OCS Study
MMS 2003-053

Consequences of Alternative Decommissioning Options to Reef Fish Assemblages and Implications for Decommissioning Policy

Final Technical Summary

Final Study Report

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

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Prepared under MMS Cooperative
Agreement No. 14-35-0001-30758
by
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U.S. Department of the Interior
Minerals Management Service
Pacific OCS Region

Camarillo
October 2003

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Suggested Citation

The suggested citation for this report is:

Carr, Mark H., McGinnis, Michael Vincent, Forrester, Graham E., Harding, Jeffrey, and Peter T. Raimondi. Consequences of Alternative Decommissioning Options to Reef Fish Assemblages and Implications for Decommissioning Policy. MMS OCS Study 2003-053. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number 14-35-0001-30758. 104 pages.

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FINAL TECHNICAL SUMMARY

STUDY TITLE: Ecological Consequences of Alternative Abandonment Strategies for POCS Offshore Facilities and Implications for Policy Development

REPORT TITLE: Consequences of Alternative Decommissioning Options to Reef Fish Assemblages and Implications for Decommissioning Policy

CONTRACT NUMBER: 14-35-0001-30758

SPONSORING OCS REGION: Pacific

APPLICABLE PLANNING AREA: Southern California

FISCAL YEAR(S) OF PROJECT FUNDING: FY 95, FY 96, FY 97

COMPLETION DATE OF THE REPORT: May 2003

COST(S): FY 95 - $101,586, FY 96 - $78,784, FY 97 - $75,325, FY 98 – no cost, FY 99 – no cost, FY 00 – no cost, FY 01 – no cost

CUMULATIVE PROJECT COST: $255,695

PROJECT MANAGER: Russell J. Schmitt

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KEY WORDS: California Outer Continental Shelf; Marine Ecology; Marine Policy; Rigs-to-Reefs; Gulf Outer Continental shelf; Artificial Reef Program; Temperate Reef Fishes; Decommissioning; Rockfishes; Garbage Can Model; Offshore Oil Platforms; Santa Barbara Channel; *Sebastes*; *Macrocystis*; Rocky Subtidal; Rocky Reefs; ROV; Diver Surveys; Fish Movement

BACKGROUND: Critical to formulation of appropriate decommissioning policy is an understanding of the ecological, economic and social consequences of different decommissioning options and identification of the mechanisms by which such information is incorporated, or not, into legislation and public policy. One particularly important ecological consequence of abandoning production platforms along the West Coast is a potential change in the species composition and structure of regional fish populations and assemblages, which may in turn influence yields to fisheries. Hard substratum reefs represent a small fraction of the available offshore habitat in California, but are sites of high fish density and production (Greene[1], Bond et al. 1999). However, prior to this study, only one study provided quantitative estimates of species composition and abundance of fishes at a single platform off southern California. Nor is it clear how and to what extent ecological information contributed past decommissioning decisions on the West Coast.

OBJECTIVES: The two broad objectives of our study were to collect and provide information that would help ascertain (1) the ecological effects of total or partial removal of offshore structures, specifically with respect to their effects on regional fish population and assemblages, and (2) whether and how scientific information has influenced prior decommissioning policy, both along the coast of California and in the Gulf of Mexico.

DESCRIPTION: Our approach to estimating the potential effects of decommissioning options on regional fish populations and assemblages included five primary components: (1) we compared the species composition, density and size distribution of reef fishes inhabiting vertical strata of six production platforms and five nearby natural reefs over a three-year period to determine what component of the regional fish assemblage occurred on platforms, (2) size distribution information provided insight into what life stages use platforms, which in turn suggests the resources provided by platforms and the fate of fishes using that habitat, (3) we estimated movement distances of fishes between natural reefs and platforms, again to determine how the presence of a platform influenced nearby natural populations, (4) we hoped to compare the relative density-specific performance (i.e. survival, growth and reproduction) of a model species between platforms and natural reefs, and (5) we hoped to use bottom maps of the Santa Barbara Channel to estimate the relative contribution of platforms to natural rocky reef habitat in that region.

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[1] Dr. Gary Greene, Moss Landing Marine Laboratories, personal communication. Dr. Greene has interpreted and categorized (by substratum type and relief) multibeam data collected by the Monterey Bay Aquarium Research Institute (MBARI) Mapping Team throughout the Santa Barbara Channel and Point Conception area: MBARI Santa Barbara Channel Multibeam Survey, Digital Data Series No. 4, 2001.

Our diver and Remotely Operated Vehicle (ROV) surveys on six platforms and five natural reefs during 1995, 1996 and 1997 identified subsets of regional reef fish assemblages that occur on platforms and the nearby natural reefs. The primary differences in these assemblages were an under-representation of reef fishes that associate with macroalgae (e.g., the giant kelp, *Macrocystis*) or with limited larval dispersal (surfperches) on platforms, and a greater representation of many midwater and deeper-dwelling rockfishes (genus *Sebastes*). Both species and size classes exhibited vertical stratification along platforms, indicating differential use of vertical portions of the platforms. Species that inhabited the upper portions of platforms (< 20 m depth) were characteristic of species that inhabit shallow rocky reefs, and were predominantly planktivores. Species in the lower portion of the platforms were predominantly midwater and benthic rockfishes. Young stages of many species occurred only in the upper portion of platforms, whereas the young of other rockfishes occurred throughout the water column or on the bottom. The vertical stratification of juveniles and adults suggests that removal of the upper portion of platforms will reduce the abundance of some species directly, curtail recruitment of others and suggesting that removal might curtail recruitment of these species to these structures. Similarly, the young of some benthic rockfishes inhabited mounds of mussel shell litter beneath platforms. With removal of the upper portion of platforms and the source of mussel shell production, this habitat would also diminish in time. This implies that removal might curtail recruitment of these species to platform habitats. This vertical stratification of juveniles and adults of some, but not all species, suggests that removal of the upper portion of platforms will reduce the abundance of some species directly, curtail recruitment of others and alter the fish assemblage that inhabits otherwise intact platforms.

Movement patterns were estimated by tagging over 450 fish, of which 50 were recaptured to provide some estimate on movement distance. Most fish were recaptured at the site of tagging, suggesting limited movement among habitat types. Patterns of the relative density of life stages between platforms and natural reefs reinforced this result for some species and contradicted it for others. Limited tagging of fishes on platforms made some of these patterns difficult to interpret.

Because no one species co-occurred in large numbers on both the platforms and natural reefs we studied, we were unable to compare density-specific performance of fishes among the two habitat types. We also were unable to obtain appropriate bottom habitat maps to estimate the relative contribution of platforms to hard substratum habitat in the Santa Barbara Channel or the study area. These two constraints are highlighted as recommended issues to be addressed in future projects.

Our approach to determining the role that ecological information has contributed to past decommissioning policy decisions required research on past decommissioning decisions in both the California and Gulf of Mexico regions. Section Three of this report describes our approaches, results and conclusions from this analysis. We use John Kingdon's "revised garbage can model" analytical framework to show that there is a political ecology to decommissioning policymaking in the Gulf and California OCS regions. Decommissioning policy (including the development of the various "rigs-to-reefs" options) is shaped by the distinct ecological and political contexts of the Gulf and California. For background, this section describes briefly the ecological, political and historical context of California OCS oil and gas activity, the policy debate over decommissioning options in the State Legislature and development of decommissioning policy in the Gulf region. Our analysis identifies strong differences in the relative roles and effects of the ecology and scientific community in these two regions.

SIGNIFICANT CONCLUSIONS: Fish assemblages on the production platforms and nearby natural reefs we studied differed in species composition and relative abundance. These differences stem from differences in the structural features of these two habitats (e.g., absence and presence of macroalgae), the surrounding landscape (platforms are located in deeper water further from shore and are isolated by deep water from natural reefs), and the unique vertical extension of platform structure from the bottom to the sea surface. Vertical stratification of different species and life stages indicate that decommissioning options that reduce the height of platforms will alter the abundance of species and the overall fish assemblage associated with such structures. Patterns of size structure and movement of some species strongly suggests that these species may recruit to natural reefs and migrate to platforms as older stages. Other species (e.g., surfperch) have such limited movement that they do not appear to migrate to platforms. Patterns of movement in the opposite direction may be substantial as well, however we were not able to conduct extensive tagging efforts on our study platforms. This is another research effort that would be useful to better understanding the role of platforms to regional fish populations.

We show that state and federal decommissioning policymaking is based on economic and ecological factors that reflect particular regional and political settings. In the Gulf region, the rigs-to-reefs "idea" was less an invention and more a mutation of an old idea. The rigs-to-reefs idea represented the coupling of an already familiar activity of building artificial reefs in the Gulf to enhance commercial and recreational fisheries. The use of familiar ideas, such as the idea of artificial reef building in the Gulf, by policy entrepreneurs and experts is referred to as the "act of recombination". The rigs-to-reef policy idea represented a recombination of an old solution (the reliance on artificial reefs to enhance fisheries) to a perceived new problem (the lack of natural habitat and potential economic impacts associated with complete removal of OCS oil and gas structures). The role of ecological research in the development of decommissioning policy in the Gulf region can be characterized as strongly supportive and directed at identifying the contribution of platforms to the enhancement of fisheries.

In southern California, the political debate over the decommissioning of oil and gas structures involves the intermingling of ecological information, economic factors, preferences and interests associated with OCS oil and gas activity. The southern California context is much different from that of the Gulf experience. Gulf states are willing to accept the rigs-to-reefs alternative, and have developed state policy and programs. Gulf state rigs-to-reefs programs continue to serve the needs and interests of commercial and sports fishing industries. In California, state legislation that could lead to the creation of a state rigs-to-reefs program under the California Department of Fish and Game has been introduced repeatedly. That legislation has been rejected for several reasons, political reasons and an expression of scientific uncertainty and mixed conclusions among marine ecologists in that region. We describe the ecological, economic and historical factors that are part of the California rigs-to-reefs debate and the roles that ecological information appears to have influenced the development of decommissioning policy.

STUDY RESULTS: In the case of the Gulf, an advocacy coalition that combined the interests of the oil industry, recreation and commercial fishing, scientists, and resource managers supported the use of offshore platforms as artificial reefs. The development of oil and gas in the Gulf OCS led to an increase in commercial and sports fishing activity. Scientific reports and workshops spoke to the benefit of artificial reefs in the Gulf. States and local artificial reef programs had been established before the passage of the National Fisheries Enhancement Act (NFEA) of 1984. In passing the NFEA, the federal government granted discretionary authority to states to create their respective platforms to artificial reef program. Many of these programs were based on existing artificial reef programs.

