billion dollars. These estimates exceed the savings experienced to-date in the Gulf by several orders of magnitude. Driving the difference in cost savings generated is the fact that oil and gas platforms off California's shore are vastly different from those that have been removed so far in the Gulf of Mexico. While the total number of platforms in the Pacific is much smaller than in the Gulf (just under 30 as compared to around 4,000), the California rigs are, on average, in much deeper water. Although there are deep-water platforms in the Gulf, the vast majority of them (and almost all of those removed to-date) are in shallow water, typically 100 feet of water or less. In contrast, most of the Pacific rigs are in deep water, reaching depths of over 12,000 feet. As a result, complete removal of the California platforms will be more complicated to design and implement than typical Gulf platform removals, more risky for the workers conducting the removal,[53] and will require the development of new technology.[54] The complicated nature of California platform decommissioning implies that the average cost savings from partial removal and conversion to an artificial reef are likely to be higher than in the Gulf. Moreover, Winmar notes that, due to the complexity of decommissioning many of the Pacific rigs, the average cost savings are more likely to exceed the median reported in Table 1 than fall short of it.

In an earlier report, Winmar decomposed the cost savings estimates by rig type. They split the 23 California offshore platforms into five groups, based on platform depth. Table 2 presents the cost savings by depth group for four of the five groups.

[53] For example, while partial rig removal would necessitate professional divers to work at depths of 85 to 100 feet, full rig removal would require special equipment, such as specially designed submersible craft capable of descending over 10,000 feet. Full rig removal would also involve underwater explosives (to sever the platform at its base), whereas explosives would be unnecessary with partial rig removal.

[54] Authors' interview with George Steinbach, Executive Director of the California Artificial Reef Enhancement program, July 2, 2003.

Table 2. Estimated One-Time Cost Savings From Partial Rig Removal By Platform Depth

Depth	Number of Platforms	Median Cost Savings Per Platform	Partial Rig Removal Total Cost Savings
100 to 225 Feet	10	$6.4M	$64.0M
225 to 450 Feet	6	$14.0M	$84.0M
450 to 850 Feet	5	$54.0M	$270.0M
850 to 1,200 Feet	2	$120.0M	$240.0M
Total	23		$658.0M

Source: Winmar Summary Report Update R2, 3/7/2000.
Notes: Assumes 6 rigs in less than 100 feet of water generate no savings (the fifth group). Assumes that all rigs would be partially removed, with the remaining rig extending from the seafloor up to a depth of 85 to 100 feet below the waterline. Savings are calculated as compared to full removal.

Table 2 highlights the strong positive correlation between a platform's depth and the cost savings generated as a result of conversion to an artificial reef. The median savings generated from partially removing one of the deepest rigs (as compared to full removal) exceed those of shallower rigs by at least a factor of two.

The Winmar estimates strongly suggest substantial economic benefits from establishing a rigs-to-reefs program in California. Converting just one rig in shallow water (100 to 225 feet) would contribute approximately $3.2 million to a rigs-to-reefs fund for reef maintenance, marine research, and conservation projects.[55] Another $3.2 million would accrue to the shareholders of the rig's lease owner, the company decommissioning the rig. If the rig were in 850 feet of water or more, converting just one rig would result in $60 million in donations and $60 million in shareholder gains. The remaining question is whether these benefits outweigh the costs identified earlier.

[55] The median cost savings of $6.4 million multiplied by the company contribution of 50 percent.

Simple calculations demonstrate that creating an offshore platform conversion program for California would be economically beneficial to the state's residents. To summarize the quantifiable costs, it would cost around $250,000 in one-time expenses to establish a rigs-to-reefs program and would cost around $250,000 annually to cover maintenance plus another $25,000 per rig for liability insurance.[56] Using a conservative starting point, assume for the moment that three of the 10 rigs in 100 to 225 feet of water that are due for decommissioning request and receive artificial reef status. Then the designated agency would receive $9.6 million in donations. After covering program set-up costs, $9.35 million would be available. Funding the first year's operational costs would leave just over $9 million for investment. At an interest rate of 4.48 percent, the interest earnings for the first year would be in excess of $400,000.[57] Thus the California program could spend interest earnings only, easily covering the annual operating expenses while still being able to devote over $75,000 a year to marine research. With as few as three of the shallowest platforms participating, the program would be able to fully fund its own operations and liability expenses and would contribute to environmental research funding. Added to these benefits, the oil and gas company's stockholders would benefit from $9.6 million in cost savings.

As Table 2 illustrates, however, cost savings from deeper rigs are substantial. Oil and gas companies would have much to gain from donating additional platforms, implying that rigs-to-reefs participation rates in California would likely be quite high. Based solely on potential cost savings, it seems reasonable to assume that 100 percent of the deepest rigs, those in 450 feet of water or more, would be donated. Participation rates for platforms in less than 450 feet of water could be lower, but are still likely to be significant. Even if none of these relatively shallower rigs participated, however, the program would receive $255 million in donations from the 7 deep rigs, benefiting the state, its residents, and its researchers. After accounting for set-up costs and the first year's operating costs, the remaining $254 million

[56] We ignore volume discounts for the insurance premiums and use the estimate of $25,000 per rig.

[57] The current rate for 10-year Treasury bills is 4.48 percent. Federal Reserve Statistical Release, Aug. 25, 2003 (visited Aug. 25, 2003) <http://www.federalreserve.gov/releases/h15/current/h15.pdf>. We assume interest is compounded daily.

would yield over $11 million a year for annual operations, marine research, and conservation projects. Company shareholders would benefit from an additional $255 million in cost savings.

Company participation rates will, of course, be sensitive to the designated donation rate. The economic motivation for oil and gas companies to participate in a rigs-to-reefs program is the expected cost savings from partial rig removal as opposed to full rig removal. If donation rates are set too high, companies will have little incentive to participate, as they will see little in the way of savings. A delicate balance must be maintained between ensuring that rigs will be available for conversion and ensuring funding for the program, research, and conservation projects.[58]

IV. CONCLUSIONS AND RECOMMENDATIONS

Our principal finding is that a well-designed rigs-to-reefs program for California would likely result in direct and indirect benefits far in excess of costs. There would be benefits for residents of the state, tourists, researchers, the marine environment, and equity owners.

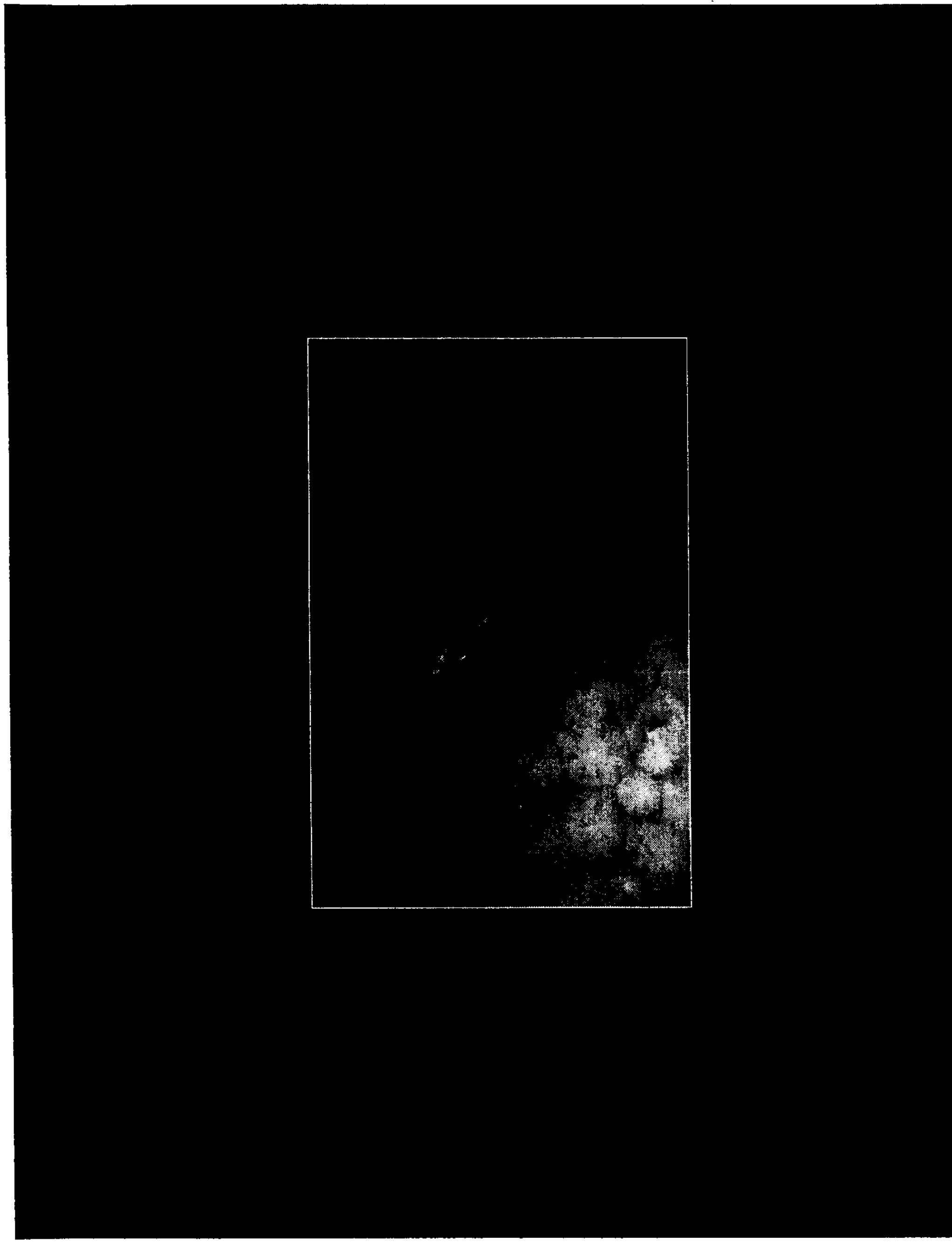
The potential costs of a program appear to be manageable. Even conservative estimates of program donations indicate that a rigs-to-reefs program in California would be self-sufficient. More realistic estimates indicate that substantial funds could be available for marine research and conservation programs.

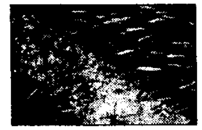
There is a growing body of evidence that suggests that offshore platforms converted to reefs do result in environmental benefits. Rigs converted to reefs help provide nursery grounds for juvenile fish and appear to assist in replenishing the population of over-fished species such as some rockfish. Increased fish stocks, in turn, benefit commercial and sport fishermen, as well as scuba divers. As artificial reef managers in the Gulf of Mexico have noted, offshore platforms create stable reefs with slow corrosion rates.

Based on our analysis, we recommend that a state and/or federal program be established that would enable citizens in California and elsewhere to reap the benefits of a rigs-to-reefs

[58] This point is underscored by the experience in the Gulf of Mexico. While the donation rates are not aggressive, set at 50 percent, shallower rigs generate lower cost savings from partial removal and thus participate less frequently.

program. This program could be modeled along the lines of successful programs in the Gulf of Mexico. The gains from a well-designed program in California could be expected to be even greater than those achieved in the Gulf of Mexico thus far, largely because of differences in the economics of offshore platform removal in the two areas.





EXECUTIVE SUMMARY

Information Needed

Production of oil and gas from offshore platforms has been a continual activity along the California coast since 1958. There are 26 oil and gas platforms off California, 23 in federal waters (greater than 3 miles from shore) and 3 in state waters. The platforms are located between 1.2 to 10.5 miles from shore and at depths ranging from 11 to 363 m (35–1,198 ft.). Crossbeams and diagonal beams occur about every 30 m (100 ft.), from near the surface to the seafloor. The beams extend both around the perimeter of the jacket and reach inside and across the platform. The beams and vertical pilings (forming the jacket) and the conductors on all platforms are very heavily encrusted with invertebrates and provide important habitat for fishes. The seafloor surrounding a platform is littered with mussel shells. This "shell mound" (also called "mussel mound" or "shell hash") is created when living mussels, and other invertebrates, are dislodged and fall to the seafloor during platform cleaning or storms.

Once an industrial decision is made to cease oil and gas production, managers must decide what to do with the structure, a process known as *decommissioning*. Platform decommissioning can take a number of forms, from leaving much, or all, of the structure in place to complete removal. Along with the platform operator, many federal and state agencies are involved in the decommissioning process. All oil and gas platforms have finite economic lives and by the beginning of the twenty-first century, seven platforms in southern California had been decommissioned and a number of others appeared to be nearing the end of their economic lives.

Management decisions regarding the decommissioning of an oil and gas platform are based on both biological and socioeconomic information. This study addressed the need for resource information and better understanding of how offshore oil/gas platforms contributed to the fish populations and fishery productivity in the Santa Maria Basin and Santa Barbara Channel. Prior to our studies, there was almost no biological information on Pacific Coast platform fish assemblages. This necessary research involved broad scale sampling at numerous oil/gas platforms and natural reefs. Research objectives included 1) characterizing the fish assemblages around platforms and natural reefs, 2) examining how oceanography affects patterns of recruitment and community structure of reef fishes, and 3) describing the spatial and temporal patterns of fish diversity, abundance and size distribution among habitat types (e.g., platforms and natural outcrops).

Research Summary

Between 1995 and 2001, we studied oil and gas platforms sited over a wide range of bottom depths, ranging between 29 and 224 m (95 and 739 ft.) and sited from north of Point Arguello, central California to off Long Beach, southern California. However, most of the platform research occurred in the Santa Barbara Channel and Santa Maria Basin. The Santa Barbara Channel and Santa Maria Basin are situated in a dynamic marine transition zone between the regional flow patterns of central and southern California. The Santa Barbara Channel is about 100 km long by about 50 km wide (60 x 20 miles) and is bordered on the south by the Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa). This area is bathed in a complex hydrographic system of currents and water masses. Generally, cool coastal waters from the California Current enter the Santa Barbara Channel through its west entrance at Point Conception. Warm waters from the Southern California Bight flow in the opposite direction into the channel through its eastern entrance. Surface waters are substantially warmer in the Bight than north of Point Conception due to less wind-induced vertical mixing, the solar heating of surface waters, and currents of subtropical waters entering from the south. The convergence of different water masses in the Santa Barbara Channel results in relatively large scale differences in physical parameters (e.g., temperature, salinity, oxygen, and nutrient concentrations) and biotic assemblages (e. g., flora and fauna).

Scuba surveys were conducted at shallow depths and submersible surveys, using the research submarine *Delta*, at greater depths. We also surveyed shallow-water and deeper-water rock outcrops, many in the vicinity of platforms. Nine nearshore, shallow-water rock outcrops, seven on the mainland and two at Anacapa Island, were monitored annually from 1995 to 2000. These natural outcrops are geographically distributed across the Santa Barbara Channel providing opportunities for spatial comparisons. In addition, we surveyed over 80 deeper-water outcrops, in waters between 30 and 360 m (100

Opposite: Juvenile widow rockfish in platform midwater. (Photograph by Lovelab, UC Santa Barbara)

From "The Ecological Role of Oil and Gas Production Platforms and Natural Outcrops on Fishes in Southern and Central California: A Synthesis of Information" by Milton Love, Donna Schroeder and Mary Nishimoto 2003 and 1,180 ft.) deep, located throughout the Southern California Bight and off Points Conception and Arguello. These sites included a wide range of such habitats as banks, ridges, and carbonate reefs, ranging in size from a few kilometers in length to less than a hectare in area. On these features, we focussed on hard bottom macrohabitats, including kelp beds, boulder and cobble fields, and bedrock outcrops. Most of these deeper-water sites were visited once, a few were surveyed during as many as four years and one outcrop, North Reef, near Platform Hidalgo, was sampled annually.

Most of our oil and gas platform surveys were conducted at nine structures (Platforms Irene, Hidalgo, Harvest, Hermosa, Holly, Gilda, Grace, Gina, and Gail) located in the Santa Barbara Channel and Santa Maria Basin. Between 1995 and 2000, we conducted annual surveys on the shallow portions of these nine platforms. The shallowest of the nine platforms, Gina, was surveyed from surface to bottom depths using scuba techniques. Deep-water surveys conducted between 1995 and 2001, using the research submersible, *Delta*, studied the same platforms excluding the bottom of Gilda and all of Gina. In 1998, one submersible survey was conducted around Platform Edith, located off Long Beach. In 2000 partial submersible surveys were completed around Platforms C, B, A, Hillhouse, Henry, Houchin, Hogan, and Habitat.

Patterns in Shallow-Water Habitats

Regional and local processes influenced patterns of outcrop fish assemblages in shallow waters. At regional spatial scales, outcrop fish abundance patterns often shifted abruptly as oceanographic patterns changed, roughly defining a cool-temperate assemblage in the western Santa Barbara Channel, and a warm-temperate assemblage in the eastern Santa Barbara Channel. This distinctive spatial pattern was observed in both oil and gas platform and natural outcrop habitats. In shallow waters, there was greater variability in platform species assemblages and population dynamics compared to natural outcrop assemblages, and this was most likely caused by the greater sensitivity of platform habitats to changing oceanographic conditions. Local processes that affected fish distribution and abundance were related to habitat features, where depth, relief height, and presence of giant kelp all played important roles. On platform habitat, we found that the majority of newly settled rockfish juveniles resided at depths greater than 26 m (86 ft.), although there were differences among species.

Characterization of the Deepwater Platform Fish Assemblages

With the exception of the shallow-water Platform Gina, all of the platforms we surveyed were characterized by three distinct fish assemblages: midwater, bottom, and shell mound. Rockfishes, totaling 42 species, dominated these habitats. Fish densities at most platforms were highest in the midwater habitat reflecting the depth preferences of young-of-the-year rockfishes. Young-of-the-year rockfishes represented the most abundant size classes in platform midwaters. Platform midwaters were nursery grounds for rockfishes as well as for a few other species, including cabezon and painted greenling. The young-of-the-year of at least 16 rockfish species inhabited these waters. Settlement success was affected by oceanographic conditions. Densities of young-of-the-year varied greatly between years and platforms. Young-of-the-year rockfish densities often varied by an order of magnitude or greater among survey years and platforms. From 1996 through 1998, rockfish settlement was generally higher around the platforms north of Point Conception as compared to platforms in the Santa Barbara Channel. This finding is reflective of the generally colder, more biologically productive waters in central California during the 1980s and much of the 1990s. Colder waters in 1999 were associated with relatively high levels of rockfish recruitment at all platforms surveyed. In 2000 and 2001, juvenile rockfish recruitment at platforms in the Santa Barbara Channel remained higher than pre-1999 levels, possibly reflecting the oceanographic regime shift to cooler temperatures that may be occurring in southern California.

Subadult and adult rockfishes and several other species dominated the bottom habitats of platforms. The bottom habitat of some platforms is also important nursery habitat as, in some instances, young-of-the-year rockfishes were observed in very large numbers. In general, more than 90% of all the fishes around platform bottoms were rockfishes. Bottom depth strongly influenced the number of species, species diversity, and density of fishes living around platform bases. This is distinctly different than the pattern observed in platform midwaters. The platform base provides habitat for not only fishes but also their prey and predators.

Shell mounds supported a rich and diverse fish assemblage. As at other platform habitats, rockfishes comprised the vast majority of the fishes. The many small sheltering sites created by mussels, anemones, and other invertebrates on the shell mounds created a habitat occupied by small fishes. Many of these fishes were the young-of-the-year and older juveniles of such species as lingcod and copper, flag, greenblotched, and pinkrose rockfishes and cowcod. The adults of these species also inhabited the platform bottom.

Platform versus Reef Fish Assemblages

We compared the species composition of the fish assemblages at Platform Hidalgo and at North Reef, an outcrop located about 1,000 m (3,300 ft.) from the platform. The assemblages were quite similar, both were dominated by rockfishes. In general, the distinctions between the platform and outcrop assemblages were based on differences in species densities, rather than species' presence or absence. Most species were more abundant at Platform Hidalgo. Halfbanded, greenspotted, flag, greenstriped, and canary rockfishes, and all three life stages of lingcod (young-of-the-year, immature, adult) and painted greenling had higher densities around the platform. Five species (pink seaperch, shortspine combfish, pygmy, squarespot, and yellowtail rockfishes) were more abundant at the outcrop. Young-of-the-year rockfishes were found at both Platform Hidalgo (primarily in the midwaters) and at North Reef. Young-of-the-year rockfish densities were higher at the platform than at the outcrop in each of the five years studied. In several years, their densities were more than 100 times greater at Platform Hidalgo compared to North Reef.

Rockfishes numerically dominated the fish assemblages at almost all of the platform and hard seafloor habitats in our study. Overall species richness was greater at the natural outcrops (94) than at the platforms (85). There was a high degree of overlap in species between platforms and outcrops and differences were primarily due to generally higher densities, of more species, at platforms. In general, canary, copper, flag, greenblotched, greenspotted, greenstriped, halfbanded, vermilion rockfishes, bocaccio, cowcod, and widow rockfish young-of-the-year, painted greenling and all life history stages of lingcod were more abundant at platforms than at all or most of the outcrops studied. Yellowtail rockfish and the dwarf species pygmy, squarespot, and swordspine rockfishes were more abundant on natural outcrops.

Findings

Our research demonstrates that some platforms may be important to regional fish production. The higher densities of rockfishes and lingcod at platforms compared to natural outcrops, particularly of larger fishes, support the hypothesis that platforms act as de facto marine refuges. High fishing pressure on most rocky outcrops in central and southern California has led to many habitats almost devoid of large fishes. Fishing pressure around most platforms has been minimal. In some locations, platforms may provide much or all of the adult fishes of some heavily fished species and thus contribute disproportionately to those species' larval production.

Platforms usually harbored higher densities of young-of-the-year rockfishes than natural outcrops and thus may be functionally more important as nurseries. Platforms may be more optimal habitat for juvenile fishes for several reasons. First, because as structure they physically occupy more of the water column than do most natural outcrops; presettlement juvenile or larval fishes, transported in the midwater, are more likely to encounter these tall structures than the relatively low-lying natural rock outcrops. Second, because there are few large fishes in the midwater habitat, predation on young fishes is probably lower. Third, the offshore position and extreme height of platforms may provide greater delivery rates of planktonic food for young fishes. Most of the natural outcrops we found that had high densities of young-of-the-year rockfishes were similar to platforms as they were very high relief structures that thrust their way well into the water column.

Our research, and reviews of existing literature, strongly implies that platforms, like natural outcrops, both produce and attract fishes, depending on species, site, season, and ocean conditions. Platform fish assemblages around many of the deeper and more offshore platforms probably reflect recruitment of larval and pelagic juvenile fishes from both near and distant maternal sources, not from attraction of juvenile or adult fishes from natural outcrops. Annual tracking observations of strong year classes of both flag rockfish and bocaccio imply that fishes may live their entire benthic lives around a single platform. A pilot study showed that young-of-the-year blue rockfish grew faster at a platform than at a natural outcrop indicating that juvenile fishes at platforms are at least as healthy as those around natural outcrops.

Management Applications

In this report, we discuss the ecological and political issues that surround platform decommissioning in California, including the ecological consequences of the four platform decommissioning alternatives: (1) Complete Removal, (2) Partial Removal and Toppling, and (3) Leave-in-Place.

Complete Removal: In complete removal, operators may haul the platform to shore (for recycling, reuse, or disposal) or it can be towed to another site and reefed.

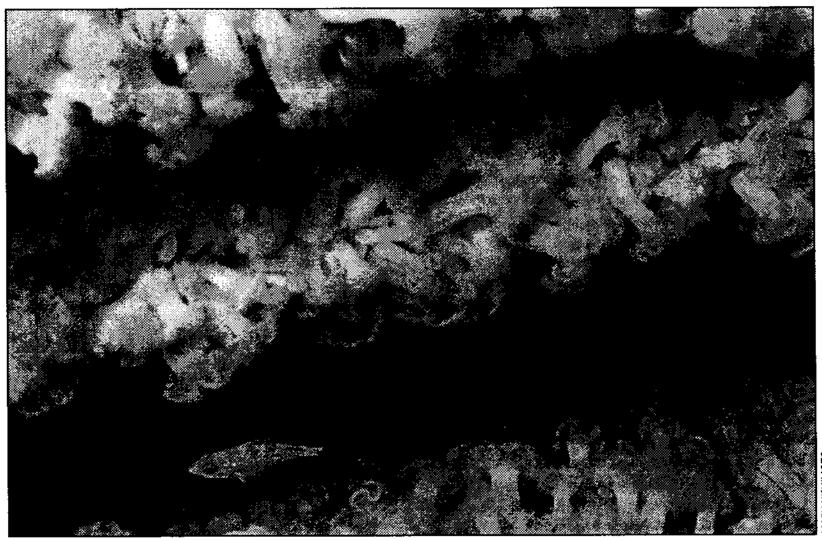
A typical full-removal project begins with well abandonment in which the well bores are filled with cement. The topsides, which contain the crew quarters and the oil and gas processing equipment, are cut from the jacket and removed and the conductors are removed with explosives. Finally, the piles that hold the jacket to the seabed are severed with explosives and the jacket is removed.

Completely removing a platform for disposal on land will kill all attached invertebrates. If some of the platform structure is hauled to a reef area and replaced in the water, some of these animals may survive, depending on water depth and the length of time the structure is exposed to the air. The explosives used to separate the conductor and jacket from the seafloor kill large numbers of fishes. In a study in the Gulf of Mexico, explosives were placed 5 m (15 ft.) below the seafloor to sever the well conductors, platform anchor pilings and support legs, of a platform in about 30 m (100 ft.) of water. All of the fishes on or near the bottom and most of the adult fishes around the entire platform suffered lethal concussions. Marine mammals and sea turtles may also be indirectly killed by damage to the auditory system.

The use of explosives to remove or topple a platform may also complicate fishery-rebuilding programs. Cowcod, a species declared overfished by NOAA Fisheries, provides an example. This species is the subject of a federal rebuilding plan that severely limits catches. In 2001, this was 2.4 metric tons or about 600 fish. Based on our research, there are at least 75 adult cowcod on Platform Gail. If explosives are used to remove Gail, all of these fish will be killed. The loss of at least 75 adult cowcod may be sufficiently large to complicate the rebuilding plan.

Partial Removal and Toppling: Under both partial removal and toppling the topsides are removed. In partial removal, the jacket is severed to a predetermined depth below the surface and the remaining subsurface structure is left standing. In toppling, the conductors and piles are severed with explosives and the jacket is pulled over and allowed to settle to the seafloor. In both partial removal and toppling, conductors need not be completely removed. Retaining conductors would add habitat complexity to a reefed platform.

While the immediate mortality impact to attached invertebrates of partial removal is greater than leaving the platform structure in place, mortality risks to both fishes and invertebrates are much lower than in both toppling and total removal. Partial removal causes fewer deaths than does toppling for two reasons. First, because partial removal does not require explosives (as does toppling), there is relatively little fish, marine mammal, sea turtle, and motile invertebrate (such as crab) mortality. In addition, when a platform is partially removed, vertebrate and invertebrate assemblages associated with the remaining structure are likely to be minimally affected. In contrast, when a platform is toppled, the jacket falls to the seafloor, and, depending on bottom depth, many, if not most of the attached invertebrates die.



*Whitespeckled rockfish and white anemones (*Metridium *sp.).*

Both partial removal and toppling would produce reefs with somewhat different fish assemblages than those around intact platforms. With the shallower parts of the platform gone, it is likely that partial removal would result in fewer nearshore reef fishes, such as seaperches, basses, and damselfishes. However, young-of-the-year rockfishes of many species recruit in large numbers to natural outcrops that have crests in about 30 m (100 ft.) of water or deeper. Thus, it is possible that partial removal would result in little or no reduction in young-of-the-year recruitment for many rockfish species. The pelagic stage of some rockfish species, particularly copper, gopher, black-and-yellow and kelp, may recruit only to the shallowest portions of the platform. For these species, both partial removal and toppling would probably decrease juvenile recruitment, depending on the uppermost depth of the remaining structure. Young-of-the-year rockfishes, which make up the bulk of the fish populations in the platform midwater habitat, would probably be less abundant around a toppled platform compared to a partially removed one. Because most California platforms reside in fairly deep water, toppled platforms might reside at depths below much rockfish juvenile settlement. Thus, toppling might result in lowered species composition and fish density. However, depending on the characteristics of the platform, a toppled structure, with twisted and deformed pilings and beams, might have more benthic complexity than one that is partially removed. This might increase the number of such crevice dwelling fishes as pygmy rockfishes.

It is difficult to catch fishes that live inside the vertically standing platform jacket. Our observations demonstrate that many of the rockfishes living at the platform bottom, such as cowcod, bocaccio, flag, greenspotted, and greenblotched rockfishes, dwell in the crevices formed by the bottom-most crossbeam and the seafloor. To a certain extent, these fishes are protected from fishing gear by the vertical mass of the platform, a safeguard that would persist if the platform were partially removed, particularly if the conductors remained in place. It would be much easier to fish over a toppled platform, as more of the substrate would be exposed to fishing gear.

Coast Guard regulations do not require a minimum depth below the ocean surface to which a decommissioned platform must be reduced. The decision on how much of the jacket and conductors is left in place is based on both a Coast Guard assessment and the willingness of the liability holder to pay for the navigational aids required by the Coast Guard. As mussels become rare below about 30 m (100 ft.) on most platforms, the mistaken assumption that all partially removed platforms must be cut to 24–30 m (80–100 ft.) below the surface has led some to conclude that this will inevitably lead to a severe reduction in the amount of mussels that fall to the bottom and, thus, to a change in or end to, the shell mound community. This is not necessarily the case.

Leave-in-Place: A platform could be left in its original location at the time of decommissioning. The topsides would be stripped of oil and gas processing equipment, cleaned, and navigational aids installed. If a platform were left in place, the effect on platform sea life would be minimal.

Pacific Coast Platforms

In this report we have also included a brief summary of information on all of the Pacific Coast platforms (Appendix 1), densities of all fishes observed at each platform during scuba and submersible surveys (Appendix 2 and Appendix 3, respectively), and a list of the 20 most important sites, both platforms and natural outcrops, for the most abundant species in our deepwater study (Appendix 4).

Research Needs

Our research demonstrates that additional biological information is needed in the decommissioning process. These information needs fall into three categories: (1) A comparison of the ecological performance of fishes living at oil platforms and on natural outcrops, (2) A definition of the spatial distribution of economically important species (of all life history stages) within the region of interest and a definition of the connectivity of habitats within this region, and (3) An understanding of how habitat modification of the platform environment (e.g., removal of upper portion or addition of bottom structure) changes associated assemblages of marine life at offshore platforms.

Major questions remaining to be addressed include:

What Fishes Live Around Platforms and Nearby Natural Reefs?

In order to assess the relative importance of a platform to its region, it is essential to conduct basic surveys not only around the platform, but also at nearby reefs. A majority of platforms have not been surveyed.

How Does Fish Production around Platforms Compare to that at Natural Outcrops?

It is possible to compare fish production between habitats by examining (1) fish growth rates, (2) mortality rates, and (3) reproductive output. A pilot study compared the growth rates of young-of-the-year blue rockfish at Platform Gilda and Naples Reef and another examining young-of-the-year mortality rates is planned. Additional work is needed to determine larval dispersal patterns and differences in densities at various study sites. For example, we now have enough data to study the relative larval production per hectare of cowcod and bocaccio at Platform Gail versus that on natural outcrops.

What Is the Relative Contribution of Platforms in Supplying Hard Substrate and Fishes to the Region?

This research would put in perspective the relative contribution of platforms in supplying hard substrate and reef fishes to their environment.

First, this requires knowledge of the rocky outcrops in the vicinity of each platform; this is derived from seafloor mapping. Once the mapping is complete, visual surveys of the outcrops, using a research submersible, will determine the fish assemblages and species densities in these habitats. Knowing the areal extent of both natural and platforms habitats and the densities of each species in both of these habitats, it is then possible to assess the total contribution of each platform to the fish populations and hard substrate in that region.

How Long Do Fishes Reside at Oil/Gas Offshore Platforms?

It is unclear how long fishes are resident to platforms. For instance, does the large number of fishes, particularly such species as the overfished bocaccio and cowcod, remain around the platforms for extended periods? Knowledge of the residence time of these species would allow us to more accurately determine if platforms form optimal habitat for these species.

What are the Effects of Platform Retention or Removal on Fish Populations within a Region?

As an example, what effect would platform retention or removal have on young-of-the-year fish recruitment? Would the young rockfishes that settle out at a platform survive in the absence of that platform? Our surveys demonstrate that planktonic juvenile fishes, particularly rockfishes, often settle to platforms in substantial numbers. If that platform did not exist, would these young fishes have been transported to natural outcrops? Knowing how long it would take rockfish larvae to reach suitable natural outcrops, and what percent of these larvae would likely die before reaching these outcrops, will give a sense of the importance of a platform as a nursery ground.

Similarly, using a synthesis of oceanographic information, it is possible to model the fate of larvae produced by fishes living at a platform.

How Does Habitat Modification of the Platform Environment (e.g., Removal of Upper Portion or Addition of Bottom Structure) Change Associated Assemblages of Marine Life?