Despite the intent of the National Fisheries Enhancement Act of 1984, which fostered the development of Gulf state rigs-to-reefs programs, there remain a number of issues and concerns associated with the use of platforms as artificial reefs in California. The major issues and concerns that general public, the scientific community and policymakers are facing include the following:

(1) *The Liability Issue*. Since the publication of the National Artificial Reef Plan, which recommended that the US Army Corps of Engineers develop specific permit standards and conditions, the issue of liability remains vague and unclear. The Corps has developed a policy requiring the permit holder of an artificial reef to prove adequate liability coverage. Gulf states with reefing programs have assumed the role of the permittee. This has necessitated a close review of the role of the states and localities in implementing the NFEA. Clarification of this issue would improve operational procedures and potentially reduce uncertainty about exposure on the part of state artificial reef managers.

(2) *Scientific Uncertainty: Production versus Aggregation*. Scientists and policymakers remain concerned about the production versus aggregation question. It remains unclear if platforms attract or produce fishes. Some scientists and policy makers contend that too much emphasis has been placed on adult fishery enhancement activity associated with offshore structures, and not enough resources have been spent on restoring essential coastal processes, such as estuarine habitats and wetland ecosystems (the "nurseries of the sea").

(3) *Limited Funding*. Since the passage of the NFEA, Gulf state and California artificial reef programs have not received adequate funding. State artificial reef programs maintain an average staff size of 1 full-time employee. Most funds are generated from either state appropriations or Wallop-Breaux funds, which refer to the 1984 Wallop-Breaux Amendment to the Federal Aid in Sport Fish Restoration Act (16 U.S.C. sec. 777 (1988)). Oil companies that "donate" structures are asked to contribute half of the disposal savings realized to the Fund. In addition, monitoring of existing artificial reefs and regulatory compliance issues remain important concerns of state artificial reef managers.

STUDY PRODUCTS:

Publications:

McGinnis, M.V. in press. The Political Ecology of the Offshore Oil Platform Rig-to-Reef Policy Debate. *Proceedings of California and the World Ocean '02.* California Resources Agency.

Carr, Mark H., McGinnis, Michael Vincent, Forrester, Graham E., Harding, Jeffrey, and Peter T. Raimondi. Consequences of Alternative Decommissioning Options to Reef Fish Assemblages and Implications for Decommissioning Policy. MMS OCS Study 2003-053. Coastal Research Center, Marine Science Institute, University of California, Santa Barbara, California. MMS Cooperative Agreement Number 14-35-0001-30758. 104 pages.

Carr, M. H. and G. E. Forrester. 2000. Ecological Consequences of Alternative Decommissioning Strategies for POCS Offshore Facilities: Preliminary Results. Pp. 499-502 in Proceedings of the Fifth California Symposium, D.R. Brown, K. L. Mitchell, H. W. Chang, Eds. (Minerals Management Service Publication 99-0038), p. 379.

Holbrook, S. J., Ambrose, R. F., Botsford, L., Carr, M. H., Raimondi, P. T., and M. J. Tegner. 2000. Ecological Issues Related to Decommissioning of California's Offshore Production Platforms. A Report to the University of California Marine Council by The Select Scientific Advisory Committee on Decommissioning, University of California. http://www.ucop.edu/research/ucmc_decommissioning/

McGinnis, M.V. 1998. An Analysis of the Role of Ecological Science in Offshore Continental Shelf Decommissioning Policy. In O.T. Magoon, H. Converse, B. Baird, and M. Miller-Henson, eds. Taking a Look at California Ocean Resources: An Agenda for the Future. Reston, VA: American Society of Civil Engineers. Pp. 1384-1392.

Databases and digital data: All databases generated from this study are available on CD and by request of Mark Carr (UC Santa Cruz). Underwater video footage collected by scuba divers and ROV during this project are available in both Hi-8 and S-VHS format. Video tapes currently reside in Dr. Carr's lab (UC Santa Cruz) and available on request with permission of the MMS-POCS office.

Presentations:

Carr, M. Understanding the Ecological Consequences of Artificial Reefs in Coastal California. Invited Speaker to the California Coastal Commission. Los Angeles, CA, August, 1999.

Carr, M., Forrester, G., and P. Raimondi. Ecological Consequences of Alternative Decommissioning Strategies for POCS Offshore Facilities: Preliminary Results. Channel Islands Symposium, Santa Barbara, CA, March 1999.

Carr, M. Decommissioning of Offshore Oil and Gas Facilities: Contrasts Between Southern California and the Gulf of Mexico and Implications for Ecological Research. Invited Speaker. California and the World Ocean '97, San Diego, California, March 1997.

Carr, M. Ecological Aspects of the Decommissioning of Offshore Oil Facilities. Invited Speaker. Santa Barbara Chapter of the League of Women Voters. Santa Barbara, July 1997.

Carr, M. Habitat Value: Summary of Research on the Ecological Role of Offshore Oil and Gas Production Facilities. Decommissioning and Removal of Oil and Gas Facilities Offshore California: Recent Experiences and Future Deepwater Challenges, Ventura, CA, September 1997.

Carr, M. Summary and Recommendations on the Disposition of Offshore Oil and Gas Facilities Offshore California. Co-Chair of the Disposition Workgroup for the Decommissioning and Removal of Oil and Gas Facilities Offshore California: Recent Experiences and Future Deepwater Challenges, Ventura, CA, September 1997.

Carr, M. Biological Research Applications of Remotely Operated Vehicles (ROV). Marine Technology Program, Santa Barbara City College, May 1996.

Carr, M. and M. McGinnis. Contrasting Issues Relevant to Abandonment Policy and Regulation in Southern California and the Gulf of Mexico: Implications for Environmental Research. Invited Speaker, International Workshop on Offshore Lease Abandonment and Platform Disposal: Technology, Regulation and Environmental Effects, New Orleans, LA, April 1996.

FINAL STUDY REPORT

Section One: Introduction

Background: Ecological Considerations of Artificial Reef Habitats

The presence of man-made structures in the ocean has drawn great attention among scientists and resource managers both with concern for potential impacts to the natural environment caused by the presence of these structures and the communities of species that associate with them, and with interest for their possible role in enhancing species diversity, populations, and associated fisheries. Scientific assessments of the ecological consequences of man-made underwater structures (aka "artificial reefs") have been the focus of a growing number of international conferences and scientific reports (e.g., volumes 44 and 55 of the Bulletin of Marine Science, volume 22 of Fisheries). One critical conceptual development in the consideration of ecological consequences of artificial reefs is the spatial scale of their influences. The importance of understanding ecological effects at a range of spatial scales stems from the complex life history of species typically associated with reef habitats and the implications for the spatial structure of their populations and communities. Most species of marine fishes and invertebrates have early life stages (i.e. spores, eggs, larvae) that can be dispersed great distances (in some cases up to hundreds of kilometers) to replenish populations elsewhere, but have adult stages that often remain in localized reef areas. As a result, populations and communities associated with a local reef habitat influence and are influenced by the dispersal of offspring and the movement of adults among populations. Thus, reef-associated populations are interdependent, and changes in habitat at any one location (a natural or artificial reef) should be viewed in the broader context of the regional set of local populations and communities. This necessitates examining the influence of structures to populations both in the close vicinity of the artificial reef as well as further away.

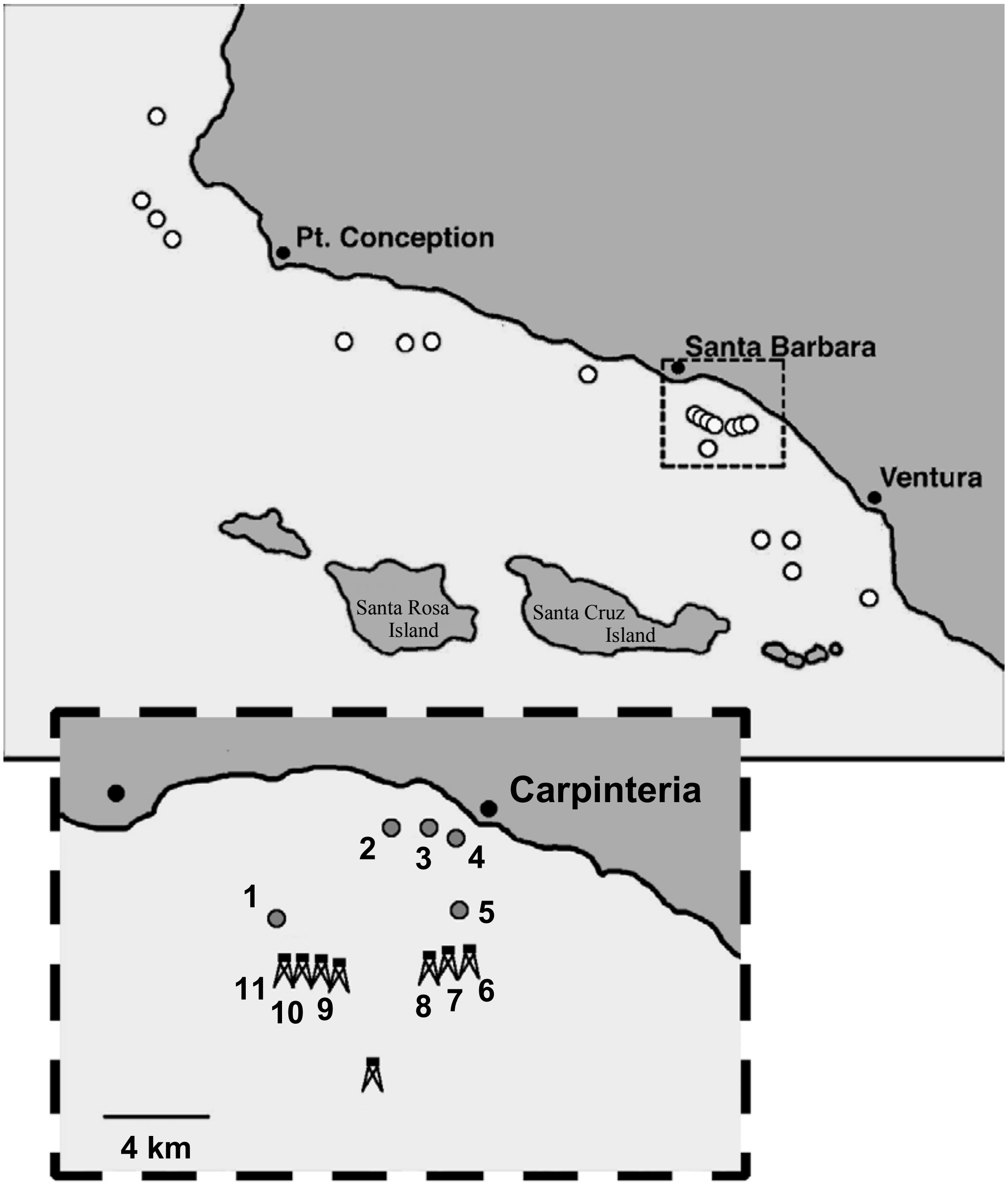
Direct assessment of the regional effects of local habitat modification are problematic because of difficulties in (1) determining the spatial pattern of effects (determined by the movement of larvae and adults among reef habitat), (2) ascertaining the actual fate of young dispersed from a local population, and (3) detecting the small magnitude of effect (e.g., increased recruitment of young to adult populations) over the large area that individuals are dispersed. One approach to ascertaining regional effects is to monitor the state of a regional population before and after introduction of a structure within that regional population. This approach can be achieved by monitoring the state of both populations associated with the artificial structure and a representative subset of natural populations and employing various analytical methods (e.g., the Before-After-Control-Impact analysis; Osenberg et al. 2002)). Alternatively, ascertaining both the local and regional ecological effects of artificial reefs can be estimated indirectly by comparing how well individuals or populations perform (with respect to growth, survival, reproduction) on artificial structures relative to natural reefs (Alevizon and Gorham 1989, Beets and Hixon 1994, Carr and Hixon 1997). If species perform equivalently or better on artificial reefs than they do on natural reefs, it is most likely that presence of an artificial habitat will benefit the regional population of that species. If species perform more poorly, than any possible benefits are tenuous. For either assessment, comparison of demographic processes (e.g., mortality, reproduction) between artificial and natural reefs is mandatory.