All decommissioning options except leave-in-place involve modification of the current physical structure of offshore platforms. Is it possible to increase fish diversity and density by altering the seafloor or the platform itself? For instance, it would be useful to add complexity, in the form of quarry rock or other structure, to the shell mound around a platform, and follow the changes in fish assemblages.

Descriptive information such as depth distribution and life history information is also useful in determining how decommissioning options affect the environment. Experimental research, using a BACI design or similar approach, can aid in predicting how the biotic community will respond to such structural changes.

Exhibit G.3.a
Attachment 6
March 2004

Fisheries, Reefs, and Offshore Development

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The Role of Fishermen and Other Stakeholders in the North Sea Rigs-to-Reefs Debate

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Abstract.—The North Sea rigs-to-reefs debate has moved forward with the formation of a multi-stakeholder steering group that oversees the development of independent research. Despite the sharp division that exists in stakeholder opinion, particularly related to whether or not such a concept constitutes an act of dumping, there now exists a proactive approach to assessing the need and potential for the formation of reefs using redundant oil and gas platforms. One influential stakeholder, Greenpeace, however, has distanced itself from the process. Liability, loss of access, and safety are of particular concern to fishermen when examining calls for offshore and nearshore reefs. The fishing industry remains unconvinced of the benefits of inshore reefs but maintains an open mind. It remains, however, committed in opposition to offshore reef creation, even more so when suggested in combination with a no fishing policy. The environmental pressure group Greenpeace is opposed to any rigs-to-reefs initiative, seeing this as a means by which offshore operators can circumvent the Oslo and Paris Commission's (OSPAR) Decision 98/3, which calls for complete removal of offshore installations. The importance of cost and the existence of willing reef beneficiaries are highlighted as important to the acceptance and success of a nearshore rigs-to-reefs venture. The creation of offshore reefs faces numerous political hurdles. The importance of a genuine stakeholder dialogue process to integrate scientific and political thinking and to avoid the re-occurrence of an event similar to the Brent Spar is stressed. The paper concludes that fishermen hold the key to the success of rigs-to-reefs ventures in the North Sea and that their cooperation and participation is essential for the promotion and success of the concept.

Introduction

The concept and implementation of "rigs-to-reefs" in any form in the North Sea has always been a source of contention between scientific, environmental, fishing, and offshore sectors. In the wake of the Brent Spar incident, the concept has come under increasing scrutiny from all stakeholders, although, for the most part, without participation from some affected parties who closely follow their own agendas. It is not a proactive, investigative effort that keeps this concept afloat in the more general debate concerning North Sea abandonment and sea disposal, but a reactionary link between all stakeholders on an issue that has not been thoroughly evaluated and that is shrouded in suspicion and mistrust.

This concept's applicability within the North Sea has been subject to scientific appraisal and speculation over the past two decades (ICIT 1991; Picken 1992; Side 1992; Baine 1995, 1998; Aabel et al. 1997; Soldal et al. 1999) concluding that fish are attracted to platforms, although only with cautiously mooted biomass estimates (ICIT 1991; Soldal et al. 1999; Picken et al. 2000). Scientific research has been promoted to bridge gaps in knowledge (Aabel et al. 1997). However, research to date has not induced the confidence needed to justify the initiation of a rigs-to-reefs program (in any form) against a background of political skepticism.

Fishermen see social and political issues inherent in the North Sea rigs-to-reefs debate as important and perhaps more crucial than any program of scientific research. Unfortunately, there has been little attention, and perhaps value, placed on many of these issues. Fishermen have publicly stated their concerns regarding any form of at-sea disposal of offshore platforms since the early 1970s. Yet, these concerns are often ignored in the limited scientific evaluation of a conceptual abandonment option. Indeed, such a concept if it were to proceed would have significant ramifications for fisheries and environmental management throughout the northeast Atlantic region.

This paper addresses the socio-political issues within the debate, concentrating on the relationship between Scottish fishermen (through the Scottish Fishermen's Federation [SFF]) and offshore operators. Information from direct contact with stakeholder representatives and output from working groups and workshops form the basis for the paper. In addition, it provides an analysis of published literature on abandonment and environmental management, stakeholder policies, and legislation. The paper concludes with a discussion of the present day status of the rigs-to-reefs debate in the North Sea and presents a way forward.

Fishermen, Offshore Operators, and Government—a Historical Perspective

With the emergence of petroleum activity in the North Sea in the early 1970s, it was recognized that there would be a lengthy period of inconvenience for fishermen. The United Kingdom (UK) government, however, assured the fishing industry that once the oil companies had completed their operations, all of the installations would be removed in their entirety, thus returning the seas and seabed to the fishermen in the condition in which the oil industry had found them. The 1958 Geneva Convention on the Continental Shelf seemingly backed this assurance, and fishermen accepted it (Allan 1986, 1992, 1994).

Concerns mounted in the fishing industry as there was a change from complete removal assurance over the following decades. Fishermen were informed that complete removal might not be obtainable. Reasons given included cost, the technical feasibility of complete removal, and the perceived uncertainty of future legislation regulating the abandonment of offshore oil and gas installations. In response, the fishing industry maintained the moral argument that promises made to completely remove offshore installations were promises that must be kept.

The development of the International Maritime Organization's (IMO) 1989 Guidelines[1] and other international and UK legislation[2] gradually led to the general acceptance, in the North Sea, of toppling and partial removal as abandonment options. The fishing industry, while remaining committed to complete removal, felt compelled to limit damage from partial removals, should the concept be implemented. Accordingly, the fishing industry pressed for six minimum safeguards (Allan 1994) in the event of a case by case consideration of partial abandonment. The six safeguards were (1) presence of the fishing industry as a witness during removal operations, (2) debris clean-up operations, (3) confirmation of debris clearance by side-scan and trawl operations, (4) regular inspection of abandonment sites, (5) establishment of a government compensation fund for loss of access to fishing grounds, and (6) establishment of an additional compensation fund for specific gear losses/vessel damage caused by debris from the oil and gas industry.

The SFF shifted its policy on abandonment in 1994 due to the excessive cost of abandonment operations to the UK taxpayer (ICIT 1994). This policy was developed before the Brent Spar incident and before the "Westhaven" tragedy. There is an economic incentive in considering partial removal options compared with complete removal. In the UK, the state bears an estimated 50–70% of the total abandonment cost. Using estimates of the total cost of removal of North Sea installations, ICIT (1994) concluded that the UK government might be able to save £1.25–1.75 billion in tax revenue if partial removal was adopted as the main abandonment practice. The ICIT (1994) further considered the implications of the projected taxpayer savings within a wider context of what it might cost to fishermen through loss of access and damage to gear if installations remained partially in place. The study utilized the compensation criterion suggested by the economists Kaldor (1939) and Hicks

[1] Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone (developed in response to Article 60(3) of the 1982 United Nations Law of the Sea Convention)

[2] Oslo Commission Guidelines for the Disposal of Offshore Installations at Sea 1991, OSPAR Convention for the Protection of the Marine Environment of the North-east Atlantic 1992, UK Petroleum Act 1987, UK Food and Environment Protection Act 1985.

(1939), which, in summary, suggests that a project is only worthwhile if the financial gain is able to compensate those who lose out from the project, thus ensuring that no one is worse off as a result of the project (the study notes that the Kaldor-Hicks principle does not take any moral obligation into account). In this instance, ICIT (1994) postulated that "it is highly unlikely that the cost of loss of access or future losses of gear by fishermen would exceed £1.25 billion," the estimated (lower) cost to taxpayers of requiring complete rather than permitting partial removal. Given that the government originally assured complete removal, that fishermen will be precluded from certain areas of the seabed, and that abandoned debris may damage fishing gear, it seems reasonable to conclude that, by adopting a partial removal program, the government and offshore industry will gain financially to the detriment of the fishing industry. It, therefore, seems realistic and rational that the fishing industry expects compensation from both the offshore operators and the UK government.

Despite the strong moral argument for complete removal of offshore installations, the SFF does not want the taxpayer to meet the majority of abandonment (complete removal) costs through lost revenues from Petroleum Revenue and Corporation Tax (ICIT 1994). Whereas previously the SFF sought complete removal and nothing else, their change in policy recognized the financial burden to the taxpayer, and accordingly, the SFF established a number of objectives that recognize partial removal as a possibility. These objectives are

- To minimize risk to fishermen to their vessels and gear and to minimize the areas of the seabed that will be lost to fishing in perpetuity as the result of the abandonment of partially removed structures.
- To ensure adequate compensation to fishermen for any damages or losses incurred as a result of the abandonment of partially removed structures and to seek the establishment of simple mechanisms for such settlements.
- To ensure that fishermen, the UK government, the offshore industry, and the public understands the reasons for the SFF change in policy.

A number of principles have also been established to guide all aspects of this policy change (ICIT 1994), including

- The "Polluter Pays Principle"

The premise is that any costs to the fishermen from pollution should be recovered from the polluter. This will depend upon the transfer of liability for abandonment; if to the UK government, then the government should accept responsibility for compensation; however, if not, then the polluter pays principle should apply.

- Compensation for damage and loss should be in accordance with the "General Principle of Strict Liability" and should be adequate and no more than adequate

In this instance, a call is made for the avoidance of costly and lengthy court actions for claims in favor of a "formal arrangement.... for the consideration of such claims that accords with the principles of strict civil liability" when the incident has occurred in areas where fishing is legal. Any encroachment into a no-fishing safety zone, for example, would not be dealt with in this manner.

- That equity between the present and all future generations of fishermen should be a guiding principle

Any compensation accepted for loss of access in perpetuity must be accepted on behalf of fishermen now and of fishermen of the future.

Fishermen, Artificial Reefs, Loss of Access, and Safety

It is somewhat difficult to uncover the attitude of fishermen to the prospects of an artificial reef created from an abandoned offshore facility without the politics of offshore abandonment, in general, clouding the issue. It is also evident that fishermen's actions often do not reflect their words, unsurprising in view of the very contentious nature of the issues involved.

At the 1994 conference on "Managing the Environmental Impacts of Decommissioning and Abandonment Offshore," Aberdeen, a representative from the SFF, made the following statement:

"We are also somewhat bemused and amused to hear of suggestions that toppled platforms may become artificial reefs. The main experiences of these have been in warm climates. The North Sea is totally different in climatic and fishing terms. However, it is fair to state that one or two Constituent Association members of the SFF have been prepared to co-operate with artificial reef projects targeted for nearshore locations."

This is fairly representative of North Sea fishermen's views on artificial reefs. They do not recognize any potential benefits from offshore reef creation, whereas in certain situations, they may recognize some value in placing a reef nearshore. These views reflect acknowledgment of the general concept of artificial reefs and are not specific to dismantled offshore installations. The formation of nearshore reefs has readily identifiable benefits in its nearshore location, most notably easier accessibility for nearshore fishermen and the greater potential for targeting specific resources such as lobster and crab. Fishermen also recognize the role that artificial reefs may play in conservation of nearshore resources, in providing safe havens and/or the exclusion of mobile fishing gear from an area. Artificial reefs exist in Poole Bay, England and Torness, Scotland and have two general points in common: (1) they were both constructed from waste material, and (2) they were both research orientated. The Poole Bay artificial reef has distinct fisheries enhancement properties particularly in relation to lobster populations (Jensen and Collins 1995); however, the program of research was discontinued on the Torness reef (Todd et al. 1992). Picken (1992) and Picken et al. (2000) also refer to the attempts to place a reef in the Moray Firth, Scotland. In 1987, a potential project entitled SPARE (Scottish Pilot Artificial Reef Experiment) was developed by Aberdeen University with the support of the SFF and the Scottish White Fish Producers Association (SWFPA) to study the use of redundant mud modules as artificial reefs with particular emphasis on fishery implications. The project, however, did not proceed due to the lack of sufficient funds. Fishermen continue to lend their support to such experimental projects. Aberdeen University is presently still pursuing, with the support of the same fishery organizations, the possibility of placing a high profile steel reef nearshore to mimic potential effects from the placement of dismantled offshore installations.

When we take a closer look at reef creation farther offshore, the situation becomes more confusing. There is very little support from fishermen for offshore reef deployment. Their doubt of any benefit to fish or fishermen is usually expressed in response to a comparison between the North Sea and the Gulf of Mexico, in particular the differences in fishing activity and environmental and climatic factors.

This refers to state-recognized artificial reef programs in the United States, most notably Louisiana and Texas. A growing acknowledgment during the late 1970s and early 1980s of the importance of oil and gas structures to fishing interests (primarily recreational) in the Gulf of Mexico and increasing concerns over the potential loss of habitat from their removal led to a general acceptance of their suitability as reef material. Conservation officials and private conservation groups, university researchers, fishing organizations, and the oil and gas industry all advocated the use of oil and gas structures as artificial reefs (Reggio and Kasprzak 1991). The work of the "Recreation, Environmental Enhancement and Fishing in the Sea" (REEFS) Task Force, established in 1983 by the Secretary of the Interior, resulted in the enactment of the National Fishing Enhancement Act (NFEA) 1984, Title II of Public Law 98–623. This, in turn, led to the formation of the National Artificial Reef Plan (Stone 1985), which establishes criteria for design, construction, and siting of artificial reefs. Local to the Gulf of Mexico, the Louisiana Artificial Reef Initiative (LARI), including, among others, representatives from the recreational and commercial fishing industry, oil and gas industry, the state, and academia, developed the Louisiana Fishing Enhancement Act (LFEA) in 1986. This established the Louisiana Artificial Reef Development Program (LARDP) in 1987, which is administered by the Louisiana Department of Wildlife and Fisheries (Reggio and Kasprzak 1991). Texas followed suit with the adoption of a similar program in 1990.

There is a valid argument against such a comparison, but the available information from North Sea studies indicates quite strongly that fish are attracted to offshore installations (ICIT 1991; Picken 1992; Side 1992; Baine 1995, 1998; Aabel et al. 1997; Soldal et al. 1999). This should provide a basis for considering and analyzing the prospects of offshore reef creation in the North Sea. Fishermen are aware of the fish aggregating properties of offshore installations in the North Sea. Fishermen sometimes deliberately fish in the close vicinity of offshore installations and along pipeline routes to take advantage of what they know is a fish aggregation response to their presence. Picken et al. (2000) quote one example of the financial benefits associated with such aggregation behavior in the North Sea, when "a fishermen was fined £8,000 for repeatedly fishing within the 500-m safety zone around platforms, during which time over £200,000 worth of fish were caught."

Distinct opposition from North Sea fishermen to the formation of offshore artificial reefs is based more on safety and political considerations and represents a defiant opposition to the offshore industry. Fishermen may see offshore artificial reef creation as an excuse or additional reason that offshore operators could utilize in their arguments for partial abandonment or toppling in place of individual installations. The fact that the structures do attract fish does not help their situation and has probably been recognized as such for many years.

Reef creation, especially offshore, carries the same issues of liability associated with partial removal and toppling, pertaining to loss of access and potential damage to fishing gear and personnel. If a platform is toppled or partially removed, the government has proposed that a 500-m "no fishing zone' remain in place for safety purposes (Select Committee 1996). This proposal was made in advance of the recent OSPAR Decision (July 1998)[3] but is still of relevance in certain scenarios. During the operational lifetime of platforms, fishermen were excluded from the 500-m safety zones, and in the instance of partial removal, for example, they lose access in perpetuity to such prescribed zones. With an estimated 91 oil production platforms (DTI 2000) on the United Kingdom Continental Shelf (UKCS), this equates to 71.435 km^2 of seabed lost to fishermen, approximately 0.012% of the total North Sea area. The UK government and offshore operators do not consider the loss of access claim to be legitimate (ICIT 1994). The SFF stated to the Select Committee of 1996 "Where the SFF believes it reasonable it will pursue a claim on behalf of present and future generations of fishermen for adequate compensation for the loss of access to fishing grounds in perpetuity.... Any settlement will be made into a fund established on the principle of equity for all fishermen of present and future generations." The United Kingdom Offshore Operator's Association (UKOOA), however, did not favor compensation for loss of access stating, "we do not see from our admittedly nonfishing background the problem with the North Sea as being lack of access; we see the problem as being lack of fish." The committee, in its conclusions, agreed with the government and offshore operators that loss of access was not legitimate, going so far as to state that "some fishing free areas, however small, may help to protect dwindling fish populations; in the North Sea the decline of fish populations is a serious concern."

It is very difficult to prove the "loss of access" argument, as noted by ICIT (1994). This relates primarily to the variability of fisheries that are natural systems and the associated variation in fishermen's earnings as a result of these fluctuations but also relates to skill, market price and level of effort. The ICIT (1994) identified that the only possible way of proving "loss of access" is through a process of argument, related to

- The occupation of different grounds by fish throughout a season being known to fishermen who then utilize their knowledge to fish grounds that yield the greatest catch per unit effort.
- The fact that there will be no loss of earnings where there is no lack of access.
- The fact that loss of access to an entire fishing ground will result in loss of earnings represented by the loss of catch associated with this ground.
- Assumptions regarding the gray area that lies between points 2 and 3, an area that fishermen see as following a linear relationship whereby loss of earnings correlates with the proportion of grounds lost.

One of the major arguments against the "loss of access" claims is that fish move and fishermen merely need to redirect their effort. The problem with this argument is that, although an equivalent level of catch may be achieved, there may be an increase in effort expended to achieve it, with fishermen thus fishing at a net loss compared with the situation where there is no "loss of access." If they expend the same level of effort, it can equally be maintained that there may be a reduction in catch, which again results in a net loss compared with the situation where there is no "loss of access." The ICIT (1994) does, however, warn that, given the natural fluctuations that occur in fisheries, it is again very difficult to specifically relate loss of earnings to "loss of access" and that a "substantial loss of access would have to occur before this was demonstrable...". It is likely that in some years natural fluctuations will be responsible for loss of earnings.

Other arguments against the "loss of access" claim (ICIT 1994) include the following:

- Fishermen achieve their quotas, set by the European Union (EU), so there is no loss of catch. This argument becomes invalid in light of the above discussions regarding effort.
- Partial offshore installations left in place provide a "reef effect" and are a gift either through their conservation promise or aggregation properties. However, fishermen disagree with this premise because they believe that fishing such areas, if allowed, would present a greater risk to personnel and equipment and thus cannot be viewed as a gift. In addition, attracted aggregations may also be viewed as fish removed from the surrounding fishable areas and may be included in any argument for loss of access.
- Platforms as obstacles to fishermen or by pro-

[3] Oslo and Paris Commissions (OSPAR) Decision 98/3 on the Disposal of Disused Offshore Installations 1998.

viding potential breeding and nursery areas for fish stocks have a conservation value that will ultimately benefit the fishermen. They may provide additional sustainability to a fishery in the same way that prohibition areas do, but the scale and degree to which this would occur is subject to much speculation.

The SFF also argued to the Select Committee (1996) that compensation was due for damage to fishing gear and boats and injury or death as a result of offshore installations and associated debris. The government believes this to be a matter solely for affected parties and owners. The SFF reiterated the difficulty in proving that removal debris was responsible for damage and that it preferred the establishment of a simple mechanism to deal with compensation. The Select Committee (1996) agreed with the government that it was a matter for affected parties and owners; however, it did also "agree in principle with the claims for compensation by fishermen."

The basis for such claims is embedded in the "polluter pays principle" and relates to the two situations whereby such damages and losses occur in areas where fishing remains lawful and in those areas where fishing is illegal (i.e., within the 500-m safety zones that are likely to be established upon abandonment).

With the government refusing to accept liability for abandonment debris, the operator thus becomes responsible for any damages or losses occurring in areas outside the safety zone, and under the general principles of Strict Liability, fishermen need only prove the cause of damage. Compensation would be sought if, despite previous assurances, debris from partial removals traveled outside the safety zone and damaged fishing gear (ICIT 1994). The pursuit of such a compensation claim through the courts is generally seen as an unfavorable option, both in the attendant publicity to offshore operators and in the likely event that the cost to fishermen would be grossly disproportionate when compared with the damage that occurred. A simple mechanism to deal with such claims is the preferred alternative. A mechanism, which at its simplest would involve the provision of compensation by the operator where damage to gear, vessels, or personnel can be attributed to abandonment debris. In the event that no single operator is found responsible, such a claim would be best directed to a collective operator's fund handled by UKOOA.

A different process would apply to claims for damage within a 500-m no-fishing safety zone. Fishing within such zones would be illegal, and the vessel skipper would be subject to prosecution. There are possible situations for safety zone infringements, including adverse weather conditions. However, it is highly unlikely that fishermen would pursue a claim for damage incurred as a result of infringement, especially if a compensatory mechanism was in place for "loss of access." In any event, such a claim would have to be pursued through the courts.

A compensation fund for fishermen was established in 1975 by UKOOA for loss and damage to gear arising from the presence of oil field debris that cannot be traced to an operator. This fund also compensates for loss of fishing time as a result of any such damage depending upon the circumstances. When the debris is attributable to a specific operator, the claim is made directly to the company; however, when nonattributable, the claim is made to the fund that is administered by fishing industry representatives. The fund settled an average of 90% of the claims made between 1975 and 1990. Gear damage constitutes the majority of claims. The value of claims increased from £15,000 in 1976 to £193,000 in 1990, although much of this can be related to inflationary factors. Average settlement was approximately £2,000 per claim. There are no examples of settled claims from safety zone infringement (ERT 1993). In the United States, fishermen are able to seek compensation from the Fishermen's Contingency Fund (FCF)[4] for property loss or damage and 50% of resulting economic loss due to oil- and gas-related activities. The National Marine Fisheries Service administers the fund. Payments of £238,404 and $311,290 from oil and gas interests were made in the fiscal years 1997 and 1998 respectively.

Potential risks to North Sea fishermen from abandonment debris are perhaps best envisaged when we consider events surrounding the "Westhaven" tragedy in March 1997 (Side 1999). Four fishermen died after the fishing vessel "Westhaven" capsized while trying to free itself after its trawl boards slipped under a gap between the seabed and the pipeline running from the Piper field to Flotta oil terminal in Orkney. The incident occurred 100 mi northeast of Aberdeen and has raised a number of questions regarding the risks posed to fishermen by freestanding areas of pipeline (spanning). Fishermen called for a wide-ranging review of offshore safety in the North Sea after a sheriff's inquiry into the disaster, even though the sheriff con-

[4] Authorization through the Outer Continental Shelf Lands Act Amendments of 1978, Title IV, Section 402.

cluded that no one was to blame for the tragedy. The sheriff's recommendations included, among others, the initiation of talks between the Health and Safety Executive (HSE) and offshore and fishing industries on fishing vessel safety around pipelines. Although this was an incident involving a pipeline, it is relevant to the issues discussed here as an indication of the level of potential risk posed to fishermen from the presence of a structure abandoned at sea.

OSPAR Decision 98/3

On 20 June 1995, Shell UK decided to abandon its plans for the deepwater disposal of the Brent Spar. The proposed deepwater disposal operation, supported by completion of a Best Practicable Environmental Option (BPEO) statement as required by UK law, had become "untenable" against a background of activity by environmental activists. A moratorium on the disposal at sea of decommissioned offshore installations was introduced before agreement was reached on Decision 98/3 under the auspices of the Oslo and Paris Commissions. It became effective in February 1999 and is representative of a hardening attitude towards marine pollution and at-sea disposal in the northeast Atlantic by member states. Decision 98/3 did, however, leave much open to debate and has perhaps served to focus even greater attention on the option of rigs-to-reefs.

The preamble to the decision contains an affirmation that disposal should be governed by the precautionary principle, which takes into account potential effects on the environment, and the recognition that reuse, recycling, or final disposal on land will generally be the preferred option for the decommissioning of offshore installations.

By definition, the decision describes a disused offshore installation as "an offshore installation that is neither

(a) serving the purpose of offshore activities for which it was originally placed within the maritime area, nor

(b) serving another legitimate purpose in the maritime area authorized or regulated by the competent authority of the relevant Contracting Party."

Point (b) of this definition means that an offshore platform that, upon the end of its productive life, is utilized for some other legitimate purpose (such as an artificial reef) is not classified as a disused offshore installation and would therefore not be subject to this decision. In this case, the OSPAR Convention 1992 under Article 8 becomes the relevant guiding legislation and requires the contracting party to authorize any placement of a disused installation or pipeline in the maritime area for a purpose other than that for which it was originally designed or constructed. Such authorization is required in accordance with relevant applicable criteria, guidelines, and procedures adopted by the commission with a view to preventing and eliminating pollution.

The Oslo and Paris Commissions have taken a much stronger position on at-sea disposal than was previously predicted. Although an alternative reuse is still possible, at-sea disposal in any other form is tightly restricted. Further, the decision states that "The dumping, and the leaving wholly or partly in place, of disused offshore installations within the maritime area is prohibited." Derogation is possible (Annex 1) provided that the competent authority of a relevant contracting party is satisfied that an assessment procedure (Annex 2) has provided "significant reasons why an alternative disposal is preferable to reuse or recycling or final disposal on land." Categories of alternative disposal are listed as

- All or part of the footings of a steel installation in a category listed in Annex 1 (i.e., weighing more than 10,000 tons in air), placed in the maritime area before 9 February 1999.
- A concrete installation in a category listed in Annex 1 (i.e., gravity based concrete installations, floating concrete installations) or constituting a concrete anchor base.
- Any other disused offshore installation, when exceptional and unforeseen circumstances resulting from structural damage or deterioration or from some other cause presenting equivalent difficulties can be demonstrated.

The Brent Spar incident and the power of public opinion added a new dimension to the decision making process concerning abandonment of offshore installations. There is a growing view within Europe that the North Sea should not be used as a "dump" by the offshore oil and gas industry. The OSPAR Decision strongly indicates that at-sea disposal is now the least favored option and will only be allowed to proceed in the strictest of circumstances. Given this legislative shift toward complete removal, it is possible that the offshore industry and government may see artificial reefs as a potential "solution" (Baine 1998). Rigs to reefs may be viewed as a viable alternative use that will involve little extra expenditure over the partial removal/toppling options, a situation more pronounced in the creation of an offshore reef. Indeed, even if there were not a shift towards complete removal, the management of partially removed/toppled structures as artificial reefs may alleviate the fears of those against partial removal and toppling, particularly as abandonment is now a highly controversial issue. It is unlikely that such a change in tactics by offshore operators and government will be viewed as genuine and not just a cost efficient means of disposal under a different guise. This is unfortunate as the option of artificial reef creation from decommissioned offshore structures is a viable one. Kjeilen et al. (1995), for example, well in advance of the Brent Spar incident, studied the possible deployment of the Odin platform as an artificial reef in the Norwegian sector of the North Sea. The "dumping in a different guise" perception is an argument that will almost certainly be used by opponents in the event of reef creation. This was highlighted at the Oslo and Paris Commission's 1996 Working Group on Sea-Based Activities (SEBA) meeting when Greenpeace International informed SEBA of the possibility of artificial reefs becoming a "tactic to circumvent Oslo Commission (OSCOM) Decision 95/1[5]," even though the OSPAR Convention 1992 clearly states in Article 1 (g ii) that 'dumping' does not include "placement of matter for a purpose other than the mere disposal thereof, provided that, if the placement is for a purpose other than that for which the matter was originally designed or constructed, it is in accordance with the relevant provisions of the Convention."

In a debate held in March 1997, hosted by the Institution of Civil Engineers (Press Release, 13 March 1997), artificial reefs were on the agenda with the motion "In the search for sustainability, abandoned oil platforms are an enhancement to the sea bed" being passed by delegates 27 votes to 23 with 4 abstentions. What was remarkable about this debate was that, in response to the argument that a small number of designated reef sites may help in offsetting the decline in North Sea fish stocks, the Greenpeace representative stated that they were in favor of measures to improve North Sea fish stocks and they were not "averse to the utilization of cleaned structures in designated areas but oppose toppling platforms in situ."

This clearly reiterates Greenpeace's argument that reef creation may well become an excuse for toppling, which they would view merely as "dumping in a different guise." However, it does lend some weight to the argument of utilizing decommissioned structures or parts thereof as nearshore artificial reefs or indeed in a specially designated area of the North Sea. This would be an approach similar to the designated reef zones in the Gulf of Mexico (Reggio and Kasprzak 1991). Greenpeace International, in collaboration with SustainAbility, developed the "Beyond Sparring" project, which was a consultation exercise aimed to help in the process of formulating an Integrated Removal Strategy (IRS) for oil and gas installations (SustainAbility 1997). It is notable that the offshore industry abstained from participating in this consultation exercise. Other primary stakeholders were identified as engineering contractors, local authorities, and environmental campaigners. In the consultation document, the authors note the growing perception that offshore at-sea disposal "whether involving in-site toppling or by another name (e.g., rigs-to-reefs) – is politically and socially unacceptable." This is in contrast to the comments from Greenpeace on artificial reefs highlighted above. The "Beyond Sparring" project did not aim to debate the merits of onshore versus offshore disposal but instead began from the standpoint of developing better onshore re-use and recycling options, bringing all stakeholders together to discuss the development of a more environmentally, economically, and socially sound approach to disposal. The lack of interest and participation of the offshore industry, however, led to Greenpeace handing control of the project early in 1998 to what was perceived as a more neutral organization, the European Commission.

The OSPAR Decision's exclusion of legitimate re-uses of offshore installations from the definition of a "disused offshore installation" paves the way for artificial reef creation to be considered a viable and legal proposition. However, for any country to attempt to implement such a re-use option, given the "spirit" of the Oslo and Paris Commission's meeting in Sintra, Portugal, in 1998, would require an exceptional degree of political maneuvering if it was to be accepted by the remaining members of the commission through the procedural and consultation process prescribed in Annexes 2 and 3 of OSPAR Decision 98/3. The Sintra meeting, which discussed the disposal of decommissioned installations as one item of a wide-ranging agenda, has been viewed as historic. In general, all parties agreed to strive towards zero concentrations of man-made hazardous substances and radioactive substances in the marine environment. One target adopted at the Sintra meeting was the cessation of discharges, emissions, and losses by 2020. Marine pollution in

[5] Oslo Commission (OSCOM) Decision 95/1, a precursor to OSPAR Decision 98/3.

the northeast Atlantic Ocean has become a focus for debate in recent years, fuelled perhaps by the Brent Spar incident. The Sintra agreement has been welcomed by Denmark and Sweden, and the pressure group Greenpeace has seen the agreement as a "vindication of decades of campaigning" (Anon 1998). Indeed, in a press release dated 23 July 1998, Greenpeace stated that it was confident that the decision means that no offshore installation will be dumped and no footings will remain. In the wake of Decision 98/3, Anon (1998) indicates that only 41 stumps of platforms are covered by the Derogation (Annex 1). The UK oil and gas industry has expressed concern at the Sintra agreement, which it said "appeared to have been based on political expediency."

Nearshore and Offshore Reef Creation for Commercial Fisheries

Before examining nearshore (within 3 nautical miles) and offshore reef creation scenarios in the North Sea in more detail, the issue of liability requires some discussion. Liability issues remain one of the largest stumbling blocks in the pathway towards any rigs-to-reefs initiative. The issue of liability (and ownership) in the event of damage caused by abandonment debris to other sea users, especially fishermen, is contentious. As noted in the 1989 IMO Guidelines, legal title to installations and structures that have not been completely removed must be unambiguous, and responsibility for maintenance and liability for future damages must be clearly established. More recently, OSPAR Decision 98/3, in its preliminaries, acknowledged that the national legal and administrative systems of the relevant contracting parties need to make adequate provision for establishing and satisfying legal liabilities in respect of disused offshore installations.

As discussed by Side et al. (1993), UKOOA's position as highlighted in the Fourth Report of the House of Commons Select Committee (Select Energy Committee 1991) is that government should assume liability. Continued liability, the practicality of such a long-term risk, and the possible sidelining of environmental factors when considering disposal options may influence an offshore operator's future borrowing power. The Select Committee agreed, recommending that the offshore industry "set up a fund to indemnify the Government against civil claims and to cover legal and administrative costs" (Side et al. 1993). The government, however, was not prepared to act as "defendant in perpetuity." To cover their liability, offshore operators are likely to establish an abandonment fund into which all UKOOA members pay. Government representative, Mr Eggar, however, addressing the House of Lords Select Committee on the Decommissioning of Oil and Gas Installations (Select Committee 1996) indicated that the government did not have a "closed mind on this" but that "we have not seen any compelling reasons as to why they [offshore operators] should not retain that responsibility." The Select Committee (1996) in its conclusions and recommendations, acknowledging that installation remains may survive in the sea for hundreds of years, noted that if an operator and partners were to disappear (being finite) then no one would be responsible for liability. Also, acknowledging the existence of problems associated with quantifying liability in perpetuity for a structure, the committee recommended further discussion between government and the offshore industry on this matter. In Norway, the government will undertake ownership of an abandoned installation with remuneration for such liability being supplied by the licensee (Petroleum Committee 1993).

In the event of reef creation, liability might be transferred to the reef beneficiaries. This is more likely to occur in situations involving nearshore reef creation or with a designated offshore site managed by a specific body, as reef beneficiaries or managers will need to be clearly defined before such a placement occurs. In this instance, the users or managers could assume ownership with the offshore operator providing some remuneration in lieu of any possible future liability. However, it is unlikely that this would occur in situations where offshore reefs are created by toppling in place. Unless toppling in situ occurs within a designated reef area, there are no readily identifiable reef beneficiaries who could assume liability. In the present climate, it is extremely doubtful that commercial fishermen would consider such a move.