Along the West Coast of North America, as in many places in the world, the most substantial man-made structures are the offshore facilities created for the extraction of oil. At present, there are 27 "production platforms", most of which are likely to end their period of oil extraction within the next two decades and at which time are required to be decommissioned. Four of these structures are in California State waters (Table 1). At the time that all 27 structures were installed, state and federal regulation required the complete removal of all structures and the return of the seafloor to pre-installation conditions at the end of their period of production (California Coastal Commission 1999). To date, only 7 smaller platforms have been decommissioned along the coast of California. The most recent decommissioning of four platforms (Hope, Heidi, Hazel and Hilda) in 1969, were removed as required by law. This activity raised interest in consideration of alternative decommissioning scenarios, particularly for decommissioning of structures at sea, to serve as artificial reef structures. This recent interest in alternative decommissioning scenarios has led to increased interest in exploring their ecological costs and benefits.

Five decommissioning options for coastal platforms have been proposed, including (1) leaving the intact jacket and superstructure structure in place, (2) complete removal, (3) top portion of platform removed to 20 – 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 (Figure 2). Two key attributes underpin the potential ecological consequences of these proposals. First is the consideration of leaving structures in place, or moving them to new locations. The ecological implication of this stems from the possible regional variation in ecological effects of structures where they currently exist or where they might be relocated. Therefore to better understand the potential local and regional ecological consequences of decommissioning at sea requires knowledge of spatial variation in the species assemblages and population attributes associated with structures in their present locations. The second, key feature of several decommissioning scenarios is the disappearance of the upper portion of platforms, either by their removal or the toppling of the structure. If the presence of the structure in the upper portion of the water column influences its ecological influence (e.g., algal and sessile invertebrate production, recruitment habitat for fishes), then understanding the ecological role of the upper portion of platforms is necessary for predicting the ecological consequences of these decommissioning scenarios.

Perhaps the most important ecological consequence of decommissioning production platforms along the West Coast is likely to be a change in local and regional fish production (the biomass of fish accrued per year) and the structure (i.e. relative abundance) of the regional fish assemblage, both of which may in turn influence yields to fisheries. Hard substratum reefs represent a small fraction of the available offshore habitat in California, but are sites of extremely high fish production. Limited information suggests that these production platforms can support large numbers of fishes that associate with hard substrata, and may therefore function as sources of biomass and larval production (Carlisle et. al. 1964, Turner et. al. 1969, Bascom et. al. 1976, Mearns and Moore 1976, Love and Westphal 1990, Love et. al. 1994, 2000). Indeed, throughout the Gulf of Mexico OCS region, where the amount of natural hard substratum is more limited, oil platforms contribute substantially (ca. 28 %; Gallaway 1984) to local and regional abundance of "reef" habitat and the abundance of reef-associated fishes (Gallaway and Lewbel 1982, Continental Shelf Associates, Inc. 1982, Stanley and Wilson 1991, Scarborough Bull and Kendall 1994). There are, however, no quantitative estimates of the extent to which offshore production platforms contribute to the total amount of "reef" habitat in the Pacific OCS region. Prior to our study there was also very little quantitative data on the abundance and structure of fish populations and assemblages associated with production platforms, and no comparative studies of platforms and natural reefs. Also uncertain was whether the fish present around platforms are the result of increased production or simply reflect the attraction of fishes that would otherwise reside on natural reefs. Therefore, one key objective of our study was to describe quantitatively the fish populations and assemblages associated with production platforms and nearby natural reefs. To determine the extent to which fish assemblages associated with platforms possibly reflected the redistribution of fishes from natural reef habitat, we used a tagging study to estimate movement of fishes among natural reefs and platforms.

Figure 1. Location of offshore oil production platforms along the coast of southern and central California. The six platforms studied in this project constitute the arc of platforms extending from shore in the eastern end of the Santa Barbara Channel (see inset). Latitude and Longitude values for the natural reefs are presented in Table 2. Values in parentheses are bottom depths of reefs and platforms.



Natural reefs

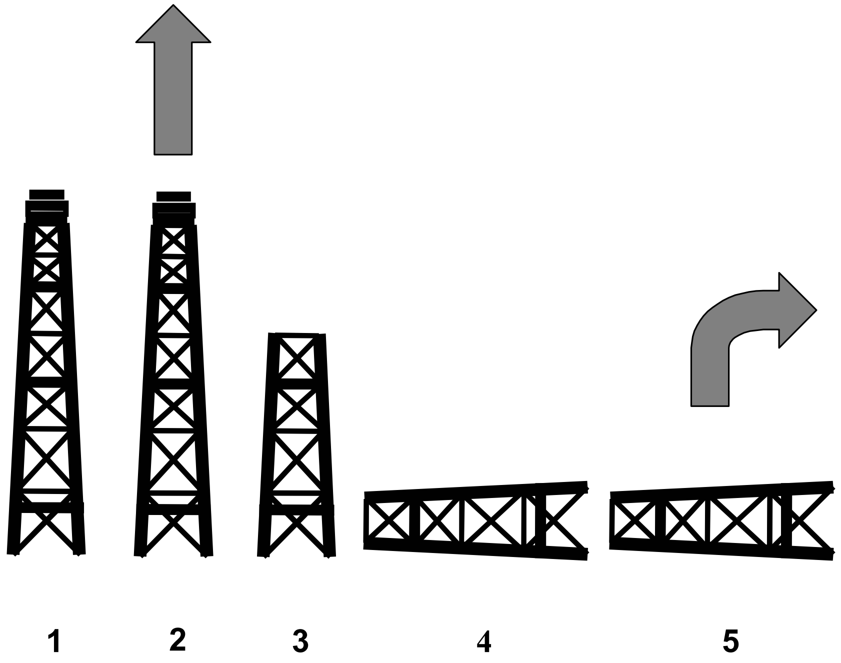
1= 4-mile reef (36m)
2= Horseshoe reef (16m)
3= 3-Spot reef (11m)
4= Carpinteria reef (8m)
5= Crouch reef (34m)

Study Platforms	Latitude and Longitude
6= Hogan (50m)	34°20.27, 119°32.48
7= Houchin (50m)	34°20.10, 119°33.13
8= Henry (50m)	34°20.00, 119°33.62
9= A (58m)	34°19.92, 119°36.75
10= B (58m)	34°19.93, 119°37.30
11= C (58m)	34°19.98, 119°37.85

Table 1. Structural characteristics of the 27 offshore platforms along the coast of California. Characteristics of the six platforms used in this study are indicated in bold font. Surface area estimates are based strictly on member dimensions and does not account for fouling organisms.

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**	**16,111**	**80,541**
10	**B**	**Federal**	**East SB Channel**	**58**	**1930**	**16,111**	**80,541**
11	**C**	**Federal**	**East SB Channel**	**58**	**1930**	**16,111**	**80,541**
12	Hillhouse	Federal	East SB Channel	58	nd		nd
13	**Henry**	**Federal**	**East SB Channel**	**52**	**1505**	**8,577**	**50,403**
14	**Houchin**	**Federal**	**East SB Channel**	**49**	**1435**	**8,190**	**68,350**
15	**Hogan**	**Federal**	**East SB Channel**	**47**	**1435**	**8,190**	**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				

Figure 2. Illustration of the five proposed alternative decommissioning scenarios. 1= leaving entire structure in place, 2= removing entire structure to shore, 3= removing upper 20 m of structure in place, 4= removing upper 30 m and toppling structure in place, 5= same as 4 but relocating structure elsewhere at sea.



Approach: Fish Assemblages on Natural Reefs and Production Platforms

Our approach to ascertaining the potential effects of decommissioning options on regional fish populations and assemblages included three components. First, we compared the species composition, density and size distribution of reef fishes inhabiting vertical strata of six production platforms and five nearby natural reefs over a three-year period to determine what component of the regional reef fish fauna occurred on platforms and natural reefs during that period. Such information is required to determine what species and life stages might be influenced by the various decommissioning options. Do fish recruit to each habitat type from the plankton (as larvae) or migrate onto one habitat type from the other as older stages (benthic juveniles and adults)? Comparison of fishes between platforms and natural reefs provides information on what stages use the two habitat types. Patterns of fish sizes over time can also provide information on how long fishes associate with each habitat type and how well they grow and survive. Such information is critical to understanding the relative value of natural reefs and platforms as fish habitat.

Also fundamental to understanding the net contribution of local populations to regional production is information on the size-specific rate of migration of fishes among local, reef-associated populations. In the context of platform decommissioning, knowledge of the net direction and rate of transfer of individuals between platforms and natural reefs is crucial. For example if fish recruit to natural reefs and eventually migrate to platforms, accumulation of fish biomass on platforms would be incorrectly attributed to production at the platform habitat.

Conversely, if platforms provide recruitment habitat for fish that eventually migrate to natural reefs, the contribution of platforms to regional production may be grossly underestimated by simply measuring production in the two habitats. Movement information is also important to determine whether the loss of fish at a site is due to emigration rather than mortality. Therefore, we conducted a tagging study to patterns of movement in the vicinity of platforms and nearby natural reefs.

Finally, for reasons mentioned above, we hoped to compare the relative performance (i.e. growth and survival) of a model species between platforms and natural reefs. We were particularly interested in species of economic importance, such as the kelp bass and kelp rockfish for the recreational and commercial fishery, respectively.