In the United States, the National Artificial Reef Plan recognizes that "improper artificial reef placement can potentially injure persons, property and natural resources," including fishing gear, vessels in transit, and impacts from movement of reef material into unauthorized areas. It is the NFEA, however, that addresses the issue of liability, noting that the donor of reef materials, once title has transferred, is immune from liability, providing the requirements of the plan are met. The state of Louisiana, for example, becomes responsible for a reef once established within a reef permit area. Reggio and Kasprzak (1991) note that the state, donors, and other participants constructing a reef under NFEA and LFEA are "absolved from liability, provided the terms and conditions of the authorizing federal artificial reef permit are met." The donee then becomes liable, although the risks are considerably reduced if permit conditions are adhered to.

Nearshore Reef Creation

Aside from scientific validation, the placement of any artificial reef for nearshore fisheries management begs the question of its need, in line with existing and potential future management options, restrictions, and goals. The real benefits will accrue in a habitat-limited fishery, possibly through one or all of the following mechanisms:

- A natural increase in biomass may result.
- Through the combination of reef placement and a program of stock enhancement whereby the reef provides suitable additional habitat to support the potential increase in exploitable biomass.
- In a situation where the reef helps as a central area to remove individuals from a fishery, acting as a reservoir or safe haven, helping to mitigate against overpressurized fisheries.

In a nearshore UK context, the main fisheries of concern will be those for shellfish, such as the European lobster *Homarus gammarus* and edible crab *Cancer pagurus*, although the recreational fin-fishing industry should also be considered. Many studies show that bottom reefs are the most appropriate for these shellfish species (e.g., Jensen and Collins 1995) as long as there is adequate space for shelter. The use of offshore platforms in this context is debatable, particularly with respect to lattice jackets, and it may be more beneficial to utilize reefs consisting of, for example, concrete blocks, which can be designed and placed in an optimum way to meet the specific needs of the species management situation. One current example of a specifically designed reef is a proposal to deploy blocks of stabilized quarry aggregate by-product (from Argyll, Scotland) with cement and fly ash in the creation of an artificial reef for research and, among other possible options, the future management of the local lobster fishery (Wilding and Sayer 1997).

A nearshore rigs-to-reefs initiative will require a beneficiary who is willing to assume ownership and liability for the structure. This is amplified by its location, which heavily influences the cost that should be, at most, equal to the cost of onshore disposal. Otherwise, donation of the structure to a rigs-to-reefs scheme by an offshore operator has little benefit to said operator in comparison with onshore disposal. The risk of adverse interaction with other sea users also increases in a nearshore context. Without a beneficiary, a rigs-to-reefs project would have no grounds on which to proceed. The demand for a nearshore reef and a demonstration of potential environmental and socio-economic benefits will also be central to

- Its identification as the BPEO, as required by UK law for the abandonment of a particular structure.
- Convincing OSPAR Contracting Parties of its acceptability.
- Counteracting any environmental campaign opposed to the use of an offshore structure as the reef.

Nearshore reef creation does not generate as much emotion from either environmental groups or fisheries representatives as does a potential offshore reef. The fishing industry remains unconvinced of the benefits of an inshore reef but maintains an open mind. Greenpeace has expressed its opposition to nearshore reef creation. Although the organization does not condemn the merits of nearshore reef creation in general, Greenpeace does condemn the use of high-grade steel in their construction, which, it maintains, would be more appropriately brought onshore for reuse and recycling.

Offshore Reef Creation

Offshore reef creation is subject to an emotional response from stakeholders. The only potential purpose of an offshore rigs-to-reefs program lies within a fisheries management context as a fish-aggregating device for a sustainable gear specific fishery or as a conservation area where fishing is prohibited. There are obvious cost-saving incentives for offshore operators through a deepwater offshore abandonment route. However, fishermen and environmental campaigners are strongly adverse to this option. The prospects are dismal for creation of an offshore artificial reef by toppling a platform in place or by moving a decommissioned structure to a designated site or either scenario being utilized in combination with a no-fishing policy. In comparison, Louisiana adopted a policy of exclusion mapping followed by public hearings before identifying, with public input, nine offshore artificial reef planning areas. The NFEA established the Louisiana Artificial Reef Trust Fund, into which oil and gas companies (donors of structures) are requested to donate half the disposal savings achieved through program participation (Reggio and Kasprzak 1991). Generated interest is utilized for management and research. The program has also benefited from research grants and funds generated by a tax on recreational fishing gear, through the Federal Aid in Sportfish Restoration Program.

The possibility of an individual offshore rigs-to-reefs scenario or small cluster of reefs in the North Sea, however, faces the following political hurdles with the first being most critical:

- An offshore reef is seen as an impediment and danger to fishermen and their fishing methods, not a benefit, and even if there is a marginal fishery benefit, the risk posed to safety would far outweigh benefits in the overall picture.
- Opposition to the concept from fishermen, which would almost certainly prevent the adoption of the concept as the BPEO in a given situation(s) and which ultimately could be used by other contracting parties to the OSPAR Convention 1992 as a significant reason for not proceeding.
- Opposition to the concept from environmental organizations, most notably Greenpeace, which sees artificial reefs as a "weak link" in abandonment legislation and believes offshore reefs could set dangerous precedents for industrial waste disposal. Greenpeace also sees the rigs-to-reefs option as a panacea for the offshore industry's abandonment problems, undermining its responsibility to clean up its own waste.
- Opposition to the concept from contracting parties to the OSPAR Convention who will view offshore reefs as being in conflict with the spirit of the Sintra agreement.
- Lack of a beneficiary (both the fishing and environmental sectors are opposed to offshore reef creation) and therefore potential transfer of liability.

A no-fishing area (sanctuary) to help conserve stocks in combination with a rigs-to-reefs program is also faced with the following hurdles:

- Opposition from fishermen centering on
  - (i) opposition to the mere presence of a no-fishing zone, never mind the combined instance;
  - (ii) the implications for the North Sea fishing industry, as it would be an area that supports a mixed fishery; and
  - (iii) the general imposition of another damaging set of regulations and level of bureaucracy.
- Opposition from Greenpeace and OSPAR Contracting Parties (many of which are members of the EU) to the rigs-to-reefs aspects of the scheme.
- The impracticalities that will exist as a result of the maze of international, EU, and national legislative and administrative procedures that will be required, including the integration of such a concept within the Common Fisheries Policy (CFP).
- Lack of sufficient scientific data to justify the use of reefs when a closed zone to fishing may be enough.
- Lack of a beneficiary and therefore transfer of liability.
- Difficulty of enforcement.
- Problems with dismantling such a scheme if ineffective or unworkable, or, indeed, if successful, there is the question of access provision and whether the reefs should be removed or left in place.

Stakeholder Dialogue

One of the main reasons for the successful implementation of the LARDP in the Gulf of Mexico is the cooperation between the government and private sectors, including the Minerals Management Service, the Louisiana Department of Wildlife and Fisheries, conservation groups, university researchers, and recreational and commercial fishing organizations. This, itself, is built upon cross-sectoral agreement on the need for the LARDP. Historically, such an approach has been lacking for the North Sea, particularly in terms of agreement on the need for a rigs-to-reefs program. This situation has, however, improved recently. The International Association of Oil and Gas Producers (OGP), formerly the Exploration and Production (E & P) Forum, initiated stakeholder dialogue in 1997 to take into account broader interests when shaping future research initiatives. A workshop held in Brussels in 1997 brought together European fisheries industry representatives, nongovernmental research institutes, the offshore industry, environmental interest groups, EU administrators, governmental research bodies, and government departments. These entities worked together to identify key issues and questions that needed to be addressed in order to determipotential for rigs-to-reefs in the North Sea (Environment Council 1997). The questions most often raised under the heading of "social and political aspects" were

- What is the criteria for [determining] success of artificial reefs?
- How can the objectivity and independence of the research be assured?
- How can we measure direct and indirect benefits compared with other abandonment options?
- How could we have rigs-to-reefs without setting a precedent for general dumping?
- How to ensure that [the] dialogue process continues with all parties and active participation in existing regulatory processes and management issues?
- Who would own artificial reefs and who would be responsible or liable in perpetuity?

The second item above is of particular note, as there has in the past been mistrust of some scientific research and its potential bias towards the oil and gas industry. The mistrust reflects the close relationship between academic rigs-to-reefs proponents and the offshore industry. As a result of the workshop, an independent rigs-to-reefs "Steering Group" was formed whose main responsibility is to assess the potential for rigs-to-reefs in the North Sea by guiding ongoing independent research into areas of need and suitability. The steering group is composed of members from the fishing industry, academia, research institutions, environmental pressure groups, and the European Commission who report back to those workshop attendees who expressed a wish to remain in the dialogue process. It should be noted that Greenpeace declined to join the steering group upon its establishment.

It is the steering group who designed the study process to examine the rigs-to-reefs concept and who choose the most appropriate organization to undertake the research. The OGP's only input is through funding. The study process is composed of three stages. Stage one sets two parallel questions to be answered:

- What are the management, environmental, and economic needs of the United Kingdom's eastern and Norway's western seaboards (including nearshore and offshore waters)?
- What functions might artificial reefs be able to perform in the North Sea context?

Stage one research has been completed (Baine and Kerr 2000) and the steering group is currently reviewing the results to determine to what extent the deliverables identified in the answer to the second question meet the needs identified in the answers to the first, compared to the other management options available (Stage two). If the steering group concludes that there is sufficient evidence to justify further investigation, two more parallel questions will be investigated (Stage three):

- Can redundant offshore installations be reused as artificial reefs, and if so, at what cost, and how could the attendant legal, political, and environmental issues be resolved?
- How else might the benefits of artificial reefs be achieved, using what materials, involving what issues, and at what cost?

At present, therefore, there is a mechanism with which to move the rigs-to-reefs debate forward. It is a way that involves all stakeholders, although Greenpeace has distanced itself from the steering group. Greenpeace has declined to join on the basis that the outcome appears to have been predetermined, with little quality discussion on whether or not the concept should have been considered any further before defining research strategies. The Greenpeace attitude embraces the precautionary principle. However, given that UK waters already feature artificial reefs constructed from waste material, combined with the informed assumption that any North Sea rigs-to-reefs program will never approach the levels witnessed in the Gulf of Mexico and that stringent legislative control would be imposed, Greenpeace should enter a dialogue process. At a minimum, the organization should support the need for further conclusive, independent, and authoritative research.

Conclusion

The impacts from the 1995 Brent Spar incident are still being determined at present, with a landmark OSPAR Decision on abandonment. Although more focused, the future of North Sea abandonment is still not entirely clear with the possibility of derogation (Annex 1 of the Decision), the uncertainty over the disposal of concrete installations, and the momentum that has gathered concerning the rigs-to-reefs debate. The rigs-to-reefs concept is by no means a trivial one and requires further close examination that can only be achieved through discussion, negotiation, and proactive participation from all the stakeholders involved. Firstly, this will enable an integration of scientific and social thinking, admittedly on a controversial subject, but nonetheless a valid one. An opportunity exists to comprehensively examine the deployment of steel lattice jackets (waste material) as a fisheries management tool in the North Sea. The success of such ventures in the Gulf of Mexico does not ensure a similar outcome in the North Sea, but it does provide food for thought. Secondly, the importance of avoiding a reoccurrence of the Brent Spar incident must not be underestimated. The relationship between science and political motivation is central to the rigs-to-reefs debate; a trusted independent and authoritative evaluation must be the preferred goal.

There is no doubting the attractiveness of the rigs-to-reefs concept to offshore operators and the opposition of a major influential environmental pressure group to such a concept. It is fishermen, though, who are the most likely to be directly affected by the implications of current abandonment legislation. The possibility of steel platform footings and concrete installations remaining behind on the seabed will entail further consultation on loss of access and potential damage to fishermen and their gear. Fishermen may well feel aggrieved at the historical chain of events that has resulted in a reversal of the promise of complete removal and that has seen countless cross-party discussions bear little fruit. They may well feel that the latest OSPAR Decision 98/3 has gone some way to alleviate those grievances, but has it gone far enough? Fishermen find themselves in the midst of contention. They strive for complete removal, yet still find themselves represented on bodies such as the rigs-to-reefs Steering Group, which indicates their willingness to participate in dialogue and their unstable situation. Greenpeace may be pleased with the direction that the OSPAR Decision has taken, the offshore industry may be dismayed, but it is fishermen who still require clarification of the future. It is the very nature of this position that provides them with the key to the success of any rigs-to-reefs venture in the North Sea. Their cooperation and participation is essential in the promotion of a concept that has been for so long promoted to them.

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GROUNDFISH ADVISORY SUBPANEL STATEMENT ON ARTIFICIAL REEFS IN SOUTHERN CALIFORNIA

The Groundfish Advisory Subpanel (GAP) received a presentation from Mr. George Steinbach regarding proposals to allow oil platforms to be kept in place in the waters off California in order to take advantage of any fish attraction qualities.

The GAP held a lengthy discussion on the benefits and costs of keeping unused oil facilities in place. Some members believed that platforms should be removed for aesthetic reasons, in order to restore fishable area and to comply with the original intent of the offshore oil leases. Other members suggested that the possible fish attraction qualities could be beneficial, that the facilities could operate as de facto marine reserves, and that there was greater potential harm to resources from removing platforms. Some members expressed concern about potential pollution problems associated with platforms and whether these problems are worse if the platforms are left intact or are removed.

GAP members had many questions about the proposed trust fund, including the amount, who the recipients would be, and how the money would be used, especially if there is a need to mitigate impacts on fisheries.

In the end, the GAP agreed there are too many unanswered questions, and the best approach would be to have an independent study, not a study conducted by potential beneficiaries, conducted to examine the questions of pollution, costs and benefits, and effects on fish and their habitat. The GAP recommends the Council exercise its authority to comment on habitat matters by requesting such a study, perhaps by the National Academy of Sciences, through the appropriate federal agency.

PFMC
03/11/04

GROUNDFISH MANAGEMENT TEAM REPORT ON ARTIFICIAL REEFS IN SOUTHERN CALIFORNIA

The Groundfish Management Team (GMT) reviewed the issue of converting Southern California oil platforms (rigs) to artificial reefs, focusing in on how these reefs might enhance or impact groundfish. While it is noted that these oil platforms do provide habitat and structure for some species of groundfish in the immediate area under and around the rig, there are still questions about the quality of this habitat and how much it contributes to the production and growth of groundfish stocks. Due to the unique environment created by the oil platform, fish densities around these platforms are higher than those observed in adjacent lower relief natural reefs. Fish are attracted to the structure, young recruits congregate within the water column around the reefs, and, because many of these rigs are over 20 years old and act as defacto reserves (fishing is not allowed near the platforms), residential rockfish populations have become established. However, the question of how much of this density of fish is due to reproduction rather than attraction has not been resolved.

Removal of the entire rig will impact the established rockfish populations in the shell mounds under the platforms but if the rigs are converted to artificial reefs, and these reefs become available to fishing, then the populations of groundfish species within these reefs will be impacted. The extent of this impact will depend upon how the harvest rates for these species compare to the production rates, particularly given the relatively small size of these areas. Non-residential species from adjacent waters, moving into the area due to the structure in the water, also will become more vulnerable to fishing around these reefs.

In addition, little information is available on the contaminants (including crude oil) present in the mud discharges around the reef and less is known about the impact of these contaminants on the resident groundfish species.

In light of the above, the GMT recommends that the Council continue to monitor this issue of converting Southern California oil platforms.

PFMC
03/11/04

Exhibit G.3.c
Supplemental HC Report
March 2004

HABITAT COMMITTEE COMMENTS ON ARTIFICIAL REEFS IN SOUTHERN CALIFORNIA

The Habitat Committee (HC) heard a presentation from Mr. George Steinbach of CARE (California Artificial Reef Enhancement Program), which advocates converting oil platforms in Southern California to artificial reefs. There are 26 platforms, 23 of which are in federal waters and are due for decommissioning over the next decade.

If oil platforms are retained in some form as habitat enhancement, the choice of whether or not to allow fishing near the structure may dramatically impact their potential benefits as habitat.

There is a large amount of information on this topic, especially from the Gulf of Mexico, but many uncertainties remain as to whether they provide management and habitat benefits applicable to Council-managed stocks (e.g., such questions as if they are aggregating devices versus enhancing larval settlement). The platforms currently serve as habitat for many species, but have altered prior habitat. There are proposals to use platforms not only for artificial reefs, but also for aquaculture, research platforms, ecotourism, liquefied natural gas terminals, and other purposes. Because there are a number of relatively similar structures, they offer a potential use as a research tool for a variety of purposes.

There are fishery management issues associated with leaving platforms in place. There are positive and negative implications for habitat, commercial and recreational fisheries, and overfished species. We are prepared to delve further into this emerging issue at the Council's request.

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MEMORANDUM

To: Pacific Fishery Management Council
From: Rod Fujita, Ph.D – Marine Ecologist, Environmental Defense
Date: March 1, 2004
Re: Implications of using artificial reefs to achieve fishery management objectives

While there is clearly abundant life associated with oil platforms, including FMP fish species such as rockfish, many open questions remain about the effects of converting platforms into artificial reefs. Before any policies regarding platforms are adopted, credible answers to these questions are needed so as to avoid potentially negative impacts. Moreover, precautionary policies (such as banning fishing around platforms that are left in place) are called for in light of the high degree of uncertainty surrounding these major policy questions. The questions include:

1. Do platform-associated populations increase the net production of fish on a regional basis, or do they simply attract individuals (resulting in no net increase in production)?
2. Is there sufficient platform habitat to significantly enhance rebuilding or yield on a regional scale?
3. Do artificial reefs make FMP species, particularly low-productivity species, more vulnerable to over-exploitation by attracting fishing effort?
4. Do the environmental and economic benefits of decommissioning and removal of oil platforms outweigh the environmental and economic costs?

NET PRODUCTION OR ATTRACTION?

The study of Love et al. (2003) is observational and depends mainly on correlations, rather than on experimental evidence. The results are therefore inconclusive regarding whether platforms are net producers of fish or not. Fish abundance and densities for certain species may be higher at oil and gas platforms than at natural reefs, but this does not answer the attraction vs. production question. Oil and gas rigs may recruit larvae, rather than only attracting adult fish away from natural reefs, but it is thus far impossible to tell whether those fish would have otherwise recruited to a natural reef, in which case platforms are detracting from natural reefs.

Any enhancement of natural production by artificial structures is likely to be highly site-specific and species-specific, dependent on whether substrate availability is "limiting" (i.e., the major constraint on survival and/or reproduction) to specific populations under a particular set of conditions. Hence, it will likely be difficult to interpret studies conducted in other geographical areas and habitat types to west coast waters. **Many studies suggest that artificial reefs (not subject to special protections) increase fishing effort, increase potential for overexploitation, and increase the probability of overexploitation (Grossman et al., 1997).**

Since the science is, thus far, inconclusive about the fish attraction and production question and because the answer to this question is likely to depend strongly on local/regional conditions, we believe that **if oil rigs are left in place, they should be placed in fully protected status until the question of production versus attraction can be resolved with empirical, manipulative experiments. In this way any benefits of oil rigs can be captured, while at the same time mitigating against any adverse effects.**

SUFFICIENT ARTIFICIAL HABITAT?

Environmental Defense concurs with the conclusion of the Select Scientific Advisory Committing on Decommissioning (Holbrook et al. 2000): **we are not aware of any scientific evidence that oil platforms can significantly enhance regional rebuilding or yields**. Most studies focus on local, not regional impacts of platforms, and so part of the reason for this lack of evidence is the paucity of appropriate studies at the appropriate scale. However, there is some reason to believe that platforms are unlikely to significantly enhance the attainment of fishery management goals; the total habitat area represented by platforms is tiny compared to the amount of natural habitat. Even if platforms turned out to be net producers of fish biomass, and even if they produced disproportionately large amounts of eggs (for example, if fishing were banned near the platforms, thus protecting the larger size classes of fish), the total contribution to recruitment would be expected to be quite small. Marine reserve models suggest that more than 25% of the total population size of a fish stock should be protected from fishing in order to significantly enhance fishery yield. Platforms represent far less area than that.

FISH MORE OR LESS VULNERABLE?

Part of the attraction of artificial reefs (and by extension, the concept of leaving platforms in place to serve as artificial reefs) is that fishermen can find them and fish them easily, particularly sportfishermen (Grossman et al., 1997). Hence, there is reason to believe that platforms would be fished more heavily than other areas, making their fish populations more vulnerable to overexploitation. **If the fish populations in greatest need of rebuilding are the lowest productivity and most vulnerable species (e.g., rockfish), and if the rationale for leaving the platforms in place is to enhance rebuilding and yields, then it follows that if the platforms are left in place fishing near them should be banned.** This would be necessary to prevent the dissipation of the potential long-term rebuilding and yield benefits in favor of short-term landing and revenue enhancements arising from the exploitation of spillover from the platforms.

LEAVE IN OR REMOVE?

There will certainly be initial adverse effects of removing platforms, such as death of organisms living on and around the platform and alteration of surrounding habitat resulting from removal activities. There are also likely to be negative impacts of leaving the rigs in place, such as heavy metal contamination of the organisms living on and around the rig, potential oil and gas leaks, potential accidents with boats, etc. Topping off the platforms and leaving them in place could potentially enhance habitat for opportunistic, invasive species. There is some evidence that other kinds of structural modifications of natural habitats may enhance prospects for biological invasions. Platforms in the Gulf of Mexico appear to provide a favorable habitat for dinoflagellate algae that cause ciguatera fish poisoning, a debilitating and potentially lethal condition that could have serious negative consequences for seafood demand (see attached powerpoint presentation). Some tropical species such as toxic dinoflagellates appear to be highly aggressive invasives, and appear to be moving into historically temperate waters due to climate change.

SUMMARY AND RECOMMENDATIONS

Environmental Defense concurs with the Select Scientific Committee on Decommissioning in their conclusion that predicting the effects of leaving the platforms in place is impossible given the current state of scientific knowledge. Making policy when uncertainty is this high would be irresponsible. Hence, we call for a precautionary approach.

Artificial reefs and platforms may have an as yet unknown potential for generating some fishery benefits (although not necessarily the enhancement of rebuilding or total yield), which may offset some of the adverse impacts of removing them. For example, they could enhance sportfishing experiences and revenues by providing larger fish and higher encounter rates, just as marine reserves do. The potential revenue stream from the oil industry for use in conservation and management in exchange for reneging on their obligations to remove the platforms is another benefit that must be weighed.

- **We recommend a set of rigorous studies designed to answer the major questions above, prior to any policy decisions on decommissioning.**

The studies should focus on: (1) empirical/manipulative tests of net production and self-seeding on platforms, versus attraction from natural reefs; (2) model of fishing effort changes in response to decommissioning; (3) model scenarios of policy options with projected ecological and economic impacts, including (a) leaving platforms in place with no-take status; (b) leaving platforms in place with no-take status with adaptive management sport-fishing only buffer area; (c) leaving platforms in place with sport-fishing only buffer area; (d) leaving platforms in place with commercial and sport-fishing allowed. The studies should be peer-reviewed. Results can be combined with results from studies and models of the impacts of removal of platforms versus leaving them in place to inform policy deliberations.

Literature Cited:

Grossman, G.D., G.P. Jones, and W.J. Seaman Jr. 1997. Do artificial reefs increase regional fish production? A review of existing data. Fisheries, April 1997, pp. 17-23.

Holbrook, S.J., R.F. Ambrose, L. Botsford, M.H. Carr, P.T. Raimondi, and M.J. Tegner 2000. Ecological issues relating to the decommissioning of California's offshore production platforms. Report to the University of California Marine Council of the Select Scientific Committee on Decommissioning.

Love, M.S., D.M. Schroeder, and M.N. Nishimoto 2003. The ecological role of oil and gas production platforms and natural outcrops on fishes in Southern and Central California: A synthesis of information. USGS OCS Study MMS 2003-032.

Ecological Issues Related to Decommissioning of California's Offshore Production Platforms

Report to the University of California Marine Council
by
The Select Scientific Advisory Committee on Decommissioning
University of California

Sally J. Holbrook, UC Santa Barbara, Chair
Richard F. Ambrose, UC Los Angeles
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November 8, 2000

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Executive Summary

The Select Scientific Advisory Committee on Decommissioning explored possible marine ecological implications related to the decommissioning of California's twenty-seven offshore oil production platforms to assess the current state of knowledge and identify a research agenda to fill information gaps. The Committee explored the ecological consequences of five identified decommissioning options for coastal platforms including (1) leaving the intact structure in place, (2) complete removal, (3) top portion of platform removed to 20 to 30 meters subsurface and remaining lower portion left standing in place ("topping"), (4) structure toppled over in the same location ("toppling") and (5) structure moved to a new location and toppled.

Biotic surveys of California platforms indicate that many different species of fish and invertebrates can be found on the current platform structures, with some of these species spending only part of their lives there. The set of species that occupies a platform is influenced by the biogeographic setting of the platform, as well as its depth. Based on existing biological information, some of the local, short-term effects of decommissioning options can be estimated, but the Committee wishes to emphasize that longer-term regional effects cannot be predicted with reasonable scientific certainty. The regional effect on stocks of species is the most important possibility to examine from an ecological perspective.

There is not any sound scientific evidence (that the Committee is aware of) to support the idea that platforms enhance (or reduce) regional stocks of marine species. The primary reason for this conclusion is that the 27 platforms represent a tiny fraction of the available hard substrate in the Southern California Bight, so their contribution to stocks of most reef organisms is likely to be small relative to the contribution from natural reefs. The Committee felt it was important, however, that it fully explore the state of knowledge on possible ecological impacts even though the habitat contribution of these platforms is, as just described, necessarily limited. In doing so, the Committee found that the possible regional effects on a stock of habitat removal are much harder to assess than the short-term ecological impacts localized at the site of the platform because most marine species are composed of a series of local populations that are connected via larval dispersal of young stages. Thus, populations are interdependent, and impacts at any one location (a reef or platform) must be viewed in the context of the regional set of local populations. Regional effects cannot be projected at present because we do not fully understand how local populations are connected (i.e., we know that larvae are transported and older individuals move between various reefs, artificial reefs and oil platforms, but we do not understand specific links among local populations) nor do we know the degree to which populations on artificial structures are self-sustaining.

A research agenda to address the marine ecological consequences of decommissioning should include (1) assessing the quality of habitat for marine species afforded by platforms compared to natural reefs; (2) estimating the connectivity between local populations; and (3) developing models of the effects on the regional population of key

species of the addition or removal of artificial structures (such as would result from the various decommissioning options). Additionally, to best evaluate decommissioning alternatives one would need several other types of information that address (1) spatial and temporal patterns of distribution and abundance of reef-associated species in different parts of the Southern California Bight, including on natural reefs and associated with platforms, (2) distribution, abundance and quality of natural hard substrate in the area, and (3) physical oceanographic data to identify patterns of water circulation off the coast of California, coupled with estimates of population connectivity for species of interest. In the opinion of the Committee, no matter what policy decision about decommissioning is made, the effects should be monitored, and the State should adaptively respond to the consequences of the decision.

At the end of its investigation of marine ecological issues surrounding decommissioning of California's offshore platforms, the Committee drew several general conclusions that could be useful to policymakers. These are reported on pages 35 – 36, and are reproduced here for convenience.

1. Surveys of platforms in California waters reveal that they harbor rich assemblages of marine organisms, including many fishes and invertebrates that typically occur on natural rocky reef substrates. The particular species present on any given platform depend on the biogeographic setting of the platform and its depth, as well as other factors. Despite the fact that platforms can harbor abundant marine life, it is the platform's contribution to regional stocks of species that is the crucial metric for evaluating its ecological impact. This is due to the fact that most marine species consist of a series of local populations (such as would occupy a reef) that are linked together by larval dispersal of young stages. The interdependence of populations means that impacts at any one location must be considered in the context of the regional set of local populations. Most extant assessments of possible biological effects of platforms are fundamentally flawed because they focus on local and not regional effects. At present there is not any sound scientific evidence (that the Committee is aware of) to support the idea that platforms enhance (or reduce) regional stocks of marine species.
2. The total "reef" area represented by the 27 California platforms is extremely small in relation to regional availability of hard bottom substrates, suggesting that for the majority of species any regional impacts (whether positive or negative) of a decommissioning option are likely to be small and possibly not even detectable empirically.
3. However, because species differ greatly in life history, population dynamics, and geographic distribution, it is possible that platforms could have a more substantial effect (either positive or negative) on some key species. These species might be of special interest from a management point of view – rare or endangered, of economic importance, etc. In such cases, further study of effects of decommissioning alternatives, using approaches outlined in this report, could yield the scientific information needed to predict impacts of decommissioning alternatives in the context of overall management strategies. Species of special

concern could include, for example, several rockfishes whose low abundance has triggered severe restrictions on harvest and the creation of rebuilding plans by the Pacific Fishery Management Council (McCall *et al.* 1999). Bocaccio, for example, is estimated to have declined to about 1 percent of virgin biomass. Love *et al.* (2000) reported that Platform Gail had a density of adult bocaccio an order of magnitude greater than the average density found on 61 natural reefs in appropriate depths. The issue, then, is to evaluate whether these higher densities of some populations on platforms persist through time, and if so, whether they could have a positive effect on regional stocks, given the very small surface area that the offshore platforms represent.

4. Decommissioning of offshore oil production facilities will involve offshore as well as onshore structures, and the various alternatives would involve a broad array of possible consequences that include not only the marine ecological effects we have addressed, but also economic, political and social impacts. These factors would need to be evaluated together to reach a final decision as to whether a decommissioning alternative other than platform removal is desirable. Nevertheless, with the current state of knowledge, predicting effects of decommissioning options on regional stocks of marine species is not possible. Indeed, there is no clear evidence of biological benefit (in the sense of enhancement of regional stocks) of the platforms in their present configuration. Thus, in light of the lack of strong evidence of benefit and the relatively small contribution of platforms to reef habitat in the region, evaluation of decommissioning alternatives in our opinion should not be based on the assumption that platforms currently enhance marine resources.

I. Introduction

I.A. Committee objectives

There are twenty-seven oil platforms off the California coast. During the next two decades a number of these facilities will reach the end of their useful life and will be decommissioned. Under the terms of current state and federal leases, platforms would be completely removed at the time of decommissioning. However, it has been suggested that using the structures for artificial reefs might provide significant benefits, and this has led to increased interest in exploring the costs and consequences of various other decommissioning strategies. These strategies could involve leaving the platform or some of its components in the same location or moving materials to form an artificial reef in a new location. At the request of State Senator Dede Alpert, the University of California Marine Council (UCMC), in consultation with the University of California Office of the President, appointed a Select Scientific Advisory Committee to explore marine biological issues related to the decommissioning of offshore oil production facilities. The first task of the Committee was to assess the state of knowledge regarding the potential ecological and environmental consequences of various decommissioning strategies, to determine what is known as well as to identify information gaps for decision makers. Additionally, the Committee has endeavored to articulate the degree of uncertainty in our current understanding of the biological issues and the extent to which this uncertainty affects assessment and evaluation of various decommissioning alternatives. The Committee has articulated a set of research questions that would need to be answered in order to evaluate the consequences of various decommissioning alternatives.

The Committee examined five identified decommissioning options of coastal oil/gas platforms. These are described in Section **II.B**. Decommissioning of offshore oil production facilities in its broad context involves offshore as well as onshore and associated structures, and a wide variety of possible consequences, including ecological, economic, cultural, political, social, ethical and aesthetic. The Committee was given the more specific focus of addressing only *ecological consequences in the marine environment*. Thus, the scope of issues addressed was restricted to marine ecological considerations and did not consider the direct or indirect ecological or environmental consequences to the atmospheric or terrestrial environments, or the many socio-economic or political considerations. Clearly, these factors should be evaluated together if the State were to consider alternatives to the present strategy for decommissioning (complete removal).

Our analysis considered the 27 platforms along the coast of California in light of their regional distribution. There are four platforms north of Point Conception in the Santa Maria Basin, sixteen platforms in the Santa Barbara Channel and seven platforms in San Pedro Bay. The Committee endeavored to identify potential ecological consequences of the various decommissioning alternatives over both short (weeks to months) and long (decades) time periods and at local (at the platform) and regional spatial scales. The importance of understanding consequences at a range of scales was motivated by the biological features of the marine life typically associated with offshore oil structures. First, most of these populations of fish, invertebrates and algae have early life stages (i.e. eggs, larvae, spores) that can be dispersed great distances (in some cases up to hundreds of kilometers) but adult stages that often remain in localized reef areas. This necessitates examining consequences to their populations in the close vicinity of the platform as well as further away, because early life stages are exchanged among local populations. Second, many of the species involved are very long-lived, and numerical effects on their populations (whether beneficial or deleterious) could take years or even decades to accrue.

I.B. Structure of this report

This report has several sections. **Section II** provides several types of background material. We briefly review the physical setting and biological features of offshore platforms in California, and outline five proposed decommissioning alternatives. Since one strategy proposed for decommissioning oil platforms in offshore California is to use portions of platforms to create artificial reefs, we review general management objectives for artificial reefs, and consider processes for evaluation of those objectives. This is followed by a summary of California's artificial reef program, and remarks on decommissioning conducted in the Gulf of Mexico, where a "Rigs to Reef" program has been in place since the 1980's.

In **Section III** biological features of marine species are described to illustrate the spatial and temporal scales that are appropriate for the study of these populations, and the types of information that are needed to assess ecological costs or benefits of any particular management strategy. Next, possible ecological responses and consequences of various decommissioning alternatives are outlined, in the context of what is known about some of the key species of fish and invertebrates that occur on offshore structures such as oil platforms. In this section we point out areas where there is incomplete knowledge to estimate potential effects (either in space or over time). **Section IV** articulates a set of key research issues and questions that could be addressed to fill information gaps, and presents the general conclusions of the Committee.

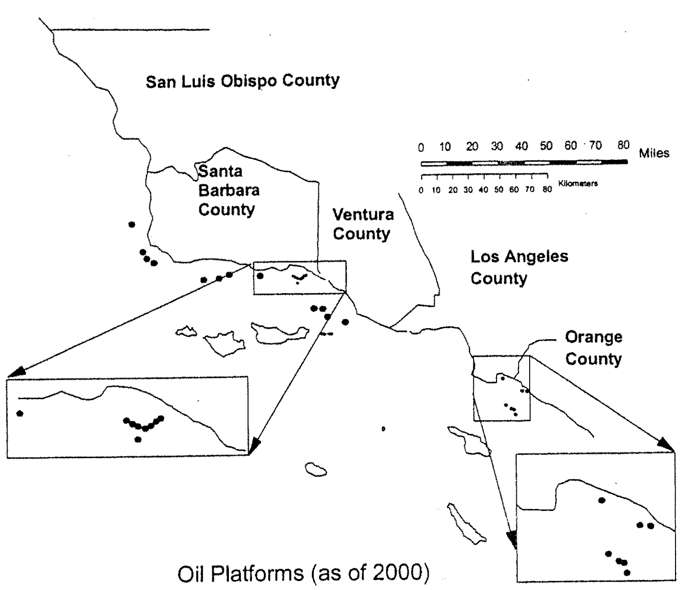
II. Background

II.A. Review of California platforms

II.A.i Geography of California platforms

The 27 existing offshore production platforms are distributed in State and Federal waters from just north of Pt. Arguello (Platform Irene) south to the suite of 7 platforms off Orange County (Figure 1, Table 1). This distribution spans four general regions, Pt. Conception, East and West Santa Barbara Channel, and Orange County. In the north, the Pt. Conception region is bathed by the colder California Current that flows south from central California. This region is also characterized by the presence of low relief rocky reefs throughout depths at which platforms occur, although the extent of this rocky bottom habitat has not been fully delineated. In contrast, the southernmost region off Orange County is bathed in warmer currents flowing northward from Mexico. This area is typified by a predominance of sandy substrate and a paucity of rocky reef habitat, particularly compared to the region around Pt. Conception. Platforms in the two regions within the Santa Barbara Channel are distributed along a gradient between these two extremes. In all locations, water conditions vary seasonally, among years due to El Nino-Southern Oscillation events, and during decade-long regime shifts. The abundance of rocky reef habitat in the Santa Barbara Channel appears to be intermediate to levels to the north and south of the Channel. These regional differences in oceanographic conditions and relative abundance of rocky reef habitat have important implications for the kinds of species inhabiting platforms and the degree to which platforms contribute to regional abundance of hard bottom habitat.

Figure 1. Distribution of offshore platforms along the coast of California.



Oil Platforms (as of 2000)

II.A.ii Physical structure of California platforms

California's offshore production platforms range widely in size, depth and structural complexity (Table 1). The underwater structure of offshore platforms is characterized by a matrix of vertical, diagonal and horizontal pipes of varying diameter. These are referred to collectively as the "jacket". Platforms typically consist of 6 to 8 large (1 to 5 meter diameter) vertical legs with a matrix of horizontal and diagonal members of smaller (0.25 to 1 meter) diameter that extend between the legs at varying depths along the entire length of the legs.

Table 1. Structural characteristics of the 27 offshore platforms along the coast of California.

Number	Name	State / Federal Waters	Region	Depth (m)	Footprint (m^2)	Surface Area (m^2)	Volume (m^3)
1	Irene	Federal	Pt. Conception	73	2633		192,793
2	Hildago	Federal	Pt. Conception	130	4154		564,086
3	Harvest	Federal	Pt. Conception	205	5859		444,720
4	Hermosa	Federal	Pt. Conception	184	5142		944,097
5	Heritage	Federal	West SB Channel	326	nd		nd
6	Harmony	Federal	West SB Channel	363	10606		nd
7	Hondo	Federal	West SB Channel	255	4649		nd
8	Holly	State	West SB Channel	66	nd		21,515
9	A	Federal	East SB Channel	58	1930	15,900	80,541
10	B	Federal	East SB Channel	58	1930	15,900	80,541
11	C	Federal	East SB Channel	58	1930	15,900	80,541
12	Hillhouse	Federal	East SB Channel	58	nd		nd
13	Henry	Federal	East SB Channel	52	1505		50,403
14	Houchin	Federal	East SB Channel	49	1435		68,350
15	Hogan	Federal	East SB Channel	47	1435		68,350
16	Habitat	Federal	East SB Channel	88	2284		nd
17	Grace	Federal	East SB Channel	96	3090		244,196
18	Gilda	Federal	East SB Channel	62	2342		132,800
19	Gail	Federal	East SB Channel	224	5327		1198,176
20	Gina	Federal	East SB Channel	29	561		16,414
21	Edith	Federal	Orange County	49	2879		nd
22	Elly	Federal	Orange County	80	2949		nd
23	Ellen	Federal	Orange County	80	2511		nd
24	Eureka	Federal	Orange County	212	4635		nd
25	Emy	State	Orange County				
26	Eva	State	Orange County				
27	Esther	State	Orange County				

II.A.iii Marine biota associated with California platforms

One prerequisite to predicting the ecological consequences of decommissioning options on communities of coastal marine species is knowledge of what species occur on offshore platforms as well as on nearby natural reefs. Some surveys of biota associated with California platforms have been conducted (Love *et al.* 1994, 1999a, 1999b, 2000, Page and Dugan 1998, Page *et al.* 1999, Carr *et al.* 1999). Data gathered to date indicate that the species composition and abundance on platforms vary spatially (i.e., among the platforms) and also over time on any particular platform. Further, the numbers of some coastal species are very low on platforms and others occur in large numbers, that is, some species appear to have a much higher propensity for occupying platforms than others. One example is provided from surveys of fishes on platforms and natural reefs located in the eastern Santa Barbara Channel (Figures 2 and 3). Relative density (the relative number of fish per volume of water) of some species was far greater on platforms than on nearby natural reefs, while other species were not observed on platforms although they were abundant on nearby natural reefs (Carr *et al.* 1999). Two studies recorded relatively large numbers of some rockfish species on platforms suggesting the possibility that these species could be influenced more by the presence of platforms, whereas several shallow-dwelling, kelp-associated species and surfperches could be less influenced (Love *et al.* 1999b, 2000, Carr *et al.* 1999).

Figure 2. Relative density of shallow-dwelling fish species (excluding rockfish) between platforms and natural reefs in the eastern Santa Barbara Channel (data from Carr *et al.* 1999). SP = Surfperch, G. Kelpfish = Giant Kelpfish

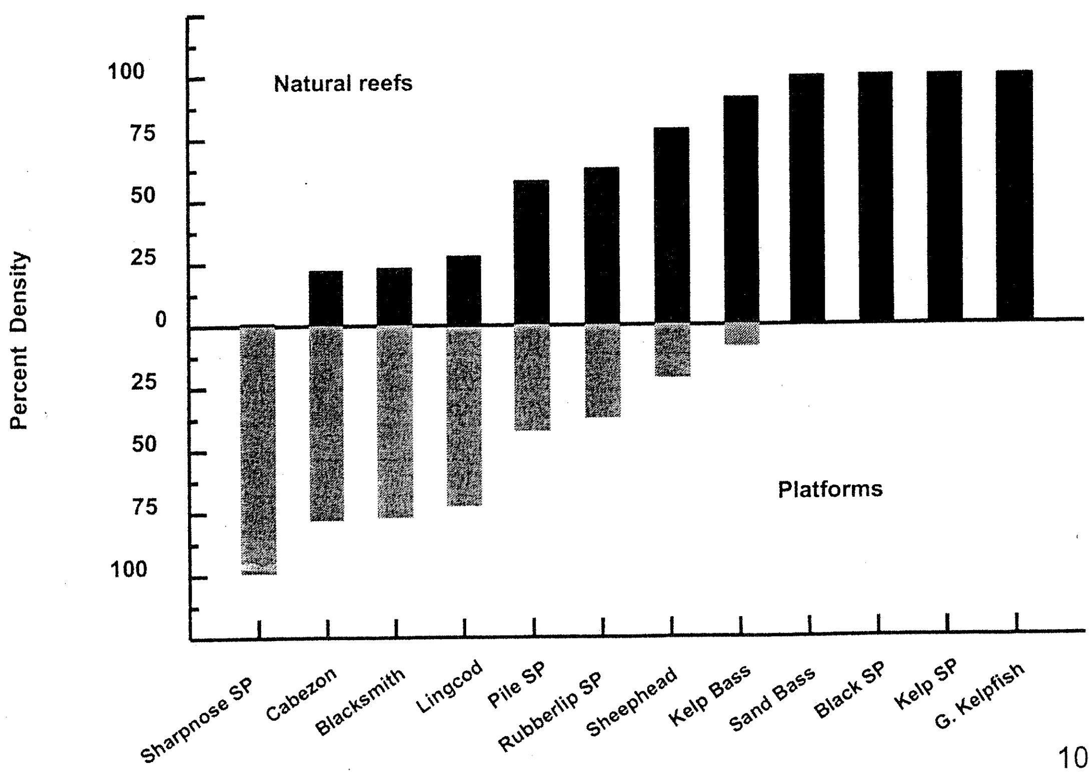
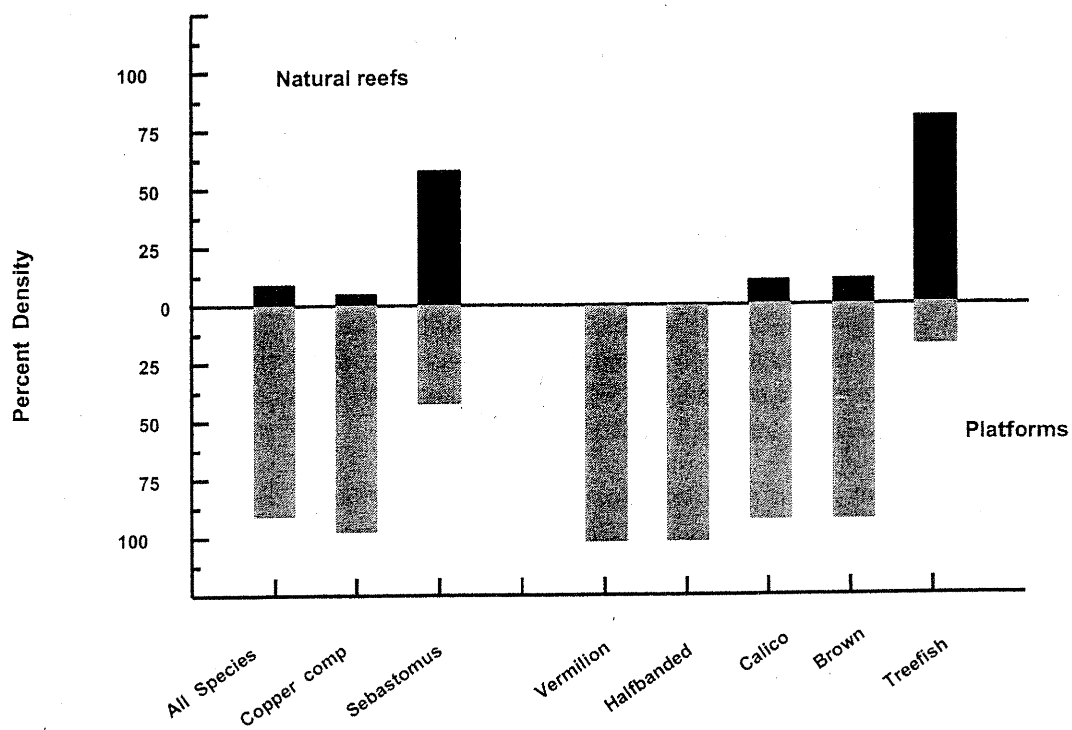


Figure 3. Relative density of some benthic rockfish species between platforms and natural reefs in the eastern Santa Barbara Channel (data from Carr *et al.* 1999).



As mentioned above, the species composition of reef fishes associated with offshore platforms differed among individual platforms, and some of this variation appeared to arise from the geographical locations where platforms occur (Figure 4). Most notably, the relative abundance of rockfishes was greater in more northern colder waters (i.e., near Pt. Conception) whereas the relative abundance of non-rockfish species (e.g., blacksmith, senorita, kelp bass) was greater on platforms in more southern, warmer waters (i.e., eastern Santa Barbara Channel). Most types of rockfishes including the "copper complex" (e.g., kelp, copper, gopher rockfish), mid-water (e.g., blue, black, olive, yellowtail rockfish), benthic (e.g., vermilion, calico, brown rockfish), and deep benthic (e.g., rosy, chilipepper, bocaccio, halfbanded rockfish) occurred at higher densities and comprised a greater proportion of the fish assemblage on platforms around Pt. Conception. Thus, for any particular location, the assemblage structure will depend on biogeographic patterns of fish assemblages, generally mimicking patterns on natural reefs among these regions. The natural patterns of distribution clearly will determine what species of fishes and invertebrates could be influenced by the presence of a platform at a particular site.

Offshore oil platforms extend throughout the water column (from the ocean bottom to the surface). Data gathered to date clearly indicate that different species of fish and invertebrates occur at different depths on the platforms. Information on the vertical (i.e., depth) distribution of species on a platform is necessary for predicting the potential consequences of various decommissioning options such as removing the upper 20 to 30 meters of a platform (i.e., Section II B; Option 3, "topping") or reducing the height of a platform by placing it on its side (i.e., Section II B; Options 4 and 5 "toppling" in place or relocating the platform elsewhere). [These options are described more fully in Section II.B.] Because of the rapid attenuation of sunlight and the strong depth stratification of larvae of most marine species, the upper 20 to 30 meter portion of a platform supports disproportionate amounts of algae as well as recruit stages and adults of some invertebrate and fish species (Figures 4 and 5, respectively). For example, the rich cover of sessile invertebrates (e.g., sea anemones, mussels, scallops) is restricted to the upper 40 meters of water depth (Figure 5). Likewise, many shallow-dwelling fishes are limited to the upper portions of the platforms.

Some species remain on platforms for only part of their lives. Some recruit from the plankton to platforms, then leave, while others arrive as adults. Some species recruit to platforms and remain for their lifespan. The data available at present indicate that recruitment of not only the shallow-dwelling invertebrates and fishes, but also some deeper-dwelling crabs and fishes, occurs primarily in the upper portions of the platforms (Figure 6, Table 2). As such, removal of this upper portion of the structure may have negative effects on those species that recruit there. In contrast, several species of deep benthic rockfish recruit directly to and remain near the bottom of platforms (Figure 6), in which case loss of the upper platform may not influence their recruitment. However, loss of the upper section of platform may reduce or eliminate production of mussels and other organisms that supply food and habitat at the bottom of the platform (e.g., mussels). Overall, species differ markedly with respect to the depths at which their young recruit and depths that adults inhabit (Table 2). Knowledge of these relationships is incomplete at present but it is necessary for the prediction of how loss of the upper portions of platforms, or reconfiguration of a platform by placing it on the bottom at a deep depth, could alter availability of habitat for recruitment or adults and thus result in changes in biota associated with a (reefed) platform.

Figure 4. Variation in the structure of fish assemblages associated with offshore platforms among regions (eastern Santa Barbara Channel vs. Pt. Conception) and platform depth (shallow and deep are less than and greater than 70 meters, respectively). Shown separately is the assemblage structure in the uppermost 40 meters of platforms (sampled by divers) and below 40 meters (sampled by ROV and submersible). Species A= shallow-dwelling non-rockfish species, B= "copper complex" rockfish species, C= mid-water rockfishes, D= benthic rockfishes and E= deep benthic rockfishes. Group E species in the upper 40-meter depth were young-of-year (i.e., new recruits) (data from Love *et al.* 1999b, and M. H. Carr, unpublished).

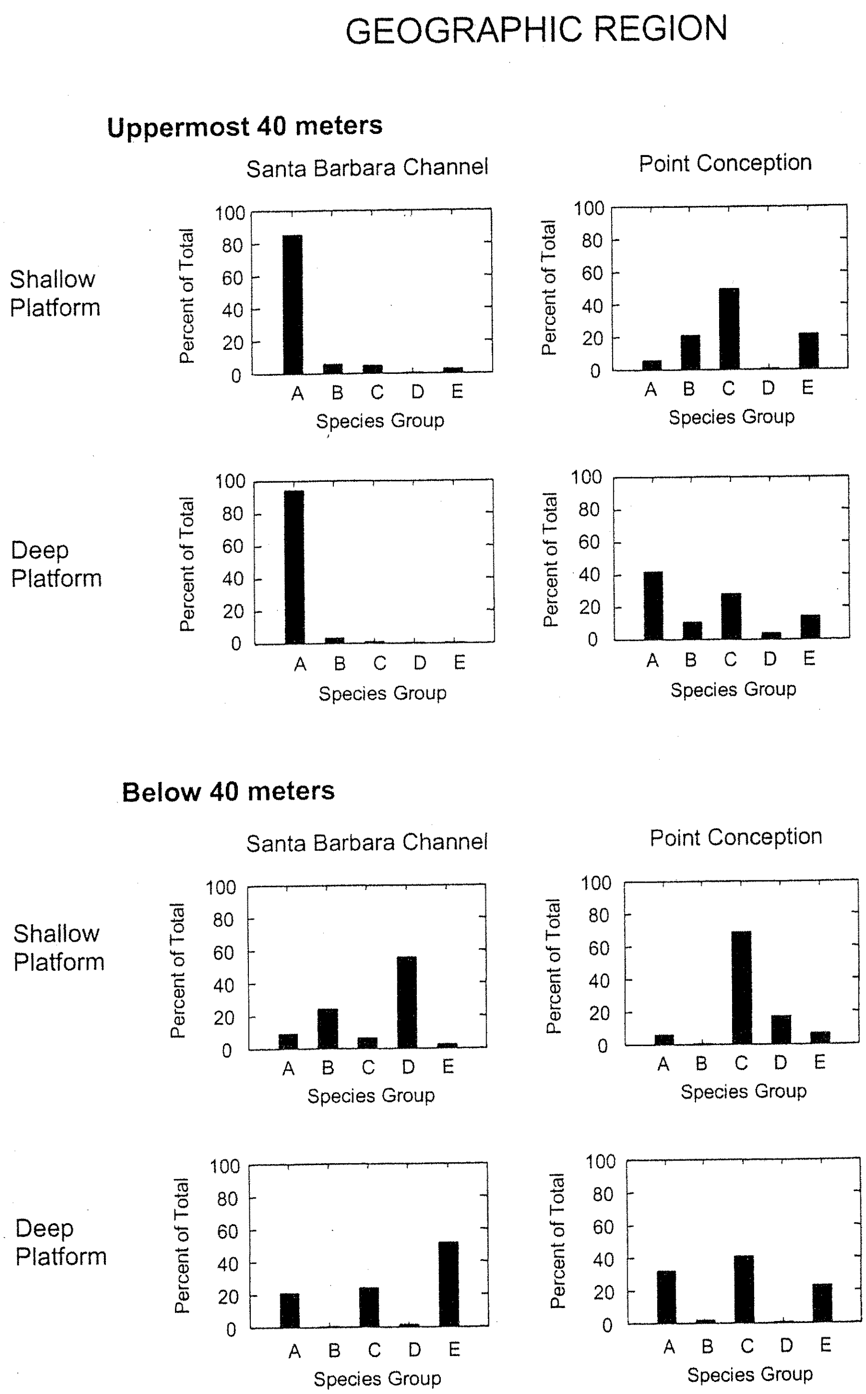


Figure 5. Vertical distribution of abundant or exploited invertebrate species on a platform in the eastern Santa Barbara Channel (data from Page *et al.* 1999, and M. H. Carr, unpublished).

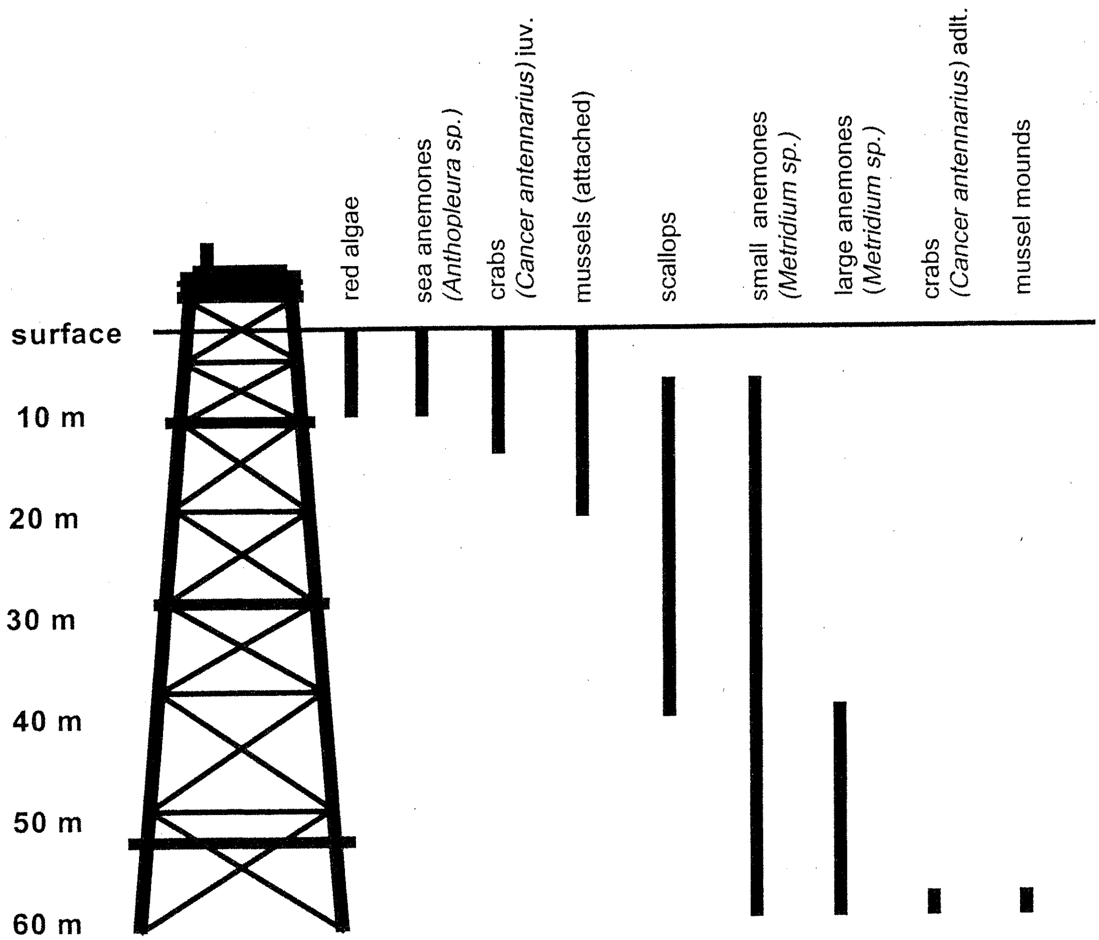


Figure 6. Vertical distribution of recruits (young-of-year) and older shallow-dwelling (copper complex), mid-water and deep benthic rockfishes. See text for implications of the three different patterns of recruitment and adult distribution for possible consequences of decommissioning options (data from Carr *et al.* 1999).

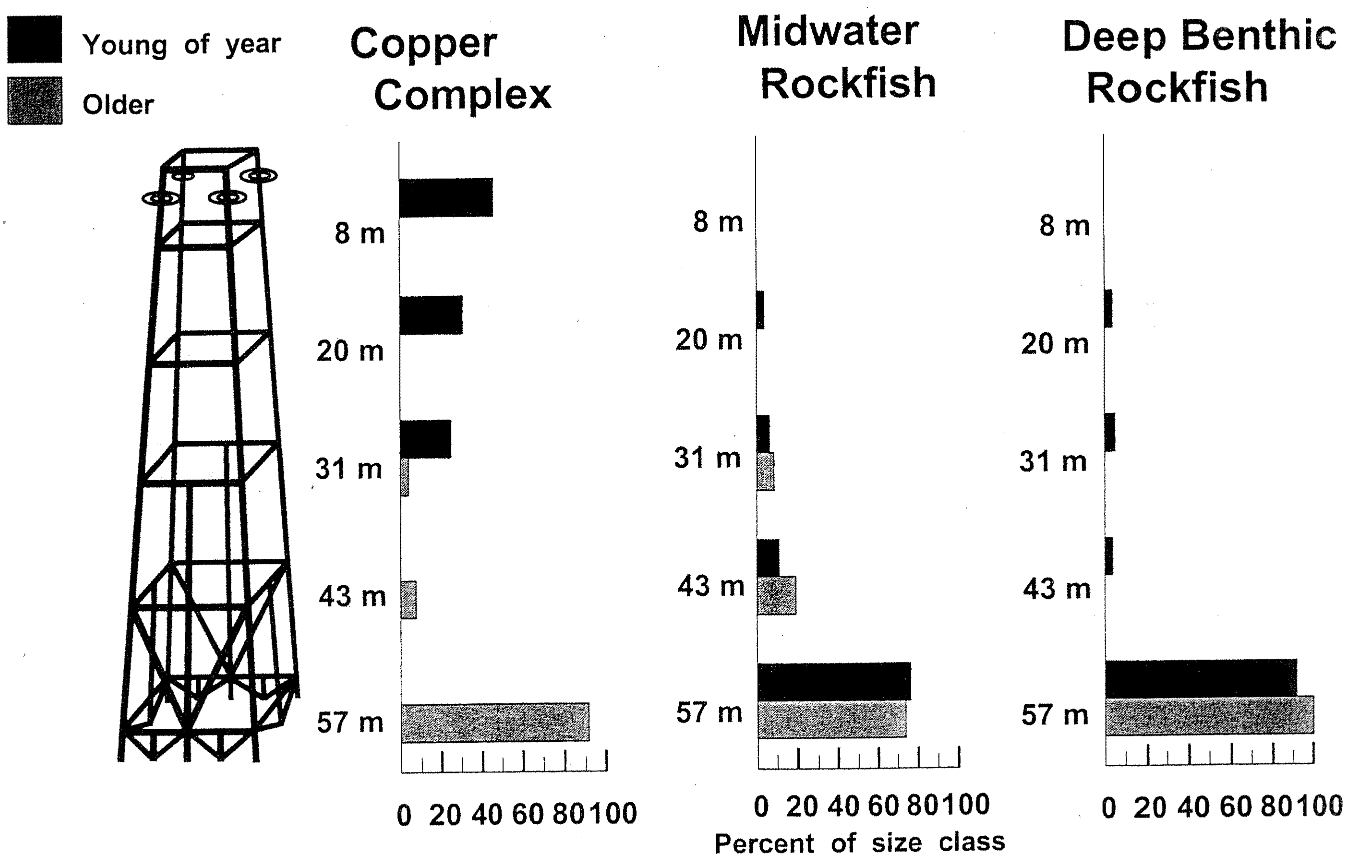


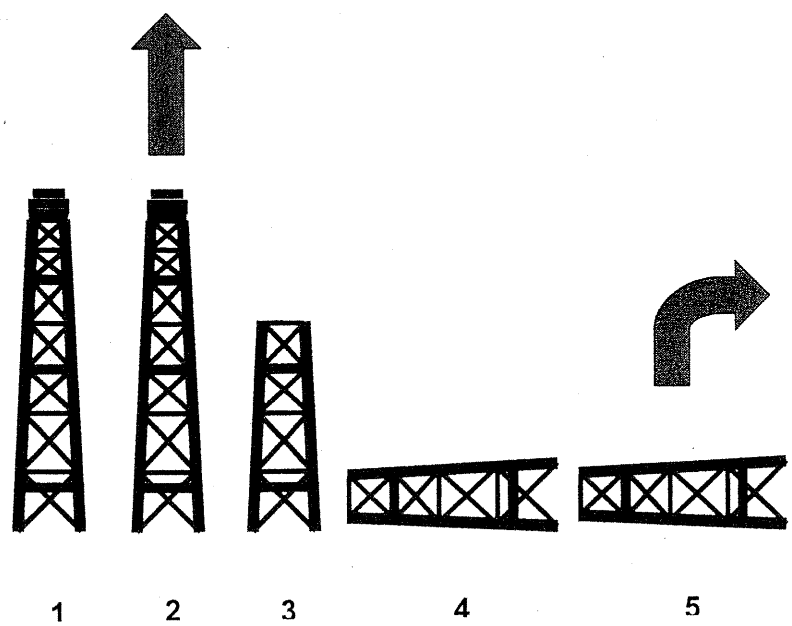
Table 2. Species differences in depth-related patterns of recruitment and adult distribution. Many species recruit to and remain at shallow depths. Other species recruit to shallow depths, then migrate deeper as they grow and age. Still others recruit directly to and remain in the deep-water portion of the platform structure. The 20-meter depth delineates the approximate depth at which a platform would be cut if the "topping" option were exercised.

		Recruitment Depths	
		Shallow (< 20 m)	Deep (> 20 m)
Adult Depths	Shallow (< 20 m)	shallow benthic rockfish, blacksmith, senorita, kelp bass, half moon, mussels, barnacles, red algae, *Anthopleura*, amphipods	none
	Deep (> 20 m)	copper rf, boccacio rf, widow rf, yellowtail rf, olive rf, lingcod, cabezon, *Cancer antennarius*	deep benthic rockfish, *Metridium giganteum*, brittle stars

II.B. Decommissioning alternatives

Here we address five decommissioning options that represent a range of possibilities that could be considered (Figure 7; Manago and Williamson 1998). These five options include (1) leaving the entire structure intact where it is currently located, (2) complete removal of the entire structure as currently legally mandated, (3) removal of the superstructure and uppermost 20 to 30 meters of the underwater structure (referred to as "topping"), (4) removing the superstructure and laying the remainder of the entire structure on its side on the sea floor in its present location, and (5) relocating either the upper portion (created by Option 3 above) or the entire structure elsewhere on the sea floor. Each of these options could have a variety of both short and long-term ecological consequences.

Figure 7. Depiction of the five decommissioning options described in the text.



In conjunction with all of the five options identified above, the mounds of mussel shells that have accumulated beneath and around the platforms might be either removed or left intact. These mounds are created from mussel production on the upper portions of the platforms (see Figure 5; Wolfson *et al.* 1979, Page and Hubbard 1987, Page *et al.* 1999). When mussels on the upper portion of the platform die or are knocked off the platform by water action, they drop to the bottom and accumulate to form large (6.5 to 8.5 meter high) mounds over the area of the structure's footprint (MBC 1987, Love *et al.* 1999a). Because most of these mussels are alive when they arrive at the sea floor beneath the platforms, they are a local source of food to organisms that accumulate beneath the platforms to feed on them. Over time, these mussels die and create a reef structure with small crevices inhabited by invertebrates and small fishes (including juveniles of large rockfishes). In combination with the live mussels, these invertebrates and small fishes attract other species including commercially important crabs (Page *et al.* 1999), sea stars (Wolfson *et al.* 1979), and other fishes (Love *et al.* 1999a) that feed on them. Surveys of fishes associated with mussel mounds indicated two general patterns. Fish assemblages associated with mussel mounds differed among platforms and these differences were in part related to differences in depth. Secondly, the fish assemblage associated with a mussel mound was more similar to the assemblage at its adjacent platform than to other mussel mounds at other platforms (Love *et al.* 1999a). Decommissioning options that remove or leave in place the upper portion of the platform structure could influence the longevity of the mussel mounds. Removal of the upper portion of the structure would prevent any continued replenishment of the mounds by terminating the production and transport of mussels to the bottom. How long the existing mounds would persist before eroding or becoming covered with sediment is not clear.

Also associated with the offshore oil platforms are the pipelines used to transport oil from the structure to shore. These pipelines differ in dimension and the extent to which they are exposed or buried by sediment. At installation, pipelines are usually left exposed on the sea floor below 8-meter water depths and are buried or covered with rock in areas that are shallower than 8 meters. Most of those that are laid on the sea floor eventually become buried. Exposed pipelines and the rocks used to cover them create hard surface for attachment of sessile invertebrate species and shelter for mobile benthic invertebrate and fish species. Like platforms and mussel mounds, organisms associated with these structures attract other species and create reef-based communities, which likely modify nearby soft-bottom communities.