Background: Ecological Information and Development of Decommissioning Policy

The transition from exploration and development to decommissioning of offshore production platforms and associated structures marks a fundamental change in the history of oil and gas activity along the West Coast. The National Research Council (1985) estimated that the cumulative costs for removal of all platforms in the offshore continental shelf (OCS) could total $2.9 billion by 2005 and $9.9 billion by 2020. The Governmental Account Office (GAO 1994) reviewed offshore structure removal operations and concluded that better understanding of the risk of ecosystem damage posed by certain decommissioning practices, such as the use of explosives as a removal technique is needed. Government agencies, scientists and special interest groups have proposed alternatives to complete removal of offshore platforms. While states on the Gulf of Mexico have developed and implemented “rigs-to-reefs” (i.e. decommissioning structures at sea) policies and programs, the different ecological setting, political culture, and the role played by the marine scientific community in California have all contributed to greater opposition in the development of similar policies here (McGinnis et al. 2001). The policy debate is trans-scientific -- it involves the intermingling of both values and facts including important perceptual, value-based and ethical issues (Shrader-Frechette and McCoy 1994). The politics of integrating scientific information into the platform decommissioning debate is a highly charged and contentious intergovernmental process that involves participants who may not share the same values about offshore oil and gas activities or the role of artificial reefs in the broader context of “enhancement” and conservation of the nearshore marine environment. Historically, OCS oil and gas activity is a political process that includes litigation (Lester 1991). Moreover, given scientific uncertainties associated with marine ecosystems, “good” scientific information is that which supports one’s position in the decision-making situation (McGinnis 1998).

Implementation of decommissioning practices for the West Coast other than complete removal will require development of new policy and legislation. The relevance of our ecological research to decommissioning decision-making and policy development assumes that knowledge of the ecological roles of oil platforms might contribute to such policy development. However, formulation of alternative decommissioning policies must also consider their political, social, and economic consequences. The extent to which ecological research will contribute to decision making will depend on at least two issues: (1) how strong of an effect the presence of offshore structures has on regional populations and communities of marine organisms, and (2) how important such ecological effects are relative to social and economic consequences of alternative decommissioning policies. A first approximation of the potential effects of ecological information on policy making along the West Coast can be gleaned from its role in the development of the current policy on decommissioning.

We explore the diverse historical, ecological, and political settings that have shaped the policymaking process associated with the development of decommissioning alternatives to complete removal of platforms on the West Coast and in the Gulf of Mexico. We conducted a comprehensive documentary analysis to investigate whether and how ecological information has contributed to the historical development of California's present decommissioning policies. Such information can provide a better understanding of how ecological, and scientific information in general, is incorporated into policy development and how that process might be enhanced. The history of decommissioning policy is far more developed in the Gulf of Mexico region. Because the perceived importance of ecological information differs markedly among communities and within communities through time, we compared our results from California with the role of ecological information in the development of decommissioning policies adopted in the Gulf of Mexico. Such a comparison will increase our understanding of the potential role of ecological information in future developments of decommissioning policy in general.

We also intended to use this initial study to develop and motivate a subsequent proposal for more extensive analysis of the influence of ecological processes (e.g., climatic and oceanographic variability) and existing institutional structures (e.g., California Department of Fish and Game's Artificial Reef program) on the development of decommissioning policy on the West Coast. This effort culminated in a subsequent MMS study and report (see McGinnis et al. 2001).

Approach: Characterization of the Role of Science and Values in Decommissioning

Our approach to determining the role that ecological information has contributed to past decommissioning policy decisions involved research on past decommissioning decisions in both the California and Gulf of Mexico regions. The choice for a decommissioning option is influenced by the ecology of the marine environment, the quantity and quality of scientific information available for that environment, and the political context that is associated with offshore oil and gas activity. The focus of this study is on both the science (and scientific communities) and politics that have influenced the choice for a particular decommissioning option. For background, this section describes briefly the ecological, political and historical context of California OCS oil and gas activity, the policy debate over decommissioning options in the State Legislature and development of decommissioning policy in the Gulf region.

It is important to note that scientific investigation does not take place in a political vacuum, but involves important perceptual, value-based and ethical issues (Shrader-Frechette and McCoy 1994). The politics of integrating scientific information in the platform decommissioning is a highly charged and contentious intergovernmental process that involves participants who may not share the same values about offshore oil and gas activity. Historically, OCS oil and gas activity is political process that includes litigation (Lester 1991). Moreover, given scientific uncertainties associated with marine ecosystems, "good" scientific information is that which supports one's position in the decision-making situation (McGinnis 1998).

Shrader-Frechette (a philosopher) and McCoy (an ecologist) received funding from the National Science Foundation to evaluate the role of ecological theory and information in policy making. Their findings are also relevant to the politics of decommissioning policymaking (McGinnis 1998). Shrader-Frechette and McCoy (1994) show the following: 1) Ecologists do not agree on what the basic principles or ecological laws ("community" and "stability") are; 2) All scientific facts are laden with epistemic or cognitive values. Values can be divided into three types: bias values, contextual values, and methodological values; 3) Ecology cannot dictate ends or goals (but can act as a guide to good environmental policy); 4) Ecologists and laypersons do not share the same uncontroversial and unambiguous goals; 5) Ecology cannot tell us what is "natural"; 6) Ecological applications arise when and because scientists have a great deal of knowledge about the (qualitative and quantitative) natural history of a specific organism or place (which is not the case in this policy area).

Given scientific uncertainty, participants in the policymaking process will act out of their perceptual and value-based understandings of the world (Stone 1985). With respect to marine ecological information, science and the scientific community cannot provide policy makers with goals or values for policies, but can guide policy makers regarding the means to attain or the reasons to not to pursue particular policy ends or goals (Shrader-Frechette and McCoy 1994). In platform decommissioning, values matter. The scientific community that is associated with the Gulf and Mexico and southern California played different roles in the political process (McGinnis et al. 2001). One reason is that the role of the marine scientific community plays in the policymaking process is predicated on the particular political setting of the decision-making situation. The biophysical characteristics of particular marine ecosystems are "interpreted" by the scientific community, and these interpretations have influenced the political debate over the future of offshore oil platforms. In short, the political debate over particular platform decommissioning options is shaped by the particular ecological setting of the region, and the specific marine scientific community associated with the place.

John Kingdon's (1995) "revised garbage can model" will be used as an analytical framework to describe the role of scientists and science in the political debate over the future of offshore oil platforms and the rigs-to-reefs option. We show that state and federal decommissioning policymaking is based on political and ecological factors that reflect particular marine ecological and political settings. In the Gulf OCS region, the platforms to reefs "idea" was less an invention and more a mutation of an old idea. The platforms to reefs idea represented the coupling of an already familiar activity of building artificial reefs in the Gulf to enhance commercial and recreational fisheries. The use of familiar ideas, such as the idea of artificial reef building in the Gulf, by policy entrepreneurs and experts is referred to as the "act of recombination" (Kingdon 1995). The platforms to reef policy idea represented a recombination of an old solution (the reliance on artificial reefs to enhance recreational and commercial fishing industries) to a perceived new problem (the lack of natural habitat in the Gulf of Mexico and potential economic impacts associated with complete removal of OCS oil and gas structures). We then consider whether and how this approach applies to the development of decommissioning policy on the West Coast.

For clarity, the remainder of this report presents separately the methods, results, discussion and recommendations for the ecological and policy research.

Section Two: Fish Assemblages on Natural Reefs and Production Platforms

Methods

Fish Assemblages on Natural Reefs and Production Platforms

Study Area

We measured attributes of fish populations and assemblages at six production platforms (A, B, C, Hogan, Houchin and Henry) in the eastern portion of the Santa Barbara Channel (Figure-Map) and five nearby natural rocky reefs. Structural features and depths of the six study platforms are summarized in Table 1 along with other platforms along the West Coast for comparison. 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. The six study platforms were both shallower (50-57 m depth) and smaller than the majority of the 27 platforms off California. We selected these platforms for study for four reasons. Firstly, owners of these platforms allowed access of both diving and ROV operations. Secondly, the close proximity to the Santa Barbara Harbor allowed frequent access by small vessels for sampling. Thirdly, the shallow depth and smaller size of these platforms allowed for a greater portion of the platforms to be sampled by scuba divers. A fourth reason for selecting these platforms was their location within an oceanographic transition area that experiences marked variation in oceanographic conditions. The eastern portion of the Channel is characterized as a transition area between the warm waters typical of further south in the Southern California Bight, and the cooler waters toward Point Conception at the western end of the Channel intermittently bathed by the colder California Current that flows south from central California (Hickey 1993, Harms and Winant 1998). Oceanographic conditions vary seasonally, among years due to El Nino-Southern Oscillation events, and during decade-long regime shifts. Because of the location of the six study reefs within this transition area, fish assemblages appear to be particularly susceptible to these long-term dynamics.

Table 2. Description of the location and depths of natural reefs surveyed in this study.

Reef	Latitude	Longitude	Survey method	Sampling depth average (meters)	Sampling depth range (meters)	Distance to shore (nautical miles)	Distance to nearest platform (nautical miles)
Carpinteria	34° 23.52	119 ° 32.72	Diver	8	5-10	0.3	3.2 to Hogan
3-Spot	34° 23.66	119 ° 33.70	Diver	11	9-12	0.9	3.5 to Hogan
Horseshoe	34° 23.71	119 ° 34.70	Diver	16	14-20	1.0	3.9 to Henry
4-mile	34° 21.29	119 ° 38.17	ROV	36	32-43	3.7	1.3 to C
Crouch	34° 21.49	119 ° 32.76	ROV	36	30-38	2.3	1.2 to Hogan

The abundance of rocky reef habitat in the Santa Barbara Channel appears to be intermediate to levels to the north (Pt. Conception) and south of the Channel. We identified five natural reefs in proximity to the six production platforms for comparison of fish assemblages. Three of these reefs (Carpinteria, Three-spot, Horseshoe) were at depth less than 30 m, allowing diver surveys and comparison with the shallow portion of platforms (Table 2). The other two natural reefs (Four-mile, Crouch) were the closest to the bottom depths of the study platforms that we could find in the study area (Table 1 versus Table 2). The substratum at Carpinteria reef was characterized by sandstone ridges (≤ 3m vertical relief), low-relief bedrock shelf, and sand intrusions. Giant kelp, *Macrocystis*, was present on Carpinteria reef in all three years of study. The substratum at 3-spot reef was characterized by boulders (to 2m diameter) on low-relief bedrock shelf. Giant kelp was present at 3-Spot reef only in the first 1.5 years of the study. The substratum at Horseshoe reef consisted primarily of boulders (to 1m diameter). No macroalgae was present on Horseshoe reef. The substratum at 4-mile reef was comprised of a pronounced sandstone ridge (≤ 4m vertical relief), boulders (to 1m diameter), and no macroalgae. The substratum at Crouch reef was characterized as a sandstone ridge (≤ 2m vertical relief), boulders (to 1m diameter), and no macroalgae.