II.C. Management issues

II.C.i Management objectives of artificial structures

To understand the motivation for and possible intended and unintended consequences of deploying artificial structures in the marine environment, it is important to recognize why emplacement of such structures is considered by managers. This section reviews the range of management objectives associated with the construction of artificial reefs.

The oldest objective, dating back centuries, is still the most common reason for building artificial reefs: to improve local fishing success. Early experiences demonstrated that fish gathered around man-made objects in lakes or oceans, providing higher catch rates than would otherwise occur there. More recent scientific studies have shown that fish densities are, in fact, often higher on artificial reefs than on nearby natural reefs (Fast and Pagan 1974, Russell 1975, Smith *et al.* 1979, Walton 1979, Jessee *et al.* 1985, Laufle and Pauley 1985, Matthews 1985, Ambrose and Swarbrick 1989). Artificial reefs are sometimes built to increase the catch of fish in an area, and sometimes to "move" the fishing to more convenient areas, perhaps close to a port. Artificial reefs built for fishing can be constructed from a wide range of materials, including natural rock, concrete, decommissioned ships, tires, and many types of scrap materials (although not all of these materials would be acceptable for use in California).

Over the past 20 years, there has been increasing recognition that artificial reefs could be used to replace aquatic resources that have been lost due to anthropogenic impacts (Swanson *et al.* 1978, Stephens and Palmer 1979, Grove 1982, Spanier and Pisanti 1983, Sheehy 1985, Sheehy and Vik 1985, Ambrose 1986). Artificial reefs have been used or proposed as mitigation for impacts to estuaries, bays or harbors (Alevras and Edwards 1985, Davis 1985, Duffy 1985, Feigenbaum *et al.* 1989, Lindeman 1989), seagrass beds (Calinski and Whalen 1987, Thorhaug 1989) and rocky habitats (Hueckel and Buckley 1986, Hueckel *et al.* 1989, Cheney *et al.* 1994, Cummings 1994). In the United States, reefs have been used for mitigation in several locations, including Delaware Bay (Sheehy and Vik 1982), Chesapeake Bay (Feigenbaum *et al.* 1989), Washington (Hueckel *et al.* 1989), and Florida (Davis 1985). In California, mitigation reefs have been built in Long Beach Harbor and San Diego Bay. In addition, the Pendleton Artificial Reef was constructed to test the feasibility of using a constructed reef for mitigation (Grove 1982, Ambrose and Anderson 1989). The largest mitigation reef in the United States has recently been required as mitigation for impacts to a kelp forest caused by the San Onofre Nuclear Generating Station (Ambrose 1994, California Coastal Commission 1991, Parry and Ambrose 1993), with the first phase of construction completed in Fall 1999.

A third objective of artificial reefs is to provide recreational opportunities for scuba divers. Some of the decommissioned ships placed as artificial reefs have been specifically designed to provide "wreck diving" opportunities. In addition to high abundances of fish, other species such as algae and invertebrates also are frequently abundant on artificial reefs, providing excellent opportunities for underwater sight-seeing or photography.

Finally, artificial reefs may be constructed for conservation purposes or to enhance the environment. Since artificial reefs constructed for mitigation must provide resources as replacement for project impacts, these reefs are tightly linked to resource impacts. Artificial reefs for environmental enhancement are not linked to resource impacts, nor are they built to enhance fishing opportunities. Rather, these reefs aim to improve the ocean environment in general. Relatively few artificial reefs have been built for environmental enhancement or conservation. One example is the reef constructed near Diablo Canyon, California, whose principal objective has been to enhance rockfish recruitment. A different conservation objective has been employed in the

Mediterranean Sea, where reefs have been constructed with projections that will snag trawl nets in order to exclude trawlers from environmentally sensitive seagrass habitats.

The different management objectives require different designs for artificial reefs. Furthermore, the constructed reefs need to provide different ecological functions and services in order to be considered successful. A key difference is whether fish production must be increased, and indeed this has long been a controversy about artificial reefs (Osenberg *et al.* 1999). Because artificial reefs attract fish, as can be seen clearly when adult fish are abundant on a reef shortly after it has been constructed, some scientists have been concerned that the reefs could be simply attracting fish rather than contributing to fish production. Much has been written about this "attraction versus production" issue (reviewed by Bohnsack and Sutherland 1985, Carr and Hixon 1997, Bohnsack *et al.* 1997), but this phrase is an oversimplification that does not do justice to the complex issue of how an artificial reef contributes to the production of fish and other organisms. In fact, attraction of fish may be a sufficient mark of success for some reefs. For example, if the purpose of the reef is to provide non-consumptive recreational use, success is based on presence of desired species and scenery; it does not matter if the reef has increased fish production. For fishing enhancement, increased fish production is not necessarily important, although it may be desirable. Sound fisheries management using artificial reefs depends on the status of the fish stock. If the stock is under-exploited, use of artificial reefs to increase efficiency by concentrating fish may be appropriate. However, if the stock is fully exploited or overexploited, employing artificial reefs could have negative consequences for the stock unless the stock is enhanced through increased production by the reefs. The use of artificial reefs as mitigation requires that the reefs produce new resources to compensate for losses due to anthropogenic impacts. We return to the issue of fish production later in this report.

The different objectives would require different criteria for evaluation of artificial reef success. For some of these objectives, such as non-consumptive recreational use or fishing enhancement, it is easy to evaluate the success of an artificial structure. But for conservation and resource enhancement, evaluation can be very complicated due to the difficulty of discerning regional, not just local, consequences of the deployment of artificial reefs.

II.C.ii California's Artificial Reef Program

Recognizing the potential of artificial reefs for enhancing sport fish habitat and catch, the California Legislature enacted AB 706 (Fish and Game Code, Article 2, Section 6420-6425) in 1985. The Legislature found that declines in marine fish species in Southern California had adversely affected sport and commercial fishing, and called for a program of artificial reef research and development to investigate enhancement of these species. It established the CDFG as the lead agency for a state artificial reef research and construction program that would coordinate ongoing studies and construction. The program was to include study of existing reefs and all new reefs placed by the program to determine the design criteria for reefs to be capable of increasing fish and invertebrate production (Wilson *et al.* 1990).

The CDFG Artificial Reef Plan for Sport Fish Enhancement (Wilson *et al.* 1990) describes the history of artificial reef studies, the materials used, and catalogues the State's inventory of reefs. Three categories of artificial reefs are designated: developmental reefs for developing better techniques and related scientific investigations, production reefs primarily intended to enhance the production of living marine resources, and fish attracting devices constructed to attract sport fishes without necessarily contributing to an increase in standing crop. The plan details the procedures to be followed for establishing a new artificial reef: defining purpose, gathering information relevant to placement and design, site selection, reef design, preparing a project narrative, obtaining necessary permits, developing a general artificial reef permit, as well as a system of fisheries enhancement areas. It also outlines procedures for reef construction, mapping, and studies of reef biota. The development of the Pendleton Artificial Reef is used as an example. To meet the goals of the program, CDFG plans to continue reef studies through 2005 and reef building through 2011. Finally, the Department believes that properly-constructed artificial reefs can be used as mitigation for impacts to rocky reef habitat, and in certain cases, for damage to giant kelp (Wilson *et al.* 1990).

Material specification guidelines and a notification procedure for augmentation of artificial reefs with surplus materials were formulated by the Department (April 4, 1991; revised October 30, 1997 and February 16, 1998). Criteria for suitable reef materials include persistence, a specific gravity at least twice that of seawater and thus dense enough to survive strong winter storms, and the absence of toxic substances such as found in automobile tires. Commonly-used materials include quarried rock and high density concrete rubble; other materials may be considered on a case by case basis.

The California Department of Fish and Game has developed a set of guidelines that it would use to evaluate any proposed rigs-to-reef project. These guidelines stipulate that the project must benefit living marine resources, habitat, and user groups; that disposal or use of contaminated materials is not permitted; that wherever possible the subsurface structure of the platform should remain in place; that where possible, subsurface structure that must be removed could be relocated to the base of the rig or other appropriate sites; and that the remaining structure be augmented by rocks or other materials to assure that the site functions as a diverse and productive reef habitat. To replace the biotic productivity from that part of the platform removed for navigational purposes, rock or concrete reefs should be placed in nearshore locations. A rigs-to-reef project sponsor must provide sufficient funds to the Department to evaluate the benefits to biotic productivity, user groups, and the overall management of fishery resources. The process would be subject to all normal review processes by appropriate regulatory agencies (FGOM Section 4322.5).

II.C.iii Decommissioning conducted in the Gulf of Mexico

There are several thousand oil and gas production platforms in Federal waters of the northern Gulf of Mexico (mostly off of Louisiana), and decommissioned rigs have been used for construction of artificial reefs by several states (Bull and Kendall 1994, Wilson *et al.* 1996). Louisiana and Texas established state-run artificial reef programs through legislation enacted in 1986 and 1989, respectively. These states set up trust funds to receive monetary donations for artificial reef development and operations, and mechanisms to transfer ownership and liability from the oil companies to the state. Although both of these states have used a variety of materials for building artificial reefs, "Rigs to Reefs" is a main focus of each of their programs (Dodrill 1999, Gibbs 2000). To a lesser extent, Mississippi, Alabama and Florida have also accepted decommissioned rigs and deployed them as artificial reefs (Seaman *et al.* 1989, Dodrill 1999). One reason underlying development of rigs-to-reefs programs in the Gulf States is that operational platforms have become a major focus of offshore fishing and recreational diving during the past several decades. For example, in Louisiana there is little natural hard substrate in offshore areas, and a majority of angling occurs in the vicinity of oil platforms where fish congregate (Stanley and Wilson 1989). In anticipation of the removal of these structures upon decommissioning as they reached the end of their production, Louisiana developed an artificial reef plan and since 1986 components of 71 platforms have been used in the creation of 25 artificial reef sites (Quigel and Thornton 1989, Kasprzak 1998). Participating companies realize cost savings by redeploying platforms as artificial reefs rather than removing them, and a portion of these savings are donated to the state to run the artificial reef program.

There are a number of critical differences between the Gulf States and California with respect to both the marine environment and the offshore oil and gas activity, and these differences must be considered when evaluating the experience of the Gulf States with respect to various decommissioning alternatives.

The first key difference between the Gulf of Mexico and California is the amount of natural nearshore rocky bottom and reef area. In the northern Gulf of Mexico where the majority of the oil and gas platforms are located, the ocean bottom is typically clay, silt or sand with little or no relief (Kasprzak 1998) and the few natural reefs that do occur are located 75 or more miles offshore (Stanley and Wilson 1989). There is a paucity of nearshore rocky reef habitat, particularly off the coasts of Louisiana and Texas. It has been estimated that hard bottom and reef habitats constitute about 1.6% of the total area of the Gulf of Mexico (Wilson *et al.* 1996). By contrast, rocky reef habitat is far more abundant along the coast of Southern California and within the Southern California Bight. Although the precise amount of subtidal rocky habitat off the California coast is not known, there are extensive areas of rocky intertidal and shallow subtidal habitats as well as offshore reefs.

A second difference between the Gulf States and California involves the level of oil and gas development in each region. There are several thousand oil and gas platforms in the Northern Gulf, and only twenty-seven off California. Thus the operating Gulf platforms contribute much more hard substrate to the marine environment, both in an absolute sense, because there are so many platforms, and in a relative sense, because hard substrate is so rare in the northern Gulf of Mexico, than do the platforms off of California. The operational Gulf platforms have been estimated to increase the overall amount of reef fish habitat in the Gulf of Mexico by twenty seven percent (Kasprzak 1998); if only nearshore waters off Louisiana were considered where natural hard substrate is essentially absent, the effect of the platforms situated there would be many times higher. Of course, since there are so many platforms in the Gulf there is a much larger potential for creation of artificial reefs at the time of decommissioning than there is in California.

A third important difference between the Gulf and California is that the biota - particularly the fish - differ. Different groups of species occur in the two geographic areas, and the effects on their populations of various decommissioning alternatives will no doubt differ as a result of differences in life history, mobility, longevity, etc. as well as in harvesting pressure. Thus, inferences about effects of any particular decommissioning strategy based on information gathered in one region on the fish assemblage in the other region would need to be made with utmost caution.

Despite the intensity of fishing and recreational diving on both operational and decommissioned (reefed) Gulf platforms (Stanley and Wilson 1989), and despite some data (reviewed in Kasprzak 1998) that abundances of a number of species of fish are higher near platforms than on nearby soft bottom habitat, there is a paucity of information regarding the influence of the platforms on fishery resources, or the effects of harvesting on platform-associated species (Bull and Kendall 1994). Species of fish most often sought by recreational anglers and divers are snappers (species in the Family Lutjanidae), but a variety of other fishes are also targeted including cobia, red drum, seatrout and mackerel (Stanley and Wilson 1989). To date, careful stock assessment studies of these taxa that estimate effects of platforms (standing or reefed) and implications of current harvesting practices at a regional scale appear not to have been conducted.

III. Biological attributes of marine species and potential ecological consequences of decommissioning alternatives

III.A. Population structure and life history characteristics of marine species

Short and long-term ecological consequences of decommissioning options are greatly influenced by the life history traits and population structure of species in the region where platforms occur. To understand the effects of human activities at the relevant spatial and temporal scales, it is important to have a basic understanding of the life histories and population structure of the various species of marine organisms involved. Many sessile and mobile marine invertebrates (e.g., mussels and crabs, respectively), as well as most marine fishes, produce young stages (usually larvae) that disperse in the plankton. Similarly, macroalgae produce spores. These offspring disperse in the plankton, and, after settling in a new area, grow to adulthood. This process of planktonic dispersal links together many subpopulations that occupy discrete habitats such as reefs, resulting in an interbreeding population that covers a large area. In some species the range of dispersal can be up to hundreds of kilometers. Individuals are transported largely by water currents.

We first consider impacts on a single, isolated population, perhaps occupying a reef (Figure 8a). This population of adults produces larvae, some of which return to provide new recruits to the population. For the population to persist through time, lifetime reproduction of adults on the reef must be sufficient to overcome the losses during the planktonic larval and recruitment phase. Essentially, individuals must replace themselves. Lifetime reproduction depends on an individual surviving until it is old enough and/or large enough to reproduce. Many marine populations appear to have excess lifetime reproduction, enabling them to tolerate some reduction in survival (by fishing for example), while still maintaining adequate larval production for sustainability.

Marine populations actually consist of a number of subpopulations similar to the single one just described that are distributed over space and linked by larval dispersal. The young produced by each local population of a reef-associated species are likely to be transported away to contribute to the replenishment of populations elsewhere (Figure 8b). This leaves the replenishment of that parental population reliant to some degree on the recruitment from the plankton of young that are produced by distant populations. Thus, each of the subpopulations (reefs in Figure 8b) need not have adequate lifetime larval production to replace themselves; they could actually be subsidized by greater larval input from other subpopulations. If that were the case, of course, other populations would have to have greater lifetime larval production than needed for replacement. It is easy to see that patterns of water currents in the region, which transport larvae among local populations, could influence the persistence of populations at various locations in that region. Population configurations such as these are much more complex than the single isolated population and their structure and function are very poorly understood. Although in recent years there has been rapid development of ecological theory that explores the population dynamics of these systems, there is still little empirical evidence that allows estimation of how strongly individual populations of marine species are linked by larval dispersal. Similarly, knowledge about the physical environment (direction and strength of water currents for example, that carry the larvae among populations) is still incomplete for the California coast.

Because of this decoupling of local offspring production from local recruitment, local effects on adult populations (e.g., creating or altering their habitat) can influence populations many kilometers away. Thus, the addition or removal of an artificial piece of structural habitat (Figure 8c) not only influences species locally, but can also influence populations elsewhere in the region. Among other things, the patterns of water currents in the region in which a platform is located will influence rates of replenishment of populations on a platform, as well as the potential for the platform to contribute larvae to other reef sites.

The resulting population structure is complex, and the details are not known, but it suggests productive ways to think about the ecological consequences of adding an artificial structure into a collection of local populations. For example, if an artificial structure intercepted larvae that would otherwise have died (perhaps before finding a suitable reef to inhabit), it would likely not have a negative effect on regional population structure. It could even have a positive impact if the intercepted larvae thrived on the artificial structure, and each produced enough larvae in its lifetime to do more than replace itself, and if the larvae then could disperse and reach suitable habitat. By contrast, if an artificial structure intercepted larvae that would have successfully settled elsewhere, and it provided poorer habitat for growth and reproduction than natural reefs, there ultimately could be a negative impact on the regional population. Introduction of an artificial structure can also affect populations if movement of adults occurs. For example, if adults migrated to the artificial structure from their natural reefs, and this diminished larval production at their reef of origin, there could be a negative effect on the regional population, unless the adults made up for that loss at the new location.

While this situation seems hopelessly complicated, and highly uncertain, we can at least identify aspects of populations associated with artificial structures that would be favorable to overall population persistence and abundance. First, the fraction of successful larvae intercepted by any particular artificial structure is likely to be low, because of the small area of the artificial structures and the mortality of larvae involved in traveling a large distance. Second, it is important for an artificial structure to provide good habitat for all juvenile and adult stages; if it does not, it is less likely that it will mitigate potential negative effects of entraining larvae that could have settled on natural reefs.

Assessment of the effects of artificial reefs is further complicated by the fact that species differ in characteristics that determine the spatial structure of populations. Because species vary markedly in such life history traits as propagule (spores, eggs, larvae) dispersal, longevity, generation time and adult mobility, the extent to which decommissioning effects are manifested only locally at a platform or extend more regionally will vary among species. The duration of propagules in the plankton also varies markedly (hours to months) among species (Table 3), which means that potential transport distances vary among species.

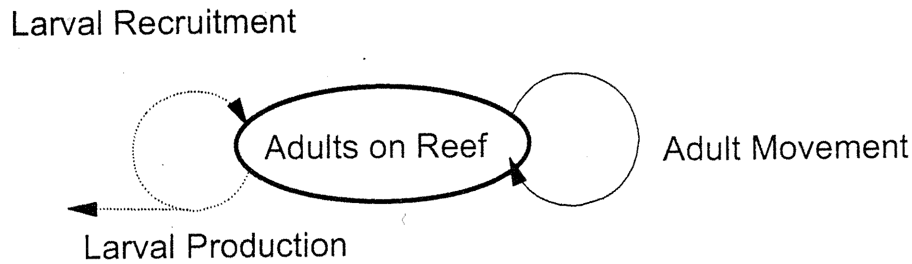
Species also differ in the degree to which their older benthic (i.e. bottom-associated) juveniles and adults move among reefs (Table 3). Many sessile algae and invertebrates do not move once the propagule stage recruits to a reef. In contrast, juveniles and adults of some reef fishes freely move kilometers between reefs. Thus, the life stages that can move to and from reefs vary among species and these differences are critical to understanding how and to what extent species can be "attracted" (i.e. move) to reefs. These distinctions are important when trying to ascertain whether species are attracted or produced by the presence of a reef and how attraction or production is manifested locally or regionally (i.e. within or among populations, respectively).

To summarize, it is not yet possible to predict the effects of adding or removing an artificial structure on long-term regional abundance of any species of interest. Even observations verifying that juveniles or adults are present (or even abundant) on rigs are not sufficient, unless they can be placed into a regional context. Ideally this would include posing the question of whether regional stock (that is, the size of all the component populations together) was ultimately enhanced by the addition of the artificial structure.

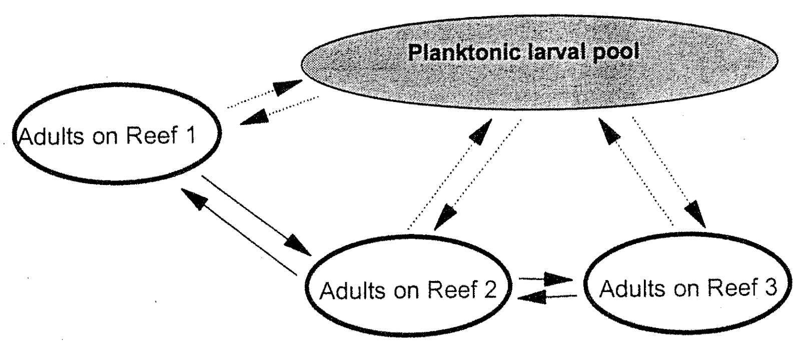
A further contribution of an artificial structure to population persistence is the reduction in risk of extinction of a species that results when another semi-independent subpopulation is added to the population. If the subpopulations are subject to independent environmental variability or independent catastrophes, the presence of an additional local population simply reduces the probability of all populations being driven to low levels simultaneously. It increases the likelihood that there will be one left to repopulate the others.

Figure 8. Spatial population structure of a typical benthic, mobile marine species (e.g., fish). Fig. 8a depicts a single isolated population of adults on a reef whose larval production and dispersal (dotted lines) consist of both export and retention, and adult movement (solid line) is confined to that population. Fig. 8b and 8c depict three natural subpopulations and a platform-associated subpopulation, each of whose larval production contributes to a regional larval pool, from which larval recruitment is derived.

8a



8b



8c

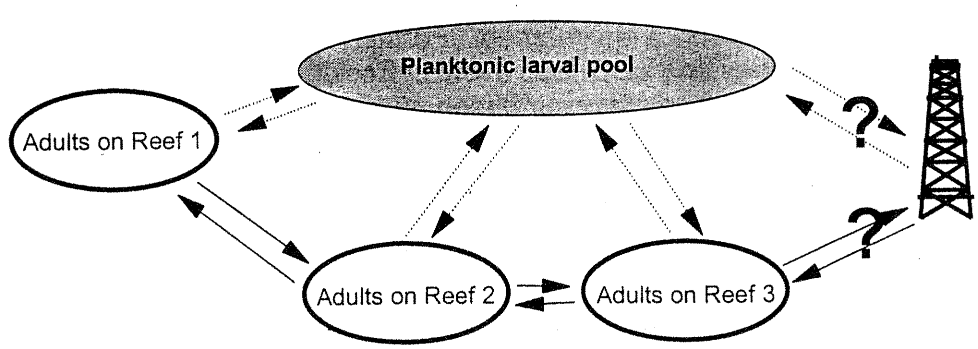


Table 3. Differences among species in relative dispersal abilities of reproductive propagules and benthic stages (adults). Propagule dispersal is estimated from its duration in the pelagic environment; longer duration (> 7 days) equates to greater dispersal. Propagules include algal spores, and eggs and larvae of invertebrates and fishes.

		Propagule Duration: Short (< 7 days)	Propagule Duration: Long (> 7 days)
Adult Movement	Sessile	scallops red algae *Corynactis* tunicates sponges	mussels barnacles *Metridium*
	Limited (< 1 km)	amphipods sculpins surfperch	sea stars crabs cabezon blacksmith benthic rockfish
	Long (> 1 km)	pinnipeds	kelp bass half moon mid-water rockfish

III.B. Potential effects of decommissioning alternatives

Each of the five identified options for decommissioning oil platforms could result in a variety of impacts to marine biota. Although some effects of each decommissioning option can be identified at this time, others are much more difficult to predict because we have incomplete knowledge of the biology of many marine species as well as the physical aspects of the offshore environment. Further, effects could vary depending on environmental fluctuations and stochastic events. Ecological impacts of any decommissioning alternative could occur during and just following the decommissioning event (removal, topping, etc.), mainly due to the procedures involved in removing or moving a platform, or effects could accrue slowly over much longer time periods (years to decades). In this report we refer to the former class of effects as short-term, and the latter effects as long-term. Additionally, effects may occur to populations only at the location of the platform and its immediate surroundings (local), or they may be expressed as a regional change in distribution or abundance of one or more species. Below we briefly point out some possible biological effects of various decommissioning alternatives. The examples are not meant to represent an exhaustive list but rather to illustrate potential differences in effects to the marine biota of various decommissioning alternatives. In general, short-term, local effects will be the easiest to quantify; longer-term, regional effects will be less likely to be detected readily and would probably have to be estimated by calculation.

The limited information that is available about patterns of distribution and abundance of platform-associated biota indicate that effects of any particular decommissioning alternative will need to be evaluated relatively specifically in the context of the biogeographic setting and water depth of the platform (and of the potential reefing site if this is a consideration). Further, the amount and quality of hard substrate in the near vicinity of the platform as well as in the region could potentially affect impacts of the alternatives. With our current knowledge it is possible to only roughly estimate potential impacts of the various options. Very few ecologically-important impacts can be predicted with certainty given the present state of knowledge. Information that would be necessary for a more complete assessment is described in Section IV.

Option 1: Leave entire structure intact in place

In this option, the entire subsurface structure is left standing in place. Since nothing would be done to move or alter the structure there would be no additional new ecological impacts at the time of decommissioning. However, whatever (positive or negative) impacts as a result of the structure being where it is that are already occurring would continue. Future environmental variation or climate fluctuation could result in additional (long-term) impacts or could change the size or direction (positive or negative) of ongoing impacts.

Option 2: Removal of entire structure from ocean

In the short term there could be several kinds of local impacts of removing the entire platform structure from the ocean. One class of effects could result from the removal procedure itself. For example, use of explosives could result in mortality to fish and other species on or near the platform. Organisms on adjacent or nearby natural hard substrate could be damaged by anchors of support vessels or barges; and anchor scars could result that alter this substrate and impact its value as habitat for benthic species. When the platform is removed from the ocean all the sessile organisms on it will die, and the mobile species (fish and invertebrates) would survive only if they could successfully relocate to suitable habitat elsewhere. On a long-term local basis, anchor scars and/or damage to the bottom could persist, thus altering the habitat quality for species associated with hard bottom substrate. A set of species associated with soft bottom would likely develop in the area previously occupied by the platform, and this would have different species composition and biomass than the assemblage that occupied the platform. Whether the long-term regional effects of platform removal would be positive or negative clearly would depend on the regional effect the platform was already having. Removal could ultimately result in enhanced regional populations if the operational platform had been negatively affecting them. But if a regional increase in stock of a species had resulted from the presence of a platform, removal could result in a negative impact on the stock.

Several of the options described, including removal of the platform, could greatly impact the mounds of mussels located underneath the platforms. In cases where all or the top part of the platform is removed, the mussel mounds would no longer have a supply of shells, organic material, settled larvae and young stages, etc. arriving from the top layers of the water column. This could have a profound impact on the biomass and species composition of the community associated with the mussel mounds. There are insufficient data at this stage to predict how long the structure of the mussel mounds would persist in the absence of the input of debris from above. Further, in some options (such as removal of the entire platform) it is possible that the mussel mound would be removed during decommissioning. Removal of the mussel mounds could have a variety of impacts. For instance, if explosives were used, many organisms in the vicinity could die. Removal of the mound structure would obviously result in a loss of this habitat for organisms. Sessile organisms would die and mobile ones would only survive if they could find suitable natural habitat nearby. To the degree that chemicals or other anthropogenic materials have become entrained in the mussel mound, these might be released during the process of removal and might potentially affect the biota.

Option 3: Topping – removal of upper 30 meters of the structure

In this scenario, the top portion (perhaps about 20 or 30 meters) of the platform is removed to reduce navigational hazard. This portion might be placed on the ocean bottom or removed from the ocean. The rest of the platform is left standing. Short-term local effects of explosives, boat traffic and the like would be similar to those outlined for Option 2. In the short-term, sessile organisms on the top (removed) part of the platform would die if it were removed from the ocean and would not be likely to survive if the top was placed in deep depths. Most of the organisms that live on the top part of the platform depend on high levels of light and nutrients that would be lacking in deep areas. Similarly, mobile species associated with the top portion of the platform may or may not be able to relocate successfully to the deeper portions left intact, depending on their habitat requirements. In the long term, local effects could include anchor scars left behind on any nearby hard substrate, and the loss of all hard substrate and associated species from the top portion of the water column. The removal of the top portion of the platform may have great effects on the biota on the lower part, and over the long term that assemblage may not be sustained. For example, the vertical transport of organic matter (especially mussels) from the highly productive top of the platform would stop when that portion was removed. The mussel mound would cease accumulating, and the organic material that provided a food supply to many species near the bottom would be greatly reduced. Patterns of larval recruitment could be affected greatly because many larvae travel in the top few meters of the water column and they might not find substrates that are 20 or 30 meters below the surface. This could result in a reduction in larval recruitment to the truncated platform. Lastly, water motion in the top portion of the water column would be different because the platform would no longer produce eddies that might entrain larvae, particulate matter, zooplankton, etc. The long-term regional effects of this option are difficult to predict, but similar to the previous options, the effects could be positive or negative depending on the prior regional impact of the operating platform.

Option 4: Topple structure in place

For this option the platform would be toppled over and left in place, either intact or cut up and positioned in a desired configuration. The impacts resulting from the procedures involving explosives, anchor placement, etc. would be similar to Options 2 and 3. In addition, there could be short-term local impacts on the bottom where the rig is placed. Habitat would be disturbed during placement, with potential negative effects on any organisms in the vicinity. In the short-term, many (sessile or mobile) organisms on the top portions of the platform would not be likely to survive if the rig was toppled at a deep depth, because their habitat requirements would likely not be met in the new location. Long-term local effects could be similar to those outlined for Option 3, and would include loss of hard substrate and associated biota high up in the water column, effects on biota located underneath the platform (such as species in the mussel mounds) due to cessation of organic input from the near surface, as well as effects on larval recruitment and on water motion in the top of the water column. There would be an increase in hard substrate near the bottom as a result of toppling. The long-term regional effect of toppling will depend greatly on the depth at which the rig is located. Toppling a rig at a great depth (a hundred or more meters) could result in a much less productive community because it is cut off from the highly productive surface waters, compared to toppling a rig in relatively shallow depths. Depending on the regional impact of the platform in its standing position, the long-term effects of toppling could be positive or negative.

Option 5: Topple and move structure to a new location

In this option the platform is moved from its operational site to a new location. Depending on the specific procedures used to accomplish the relocation, short-term local effects from use of explosives or from anchoring activities will be similar to those previously described for Options 2 and 4. The bottom and associated organisms are likely to be disturbed, the severity of this would depend on whether the platform makes contact with the bottom during the process of removal. Both sessile and mobile species that occupy the platform would be impacted during the movement process, and might not survive in the new location if their habitat requirements were not met. In the new location the natural bottom substrates could be damaged by anchoring, and will be covered up by the introduction of the platform. The long-term local impacts at the removal site would be the same as for Option 2. At the new location there would be a loss of soft-bottom habitat and an increase in hard substrate, along with associated changes in biota. Whether the regional long-term impact of this option is positive or negative would depend on the previous impact of the platform on regional populations compared to the regional impact that accrues from relocation to the new site.

IV. Research agenda and general conclusions

The key marine ecological question that needs to be addressed in the context of decommissioning is, "What is the effect of each decommissioning alternative on regional stocks of reef-associated species in general, or of particular targeted species?" As outlined earlier, because regional stocks of reef-associated species are composed of linked local populations, it is not sufficient to evaluate any particular local population (whether a natural reef or a platform) in isolation (Osenberg *et al.* 1999). The fact that an artificial structure has lots of organisms on it does not necessarily imply its presence has enhanced regional stocks. The artificial structure may have merely attracted individuals from more suitable habitats, via larval settlement or movement of adults. Those individuals might have made a larger (or smaller) contribution to their regional population stock had they lived in a different location, due to higher (or lower) survival, growth and reproduction.

It is unlikely that the positive or negative effects of any particular decommissioning option on regional stock of, for example, a fish species, could be assessed confidently by direct measurement. There are a number of reasons for this, but a central one is that the magnitude of the effect of an individual artificial structure (or indeed a single natural reef) is likely to be very small relative to the size of the overall regional population, and both of these (the impact of the structure on the stock and the size of the regional population) cannot be measured precisely. This is not to say that a particular decommissioning configuration could not have a strong local effect. For example, if a reefed rig is placed in an area that is primarily covered with soft bottom, a community of reef-associated species will likely develop there. Obviously there has been a strong local effect, but it is the regional effect that truly matters from an ecological perspective. While direct measurement of a regional effect seems infeasible, the effect could be estimated using a combination of empirical information and modeling. This effort would be comprised of several parts.

1. <u>Assessment of quality of platforms as reef habitat</u>. It would be critical to evaluate the ecological performance of different local populations on natural reefs and on platforms, by assessing demographic rates such as individual growth, reproduction and mortality. Such estimates would need to take into account both temporal and spatial variability such that sampling to derive the estimates would need to be conducted at a number of locations (perhaps regionally over the range of California's platforms) and over time. The appropriate spatial and temporal scales also would depend on the lifespan and spatial distribution of the particular species of interest. These estimates

of demographic rates would allow some comparisons to be made of the quality of the various natural (reef) and artificial (platform) habitats.

2. Estimate connectivity between local populations. The second set of measurements to be made would estimate connectivity between the various component populations (platforms and natural reefs). The dispersal potential of various species of interest could potentially be estimated by physical oceanographic monitoring of surface and subsurface currents, in relation to the distribution of natural and artificial patches of habitat. This information would be combined with information about the timing of larval release, length of larval life and location of larvae in the water column (surface or subsurface) to model movement of larvae over the relevant spatial scale. Emerging genetic and chemical techniques to identify source populations could also be utilized in this effort.
3. Model effects on the regional population of adding or removing artificial structures. Finally, it should be possible to develop population dynamics models for species whose demographic performance on natural reefs and artificial structures is known, and for whom population connectivity has been estimated. These models could be used to estimate effects on the regional population of adding or removing artificial structures with certain (predicted) quality in specific locations of the region, and in relation to the distribution of biota on natural reefs.