Fish Assemblages on Shallow Portions of Platforms

Sampling schedule--The fish assemblages associated with shallow (< 33m) portions of the six production (Hogan, Houchin, Henry, A, B, and C) were sampled in June, August, and October 1995 and February 1996 using visual scuba diver surveys (Table 3). Platforms were sampled by scuba divers a total of 16 times (three surveys in 1995, seven in 1996, and six in 1997). In 1995, the sampling interval was approximately once every two months (June, August, and October). Sampling was conducted monthly between June and October of 1996 and 1997, with the addition of one winter sample (February, 1996).

Density estimates--Surveys conducted by divers on production platforms involved estimates of the density and size of individuals of each species along 2 m wide x 2 m tall belt transects at predetermined locations and depths. Transect location and depth corresponded with vertical legs and horizontal cross members. Transects varied in length corresponding to the length of the crossbeam where the transect was located. Crossbeam lengths were determined from schematic diagrams provided by the platform operators. Thus, a known volume of water was sampled for each transect. For comparisons among platforms or depths, the concentration of fish (number of individuals per volume), rather than absolute abundance, was analyzed. Divers used waterproof data sheets and plastic slates to count and record all fish encountered on transects during the dive. Fish were identified to species, or occasionally to broader groups consisting of two or more species.

Table 3. Sampling frequency of study platforms and natural reefs with divers (D) and ROV (R). Carp = Carpinteria Reef, Horse= Horseshoe Reef.

		Platforms						**Natural Reefs**				
Year	**Month**	**Henry**	**Hogan**	**Houchin**	**A**	**B**	**C**	**Carp**	**3-Spot**	**Horse**	**4-Mile**	**Crouch**
1995	6	D,R	D,R	D,R	D,R	D,R	D,R	D	D			
	8	D,R	D,R	D,R	D,R	D,R	D,R	D	D	D,D	R	R
	9							D	D	D,D		
	10	D,R	D,R	D,R	D,R	D,R	D				R	R
1996	2	D	D	D	D	D	D	D	D	D,D		
	5	D	D	D	D	D	D		D	D		
	6	D,R	D,R	D,R	D,R	D,R	D,R	D	D	D,D	R	R
	7	D	D	D	D	D	D	D	D	D,D		
	8	D,R	D,R	D,R	D,R	D,R	D,R	D	D	D,D	R	R
	9	D	D	D	D	D	D	D	D	D,D		
	10	D,R	D,R	D,R	D,R	D,R	D,R	D	D	D,D	R	R
1997	5	D	D	D	D	D	D	D	D	D,D		
	6	D,R	D,R	D,R	D,R	D,R	D,R	D	D	D,D	R	R
	7	D	D	D	D	D	D	D	D	D,D		
	8	D	D	D	D	D	D	D	D	D,D		
	9	D	D	D	D,R	D,R	D,R	D	D	D,D		
	10	D	D	D	D	D	D	D	D	D,D		

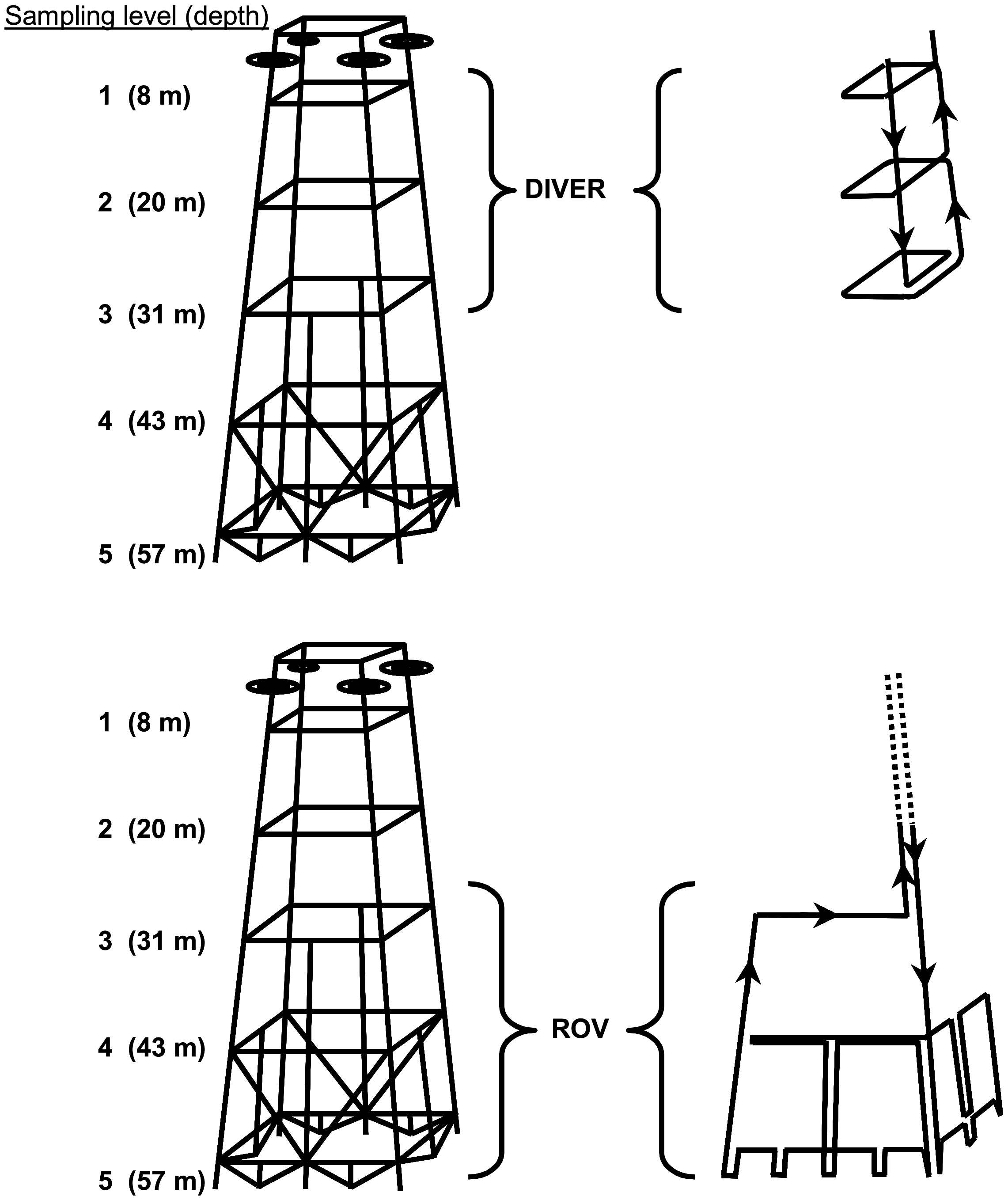
Sampling design--Divers worked in teams of two and followed a standard swim pattern when sampling each of the six platforms (Figure-diver path). From the surface, they descended directly along one of the corner legs to the third main set of horizontal crossbeams (30 – 39 m, depending on platform). At this depth, they sampled a portion of the platform's perimeter and interior by swimming (at a moderate and constant speed) just above the horizontal crossbeams. From here they ascended to the next shallower set of crossbeams and repeated the perimeter/interior swim loop. A total of three depth levels were sampled at each platform, plus the vertical transects along the corner legs during the descent and ascent between levels. Across all study platforms and sampling dates, a total of 379,613 m^3 was sampled over the course of the study.

Two dives, one after the other, on opposite sides of the platform were conducted on each sampling date. The total sample incorporated all four-corner legs as well as most of the major horizontal crossbeams of the jacket and a substantial portion of the interior. Each dive required about 30 minutes, and individual divers made a maximum of two platform dives per day. All dives were conducted within no-decompression dive limits (using dive computers). In most cases, all six platforms were sampled in two consecutive days by six divers.

Size distribution--Size estimates (total length) were made for individual fish (to the nearest 1 cm for fishes less than 15 cm TL, and to the nearest 5 cm for fishes greater than 15 cm TL). When groups or schools of fish were encountered, a *range* of sizes was recorded. All divers performing visual counts had previous training in size estimation. In addition to the first diver's visual size estimates, direct *in-situ* laser measurements of fish size were recorded on video. One member of each dive team (the diver not responsible for visual counts) used a video camera (Sony Hi-8, TR700) in an underwater housing (Light and Motion) to film fishes on and adjacent to the sampled transects. Two parallel-mounted red lasers (Quarton, 5mW) attached to the housing projected beams through the camera's center of view. The distance between the beams was fixed (at 25mm), and they were clearly visible in the videotape image as points of bright light on objects up to 4 m from the camera (depending on water clarity). The objective was to strike the fish with the beams perpendicular to the main body axis.

In the laboratory, size estimates (TL) were made by measuring (with a ruler or calipers) the beam separation and fish length directly from the video monitor. From these two measurements and the known beam separation, the true fish length was derived. There are several potential sources of error in laser size estimates, including (1) fish body angle less than 90 degrees from beams, (2) body curvature, (3) fish too far away, and (4) blurring/dimming of beams caused by water turbidity. To account for these potential sources of error, each measurement was rated for potential accuracy on a subjective scale of one (good) to three (poor). Volunteer undergraduates who were trained in fish identification and the measuring process made all video-based size estimates in the lab.

Figure 3. Pattern of sampling conducted by divers and ROV on platforms. Depicted are the five depth levels of which divers sampled levels 1-3 and the ROV sampled levels 3-5. The actual number of horizontal cross members varied from four (Henry, Houchin, Hogan) to five (A, B, C). The diver and ROV patterns illustrated here indicate one half of a sample. The path of the divers and ROV was duplicated on the opposite side of the platform to complete a sample on a sampling date.



Fish Assemblages on Shallow Natural Reefs

Sampling schedule-- In order to compare fish assemblages between oil platforms and natural reef habitat, three shallow rocky reefs (Horseshoe, 3-Spot, and Carpinteria) in the vicinity of the oil platforms were also sampled by scuba divers (Figure 1). These three reefs were selected because they were the only three shallow reefs in close proximity to the study platforms. Carpinteria and 3-Spot were sampled at the same frequency as the platforms and always within one week of the platform sample date (15 and 16 samples, respectively; Table 3). Horseshoe reef was sampled twice in each sampling period (32 samples), usually on two consecutive days within one week of the platform sample (Table 3). Data collected were the same as that on production platforms, but surveys of natural reefs also included quantification of habitat variables (e.g., substratum type and relief, epibenthic cover, density and size of macroalgae, temperature and visibility) that might explain patterns of species abundance.