The approach just outlined would need to be implemented in an environmental and biogeographic context, and take into account the impact on species of specific decommissioning actions. Clearly, removal, topping, toppling, etc. would likely have very different effects on the species of interest, and these effects might vary regionally due to depth, availability of hard substrate, and biogeographic constraints. And, as stated previously, since different species are likely to be affected in different ways by each decommissioning option, it would be most informative if this approach were used for a variety of species of representative life histories, including those of special economic or regulatory interest. An example of the latter are some of the rockfishes whose low abundance has triggered severe restrictions on harvest and the creation of rebuilding plans by the Pacific Fishery Management Council (e.g., McCall *et al.* 1999).

If, in fact, the approaches described just above were employed and the results suggested that decommissioning options that involve reefing of platforms could have a strong positive effect on regional stocks of species of interest, then alternate reefing options could be more explicitly explored. These studies would probably only be conducted if there was relatively clear evidence of the beneficial impact of reefing. Several types of information for this effort would be critical, and a number of different approaches are possible. Below are some possible options for such studies.

1. Detailed natural history information based on surveys of biota in deep and shallow areas, and across the biogeographic range from Pt. Conception southward would shed light on the appropriate depths and locations for placement of structures. Some of this information may be available at the present time since some areas have been sampled, but

the data appear to be incomplete, especially for the southern region. Without this information an informed decision could not be made regarding reefing options (if they were to ever occur), especially if particular species are being targeted for enhancement.

2. Information on temporal patterns of distribution and abundance of key mobile species on platforms is needed. Little temporal sampling of mobile species (particularly fish) has been conducted to date on the platforms, but the data suggest that populations of fish associated with any particular platform can be quite variable in time. Additional information is needed to estimate how temporally variable these populations are compared to populations that inhabit natural reefs. The underlying source of the temporal variability could be movement, mortality, or both, and understanding the causes for platform-associated populations will be a critical element in the evaluation of the value of platform structures as artificial reefs.
3. Information available at present suggests that topping (and leaving the rest of the platform standing in place) could have profound effects on the biota that would persist there in the future. Uncertainty regarding this option could potentially be reduced by experimentally topping one or two platforms and following the biota over time (with untopped rigs as controls). In this experiment the tops would be removed from the marine environment for disposal. After a set period of time (maybe 5 years) the performance of the structure and its contribution to regional stocks could be evaluated (using methods described above), and the structure could be completely removed (or reconfigured in some other way) if the effects on regional stocks were not positive.
4. Another experimental approach for exploring decommissioning options could involve the use of a Before-After – Control-Impact Paired Sampling (BACIPS) design, where an option (say toppling in place) is exercised for a single platform. In a BACIPS experimental design, a temporal series of data on species of interest taken on the platform prior to decommissioning and following it is compared to data sampled from a Control (comparison) platform over the same time period. Statistical techniques can be employed to test whether there has been an effect of a perturbation (in this case the decommissioning action). The information derived from this approach could also be used to estimate effects on regional stocks of implementing the decommissioning.

If decommissioning alternatives are evaluated experimentally (as in (3) and (4) above), or if a decision is made to reef one or more rigs (outside of an experimental context), it will be crucial to conduct careful monitoring studies to track the ecological performance of the biota. Monitoring would be conducted at the reefed site as well as on natural (comparison) reefs. This monitoring will be important to assessing impacts of the reef on stocks and will provide information to be used in future evaluations of potential decommissioning options.

There are several other research themes that, if explored, could greatly add to the information base needed for the decision-making process. One of these regards the mussel mounds that accumulate under platforms. During decommissioning these would likely be removed, but their removal could have impacts on marine biota (that derive from loss of hard substrate, release of toxins, etc.). It might be possible to assess the impacts of removing mussel mounds, as well as project their longevity if left in place after platform removal. For example, studies could be conducted on the mussel mounds of several platforms recently removed from the Santa Barbara coast, to assess toxicity of the sediments underlying and inside the mounds, and to gauge their deterioration and biological features by comparing them to mounds under active platforms.

Several of the research initiatives mentioned above, and indeed, the full assessment of decommissioning options, require environmental information. At least two major types are needed. The first is information about the amounts and quality of hard substrate off California south of Pt. Conception. As mentioned previously, this information is largely lacking, yet it would be needed to evaluate reef placement if decommissioning involved something other than complete removal. This information would also be of tremendous benefit to any modeling effort on effects of artificial structures on regional stocks. Similarly, a second information need in these contexts (modeling stock effects, potential reef placement) is physical oceanographic information. Our understanding of patterns of water circulation off the coast of California is still incomplete, yet this information would be of great utility in the evaluation of decommissioning options.

General Conclusions and Synthesis

1. Surveys of platforms in California waters reveal that they harbor rich assemblages of marine organisms, including many fishes and invertebrates that typically occur on natural rocky reef substrates. The particular species present on any given platform depend on the biogeographic setting of the platform and its depth, as well as other factors. Despite the fact that platforms can harbor abundant marine life, it is the platform's contribution to regional stocks of species that is the crucial metric for evaluating its ecological impact. This is due to the fact that most marine species consist of a series of local populations (such as would occupy a reef) that are linked together by larval dispersal of young stages. The interdependence of populations means that impacts at any one location must be considered in the context of the regional set of local populations. Most extant assessments of possible biological effects of platforms are fundamentally flawed because they focus on local and not regional effects. At present there is not any sound scientific evidence (that the Committee is aware of) to support the idea that platforms enhance (or reduce) regional stocks of marine species.
2. The total "reef" area represented by the 27 California platforms is extremely small in relation to regional availability of hard bottom substrates, suggesting

that for the majority of species any regional impacts (whether positive or negative) of a decommissioning option are likely to be small and possibly not even detectable empirically.

3. However, because species differ greatly in life history, population dynamics, and geographic distribution, it is possible that platforms could have a more substantial effect (either positive or negative) on some key species. These species might be of special interest from a management point of view – rare or endangered, of economic importance, etc. In such cases, further study of effects of decommissioning alternatives, using approaches outlined in this report, could yield the scientific information needed to predict impacts of decommissioning alternatives in the context of overall management strategies. Species of special concern could include, for example, several rockfishes whose low abundance has triggered severe restrictions on harvest and the creation of rebuilding plans by the Pacific Fishery Management Council (McCall *et al.* 1999). Bocaccio, for example, is estimated to have declined to about 1 percent of virgin biomass. Love *et al.* (2000) reported that Platform Gail had a density of adult bocaccio an order of magnitude greater than the average density found on 61 natural reefs in appropriate depths. The issue, then, is to evaluate whether these higher densities of some populations on platforms persist through time, and if so, whether they could have a positive effect on regional stocks, given the very small surface area that the offshore platforms represent.
4. Decommissioning of offshore oil production facilities will involve offshore as well as onshore structures, and the various alternatives would involve a broad array of possible consequences that include not only the marine ecological effects we have addressed, but also economic, political and social impacts. These factors would need to be evaluated together to reach a final decision as to whether a decommissioning alternative other than platform removal is desirable. Nevertheless, with the current state of knowledge, predicting effects of decommissioning options on regional stocks of marine species is not possible. Indeed, there is no clear evidence of biological benefit (in the sense of enhancement of regional stocks) of the platforms in their present configuration. Thus, in light of the lack of strong evidence of benefit and the relatively small contribution of platforms to reef habitat in the region, evaluation of decommissioning alternatives in our opinion should not be based on the assumption that platforms currently enhance marine resources.

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Ciguatera Fish Poisoning associated with oil production platforms along the Texas coast

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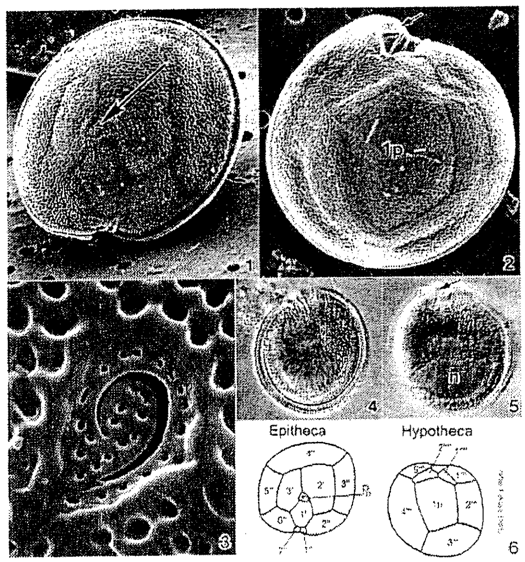
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Ciguatera Fish Poisoning

- Caused by consumption of polyether sodium channel activator toxins (ciguatoxins)
- Variety of neurological, gastrointestinal and cardiovascular disorders, can be fatal (rare)
- 50,000-500,000 people affected annually (Fleming et al. 1998), significant under-reporting
- Public health cost in U.S: $21,000,000 annually. All other HAB toxins costs: about $1,000,000 (Anderson et al. 2000)

Gambierdiscus toxicus: only known source
gambiertoxins ⟶ ciguatoxins



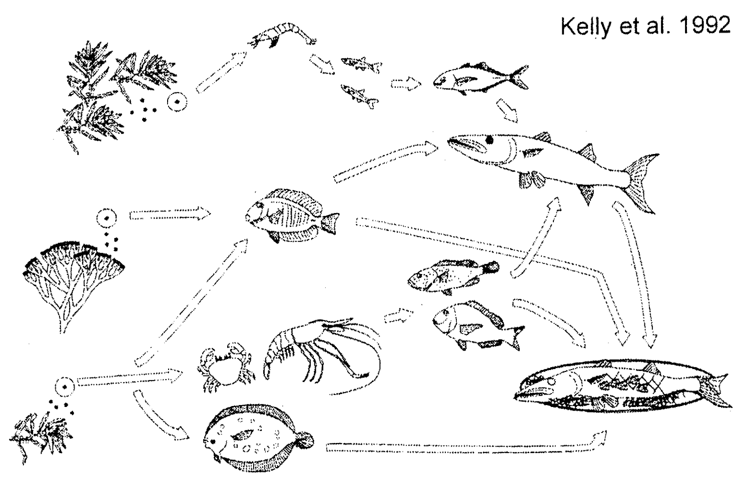
Faust and Gulledge 2002

www.nmnh.si.edu/botany/projects/dinoflag/index.htm

Multiple routes through food web to predators

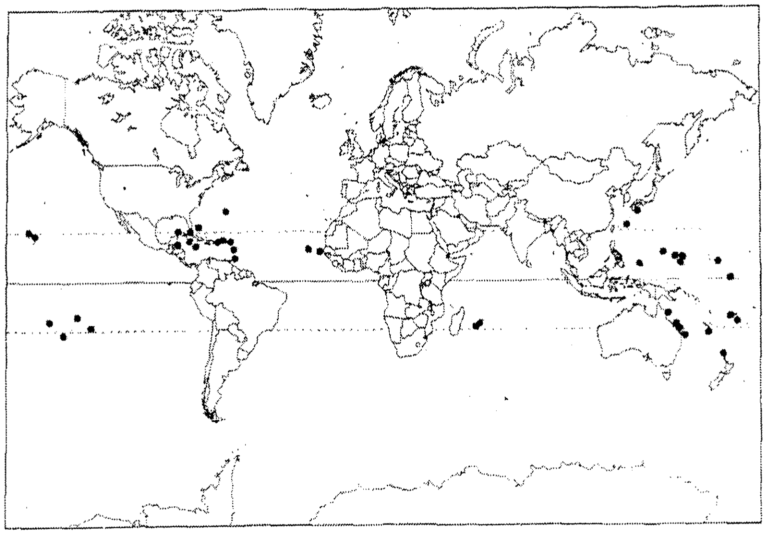
Typically associated with coral reefs on islands

Kelly et al. 1992



Possible association of other toxins from *Prorocentrum*, *Coolia*, *Ostreopsis*, and *Amphidinium*

G. toxicus distribution



Tindall and Morton (1998)

Ciguatera in the NW Gulf of Mexico

Barracuda are commonly eaten along the Texas coast. There is no public perception that it is a threat

No published reports of *G. toxicus* in this area

Only coral reef habitat in the western U.S. Gulf of Mexico: Flower Garden National Marine Sanctuary (175 km off the TX/LA coast, 120 km^2)

Listed by Lewis (2001) as moderate to high risk in northwestern Gulf of Mexico

1 outbreak reported from locally caught fish (barracuda): 3 individuals sickened by 16-18 kg barracuda (Bogart and Perotta (1989).

Two questions:

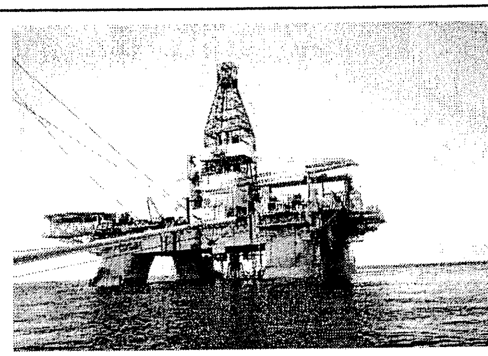
1. **How common are toxic barracuda off the Texas coast?**
2. **Are members of the ciguatera-associated dinoflagellate community present?**

With very limited coral reef habitat in the western Gulf, are there other types of habitat that could be sources of ciguatera?

Two likely possibilities:
Sargassum community
Oil production platforms

Oil production platforms
2001

2,946 producing oil platforms
3,048 natural gas wells
205 drilling rigs



Part of large artificial reef program in Louisiana

Provide hard substrate in region dominated by soft, muddy bottoms

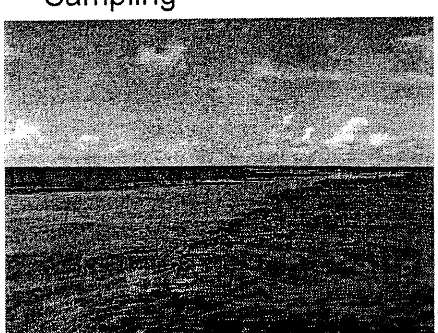
Other artificial reefs: sunken transports, soon to be: aircraft carrier

Complex 3-D environment

Macroalgae not abundant

Fouling community of tunicates, bryozoans, gorgonians, sponges, occasional hard coral

Sampling



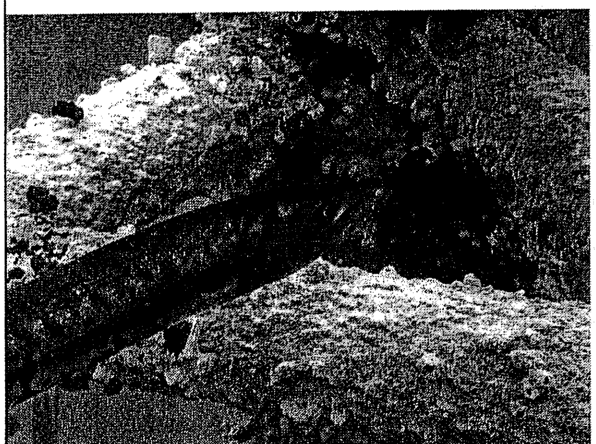
Offshore collections for *Sargassum*

Fouling community collected by SCUBA divers or snorkellers.

Samples were bagged, returned to the lab, sieved (153 and 50 µm), preserved for light and scanning electron microscopy

Great Barracuda (*Sphyraena barracuda*):
Recorded length, weight, date caught, location, water temperature

Sampled liver, flesh, fin snips (genetics), scales (C and N isotopes)



Toxicity assayed using a Na^{+} channel-specific receptor binding assay standardized to C-CTX 1 (Lombet et al.1987).

Cross reaction w/ brevetoxin possible, but unlikely in these fish

BARRACUDA CONTEST

Attention Fishermen!

University of Texas Marine Science Institute
Seeking barracuda either caught on hook and line or speared.

We need barracuda for important research on ciguatera toxin in the Western Gulf of Mexico

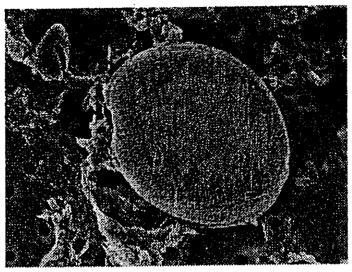
The 50 largest barracuda will win a beautiful and unique polo shirt with an embroidered barracuda (and all will win our gratitude).

We need:
- the fish (frozen or on ice)
- information on how to contact you (such as name, address, phone #, email address, and shirt size?)
- information on the location where it was caught, either
  latitude and longitude of capture,
  GPS coordinates,
  -or-
  nearest identifiable map feature

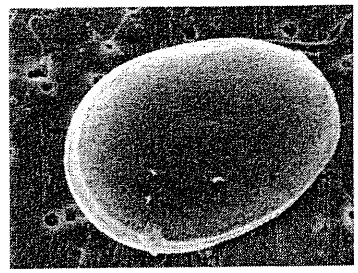
Contact us or deliver fish to UTMSI in Port Aransas
Shari Hanson (361) 936-9563
Tracy Villareal (361) 749-6732, tracy@utmsi.utexas.edu
website:
May 10th thru September 31, 2003

Barracuda collected by recreational fishers as part of a UTMSI sponsored contest. Polo shirts w/ logo for 50 biggest fish, local dive shop donated a spear gun as a prize

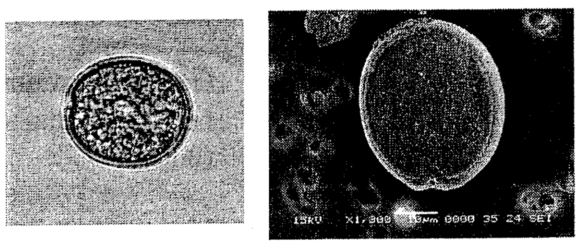
Species noted on production platforms and *Sargassum*



Gambierdiscus toxicus

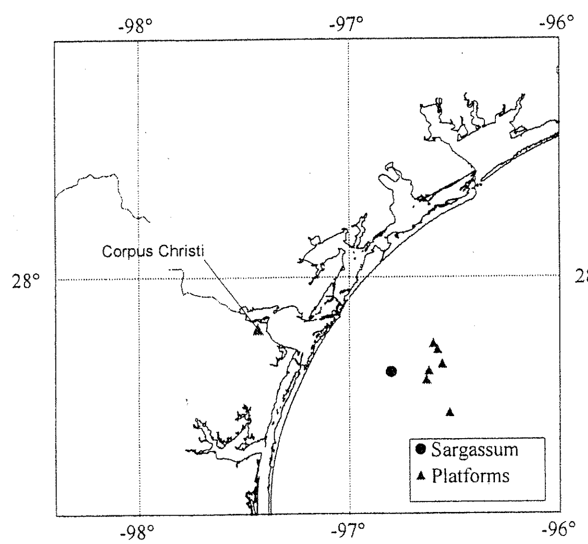


Prorocentrum lima



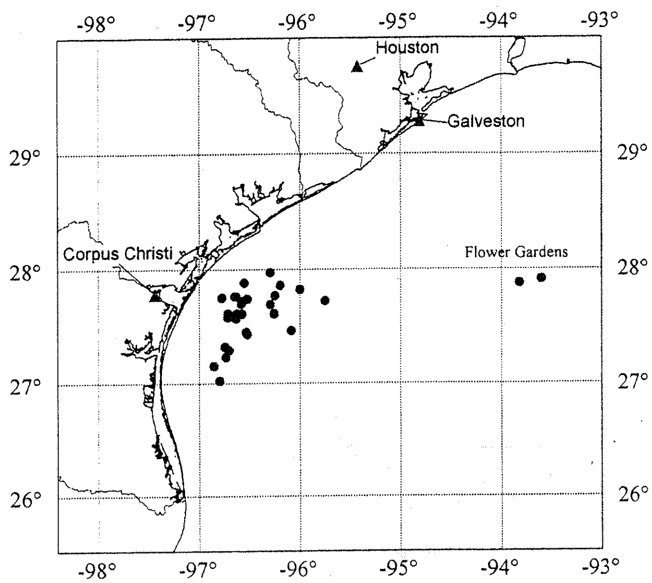
Prorocentrum sp., probably undescribed

Map of *G. toxicus* on rigs and *Sargassum*



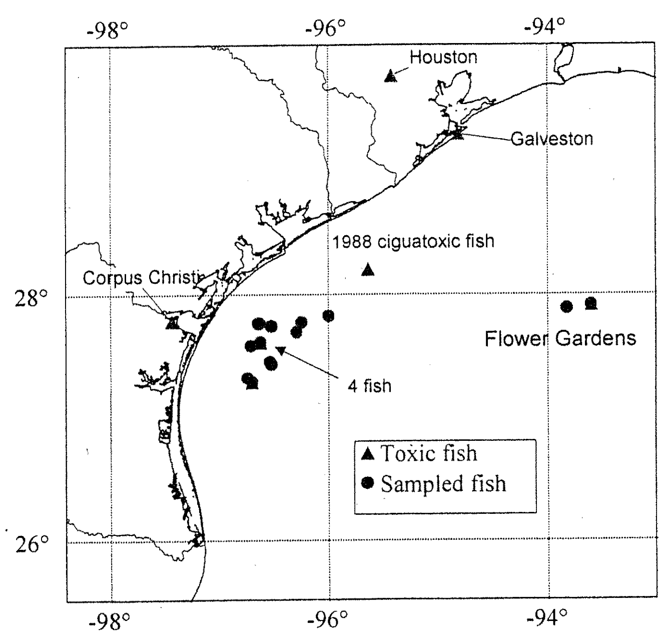
Present on all rigs below the swell zone (approx. 2 m)

Present on *Sargassum,* not as common as *Prorocentrum*



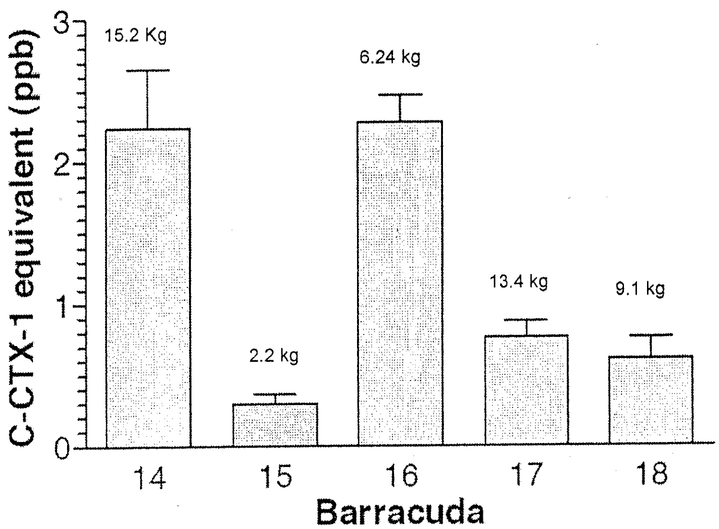
169 barracuda returned to UTMSI, May -Sept. 2003 (1153 kg of fish)

5 barracuda from the Flower Gardens National Marine Sanctuary (2002)



Toxicity assayed in 30 Texas fish to date, 5 fish with > 0.2 ppb toxin activity

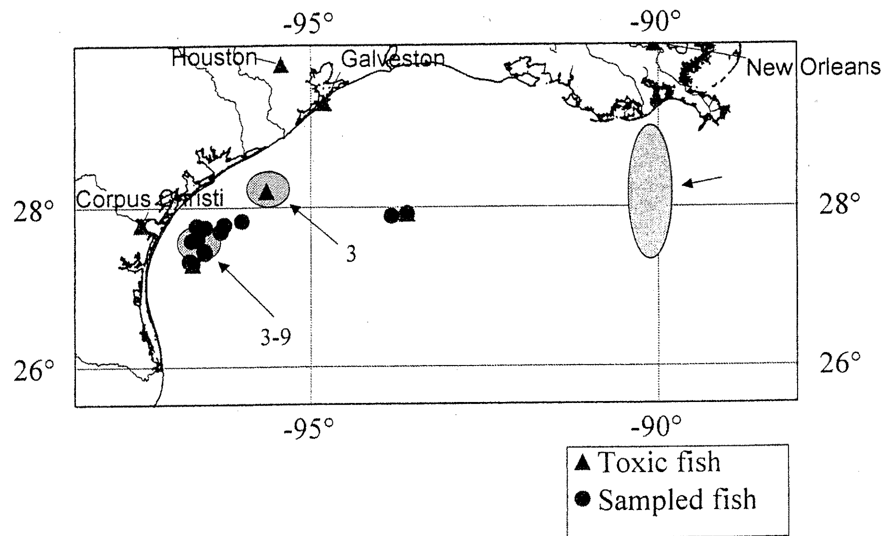
2 of 5 fish from the Flower Gardens NMS slightly toxic



0.1 ppb CTX will induce human illness (Lewis 2001)

Vernoux and Lejeune (1994): no size-toxicity relationships found in barracuda in St. Barthelemy

Ciguatera cases- based on published reports or data collected during this study



Luber, Backer, Villareal, unpubl.

Summary

Gambierdiscus toxicus was present below the swell zone on every rig examined as well as on *Sargassum*

These are new records for this section of the Gulf of Mexico

Other toxic benthic dinoflagellates (*Prorocentrum* sp.) are present

Oil production platforms are a new type of purely anthropogenic habitat for the ciguatera-associated dinoflagellate community

Summary -cont.

Oil production platforms are creating habitat that ciguatoxic fish species exploit

Likely that ciguatera occurs more frequently than reported along this coast

It is unclear if toxic fish are endemic or migratory stocks, but all components of the ciguatera food web appear to be present

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Funded by Environmental Defense

…the Northwestern Hawaiian Islands, Vol. 2. Sea Grant Miscellaneous Report …NT-MR-84-01. 353 pp.
… J. H. Parker and I. W. Duedall. 1982. The coal-waste artificial reef program …v resource potential for fishing reef construction. U.S. Natl. Fish. Serv., Mar. …): 16–23.
… The fishery and the biology of the Hawaiian opelu, *Decapterus pinnulatus* …leyet). Master's Thesis, Univ. Hawaii, Honolulu. 125 pp.

…ril 28, 1988.

…tional Marine Fisheries Service, Southwest Fisheries Center, Honolulu Labora- …, Honolulu, Hawaii 96822-2396.

ARE HIGH DENSITIES OF FISHES AT ARTIFICIAL REEFS THE RESULT OF HABITAT LIMITATION OR BEHAVIORAL PREFERENCE?

James A. Bohnsack

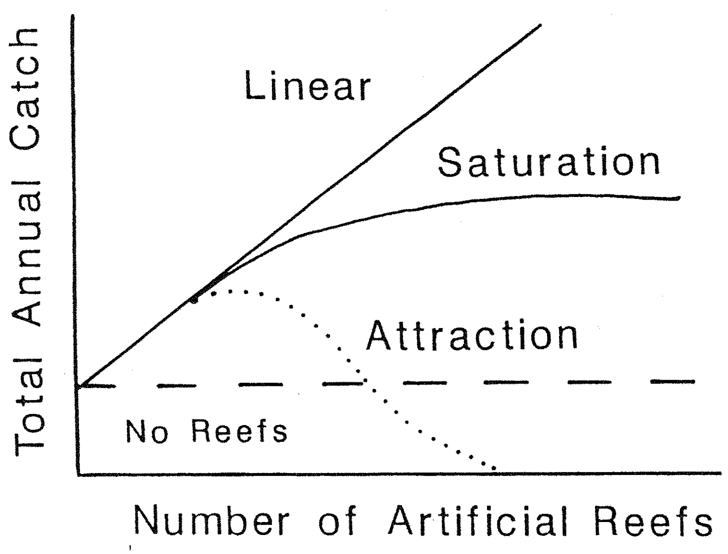
ABSTRACT

Rapid colonization, high fish densities, and high catch rates at artificial reefs have been used as evidence for habitat-limitation and increased production of reef fishes. An alternative hypothesis is that artificial reefs attract fishes due to behavioral preferences but do not increase reef fish production or abundance. Reviewed literature reveals that except in one case evidence for increased production is mostly anecdotal and inadequate. Attraction and/or production by a particular artificial reef is predicted to depend on the species and individual ages (size) of reef fish, and on reef location. Factors predicted to be important are natural reef availability, mechanisms of natural population limitation, fishery exploitation pressure, life history dependency on reefs, and species-specific and age-specific behavioral characteristics. Increased production is most likely at locations isolated from natural reefs, and for habitat-limited, demersal, philopatric, territorial, and obligatory reef species. Attraction should be more important in locations with abundant natural reef habitat; where exploitation rates are high; and for recruitment-limited, pelagic, highly mobile, partially reef-dependent, and opportunistic reef species. Artificial reefs are unlikely to benefit heavily exploited or overfished populations without other management actions.

Artificial reefs are used in fisheries to create fishing opportunities, reduce user conflicts, save time and fuel, reduce fishing effort, make locating fish more predictable, increase public access and safety by deployment near ports, and increase fish abundance at deployment sites by attracting dispersed fishes and producing new fish biomass (Stone, 1985; National Academy Press, 1988).

Questions persist, however, about the importance of artificial reefs for producing new fish biomass versus attracting and aggregating fishes from surrounding areas without increasing total biomass (Bohnsack and Sutherland, 1985; Munro and Williams, 1985; Solonsky, 1985; Bohnsack, 1987; National Academy Press, 1988). The resolution of this controversy has important implications for fisheries management. Artificial reefs that produce significant new biomass may be useful for increasing fishery resources. However, artificial reefs that act primarily by attraction may promote overfishing under heavy fishing pressure by increasing fish catchability (the proportion of the population removed by one unit of effort). Fishes normally dispersed over a wide area would be concentrated and possibly depleted more rapidly (Samples and Sproul, 1985).

An underlying rationale for artificial reef deployment is the production hypothesis: that artificial reefs provide additional critical habitat that increases the environmental carrying capacity and eventually the abundance and biomass of reef fishes. Barren, unproductive substrate is turned into a highly productive environment (Stone et al., 1979). Mechanisms suggested for this transformation include (1) providing additional food, (2) increasing feeding efficiency, (3) providing shelter from predation, (4) providing recruitment habitat for settling individuals that would otherwise have been lost to the population, and (5) indirectly, because fishes moving to artificial reefs create vacated space in the natural environment that allows replacement from outside the system (Randall, 1963; Ogawa, 1973; Stone et al., 1979; Matthews, 1985).



ıre 1. Predicted effects of the attraction and production hypotheses on catch. The production othesis predicts increased catch as some function of the amount of deployed reef material (solid s). The attraction hypothesis (dotted line) predicts an initial increase in catch followed by stock letion and decline to levels below ambient catch without artificial reefs (dashed line). See text for ıils.

ʌn alternative attraction hypothesis is that artificial reefs attract fishes as the ult of behavioral preferences but do not significantly increase total fish biomass. ʔossible effects of the production and attraction hypotheses on catch are illus- ted (Fig. 1). The production hypothesis predicts that biomass production and ch will increase as some function of the amount of material deployed. Possi- ities include direct linear or saturation functions. Saturation results when reef ources no longer limit populations so that constructing additional reefs does not ther increase production. The attraction hypothesis predicts as a worst case an tial increase in catch followed by a decline to levels below what existed without ificial reefs. Total catch should eventually fall because of depletion due to reased catchability. However, higher total catch may be sustained under the raction hypothesis if replacement occurs from a large stock of migratory in- ·iduals (not illustrated).

A better understanding of the relative importance of attraction and production critical for wise fisheries management and the effective construction and de- ɔyment of artificial reefs. Although the controversy has been recognized for a ıg time, progress toward resolving it has been slow. Here I attempt to elucidate ɛ controversy and facilitate its resolution by recasting it into a theoretical and ıtable framework.

Methods

I reviewed the relevant scientific literature emphasizing reef fish ecology, population limitation, havior, and effects of artificial reefs on fish populations. Some described behavioral attraction ·chanisms have not been tested on fishes although examples using fish were cited where possible. sed on the review I predicted conditions under which attraction (reefs primarily aggregate fishes thout necessarily increasing biomass) or production (reefs increase biomass by providing shelter or food for resource-limited populations) should operate. Existing data and experimental approaches for testing the relative importance of attraction and production are discussed.

Reefs were broadly defined to include true coral reefs, rock outcroppings, wrecks, fish aggregating devices (FADs), oil production platforms, breakwaters, and other artificial structures. For this paper reef fishes include any fish frequently associated with natural or artificial reefs. Recruitment was defined as the process of larval settlement and post-settlement survivorship to initial census observation (Richards and Lindeman, 1987). Production was defined as the net increase in fish biomass, not harvest rate or harvest quantity (Bohnsack and Sutherland, 1985). Growth overfishing was defined as the process of harvesting fishes before they have had a chance to put on weight; recruitment overfishing was defined as the process of reducing adult stocks to a point where recruitment fails from a lack of sufficient larvae (Cushing, 1973).

Results

Reef Fish Ecology

Life History.—Reef fish biology and fisheries have been reviewed by Sale (1980), Huntsman et al. (1982), Munro (1983), Polovina and Ralston (1987), and Richards and Lindeman (1987). Almost all reef fishes have a planktonic larval dispersal phase that lasts from weeks to months (Sale, 1980; Brothers et al., 1983; Victor, 1986b). Many reef fishes are sedentary; after their young settle directly on reefs, they remain there for the rest of their lives. Many commercially and recreationally important reef fishes such as lutjanids, serranids, haemulids and sphyraenids settle in other habitats before moving to a reef (Starck, 1968; 1970; Moe, 1969; Shulman and Ogden, 1987). Obligate reef species require reef habitat while opportunistic species may use reefs as well as other habitats. Some species move off a reef daily to feed in surrounding areas (reviewed by Helfman, 1986). Many commercially and recreationally important reef fishes are characterized by long life, slow growth, low natural mortality, and high reef fidelity (Huntsman, 1981; Manooch, 1987). Factors generally considered most likely to limit adult population size are habitat, larval supply (recruitment), and fishery exploitation (Sale, 1980; Richards and Lindeman, 1987).

Habitat Limitation.—The belief that animal populations exist close to the carrying capacity of an environment is well established in ecological literature (MacArthur, 1972), especially for more stable environments (Menge and Sutherland, 1976). Reef fish abundance has traditionally been considered limited by habitat or space partly because reefs are a patchy resource, limited in geographical coverage and separated from other reefs. Sale (1980) noted a widespread assumption that the number of larvae able to settle on natural reefs was in excess of the resources available after settlement. Competitive interactions among individuals was thought to determine abundance on a reef (Sale, 1980; Munro and Williams, 1985), and scarcity of reefs limited sustained fishery yields (Huntsman, 1981).

Habitat is thought to be limiting primarily by availability of food or shelter from predation. Shelter is generally considered more important (Sale, 1980) although proximity of food in sea grasses and plankton availability may limit some fish populations (Randall, 1963; Glynn, 1973). Shulman (1984) found that food availability did not directly influence settlement or early survivorship. Ross (1986) suggested, however, that food limitation was more important than generally recognized based on evidence that trophic resource partitioning was more important than habitat partitioning among temperate and possibly tropical marine reef fish assemblages. Richards and Lindeman (1987) noted that food shortage can be difficult to show because starvation and slower growth interact with predation.

Predation has been shown to be an important source of mortality especially among newly settled juveniles (Shulman, 1984; Doherty and Sale, 1986; Shulman and Ogden, 1987). Shulman (1984) found shelter site availability limited recruitment and/or early survivorship presumably through its effects on predation rates. Hixon and Beets (1989) showed inverse relationships between prey and predator abundance influenced by shelter availability.

Sale (1980) concluded that space-limited assemblages existed but were less general than previously claimed. Out of four studies claiming a relationship between species richness and topographic complexity, only two (Risk, 1972; Luckhurst and Luckhurst, 1978) demonstrated such a relationship (primarily for sedentary species). Sale (1980) noted that four lines of evidence were used to support the importance of topographically structured space-limitation for reef fishes: (1) the very rapid colonization of artificial reefs and denuded natural reefs; (2) faster recruitment to empty versus occupied natural and artificial reefs; (3) conspicuous interspecific territorial defenses; and (4) constancy of numbers in some sites and microhabitats. Sale rejected the constancy of numbers as evidence after noting many reports of wide variations of fish abundance, even by authors concluding persistence of fish assemblages. Bohnsack (1983) showed that the appearance of constancy could be an artifact of the time interval between censuses.

Sale (1980) concluded that competitive and predatory responses by resident fishes did not always influence recruitment rates. Munro and Williams (1985) concluded that with the exceptions of Sale (1976) and Shulman et al. (1984), most studies found either no recruitment inhibition or enhanced recruitment by resident populations. Shulman (1985b) concluded that spatial patterns of recruitment interacting with predation may influence population abundances and species composition of reef fishes. Sweatman (1985) found high resident fish densities reduced larval recruitment by other fish species but this response was not related to resource availability. Jones (1987) found for one damselfish that juvenile density or adult presence had substantial effects on growth and maturation but not on juvenile survivorship.

Recruitment Limitation.—Although research in the 1970's tended to assume that availability of demersal resources was limiting to adult populations, studies in the 1980's have demonstrated the importance of recruitment-limitation; larval survival, dispersal, or settlement survivorship may limit adult populations (Sale, 1980; Munro and Williams, 1985; Richards and Lindeman, 1987). Indirect evidence of recruitment limitation includes large spatial and temporal variation in recruitment and adult population size that could not be explained by differences in reef structure (Munro et al., 1973; Sale, 1980; Sale et al., 1984; Munro and Williams, 1985; Shulman, 1985a; Doherty, 1987).

Three lines of direct evidence show the importance of recruitment limitation as opposed to resource limitation in controlling adult population size. First, the lack of density-dependent post-settlement mortality (Doherty, 1982b; Victor, 1983; 1986a) indicates competition or predation may not be as important as larval supply. Second, a shortage of competent larvae can keep reef fish populations below the levels at which the supply of food and space limits population sizes for damselfish (Williams, 1980; Doherty 1982a; 1982b; 1983) and wrasses (Victor, 1983; 1986a; 1986b). Third, greater benthic resources did not increase damselfish abundance (Wellington and Victor, 1985) nor have artificial reefs increased regional reef fish production (Munro and Williams, 1985).

In opposition, Shulman and Ogden (1987) predicted that mortality of post-settlement juveniles would have a much stronger influence on adult population abundance than proportionately equivalent changes in recruitment rate, particularly for species with high natural mortality rates. Recruitment limitation was

predicted to be more important for species with low natural mortality. They found that postsettlement mortality had a stronger influence on adult population size than proportionately equivalent changes in recruitment rates for two out of three species for which recruitment limitation had been demonstrated. Also, causes of population limitation can change over time (Wiens, 1977; Ross, 1986). Artificial reefs could increase production of species that are not normally habitat-limited during "environmental crunches" where unusual environmental conditions or extremely good recruitment years increase competition and habitat limitation.

Fishery Exploitation.—Fishery exploitation can be a significant factor in limiting adult population size, especially for long-lived species (Cushing, 1973; Gulland, 1977). Overfishing of tropical reef resources, in particular, has now been documented as a widespread problem (Pauly and Murphy, 1982; Munro, 1983; Appledoorn and Lindeman, 1985; Bohnsack, in press). Surplus production models (Ricker, 1977) predict that the standing stock biomass will be around half of its unexploited value for fisheries operating at the maximum sustained yield (MSY). Biomass should be less for overfished stocks. Samples and Sproul (1985) modeled FAD fisheries and concluded that unregulated, low-cost, efficient fishing effort near fish aggregators could deplete stocks and reduce gross fishery revenues.

Behavioral Studies

Behavioral studies have shown mechanisms applicable to the attraction of reef fishes to artificial reefs. Many fishes tend to orient and position themselves in size-specific and species-specific ways to structure and light (Abel, 1962; Ogawa, 1968; Grove and Sonu, 1985). The most basic mechanisms are instinctive orientation responses (taxes or kinesis) to structure or current and thigmotropic responses (contact with objects) (Breder and Nigrelli, 1938; Ogawa, 1968). Helfman (1979) showed that fishes may move to shade because they can better see objects in surrounding sunlit waters, such as approaching predators or prey. Some fishes may use structure for orientation and navigation purposes without directly obtaining food or shelter (Bohnsack and Sutherland, 1985). Curiosity may be important for some species. Mice have been shown to spend considerable time exploring novel, structurally complex environments that are unlike their home environment (Berlyne, 1966). Structural complexity of artificial reefs may also moderate predation by providing more refuges and thus decrease the foraging efficiency of predators (Menge and Sutherland, 1976; Rosenzweig and MacArthur, 1963; Ware, 1972; Hixon and Beets, 1989).

Reef fishes have been shown to select habitats and to change habitat requirements with age (Sale, 1968; 1969; Starck, 1970). Sale (1969) predicted that fishes will accumulate in preferred habitats through a process of appetitive exploration, where fishes in adequate environments will spend little time exploring new environments while fishes in less adequate environments will spend more time exploring new environments. Wecker (1963) showed the accumulations of mice in preferred habitats because individuals moved slower in preferred habitats and speeded up in less preferred habitats.

Predator abundance at artificial reefs has been correlated with prey availability (Ranasinghe, 1981; Kock, 1982; Buckley and Hueckel, 1985). Predators can accumulate in the vicinity of prey by means of "area restricted searching," where predators slow down their normal movements or increase their rate of turning after finding a prey item (Hassell and May, 1974). Thomas (1974) showed that fishes decrease the linear distance traveled after successfully discovering food and increased it after rejecting a food item. This behavior facilitates avoiding the unproductive foraging areas, increasing the chances of discovering productive areas, and remaining in the proximity of discovered food.

Optimal foraging theory (reviewed by Krebs, 1978; Hughes, 1980; Hart, 1986) could also be applied to movements of fishes, especially predators, between reefs. Fishes are predicted to distribute themselves and to move between reefs so as to maximize net energy gain. Fishes should distribute themselves between reefs according to relative reef profitabilities (food intake) (Godin and Keenleyside, 1984). Theories of "marginal value" (Charnov, 1976; Hart, 1986) and "giving up time" (Krebs et al., 1974; Krebs, 1978; MacNair, 1982) predict that predators should leave a reef when the energy yield from food resources is reduced to a certain level. Foragers should spend more time at reefs with abundant food resources than at reefs with low food availability. Model predictions may be modified to account for unequal foraging and learning abilities, risks of predation, presence of conspecifics, unpredictability of available food, and the costs and time to travel between patches (Regelmann, 1984; Milinski, 1984; Hart, 1986; Milinski, 1986).

Artificial Reef Studies

Bohnsack and Sutherland (1985) reviewed artificial reef literature and found numerous, well-documented observations of rapid colonization rates, high fish densities, and high catch rates. With few exceptions (Burchmore et al., 1985), fish densities, biomass, and catch rates were often higher on artificial reefs than on natural reefs (see also Buckley and Hueckel, 1985; Matthews, 1985). Fishes often appeared within hours and average numbers of individuals and species often occurred within days, weeks, or months. Observations of fish feeding on and around artificial reefs were common. Nelson (1985) reported that gray triggerfish grew faster at oil production platforms than in natural habitats.

Some evidence shows fish attraction and possibly behavioral preference for artificial reefs. Tagging studies have demonstrated fish movement from natural reefs to artificial reefs (but not vice versa) in Puerto Rico (Fast and Pagan, 1974) and in California (Matthews, 1985; Solonsky, 1985). Buckley and Hueckel (1985) demonstrated the importance of rockfish and ling cod immigration in replacing fishery losses on artificial reefs in Puget Sound.

Munro and Williams (1985) noted there was little evidence showing that artificial reefs increased the total fish production in a given area, despite the fact that numerous artificial reefs had been constructed in many parts of the world. Japanese artificial reef programs, the most extensive in the world, were usually justified based on popularity and economics by comparing the value of the harvest to the cost of building reefs (Grove and Sonu, 1985; Mottet, 1985; Nakamura, 1985; Sato, 1985). Grove and Sonu (1985) concluded that the evidence for increased artificial reef productivity from before and after surveys was far from conclusive, even though dramatically increased landings had been reported from particular areas. Mottet (1985) also concluded that insufficient biological data were available to judge the effectiveness and practicality of many of the Japanese enhancement efforts. Sakai (1982, cited in Kawasaki, 1984) concluded that no significant economic benefits were attributable to the artificial reefs after comparing the fish production value between the 5-year period before and the 10-year period after artificial reef installation off Hokkaido, Japan. Kawasaki (1984) examined data from the first two years after a 5-year installation program in Yuriage Miyagi Prefecture, Japan, and found uncertain economic benefits because artificial reefs attracted some species but repelled others. Polovina and Sakai (1989) showed that artificial reefs in one region increased the production of octopus but only aggregated four flatfish species.

Discussion

Attraction and production are not mutually exclusive and can be considered opposite extremes along a gradient. While artificial reefs may merely attract and concentrate some fishes, they may promote the production of others. Most fishes probably lie somewhere between the two extremes.

Behavioral studies show many mechanisms to explain fish attraction to artificial reefs. However, demonstrating attracting mechanisms does not refute the possibility of increased production. Fish attraction behavior presumably evolved because of some selective advantage (i.e., faster growth, increased survival, and reproduction). The concern here is that artificial reefs may provide cues beyond the evolutionary experience of fishes and elicit responses that are not necessarily adaptive. An analogous example is the concentration of fishes in warm water plumes from power plants (reviewed by Goodyear et al., 1974). Under natural situations, moving to the warmest water may be adaptive, but in power plant plumes fishes may spawn at the wrong time of year or die when the plant is temporarily shut down. Similarly, fishes attracted to artificial reefs may face higher mortality from natural predators (Hixon and Beets, 1989) or fishermen (Matthews, 1985; Solonsky, 1985).

Evidence for the five proposed mechanisms for increasing total biomass production with the addition of artificial reefs is limited and mostly circumstantial:

Artificial Reefs Provide Additional Food.—Many studies have reported observations of fishes feeding at artificial reefs. Added substrate undoubtedly provides additional food but it remains to be shown how much new fish biomass is consequently produced and whether the added biomass is a significant contribution to stock size.

Artificial Reefs Increase Feeding Efficiency.—Improved feeding efficiency implies faster growth rates on artificial reefs than for fishes in natural habitat. This has not been demonstrated on a general basis but has been claimed for one species (Nelson, 1985).

Artificial Reefs Provide Shelter from Predation.—Many studies have reported observations of larvae and juvenile fishes at artificial reefs. This is not sufficient evidence because individuals present do not necessarily survive or make a significant contribution to the population. Shelter from predation implies higher survival at artificial reefs than in natural habitats, which was supported by some experimental studies discussed earlier. The significance of increased survival on total stock sizes remains to be determined.

Artificial Reefs Provide Recruitment Habitat for Settling Individuals that Would Have Been Lost to the Biota Otherwise.—This is difficult to test although Polovina and Sakai (1989) provide some supporting evidence for octopus. To my knowledge no other published data support this possibility.

Artificial Reefs Increase the Production of Natural Reef Environments by Creating Vacated Space.—This mechanism is most applicable to unexploited, habitat-limited populations near their environmental carrying capacity; it is less likely to apply to recruitment-limited, heavily fished or overfished populations. Under these conditions, populations are below carrying capacity, face reduced competition, and are less likely to be habitat-limited. However, artificial reefs may help mitigate natural reef damage or loss due to pollution or other causes.

Some of the proposed mechanisms conflict. For example, increased shelter and survival implies reduced predation. However, additional food and increased predator feeding efficiency suggests higher predation rates and increased prey mortality. Also, benefits from changes in one factor may be counteracted by other factors. For example, increased recruitment can be negated by increased mortality from higher fishing intensity on artificial reefs than on natural reefs (Bohnsack and Sutherland, 1985; Matthews, 1985; Solonsky, 1985).

Experimental Approaches

The best direct evidence proving increased production would be an increased total regional catch or standing stock in proportion to the amount of artificial reef material deposited, while controlling for fishing effort, attraction from surrounding areas, and changes in year class strength. While seemingly difficult, one study discussed earlier (Polovina and Sakai, 1989) has met these criteria and has distinguished between mere attraction and new biomass production.

High fish densities, rapid colonization rates, and high catch rates at artificial reefs are well-documented but are not sufficient evidence to prove increased production or habitat limitation. The attraction hypothesis has fewer assumptions, can explain the same phenomena, and should be refuted before increased production is assumed. Both hypotheses, for example, predict high fish densities at artificial reefs. Claiming that habitat is limiting because of high fish densities (or rapid colonization) is analogous to claiming that warm water is limiting because fishes are attracted to warm water plumes from power plants.

Rapid initial colonization likewise can support either hypothesis, except that large fishes aggregating around artificial reefs within days, weeks, or even a few months is clearly the result of attraction. Initial attraction does not refute, however, the possibility of increased production over longer periods. A delayed response would be expected for fish to recruit and grow (Grove and Sonu, 1985).

Both hypotheses can also explain higher catch rates at artificial reefs. However, excessively high catch rates relative to the standing stock size show attraction is operating (Buckley and Hueckel, 1985). Long-term increased Japanese fish landings after installing artificial reefs has been claimed as evidence for increased production, although this information is not conclusive. With the exception of Polovina and Sakai (1989), results do not show whether increased landings were the result of increased fishing effort (or effectiveness), changes in year class strength, or attraction from other areas. Catches in one region may be at the expense of another region. Also unanswered is whether the increased catches could have been made without building artificial reefs.

Determining the importance of attraction and production will require very careful monitoring and assessment of artificial reefs with careful attention to catch rates, fishing effort, species composition, standing stock abundance, recruitment, age composition, growth, and turnover rates. Detailed information about the biology and natural history of resident species would be helpful.

Some indirect evidence supporting increased production by artificial reefs would be provided by experimentally demonstrating the existence of the hypothesized production mechanisms discussed earlier, such as increased growth rate or better survival at artificial reefs. Documenting food web relationships and energy budgets could demonstrate the potential of increased production, especially for food limited systems. Polovina (1984) provided a possible model which estimates mean annual biomass, production, and consumption for ecosystem components. The importance of attraction could be shown by tagging studies, high fishery removal rates relative to standing stock size, and rapid colonization by larger fishes.

Predicted Important Gradients

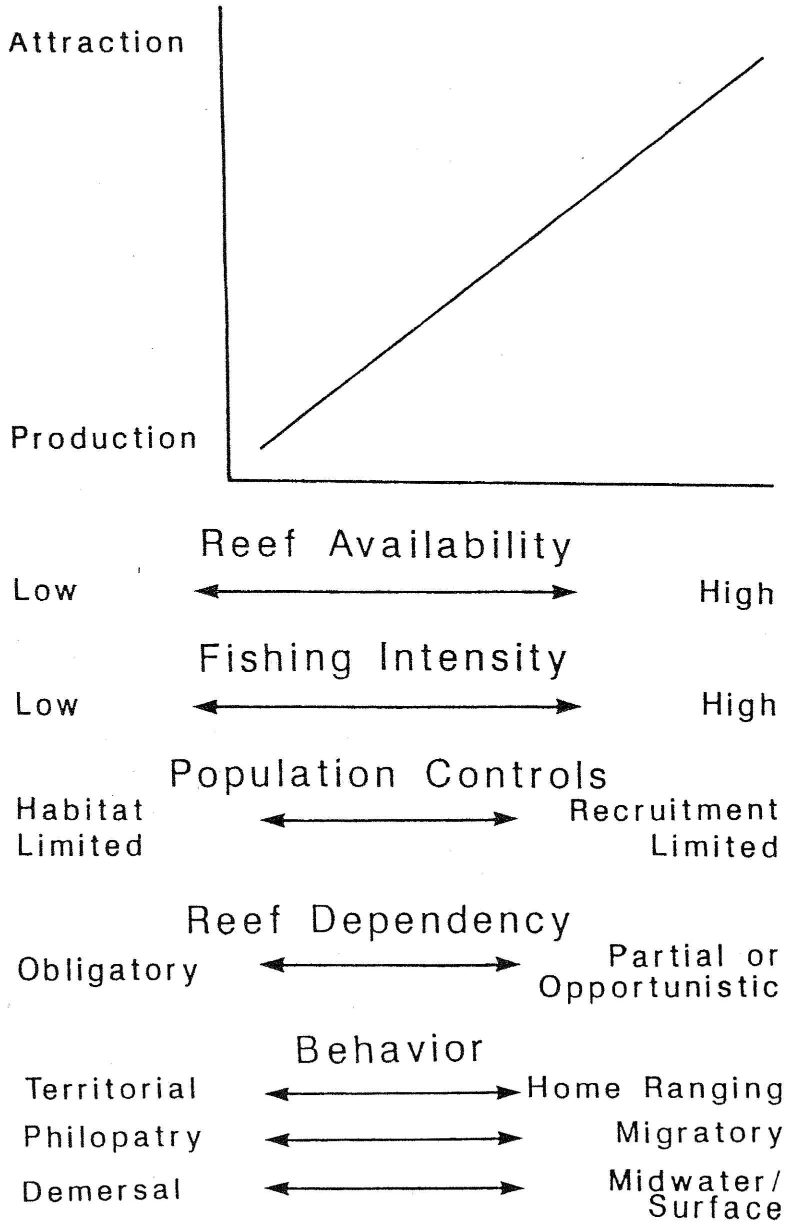
Based on reviewed literature, I predict several gradients should be important for artificial reef attraction or increased production. These gradients are: natural reef availability, mechanisms of natural population limitation, exploitation pressure, life history dependency on reefs, and species-specific and age-specific behavioral characteristics (Fig. 2). Increased production is most likely at locations isolated from natural reefs; and for habitat-limited, demersal, philopatric, territorial, and obligatory reef species. Attraction should be more important in locations with abundant natural reef habitat; where exploitation rates are high; and for recruitment-limited, pelagic, highly mobile, partially reef-dependent, and opportunistic reef species. Each gradient is discussed below.

Reef Availability.—Munro and Williams (1985) asked whether recruits to artificial reefs would have survived in available natural habitat. I predict artificial reef production should be more important for reef dependent species in locations more isolated from reef habitats. Here potential larval recruits would undoubtedly die if no reef habitat was within range. The proportion of recruits finding suitable habitat should increase with greater habitat availability. Also, species that feed away from reefs are more likely to find unexploited foraging areas in locations isolated from other reefs. Increased production by opening up new foraging areas should be less important with high reef density because surrounding areas are more likely to be exploited by residents of other reefs.

Predictions from behavioral models suggest that fish attraction should be favored at locations with high natural reef availability. Fishes are more likely to select and move between reefs because of reduced travel costs and predation risks with shorter inter-reef distances. Alevizon et al. (1985), Matthews (1985), and Solonsky (1985) provided some support for this model by showing high movement rates to artificial reefs when distances to natural reefs are short.

Population Limitation.—Increased production should be more important for habitat-limited than recruitment-limited species. Both limitations have been demonstrated, although little agreement exists about the species and conditions under which these two factors operate. The ecological literature shows that evidence supporting reef fish habitat-limitation is not as strong as once thought and its acceptance not as widespread as in the past. Even where habitat is limiting, the amount of added artificial reef material may not be significant to population size or economically justified. Huntsman (1981) concluded that although artificial reefs were useful for increasing recreational opportunities, they were impractical for increasing commercial catches because reefs were expensive and time consuming to build and could only provide a small amount of additional habitat relative to available natural habitat. He noted that only four acres of artificial reefs had been constructed in South Carolina after several years of effort. This addition was insignificant relative to the existing natural reef habitat. Ambrose and Swarbrick (1989) suggest similar results for California.

Fishery Exploitation.—Fishery exploitation is likely to significantly affect habitat limitation and production by artificial reefs. Populations exploited at MSY, with approximately half the virgin standing stock biomass of an unexploited stock, should have greatly reduced competition and resource limitation. Overfished



gure 2. Gradients predicted to be important for attraction or production of fishes at artificial reefs. near responses are shown only for illustration purposes.

populations should have even less competition and resource limitation. By definition, recruitment overfishing implies recruitment limitation. Thus, when overfishing occurs, artificial reefs are less likely to increase production. On the other hand, there is no evidence that exploited populations will necessarily be more attracted to artificial reefs.

Life History and Behavior.—Ontogenetic changes and life history have been shown to be important factors. Reef dependency and site attachment varies between species and with age (size) for some species (Sale, 1969). Artificial reefs are unlikely to increase abundance or biomass if bottlenecks to population growth occur in non-reef habitats, or during life history stages not dependent on reefs. For example, reefs designed primarily for adult fishes may not increase production for species that recruit to other habitats, such as many commercially and recreationally important species (e.g., snapper, grouper, grunt, barracuda) that first settle in sand, sea grasses, mangroves, and estuaries. However, suitable enhancement of those habitats may be beneficial.

Production enhancement is more likely for highly territorial, philopatric, and obligatory reef species (e.g., damselfish) that are most likely to be habitat-limited. Attraction should be more important for gregarious, roaming, or facultative reef species (e.g., jacks, barracuda) with less substrate attachment and site dependency because these species are more able to select habitats. Similarly, production enhancement should be more important for demersal species, which are ecologically more closely tied to the benthos, than for surface and midwater pelagic species.

Tests of Predictions.—Polovina and Sakai (1989) provided an independent, partial test for some predicted gradients. Increased production was demonstrated for *Octopus dofleini*, an obligatory demersal reef species that is territorial, philopatric, and has low mobility (Hartwick et al., 1978). In contrast, artificial reefs primarily attracted flatfishes which are more mobile, less territorial, facultative reef species with low philopatry. The octopus appeared also to be habitat-limited while the flatfishes showed some evidence of recruitment-limitation with temporal year class variations independent of habitat availability.

Management Implications

Understanding the extent to which artificial reefs attract or increase fish biomass is important for wise fishery management and the effective construction and deployment of artificial reefs. The relative importance of these two possibilities has not been determined for most species and locations. However, even if artificial reefs primarily redistribute existing fishes, they can still be useful fishery management tools for increasing catchability, making fishes easier to locate, retaining highly migratory species in the local area, and moving stocks closer to fishing ports. Attraction is no problem where (a) fishing effort is low, (b) a large stock reservoir exists relative to catch, (c) fish density is too low to be efficiently fished without artificial reefs, (d) high rates of stock immigration exist, or (e) little natural reef habitat exists. However, while a few reefs can concentrate a stock, too many reefs could again dilute the stock or may not be economically justified.

Artificial reefs may not be effective for increasing fish biomass under some circumstances and enthusiasm for them may detract from more productive management approaches. Artificial reefs may not increase production of recruitment limited populations. If artificial reefs primarily attract fishes, they may not increase total biomass and can even accelerate stock depletion by increasing catchability, especially under heavy fishing pressure. Artificial reefs are unlikely to increase biomass for intensely exploited or overfished populations without other management actions. Interestingly, the incentive to build artificial reefs is most likely to increase when signs of overfishing occur. Under these circumstances other management actions may be needed in addition to, or instead of, building artificial reefs.

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Can Science Resolve the Attraction-Production Issue?

By William J. Lindberg

Artificial reefs have long been popular with the saltwater-fishing public because they "produce" fish for anglers. Favorable catch rates and high densities of fish have been taken as proof by the public that artificial reefs benefit fisheries stocks. Obviously, when reefs were built, some fishes became abundant at locations where few or none had previously been caught. Nevertheless, the asserted benefit to fish stocks was very much more an assumption in need of testing than a logically valid conclusion. In my opinion, the assumption was readily accepted because it made artificial reef development compatible with the conservation ethic of most anglers. However, more than a decade ago a few concerned fishery scientists challenged that assumption by asking whether artificial reefs actually produced more fish or simply aggregated them, making them easier to locate and catch. This became known as the attraction-production question, which I now refer to as an issue because of the complexity in resolving it.

To understand the issue and how it might be resolved, one must understand its origins. Prior to the challenge by some fishery scientists, high densities of fish at artificial reefs were uncritically interpreted as evidence that the amount of hard-bottom habitat was limiting reef fish population size. Hard bottom was popularly assumed to be the foundation of the food web for reef fish assemblages (i.e., supporting essential primary and secondary production), so the addition of artificial reefs made sense as a way to alleviate that perceived habitat limitation. However, critical fishery scientists at the 1983 Third International Artificial Reef Conference in Newport Beach, California, challenged the assumption of habitat limitation on logical grounds (e.g., Bohnsack and Sutherland 1985).

The critical reasoning generally went like this: Before reef fishes were heavily exploited, the existing natural habitat supported an abundance of reef fish, presumably at or near carrying capacity. Fishing mortality then reduced stocks to some lower level, yet the amount of natural habitat remained the same—still capable of supporting higher numbe[rs]. With fish stocks substantially below carrying ca[paci]ty, the amount of hard-bottom habitat could no[t be] the factor limiting population size, in which cas[e] addition of artificial reefs would not benefit fish stocks by alleviating a limitation to produce mo[re] fish. Nevertheless, the commonly observed high [den]sities of fish at artificial reefs required an explan[ation]. To this, Bohnsack (1989) responded with the alter[na]tive explanation of behavioral attraction, the infer[ence] being that high densities were an artifact of behavioral preferences, which were presumed to b[e] adaptive in natural habitat but which became mal[]adaptive at artificial reefs because of intensified fis[h]ing mortality. If artificial reefs merely aggregated fish, critics argued, then continued construction would not serve the conservation ethic, and artifici[al] reefs would best be viewed as a fishing gear. (Obvi[]ously, I have summarized the case melodramatically; interested readers should refer to Bohnsack (1989) and Polovina (1991) for more balanced presentatio[ns].)

a thorough resolution of the attraction-production issue will require not only rigorous sc[ience] which has been in progre[ss] but also an education of inte[rested] parties as to what would cons[titute] an adequate answer

As compelling as this critical reasoning may be, logic alone cannot resolve the truth of the matter. Only good science guided by good questions can do that.

After more than a decade of living with the attraction-production issue, is it any wonder that anglers, reef builders, and resource managers might be frustrated with researchers for not yet answering their question (thus, the title of my essay)? In defense of the research community, a thorough resolution of the attraction-production issue will require not only rigorous science, which has been in progress, but also an education of interested parties as to what would constitute an adequate answer. Most laypersons, a[nd] perhaps many professionals, seem to believe that s[ci]ence attempts to prove things to be true when, in f[act]

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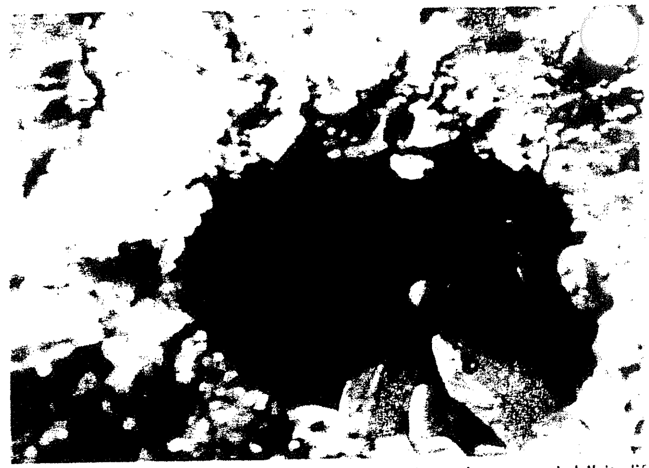
Science makes its greatest advances by proving things (i.e., hypotheses) to be false. Sir Karl Popper, one of the twentieth century's most influential philosophers of science, referred to falsifiability as the "criterion of demarcation" between empirical science and metaphysics (and from pseudoscience). We use a variety of scientific approaches appropriately (i.e., descriptive, comparative, correlative, and experimental), yet these differ in their ability to refute or disprove general hypotheses. If one scans the proceedings of past international reef conferences [Bull. Mar. Sci. 37(1), 44(2), and 55(2–3)], a great many artificial reef studies have been quantitatively descriptive or correlative. Some have been comparative, yet surprisingly few have been truly experimental (i.e., with controls, treatments, replication, and interspersion). I say "surprisingly" because artificial reefs lend themselves so well to experimentation.

On the other hand, perhaps a paucity of experiments should not be surprising. From a practical perspective, meaningful reef experiments often require direct cooperation by resource managers, reef builders, and anglers. These users of research results must facilitate research in the first place. From a philosophical perspective, new fields of inquiry typically begin with observation, a search for quantitative relationships, and inductive reasoning. New fields then mature with deductive reasoning and explicit tests of *a priori* hypotheses. Thereafter, mature fields may proceed through iterations of induction and deduction whenever pivotal hypotheses are proven false.

My own contention is that inductive reasoning alone, as often expressed through multiple regression techniques, will not resolve the attraction-production issue. The required scale of sampling, precision of measurements, numbers of factors, and natural variability in marine systems are collectively prohibitive. Consequently, researchers and resource agencies using this approach are already data rich and conclusion poor. By the same token, rigorous hypothetico-deductive experiments may resolve the central issues of attraction-production yet leave fisheries managers short of the predictive capabilities they desire. Those of us opting for an experimental approach may establish primary cause-and-effect relationships to gain general predictability but still not adequately



Different architecture of artificial reefs might enhance or inhibit dif ecological processes, or alter the same processes to various degre

describe the shape of quantitative relationships and their confidence limits or predictor limits. The calibe of research reported at the 1995 AFS symposium in Tampa, Florida (i.e., "Future Artificial Reefs in the U.S. Coastal Ocean: Can Science Resolve the Biological Enhancement Question?"), indicates that reef research has indeed matured tremendously since the 1991 International Conference on Aquatic Habitat Enhancement [Bull. Mar. Sci. 55(2–3)]. Interestingly, i I may speak for my colleagues, none of the rese ers who presented at the AFS symposium would label himself or herself as an artificial reef ecologist, rather we consider ourselves to be marine ecologists of various kinds who have found reefs to be effective experimental systems for testing natural ecological processes. In this respect, artificial reef research has entered the mainstream of ecological research.