Sampling design-- On natural reefs, divers identified, counted, and recorded sizes for all fish encountered on transects of standardized volumes (2 m wide x 2 m tall x 30 m long). Two of the reefs (Carpinteria and 3-Spot) contained beds of giant kelp (*Macrocystis pyrifera*) during some or all of the surveys. At these two reefs, divers sampled three different depth strata: 1) <u>surface</u>, 0-2 m below the kelp canopy; 2) <u>mid-water</u>, halfway between the surface and the bottom, and; 3) <u>bottom</u>. Each of the three depth strata was sampled four times on each sampling date. Horseshoe reef, the deepest of the group, never contained giant kelp. Due to the absence of canopy fish habitat, the surface stratum was not sampled at this site. Because there was no kelp on which to attach a meter tape, mid-water transects at Horseshoe reef were located 3-5 m above the bottom, and the bottom tape was used as a visual reference for transect length. Transects were stratified horizontally across the reef from onshore to offshore in order to encounter fish distributed throughout the kelp forest and across all depths of the reef. Transect locations were established haphazardly within each depth stratum across the reef at each visit. At the start of each transect, the fish-counting diver temporarily fastened to the substratum, or to kelp stipes, a 30 m tape. Following a compass bearing parallel to the depth contour, the diver swam at a slow, steady rate while counting fish and deploying the tape. Upon reaching the far end, the tape was tied in place and the diver proceeded to the next depth level (above the bottom transect). Other divers following the fish counter collected habitat data and retrieved the tapes. Across all three reefs and sampling dates, a total of 69,120 m^3 was sampled over the course of the study.

Size distribution--In addition to the size estimates made by the diver recording fish density, a second diver made size measurements using the paired-laser video method described in the *Size distribution* section above.

Reef habitat attributes--In addition to fish density and size estimates, divers quantified the relief, substratum, and macroalgal characteristics of each natural reef on each sampling date. The abundance (density or cover) of key reef substratum and macroalgae characteristics were estimated as follows:

1. <u>*Macrocystis* canopy percent cover</u> (recorded in the surface stratum only): Divers visually estimated the presence or absence of *Macrocystis* canopy directly above 60 stratified-random points (2 random points per m) along each of the 30 m long surface transects.

These samples generated an estimate of the percent cover of *Macrocystis* canopy for each replicate transect.

2. *Macrocystis* stipe density (surface and bottom transects only): Divers visually counted the number of *Macrocystis* plants, and number of stipes per plant within the 2 m wide X 30 m long belt transect. These counts generated an estimate of the density of *Macrocystis* plants (number per $60m^2$) and stipes for each replicate transect.

3. *Pterygophora* stipe density (bottom transects only): Divers counted the number of *Pterygophora californica* plants, a prominent understory macroalga, within the 2 m wide x 30 m long belt transect. These counts generated an estimate of the density of *Pterygophora* plants (number per $60m^2$) for each replicate transect.

4. Substratum type and cover (bottom transects only): Classification of the substratum at 60 stratified-random points (2 random points per m) along each of the 30 m long bottom transects. Substratum type was categorized by the bare substratum type (mud/sand/cobble/shell/rock) or the invertebrate or macroalga directly attached to the substratum (e.g., *Diopatra* tubes, erect coralline algae, foliose red algae, *Macrocystis* holdfasts). These records generated an estimate of the percent cover of substratums for each replicate transect.

5. Reef vertical relief cover (bottom transects only): Divers visually estimated the vertical relief within 1 m of 60 stratified-random points (2 random points per m) along the 30 m long bottom transect. Relief was categorized into one of four categories (0-0.1m, 0.1-1m, 1-2m, >2m). These records generated an estimate of the percent cover of substratum relief for each replicate transect.

Fish Assemblages on Deep Portions of Platforms

The deepest portions of the six study platforms, from 39 to 57 m depth, were sampled with a Remotely Operated Vehicle (ROV), a tethered submersible controlled from the surface. The ROV (a Phantom 500, operated by the Marine Diving Technology program at Santa Barbara City College) was capable of moving in 3-dimensions and following transects at speeds equivalent to scuba divers. The ROV carried lights and a forward-looking black and white video system cabled to a monitor on the vessel at the surface. The video and surface monitor allowed the vessel path to be directed by the operator while an observer logged the depth and location of transects, and identified fish species throughout the sampling period. The video was recorded on Hi-8 videotape.

Sampling schedule-- ROV samples were taken on a total of seven or eight dates at each platform: three samples in 1995, three in 1996, and one or two in 1997 depending on the platform (Table 3). In 1997, sampling was incomplete due to mechanical failure of the ROV, and was limited to one (platforms Hogan, Houchin, and Henry) or two samples (platforms A, B, and C).

Density estimates-- All fish counts and species identifications for ROV samples were taken directly from video. To provide a scale of reference and to avoid getting lost, the ROV always followed and filmed the platform legs and crossbeams when sampling. These structures, of known diameter, provided a scale for estimating transect width and height. All fish within approximately 1-2 m of the legs and crossbeams were considered "on the transect" and counted. Fish were identified to species, or in some cases to broader categories when species identification was impossible. Juvenile rockfish, in particular, were difficult to identify to species from ROV videos, and were usually classified by group (see Table 4). These surveys generated fish density estimates (fish per water volume sampled) for replicate transects along the length of structural members.

Table 4. Taxonomic categories of rockfish species used for analyses.

Copper complex

kelp rockfish (*S. atrovirens*)
copper rockfish (*S. caurinus*)
gopher rockfish (*S. carnatus*)
black & yellow rockfish (*S. chrysomelas*)
Unidentified "copper complex" Young-of-Year

Midwater complex

olive rockfish (*S. serranoides*)
blue rockfish (*S. mystinus*)
widow rockfish (*S. entomelas*)
squarespot rockfish (*S. hopkinsi*)
bocaccio rockfish (*S paucispinis*)
yellowtail rockfish (*S. flavidus*)
Unidentified "blackspot" Young-of-Year

Shallow benthic complex

vermilion rockfish (*S. miniatus*)
calico rockfish (*S. dalli*)
brown rockfish (*S. auriculatus*)
treefish rockfish (*S. serriceps*)
flag rockfish (*S. rubrivinctus*)
halfbanded rockfish (*S. semicinctus*)
Unidentified Sebastomus rockfish (rosy, starry, greenspotted)
Unidentified "benthic" Young-of-Year

Analyses of the videos for fish identification and species counts were limited to transects along the vertical, horizontal, and diagonal legs and crossbeams of the platform perimeter, and to the seafloor at the base of the structure. The vehicle was not able to survey the interior of the platform because of the risk of entangling the umbilical line. Due to the presence of submerged cables, sunken debris, and occasionally strong water currents, the ROV was not able to follow a standard path on each of the platforms. For this reason, sample volume varied slightly from platform to platform and from date to date. Nonetheless, for each sampling date on each platform, similar paths were attempted, which included several vertical legs, horizontal and diagonal members at each depth from roughly 35 m depth to the bottom, and surveys along short sections of the bottom from a vertical leg. ROV sample volumes were calculated by summing the total distance traveled by the vehicle at each depth, and multiplying this distance by the dimensions of the transect. Across all study platforms and sampling dates, a total of 92,524 m^3 was sampled over the course of the study.

The linear distance was computed by summing the length of all the legs and crossbeams sampled. Crossbeam lengths were obtained from schematic diagrams of each platform. The height and width of the transect dimension (i.e. field of view) varied with visibility (i.e. depth of field) and sample location (i.e. whether the ROV was moving vertically, horizontally, or rotating on the bottom). Visibility (i.e. water clarity) was typically consistent within a depth level on a given day at a given site. Depth of field was estimated as visibility changed between depth levels and sites.

Field of view (height and width of view) along a horizontal transect was estimated from (1) the relationship between visibility and the horizontal field of view, and (2) the ratio of the horizontal to vertical field of view. (1) was derived from the relationship between the distance that an object of known size (e.g., structural member dimension) became clearly visually detectable and the total width of view (H), determined by the width of that object relative to the total width of the field of view. (2) was derived from the constant ratio of horizontal to vertical dimensions (vertical = 0.756 horizontal dimension) of an image on the monitor, as determined by the fixed field of view of the camera lens (82^o horizontal).

Field of view (height and width of view) along a vertical transect was estimated from (1) the relationship between visibility and the horizontal field of view (H), and (2) the area of a sector for that horizontal field of view. (1) was derived as described in the preceding paragraph. (2) was derived from the horizontal field of view (H), the fixed field of view of the camera lens (82^o= 1.43117 radians), and r, the radius of the sector (0.7621 radians x H). Thus, the horizontal area of the sector of view was $\frac{1}{2} r^2(1.43117)$. This horizontal area was multiplied by the transect length to determine the total volume sampled.

Field of view (height and width of view) as the ROV rotated in a circle on the bottom, was calculated from (1) the relationship between visibility and the horizontal field of view (H), (2) the area of a sector for that horizontal field of view, and the constant ratio of the horizontal field of view and the vertical field of view (vertical = 0.756 horizontal dimension). All three values were derived as in the previous two paragraphs. The number of contiguous sectors sampled was determined by objects identified on the bottom.

Size distribution-- Fishes recorded on ROV transects were classified as Young-Of-Year (YOY) or adult, based on estimated size. The ROV also carried two parallel-mounted lasers to aid in size estimation. Due to the limited ability of the ROV to turn and aim its lasers quickly, hits were less frequent in ROV samples than diver samples.

Fish Assemblages on Deep Natural Reefs

To compare fish assemblages inhabiting the deep portion of platforms with nearby natural reefs, two deep rocky reefs, 4-Mile and Crouch, were also sampled by ROV (Figure 1). These two reefs, though shallower than the bottom of the study platforms, were the only rocky reefs in the study area. Characteristics of the substratum are described qualitatively in Table 2.

Sampling schedule--These two reefs were sampled in conjunction with the ROV platform samples: three times in 1995, three in 1996, and once in 1997 (Table 3).

Density estimates-- Deep reef transects were sampled by running the ROV parallel to the bottom, < 1 m above the substratum, and slowly following the contour of the ridges and boulders encountered. The ROV sampled out-and-back transects of variable length, in four directions (N, S, E, and W) radiating out from a central reference point near the ship's anchor. Across both natural reefs and sampling dates, a total of 5,764 m^3 was sampled over the course of the study. The ROV carried four lasers on reef dives: two parallel-mounted lasers for measuring fish length, and two crossing lasers to establish the distance to objects in the foreground. The crossing lasers bisected each other at a known distance (2.0 m) in front of the ROV. It was possible to estimate the vehicle's speed by timing it over this distance as it approached and passed boulders and ridges. Transect length was estimated by multiplying the vehicle's average speed by the time required for each transect. Because water clarity was often quite poor (< 2 m visibility) on deep natural reefs, transect width and height varied to reflect ambient conditions. Visibility (i.e. water clarity) was typically consistent within a given day at a given site. Depth of field was estimated as visibility changed between sampling days and sites. Field of view (height and width of view) along a horizontal transect was estimated from (1) the relationship between visibility and the horizontal field of view, and (2) the ratio of the horizontal to vertical field of view. (1) was derived from the relationship between the distance that an object of known size (e.g., boulder) became clearly visually detectable and the total width of view (H), determined by the width of that object relative to the total width of the field of view. The width of objects along the transect were derived by extrapolating the known distance between the parallel laser points across the total horizontal width of the object. (2) was derived as described above for the platforms; from the constant ratio of horizontal to vertical dimensions (vertical = 0.756 horizontal dimension) of an image on the monitor, as determined by the fixed field of view of the camera lens (82^o horizontal).

Analyses

We used two general approaches for comparing the fish assemblages and the relative density of species on the study platforms and the natural reefs. We used the density estimates (number of fish per unit volume of water) generated from the diver and ROV surveys to calculate the relative density of a species between the two habitat types. These data allowed us to identify which species occur on platforms, how their densities compare with that on natural reefs, and provide us with a first approximation of whether of not activities associated platforms would substantially influence regional populations on natural reefs. For example, if a species was common on natural reefs but rarely encountered on platforms (95% and 5% relative density, respectively), any decommissioning option would likely be of little importance to the region-wide population of that species. Fish density was calculated as the total quantity of each species divided by the total volume of water sampled by divers and ROV in each habitat, combined over all three years of study. For comparison between habitat types (platforms versus reefs, between depth strata), the relative density of species or species complexes was calculated. These values indicate the relative density of a species across the habitats compared. For example, percent density of species X on natural reefs = (density of X on reefs) / [(density of X on reefs) + (density of X on platforms)]. These values allow one to compare the relative number of a species associated with a comparable (i.e. standardized) volume of water in each habitat type.

A second approach to comparing the patterns of fish assemblages among habitat types involved multivariate canonical discriminant analyses (CDA). This analysis considers the assemblage structure (absolute and relative abundance of fish species) of 1 year and older fishes sampled by either divers or ROV, separately, in each year and examines the amount of variation in assemblage structure explained by five different depth strata ("levels") and habitat type (platforms and natural reefs). Thus, the CDA calculated the yearly centroids for a given site/level combination (ie. the average of samples within a single year) for a combined site||level classification variable. Examination of the bi-plots of the first two canonical variates allows one to examine how much variation is explained by each variate and what factors contributed to explaining that variation. Also, a bi-plot of the first two structure coefficients allows one to examine which species contributed to the variation among site||levels. Data were root-root transformed ($X^{0.25}$) to reduce both skew and the effect of particularly abundant variables (fish taxa). Taxa that occurred in less than 20 samples were not included in the analyses.

Data were transcribed from underwater sheets (divers) and videotapes (diver and ROV) to Microsoft Excel spreadsheets. Univariate parametric analyses were conducted with Systat. Multivariate analyses (canonical discriminant analysis: CDA) were conducted with SAS.

Vertical Stratification of Fish Species and Life Stages on Platforms

Most of the proposed platform decommissioning options result in a marked reduction in the overall height of the structure above the seafloor (Figure 2). The absence of structure in the upper portion of the water column may result in substantial reductions of species in one of three ways. First, species that associate with the shallow portions of platforms as adults may not occur on platforms in the absence of that structure in the upper portion of the water column. Secondly, species that occur in the deeper portion of platforms may recruit from the plankton to the upper portion of platforms and eventually move to the bottom as they get larger. Removal of structure in the upper portion of the water column may prevent recruitment of these species and eventually cause reductions or absence of these species on decommissioned platforms. A third scenario involves the production of mussels on the shallow portion of platforms that eventually fall to the seafloor beneath platforms. For species that use the mounds of mussel shells that form beneath platforms as recruitment habitat, adult habitat or a source of food, loss of structure in the upper water column may cause reductions or loss of these species. Therefore, predicting the consequence of alternative decommissioning options to fish populations and assemblages requires knowledge of the relationships between species, their life stages and the presence of shallow portions of platforms as well as with the mussel mounds that form beneath platforms.

To address this, we quantified both the abundance and size distributions of fishes at discrete depth strata along the entire height of the study platforms (Figure 3). We used these data to describe which species use the shallow portions of platforms as either recruitment and/or adult habitat. We also noted which species and life stages (juveniles or adults) associate with mussel shells on the seafloor beneath the platforms.

Comparison of Fish Density Estimates by ROV and Diver Surveys
To compare the estimates of total fish and species density (number of individuals and species per distance sampled, respectively) generated from diver and ROV sampling, we sampled the same depth stratum (level 3: 30 – 39 m) of three production platforms (Henry, Hogan and Houchin) on seven sampling periods with both divers and the ROV (Figure 3). Diver and ROV samples were typically conducted within a two-week period of one another. Over the three-year sampling period, a total of seven ROV and diver comparisons were made. Both total fish density (all species combined) and species richness (number of species) were standardized per 100m distance. To examine variability among platforms in the difference between diver and ROV estimates, the mean total fish and species density across the seven sampling dates (n= 7) was compared for each platform. To examine temporal variability in the difference between diver and ROV estimates across the seven sampling dates, we compared the mean of each variable across the three platforms on each date.

Fish Movement Among Natural Reefs and Platforms

Our approach to estimating the net movement of fishes among reefs and platforms involved tagging fishes individually at all five of the natural reefs surveyed by divers and ROV. Initially we also planned to tag fish at the six study platforms in addition to the five natural reefs, but the platform operators were unable to grant us permission to fish in close proximity to the structures (perhaps because doing so would have involved anchoring or tying to the structure or encouraged other sport fishing boats to attempt the same; in almost all cases, recreational boats are not permitted within 400 m of oil platforms). We were able to tag fish just once at one of the study platforms (Houchin).

Fish were caught by hook and line using standard recreational fishing equipment, identified, measured, tagged in the dorsal musculature with standard 60mm-long Floy tags, and immediately released. When necessary, their swim bladders were vented to enable fish to return to the bottom. Floy tags are external and are similar in design to garment tags, and each tag bears a unique tag number and other information (in this case, the word “reward” followed by the name and phone number of Mark Carr). This allowed fishers to call and inform us of where and when they caught each fish. Tags were color coded by the reef on which they were tagged and released. Tagged fish were also occasionally seen by divers and the ROV during censuses, and in most cases the color of the tag could be determined.

We conducted sixteen fishing/tagging trips between June 1996 and January 1997, utilizing anywhere from 3 to 20 volunteer fishers per trip (Table 5). Collectively, 459 fish of 26 species were tagged at the 6 tagging sites (Table 6).

Over 600 fisherman-hours contributed to the tagging effort. Tagging was conducted from two platforms; university vessels and the Channel Islands National Marine Sanctuary’s *R/V Ballena*. CINMS kindly volunteered their research vessel and her captain for four days of tagging. More than 40 volunteers from the University of California at Santa Barbara and others from the local sportfishing community also joined us one or more times. The local sport fishing community and sport vessel operators were very supportive. Tag returns and information on recaptures could not have been obtained without the interest and assistance of the sport fishing community. As a reward for returned tags and recapture information (date and location of catch), we sent a pair of California lottery tickets.

Table 5. Date and location of fishes (all species combined) tagged during the movement study.

Date	**Location Tagged**						
Tagged	3-spot	4-mile	Crouch	Carpinteria	Horseshoe	Plat. Houchin	Total
6/12/96	5			30	26		61
6/13/96	31	9			4		44
6/14/96	8	6	1	3	5		23
6/15/96		2					2
9/5/96	9	1		1	2		13
9/12/96		16			83		99
9/22/96					16		16
10/5/96	6	1		1	10		18
10/10/96	2	15			11		28
11/5/96				3	5		8
11/6/96	6				20		26
11/16/96					29		29
12/5/96	10	5					15
12/8/96		4				15	19
12/15/96					36		36
1/30/97	11	2	2		7		22
Total	88	61	3	38	254	15	459

Table 6. Number of individuals of each species tagged at each site where tagging was conducted. Numbers are for all dates combined at each site.

Species	**Location Tagged**						
Tagged	3-spot	4-mile	Crouch	Carpinteria	Horseshoe	Plat. Houchin	Total
kelp bass	48	8	2	7	97	1	163
brown rockfish	1			5	38	13	57
barred sandbass	12			23	17		52
blacksmith	11	3	1		25		40
gopher rockfish	1	6			26		33
treefish rockfish		15			11		26
squarespot rockfish		15					15
senorita	8				5		13
olive rockfish	1	1			6		8
copper rockfish					7		7
ocean whitefish		5			1		6
kelp rockfish	1				4	1	6
California scorpionfish		2			3		5
California sheephead	1	1			3		5
smoothhound shark	2				3		5
swell shark		2			2		4
black and yellow rockfish				1	2		3
white seabass				2			2
calico rockfish					2		2
spiny dogfish					1		1
lingcod		1					1
rubberlip surfperch	1						1
California barracuda	1						1
unidentified sculpin					1		1
vermilion rockfish		1					1
rosy rockfish		1					1
Total	88	61	3	38	254	15	459

Relative Performance of Fishes on Platforms and Natural Reefs

Our approach to determining the relative performance of fishes on platforms and natural reefs was to compare cohort growth and survivorship for a species that co-occurred abundantly in both habitat types. Our approach was to identify a group of fishes of the same species that had recently settled from the plankton and follow the modal individual length of the cohort to determine an average individual growth rate. Following change in abundance of that cohort could also estimate the rate of loss of individuals. With assumptions for the source of losses (mortality versus emigration), attributing losses to actual mortality might be inferred.

Contribution of Platforms to the Abundance of Regional Reef Structure

To determine the relative contribution of platforms to the total amount of hard substratum in the study area, we first determined the basal footprint and total submerged surface area of the six study platforms based on detailed schematic diagrams provided by the platform operators. We calculated the footprint of each platform as the area of the seafloor enclosed by the platform at the base of the platform jacket. The surface area of each study platform was calculated by adding the total length of all underwater structural elements (i.e., all platform legs, well conductors, and horizontal, diagonal, and vertical crossmembers) that appeared on the schematic diagram, and multiplying these values by the circumference of the crossmember. Since all main structural elements consist of cylindrical steel pipe, the circumference of each leg or crossmember can be determined from the diameter of the pipe, which in most cases was indicated on the diagrams provided. On average, platform legs (vertical piles) are just over 1 m diameter, whereas horizontal and diagonal elements and well conductors are about 0.5 m diameter. Surface area calculations did not account for the fouling organisms (mussels, scallops, anemones) that grow abundantly on the structure and add a complex organic matrix up to 0.3 m thick throughout the upper portion of each platform.