If one accepts that good science is being done, then resolution of the issue will depend on asking the right questions. For resource managers, reef builders, and anglers, the first question ought to be, "What is your management objective?" I would hop

I fear that too often the actual objective is simply to put more fish in the cooler.

that for artificial reefs the overriding objective is to biologically enhance fisheries stocks. Whether that is attainable is the core of the debate. However, it seems likely that we are on the threshold of specific applica tions for selected species [e.g., spiny lobsters (*Panulirus argus*) and gag grouper (*Mycteroperca microlepis*)]. Nonetheless, I fear that too often the actu objective is simply to put more fish in the coole we all must be honest about our underlying values and intent and acknowledge how they might shade our interpretations of research results. Anything less would be hypocrisy.

For researchers as well as user groups the wrong question to ask is, "Do artificial reefs attract fish or produce them?" Several reasons argue against this phrasing. First, it imposes an unrealistic either-or dichotomy reminiscent of the beer commercial, "Less filling! Tastes great!" As Bohnsack (1989) made clear, the issue very likely involves a continuum with a variety of factors, especially the target species. Second, this question does not suggest what specific comparisons, or null hypotheses, are appropriate for

an obvious question pertaining to attraction has been overlooked. Are artificial reefs inherently more attractive to fish than natural reefs?

empirical testing. Consequently, we get elegant quantitative descriptions from single reefs that demonstrate fish or shellfish in abundance, growing, surviving, and reproducing. But that is what living creatures do! To help resolve the attraction-production issue, a contrast would be necessary to test whether reefs can actually alter such measures of production. Third, this broad question implies an inference space covering all artificial reefs. It is unlikely that *all* reefs function identically. Different architectures might enhance or inhibit different ecological processes, or alter the same processes to differing degrees. Either way, the consequences could and probably would be different. Likewise, the same architecture in different locations could conceivably yield different results, particularly if the ecological processes affected by reef architecture depended on characteristics of the locale, e.g., circulation patterns or base productivity. Given these complexities, what are some of the right questions and the answers to date?

Most of our collective research efforts have been directed toward fish production; meanwhile, an obvious question pertaining to attraction has been overlooked. Are artificial reefs inherently more attractive to fish than natural reefs? This question cuts right to the heart of the challenge that originally began the attraction-production issue. At the 1995 AFS symposium, Hixon and Carr (see companion essay, pages 28–33, this issue) described an elegantly straightforward experiment with results apparently refuting the hypothesis that high fish densities at artificial structure were simply an artifact of behavioral preference. Their findings reinforced my own interests in habitat selection processes and how these relate to biological productivity. By contrast, no single experiment is likely to test fish production or productivity (including survivorship) directly at th levels that count most, i.e., breeding populations or fishery stocks. Instead, indirect tests in the deducti traditions of more mature sciences are the only rou to follow. A sequence of guiding questions seems useful:

(1) By what mechanisms or processes *might* artificial reefs enhance fish production (e.g., reduce habitat limitation on larval settlement, alleviate post-settlement demographic bottlenecks, enhance bottom-up production within reefs, or facilitate trophic coupling to off-reef production These constitute alternative, but not mutually exclusive, hypotheses.

(2) Are any of these mechanisms or processes affected by characteristics of artificial reefs (e.g structural complexity, location, reef dimension densities or patchiness)? The null hypothesis to be tested is "no effect" under conditions in which you would most expect an effect from specific processes.

(3) Can the rates of processes, confirmed under question 2, be shifted favorably relative to control conditions? Whereas question 2 can be answered by reef-to-reef comparisons, this question requires rate estimates and a contrast with productivity in appropriate natural habitat. The designation of what is appropriate deserves careful consideration.

(4) If the answers to questions 2 and 3 are "yes," then is the gain in productivity or production sufficient to offset associated fishing mortality? Ultimately, this is the important question for *sustainable* reef fisheries.

These are not easily answered questions, and they increase in difficulty from 1 through 4. Substantial progress has been made, but in fairness to the investigators, I can only highlight recent contributions from key research programs. I have already noted the importance of Hixon and Carr's most recent contribution. Earlier work by Hixon and Beets (1993) established refuge from predation as an important function of reef structure. Likewise, earlier work by Bohnsack et al. (1994) impugned the hypothesis that habitat for larval fish settlement was limited. Instead, the most highly valued fishes settled elsewhere and then colonized artificial reefs at later life history stages. Such findings are at least consistent with the hypothesis that habitat-related bottlenecks could affect the demographics of a population. The best example of this comes from Herrnkind and Butler's work with spiny lobsters (see companion essay, pages 24–27, this issue), which was reported at the 1995 AFS symposium. One application for artificial reefs might eventually be to slightly reduce natural

...tality during structure-dependent juvenile life ...tory stages of targeted species, which might then ...slate into increased abundances at later life ...tory stages.

...hile survivorship is an obvious component of ...duction at the population level, production also is ...mmonly considered with respect to assimilation, maintenance of fish biomass, growth, and repro... ...ction. The source of food supporting reef fish assim... ...ation should directly affect how artificial reefs func... ...tion. At the 1995 AFS symposium, Bohnsack, Ecklund, ...n. At the 1995 ...nd Szmant (see companion essay, pages 14–16, this ...sue) reported that a lack of on-reef primary and ...condary production had no effect on reef fish ...anding stocks. These negative results are important ...cause they refute the original dogma that had justi... ...ed artificial reefs as new foundations for the food ...eb supporting reef fish. By eliminating an alterna... ...ve hypothesis, this work also points out that trophic ...upling to off-reef production must be an important ...rocess supporting reef fish assimilation.

Effects of reef design on the trophic coupling to off-...eef production have been the subject of my own re...search program, in collaboration with many others. We ...xpected reef habitat patchiness to affect coupling to ...oft-bottom production with negative feedback to, ...nd observable effects on, reef-fish standing stocks. ...lthough our initial hypothesis may be correct, results ...o date also indicate important seasonal coupling to ...elagic production. Our research, like that reported ...y Herrnkind and Butler at the symposium, is now ...proceeding from question 2 toward questions 3 and 4.

The original question for this essay was, "Can science resolve the attraction-production issue?" My answer is "yes," but have we? Not yet, although we are much closer than we were five years ago. I believe that artificial reefs have the potential to become useful tools in fisheries management when used appropriately in conjunction with other management practices. Whether artificial reefs ultimately benefit fisheries stocks will likely depend on their management objectives. By analogy, nuclear fission can light up a city or level it, depending on how it is used. To paraphrase Albert Einstein, the serious problems that we have cannot be solved at the same level of thinking we were at when we created them.

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Do Artificial Reefs Increase Regional Fish Production? A Review of Existing Data

By Gary D. Grossman, Geoff P. Jones, and William J. Seaman, Jr.

ABSTRACT

We reviewed the scientific literature to determine whether the construction of artificial reefs increases the regional production of marine fishes. An evaluation of this technique is warranted by its high cost and logistical difficulty. Our review indicated that reef construction may have potentially deleterious effects on reef fish populations, including (1) increasing fishing effort and catch rates, (2) boosting the potential for overexploitation of stocks by increasing access to previously unexploited stock segments, and (3) increasing the probability of overexploitation by concentrating previously exploited segments of the stock. In contrast, the literature contained few studies that unambiguously demonstrated that artificial reefs increased regional fish production rather than merely concentrated available biomass. In addition, the literature on population regulation in reef fishes did not provide convincing evidence that reef fishes were limited by insufficient quantities of hard-bottom habitat. Consequently, potential positive and negative aspects of reef construction should be carefully evaluated prior to the addition of new reefs to marine environments.

During the last 30 years, the construction of artificial reefs has become a popular management tool employed by both government and private groups (Seaman and Sprague 1991). During this period more than 500 reefs have been constructed in U.S. coastal waters. Almost half the national total (at least 350 reefs) are located in Florida, where state funding related to reef construction and management have averaged close to $1 million annually (Pybas 1997). Despite these figures, our understanding of the biological effects of reef deployment on marine ecosystems is still quite limited. In particular, scientists are concerned that artificial reefs may harm fish stocks if they merely concentrate available biomass rather than increase its production on a regional basis (Polovina 1991). Our purpose for this paper is three-fold. First, we describe the utility and consequences of reef construction for marine fisheries management. Second, we review aspects of reef fish population dynamics that are relevant to the production-v-attraction question. Finally, we evaluate the conjecture that artificial reefs increase the regional production of economically important marine fishes and propose an experimental test to resolve the production-attraction dichotomy.

Why is the Construction of Artificial Reefs so Widespread?

This question has a simple answer: There is tremendous popular support for the construction of reefs because anglers visiting these habitats frequently experience high catch rates. High catch rates are supported by the relatively rapid colonization of artificial reefs by economically important species (Bohnsack et al. 1991). In addition, political reasons may favor the continued construction of artificial reefs. For example, fabrication of artificial reefs involves highly visible management activities (i.e., gathering and deploying cubic tons of concrete or scrap materials for the reef body). Given that anglers are typically required to purchase an annual fishing license, we suspect that user groups are more likely to feel that their money is being spent wisely when they can see the tangible efforts of management activities. Consequently, user groups likely exert tremendous pressure to continue the production and deployment of artificial reefs, despite the lack of rigorous scientific data regarding

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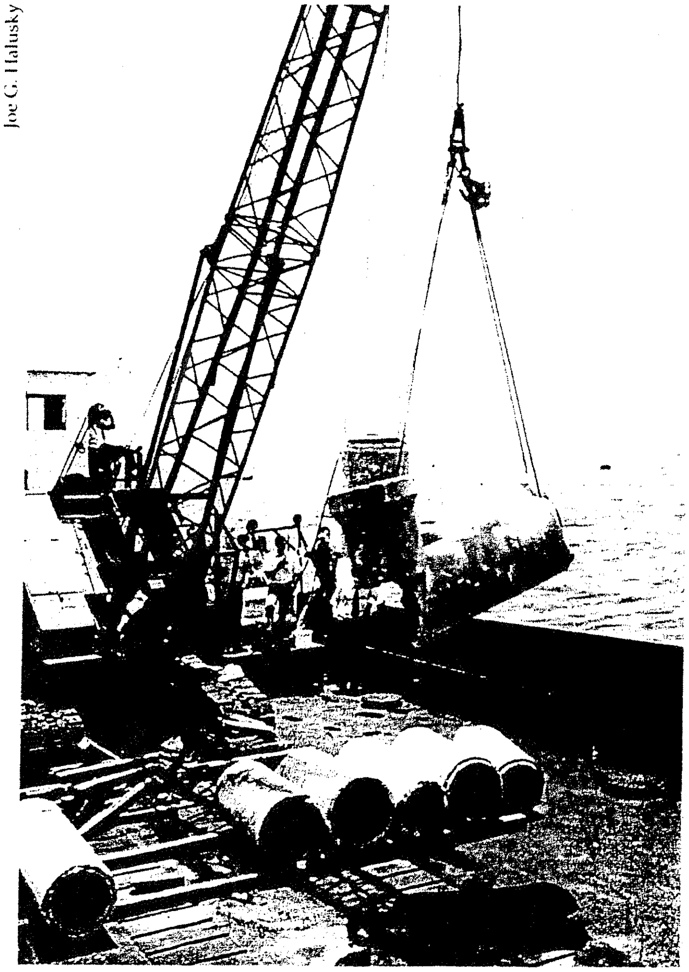
Joe G. Halusky



Scientists place culverts in the Gulf of Mexico for the Pinellas County Reef Program.

whether reefs have a positive or detrimental effect on marine ecosystems.

The Real and Potential Effects of Artificial Reefs on Marine Fisheries

The basic philosophical assumption underlying the continued deployment of artificial reefs is that regional fish production is limited by a paucity of hard-bottom habitat (Bohnsack 1989; Bohnsack et al. 1991; Polovina 1991). However, this assumption is supported mostly by short-term descriptive studies of individual reefs (Bohnsack 1989; Bohnsack et al. 1991). Nonetheless, if habitat is limiting, new reefs can potentially increase fish production through three mechanisms: (1) an increase in the foraging habitat of adult, juvenile, or newly recruited fishes; (2) an increase in the nesting habitat of adult fishes; and (3) an increase in the amount of resting habitat or refuges from predators. As a result, stock sizes of economically important species increase, and both recreational and commercial fishers benefit.

It also is possible that hard-bottom habitat does not limit regional fish production, especially if exploitation has already reduced stocks to levels substantially below carrying capacity. If true, construction of additional artificial reefs will have no effect on fish production; it will merely cause a redistribution of existing biomass (Bohnsack 1989; Polovina 1991). This may have differing effects on stock size depending on the stock segment affected. For example, if reefs disperse exploitable biomass and have no effect on unexploited biomass, then construction of new reefs should reduce the chance of stock overexploitation, assuming that fishing effort or power does not increase (Polovina 1991). However, if reefs concentrate both exploited and unexploited segments of a stock, then the probability of stock overexploitation increases, even if effort does not change (Polovina 1991). If effort increases concomitantly, then the probability of overexploitation may increase substantially.

Given that the relationship between reef construction and the probability of stock overexploitation is influenced by changes in fishing effort, it is appropriate to assess the likely effects of new reefs on fishing effort in a given area. We believe that reefs almost certainly increase access, and perhaps fishing effort, on hard-bottom habitat (McGlennon and Branden 1994). This assertion can be made with confidence because artificial reefs generally are placed in areas thought to have "insufficient" hard-bottom habitat. However, if new reefs are attracting fishers who previously did not fish hard-bottom areas due to a lack of availability, the probability of stock overexploitation may increase. In addition, several investigators have suggested that artificial reefs and pelagically located fish-attracting devices also may increase catch rates (Buckley 1989; Polovina and Sakai 1989; Friedlander et al. 1994). Consequently, the combined results of artificial reefs on angler effort (i.e., increases in angler access, fishing effort, and catch rates) may deleteriously affect the resource, especially if artificial reefs redistribute regional biomass rather than increase it.

Is Habitat Limiting for Reef Fishes?

The question of habitat limitation lies at the heart of the artificial reef controversy. We address it by briefly summarizing aspects of the relevant literature on population regulation of coral reef fishes (see Sale 1991). First, we examine the methodological strengths and weaknesses of the data; second, we evaluate the evidence in support of, and in opposition to, the habitat limitation hypothesis. In general, three types of studies have sought to identify the role of

...tat limitation in structuring ...sh assemblages: (1) descrip... studies of artificial reefs, (2) ...riptive studies of natural ... and (3) experimental studies ...reef isolates. Most studies that ...amine the effects of reef con...struction are (1) relatively short-...term (one to five years), (2) lack ...dequate control sites, and (3) ...ave no replication (i.e., one reef is ...amined). Thus, conclusions ...rawn from such investigations ...ay be of limited scientific value. ...t is noteworthy that much of the ...search reported in this volume ...oes not suffer from the aforemen...tioned experimental flaws (e.g., ...ort time span, no controls or ...eplication).] Similar problems ...ypically are found in data gath...ered from descriptive studies of ...atural reefs. Conversely, experi...mental studies on reef isolates ...solated coral heads or artificially ...onstructed units that mimic coral ...heads) generally have adequate ...ontrols and are well replicated. ...ome of these studies also are rel...atively long-term (Sale et al. 1984). Nonetheless, it is entirely possible that the dynamics of fishes on these habitats do not mimic those of the reef fish populations on larger reefs (i.e., the spatial scale may not be appropriate for identi...ying processes regulating popula...tion size; Tolimieri 1995). In addi...tion, most studies on reef isolates examine species that typically are not exploited by fishers (e.g., labrids, chaetodontids, holocan...thids, pomacentrids, blenniids); hence, we also are assuming, per...haps inappropriately, that the population processes regulating these taxa are similar to those governing exploited species such as serranids and lutjanids. Consequently, methodological shortcomings may mar the results of many studies relevant to the habitat limitation question.

Recognizing the potential limitations of existing data, we will now examine five lines of evidence in our assessment of whether habitat is limiting for reef fishes: (1) habitat abundance relationships, (2) effects of reductions in available habitat on reef fish assemblages, (3) tests of whether refuges from predation limit reef fish populations, (4) tests of whether recruitment affects the size of adult populations, and (5) tests of whether removal of reef residents (typically adults) produce a change in subsequent recruitment to the population.

Habitat-Abundance Relationships

These studies test the null hypothesis that the abundance and/or distribution of species on one or more reefs is not correlated with an environmental factor(s). If a positive correlation is obtained, some investigators have concluded that space is limiting for these fishes (e.g., Luckhurst and Luckhurst 1978), although such a finding does not necessitate habitat limitation (i.e., it could also be produced by food limitation or recruitment limitation). The evidence for habitat limitation in reef fishes based on habitat-abundance relationships is equivocal. Several descriptive studies demonstrate such a relationship (de Boer 1978; Luckhurst and Luckhurst 1978; Roberts and Ormond 1987). However, two other studies (Robertson and Sheldon 1979; Robertson et al. 1981) that experimentally reduced the amount of available space did not observe concomitant negative responses in a variety of population and demographic parameters (e.g., abundance, survival, body weight, and fat reserves) of two common reef species: three-spot damselfish [*Stegastes* (= *Eupomacentrus*) *planifrons*] and bluehead wrasse (*Thalassoma bifasciatum*). As a result, the less-powerful descriptive studies provide evidence that positive relationships exist between reef fish abundance and distribution, and habitat availability, although such findings do not require habitat to be limiting (den Boer 1978; Luckhurst and Luckhurst 1978; Roberts and Ormand 1987). Conversely, more rigorous but smaller-scale experimental studies do not support the contention that overall reef size or the availability of sleeping sites limits two common reef species (Robertson and Sheldon 1979; Robertson et al. 1981). Resolution of habitat availability v fish abundance relationships only will be accomplished with further experimentation at spatial scales ranging from reef isolates to entire reefs.

Although there is fairly strong evidence that increases in refuge availability may positively affect some reef fishes, including predators, this does not mean that constructing artificial reefs always will increase fish production.

Reductions in Available Habitat

These studies generally examine fish assemblage structure before and after declines in available habitat. The declines are caused by a variety of factors including (1) hurricanes (Kaufman 1983), (2) unusual sea temperatures (Wellington and Victor 1985), and (3) biological agents such as crown-of-thorns starfish (*Acanthaster planei*) (Sano et al. 1987). The general pattern observed is that corallivorous fishes decline in abundance when living coral biomass is reduced by a disturbance (Pfeffer and Tribble 1985; Sano et al. 1987; Jones and Kaly 1996).

Nonetheless, scientists have observed a variety of results for noncorallivorous fishes. In some locations these species decrease in abundance in response to declines in coral abundance (Sano et al. 1987); however, in other areas they either increase (Jones and Kaly 1996) or display no change in abundance (Wellington and Victor 1985; Williams 1985). Consequently, it seems likely that the abundance and distribution of corallivorous fishes may be limited by the amount of living coral habitat on a reef, but this relationship does not always hold for noncorallivorous fishes. Finally, it should be noted that most of the species that anglers seek as sport or commercial targets are noncorallivorous (e.g., serranids, lutganids, scombrids).

Refuge Limitation

Several researchers have suggested that predators are capable of limiting reef fish populations and, thus, increasing the availability of refuge sites will increase fish production (see Hixon 1991). Artificial reefs provide a potential mechanism for attaining this goal. The evidence regarding refuge limitation comes from several sources: descriptive studies correlating fish abundance or survivorship and refuge availability, predator removals on natural reefs, and experimental manipulations of refuge availability on reef isolates. A number of investigators have demonstrated positive correlations between fish abundance and the topographical complexity of reefs or numerical abundance of refuge sites (de Boer 1978; Shulman 1984, 1985; Roberts and Ormond 1987). Evidence from predator removal studies is equivocal. Bohnsack (1982) showed that several small species (including *T. bifasciatum*) increased in abundance when human exploitation reduced the number of large predators on a Florida reef in comparison with a similar unfished reef. However, this effect was not observed in most species occupying the reef. The predator exclusion experiments of Doherty and Sale (1985) produced similar results (i.e., some species affected, others unaffected), although their results also may suffer from several potential limitations typical of caging studies (Hixon 1991; Jones 1991). Finally, several investigators have demonstrated that refuge availability may limit both assemblage structure and survivorship of several reef species on reef isolates (Molles 1978; Hixon and Beets 1989, 1993; Buchheim and Hixon 1992). Although there is fairly strong evidence that increases in refuge availability may positively affect some reef fishes, including predators, this does not mean that constructing artificial reefs always will increase fish production. For example, even when a positive effect can be demonstrated (e.g., a one- to two-year increase in fish abundance in increased-shelter treatments), the population-level consequences of these increases are unknown. Hence, it is unclear whether local increases in refuge availability will then be translated into sustained regional increases in fish abundance and production because we do not know whether regional abundance is more strongly affected by recruitment limitation or refuge limitation (Tolimieri 1995). Nonetheless, based on the positive results obtained in small-scale studies, it is possible that artificial reefs could be used to increase local population sizes for reef species that are clearly limited by refuge availability.

Effects of Recruitment on Population Size

The null hypothesis examined in recruitment studies is that recruitment (i.e., number of larvae settling and surviving to eit[h]er ju]venile or adult status) has no effect on population size (Jones 1991). If hard-bottom habitat is a limiting resource, then variation in recruitment should have no effect on subsequent population size because all available habitat would be occupied. This presumes that recruitment always is sufficient to balance mortality from predation, disease, starvation, etc. Doherty and Williams (1988) have reviewed the data on recruitment variation in reef fishes; hence, we will merely summarize their results and discuss several more recent studies. The results of many recruitment studies demonstrate a positive correlation between recruitment and subsequent adult population size. Consequently, when recruitment is high, adult populations increase, and when recruitment is low, populations decrease (Doherty 1991; Jones 199[?]; Tolimieri 1995). This suggests t[hat] habitat may not be limiting to many reef fish populations. Nonetheless, this relationship is not universal (Jones 1991), and several investigators have shown that recruitment does not strongly affect subsequent adult population size, nor is it significantly reduced by post-settlement mortality, presumably through intraspecific competitions (Robertson 1988a,b; Jones 1991; Forester 1995). In these systems, adult population size is regulated by a variety of post-recruitment processes, including food availability and complex social interactions. In conclusion, it appears that both recruitment and post-recruitment processes may limit adult population size of coral reef fishes. The relative importance of the two types of processes depends on the species being examined.

Resident Removal Studies

These studies involve the removal of resident adults to test th[e]

...thesis that adult presence influences future settlement rates and eventually, adult population (Jones 1991). If habitat is limiting rather than recruitment or some other post-recruitment factor, one would expect successful recruitment to increase as new individuals replace the adults removed, and population size eventually returns to preremoval levels. If habitat is not limiting, then we would expect recruitment to either remain unchanged or decrease after resident removals. Resident removal studies have produced all three of the aforementioned results: (1) increased recruitment (Shulman 1984, 1985; Jones 1987), (2) no change (Doherty 1983; Sweatman 1985; Jones 1987), and (3) decreased recruitment (Sweatman 1985; Jones 1987; Tupper and Boutilier 1995). As with all other lines of evidence, resident removal experiments provide results that are consistent with the predictions of a variety of mechanisms capable of limiting reef fish populations.

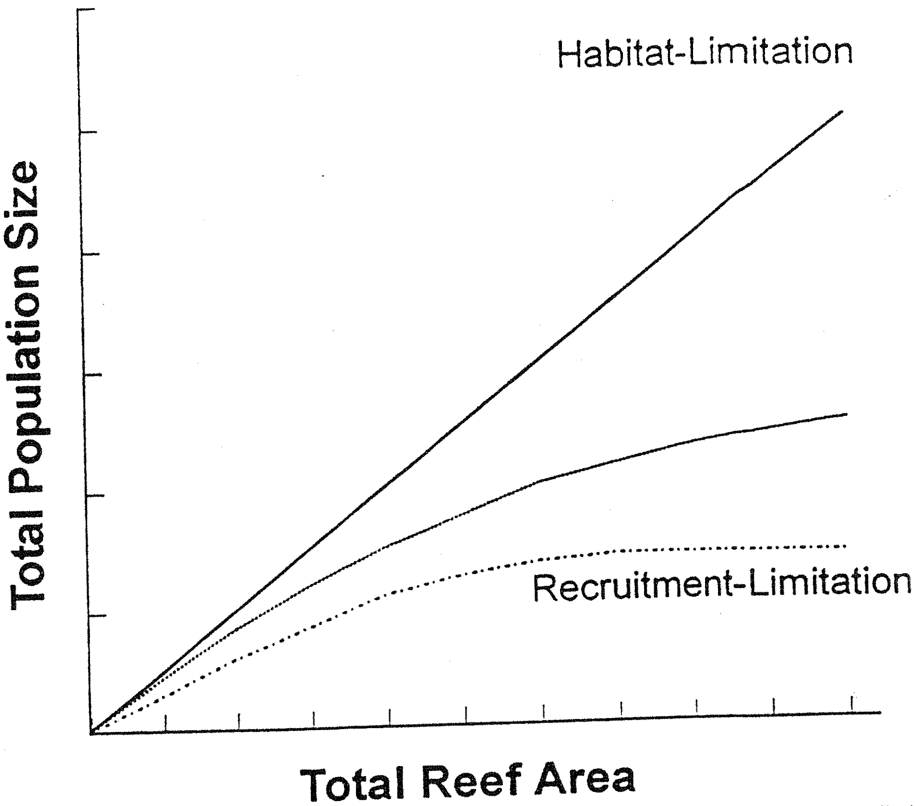


Figure 1 represents a graph of the expected results on reef isolates where populations are limited by either habitat or recruitment. See text for further information.

Do Artificial Reefs Increase Regional Fish Production? An Experimental Test

Because all artificial reefs are colonized by fishes at the level of the individual reef, increasing habitat usually produces a local increase in fish abundance or biomass. Nonetheless, this result can occur either when habitat is limiting (as carrying capacity increases with reef size) or recruitment is limiting (larger reefs attract more recruits). However, the issue of interest is whether or not regional fish abundance (or biomass) increases as more reefs are progressively added to a region? Does stock size continue to increase as some function of total reef area (Figure 1, habitat-limitation line), or will the population plateau since all available recruits have found suitable habitat (Figure 1, recruitment-limitation line)? In the latter situation, increased populations on individual reefs must reflect colonization via movement and must be compensated for by a decline on the source reefs. Total population size should remain the same. The contrasting relationships in Figure 1 represent two extremes, and the real situation may lie somewhere between the two curves (e.g., Schroeder 1987). The relative importance of habitat and recruitment-limitation might be tested by progressively increasing the number of artificial reefs within an area largely free of natural reefs, and measuring the form of this relationship. Any positive relationship will indicate some value in constructing artificial reefs, but there may be some density after which adding new reefs becomes superfluous.

An alternative approach to resolving this issue may be to survey a small cluster of natural reefs and use stratified sampling procedures to estimate the total population size of the cluster (c.f. McCormick and Choat 1987). Artificial reefs then could be constructed within the general area. Continued monitoring of both natural and artificial reefs would provide estimates of the population size on individual reefs and the total regional population size (natural plus artificial reefs). If colonization of natural reefs simply represents a redistribution of individuals, the total population estimate would not significantly increase. An intensive tagging program could provide additional information on the degree of colonization by movement.

Conclusion

Constructing artificial reefs is costly and logistically difficult (Seaman and Sprague 1991). Hence, an evaluation of the scientific basis for reef construction and deployment is critical. Nonetheless, existing data yielded mixed results when used to test the primary assumption underlying reef deployment (i.e., that hard-bottom habitat is a limiting resource for reef fish populations). This makes the continued construction and deployment of artificial reefs problematic, especially when there are competing management options. Without being overly pessimistic, however, there are cases where artificial reefs may increase the production of organisms favored by sport or commercial fishers. For example, Polovina and Sakai (1989) showed that refuges were probably limiting to octopi (*Octopus dolfleini*) in Japan and that adding structure to soft-bottom habitat increased refuge availability, which then resulted in increased octopi yields. Thus, if a species is limited by refuge availability, deployment of a reef with the appropriate refuges may result in increased regional production with subsequent increases in yield. Another example of reef deployment that is unlikely to cause widespread ecological damage is the creation of a geographically restricted, hard-bottom fishery in an area of extensive soft-bottom habitat. Nonetheless, if individuals are merely being attracted from other locations rather than being produced by the new reef, this may increase the probability of stock overexploitation. The likelihood of this possibility could be minimized by ensuring that new reefs are located well outside the home ranges or migration paths of species inhabiting nearby reefs. However, if managers choose to create such a fishery, they also should ensure that the reef does not cause extensive harm to the biota of the soft-bottom habitat.

We also want to comment on several aspects of current and future research on the production-v-attraction question. First, it is clear from the results described in this volume that scientists have made great strides in the design and execution of artificial reef studies. More studies now include control sites and adequate replication, and more emphasis is being placed on experimental or mechanistically oriented aspects of reef research (see Bohnsack et al., Herrnkind et al., and Carr and Hixon, all this issue). In addition, artificial reef researchers now realize that reef fish populations are embedded within a larger spatial matrix that may profoundly affect the local distribution and abundance of fishes through its effect on recruitment (Doherty 1981; Hixon and Beets 1993; Tolimieri 1995). It remains to be seen whether these broad-scale spatial factors (e.g., current patterns, distances from source populations, etc.) have a stronger regulatory effect on the reef-wide abundance of resident fishes than on local physical factors such as reef size and refuge number. Nonetheless, recognition of all of these factors will greatly increase our ability to answer the attraction-production question in a more timely manner.

In summary, the current evidence is insufficient to support the contention that hard-bottom habitat is limiting to most reef fish populations. Thus, the construction of future reefs must balance uncertain increases in organismal production against the potential problems of high cost and possible increased probability of stock overexploitation.

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United States Department of the Interior

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PFMC

Dr. Don McIssac
Executive Director
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 200
Portland, Oregon 97220

Dear Dr. McIssac:

At the request of NOAA Fisheries, I am sending you two CDs of the proceedings of the October 27-29, 2003 Minerals Management Service (MMS) Environmental Studies Workshop on Decommissioning Offshore Platforms & Pipelines. Marty Golden (NOAA Pacific Recreational Fisheries Coordinator) indicated that the materials would probably be useful in discussions at the upcoming PFMC meetings, March 7-12, 2004.

Additional copies of the CD may also be ordered by calling the MMS public access at (800) 672-2627.

If you have any questions, please contact me at (805) 389-7815.

Sincerely,

Maurice L. Hill

Maurice L. Hill
Environmental Coordinator

UNITED STATES DEPARTMENT OF COMMERCE
Office of the Assistant Secretary for
Oceans and Atmosphere
Washington, D.C. 20230

FEB 25 2004

Ms. Patricia E. Morrison
Principal Deputy Assistant Secretary
Land & Minerals Management
U. S. Department of the Interior
200 Constitution Avenue, N.W.
Washington, D. C. 20210

Re: Rigs to Reefs

Dear Ms. Morrison: *Patti*

I am writing to request your assistance in exploring the feasibility of modifying the Department of the Interior, Minerals Management Service's (MMS) regulations, dealing with partial removal or toppling in place of decommissioned oil and gas platforms for use as an artificial reef.

By way of background, a broad coalition of energy companies, represented by ChevronTexaco, and nongovernmental organizations, representing sportsfishing interests and proponents of artificial reef enhancement approached NOAA, MMS and other agencies, to determine whether they would support a proposal relating to procedures and criteria for the decommissioning of 23 oil and gas platforms in Federal waters off California, on a case by case basis. Specifically, these organizations propose to convert some or all of the decommissioned platforms to artificial reefs. This action seeks to preserve the marine habitat on and around the platforms, while potentially providing a significant cost savings to the oil industry. In return, the oil industry has proposed to use a substantial portion of the savings to establish an endowed trust fund for which the proceeds would be used for living marine resource research and management activities as well as for maintenance, monitoring, conservation, and research activities related to rigs to reefs efforts.

NOAA has reviewed this proposal and has been exploring ways to implement a Rigs to Reefs program in Federal waters off California. NOAA has determined that one possible approach is to work with MMS to study the feasibility of modifying federal regulations dealing with the decommissioning of oil and gas platforms. According to MMS's regulations at 30 CFR 250.1730, an MMS Regional Supervisor may:

> Grant a departure from the requirement to remove a platform or other facility by approving partial structure removal or toppling in place for conversion to an artificial reef or other use if...(a) the structure becomes part of a State artificial reef program, and the responsible State agency acquires a permit from the U.S. Army Corps of Engineers and accepts title and liability for the structure; and (b)

you satisfy any U.S. Coast Guard (USCG) navigational requirements for the structure.

NOAA proposes that MMS engage in rulemaking to authorize the transfer of title and liability of a decommissioned oil and gas platform to a non-profit or private entity for the purpose of creating an artificial reef or other uses relating to living marine resource research and management activities. As the state of California does not currently have a State artificial reef program, one option would be to allow a non-profit or private entity to act in the State's place, subject to all of the remaining regulatory requirements applicable to the construction and maintenance of an artificial reef in Federal waters.

I would be interested in discussing this matter with you in greater detail. You may reach me at (202) 482-3567. I look forward to hearing from you in the near future.

Sincerely,

Timothy R.E. Keeney
Deputy Assistant Secretary
for Oceans and Atmosphere

cc: Samuel D. Rauch
Assistant General Counsel for Fisheries, NOAA

William T. Hogarth, Ph.D.
Assistant Administrator, NOAA Fisheries

Scott Rayder
Chief of Staff to the Under Secretary, NOAA