To determine the total amount of natural hard substratum (rocky reef) in the study area, we attempted to obtain detailed seafloor maps or seafloor sonar images of the Santa Barbara Basin and the coastal shelf between Pt. Conception and Ventura. Specifically, we tried to obtain maps that would show quantifiable zones of hard rocky bottom in 10-100 m water depth in the vicinity of the six study platforms and five natural reefs. We contacted various agencies, including the U.S. Geological Survey, National Oceanic and Atmospheric Administration, California Department of Fish and Game GIS Laboratory, Monterey Bay Aquarium Research Institute, California State University at Monterey Bay, Moss Landing Marine Laboratory, and maps stored at the Camarillo Office of the Minerals Management Service (e.g., Southern California Possible Hard Substrate Areas, *in* Disturbance of Deep Water Reef Communities by Exploratory Oil and Gas Operations; MEC Inc.).

Results

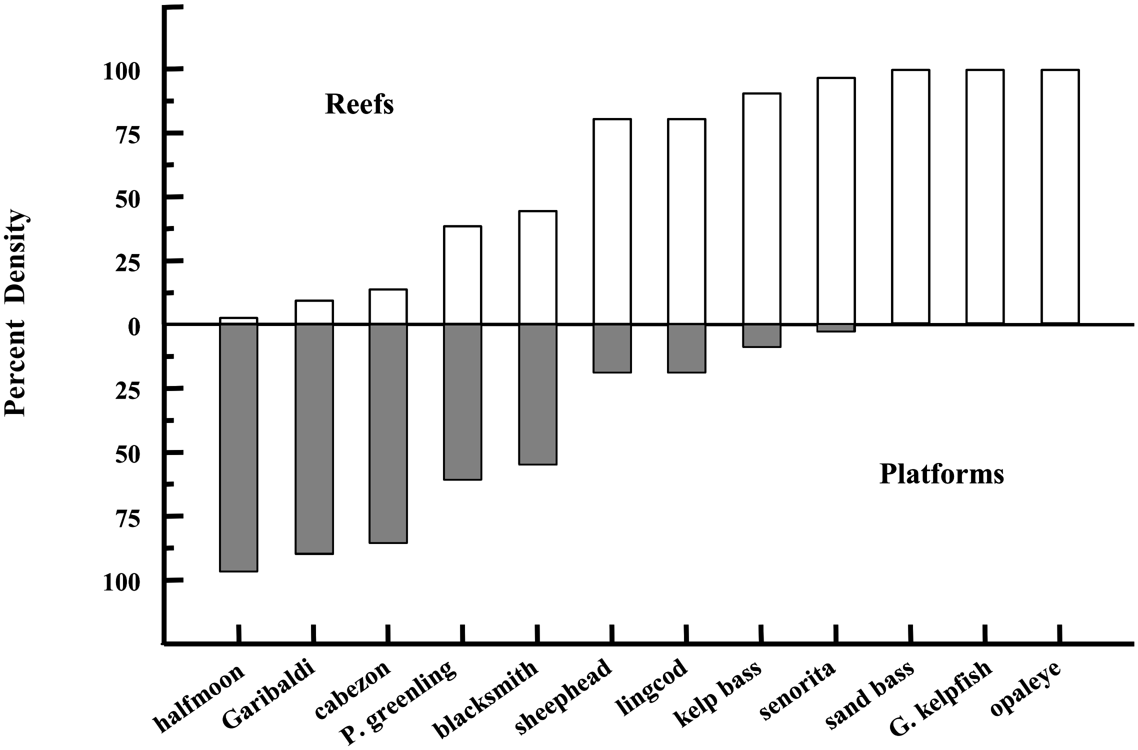
Fish Assemblages on Natural Reefs and Production Platforms

Our quantitative comparisons of the species composition, sizes and vertical distribution of fishes associated with shallow and deep portions of production platforms and natural reefs revealed several patterns pertinent to predicting and understanding the consequences of alternative decommissioning scenarios. It was sometimes difficult to visually identify some fish to species, particularly the younger stages of rockfishes, with poor visibility and using the ROV. Therefore, results are presented for both individual species and species complexes (Table 4). The common and scientific names, taxonomic categories and relationships (i.e. families) observed and used for analyses are summarized in Appendix 1. Because of the economic importance and preponderance of rockfishes observed on production platforms, patterns of rockfish and other species are often presented separately.

A number of non-rockfish species (opaleye, giant kelpfish, sandbass) were not observed on the six study platforms, but present on nearby natural reefs (Figure 4). This was particularly evident for several species of the “live bearing” surf perches (Figure 5). Other non-rockfish species occurred on platforms, but their relative density was far greater on natural reefs. Most notably, the relative density of senorita, kelp bass, lingcod and sheephead on platforms was less than 25 percent of that on natural reefs (Figure 4). Possible explanations for these patterns include the affinity of many non-rockfish species for macroalgae, and the limited dispersal of the live borne young of the surfperches. We explored the relationship between reef fishes and macroalgae at Carpinteria reef, where the density of the giant kelp, *Macrocystis pyrifera*, varied temporally from year-to-year and spatially across the reef. The density of several species was positively related to the density of giant kelp as indicated by both or either a significant regression or rank

(Spearman r_S) correlation (Table 7). In particular, the kelp fishes, kelp surfperch, kelp bass and senorita were most strongly associated with the local density of giant kelp. In contrast, macroalgae on production platforms is typically comprised of foliose red species, and large kelps are conspicuously absent. Thus, the paucity of several of these species may reflect the absence of the macroalgal habitats with which they associate. The absence of several species of surfperches more likely reflects the limited dispersal of young and their restricted presence in shallow water. Together, these traits suggest that surfperches associated with shallow natural reefs neither recruit or migrate to offshore platforms isolated by deep water. The lower density of California sheephead may reflect the low density of their primary prey (urchins) on platforms and their requirement to shelter on the reef substratum at night.

Figure 4. Relative density of shallow **non-rockfish species between platforms and natural reefs**. Data are combined across all size classes, all three years (1995-1997) and both sampling methods (divers and ROV) combined. Open bars are natural reefs, shaded bars are platforms. Relative density is explained in the Methods section text. Actual density values are presented in Appendix 2a.



In contrast, the relative density of several non-rockfish species was at least as great on platforms as on natural reefs. This included blacksmith, painted greenling, cabezon, Garibaldi and halfmoon. The high densities of the planktivorous blacksmith and halfmoon probably reflect the great availability of zooplankton that constant passes through the platform structures. The presence of the other species appears to reflect their strong affinity to reef structure and low affinity for macroalgae (Table 7). All of these species produce young that disperse in the plankton, enabling them to recruit to and colonize isolated structures offshore.

Figure 5. Relative density of seven common species of **surfperch (Embiotocidae) between platforms and natural reefs**. Data are combined across all size classes, all three years (1995-1997) and both sampling methods (divers and ROV) combined. Open bars are natural reefs, shaded bars are platforms. Relative density is explained in the Methods section text.

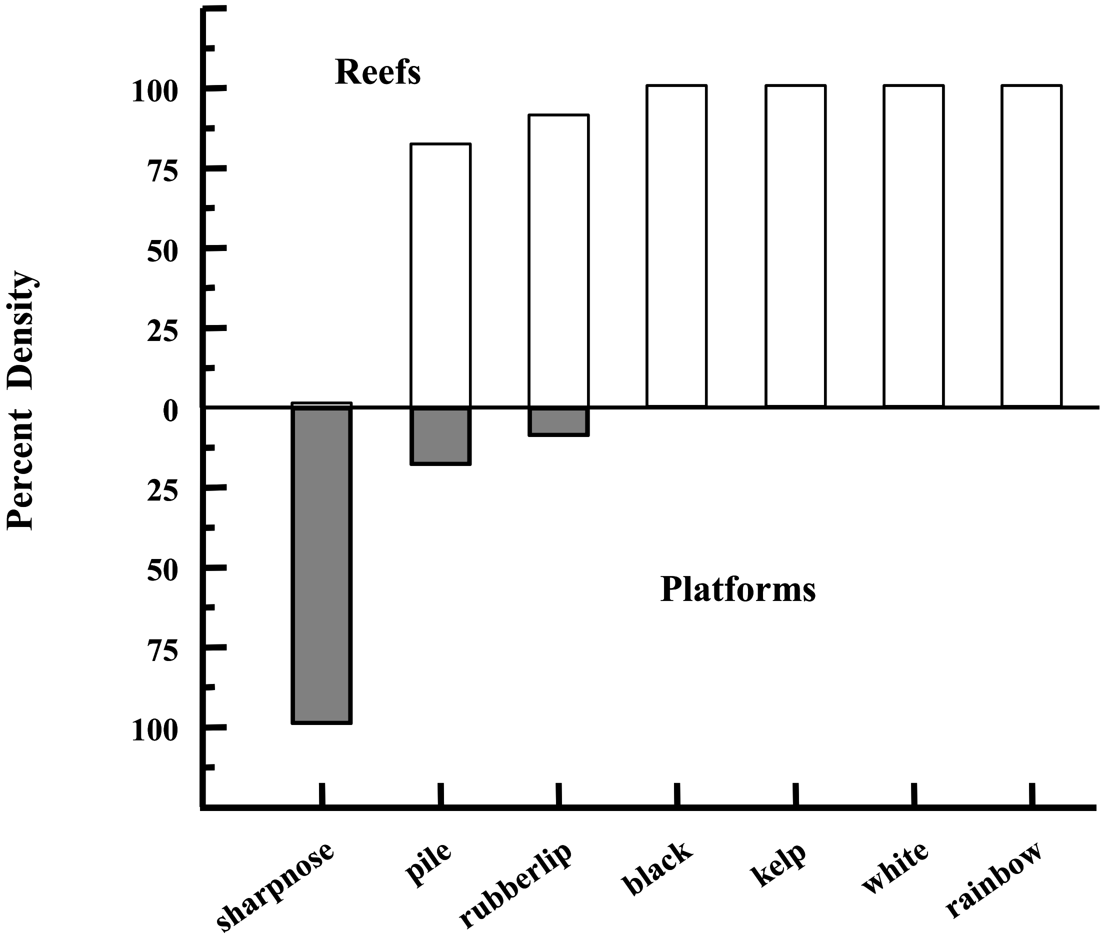
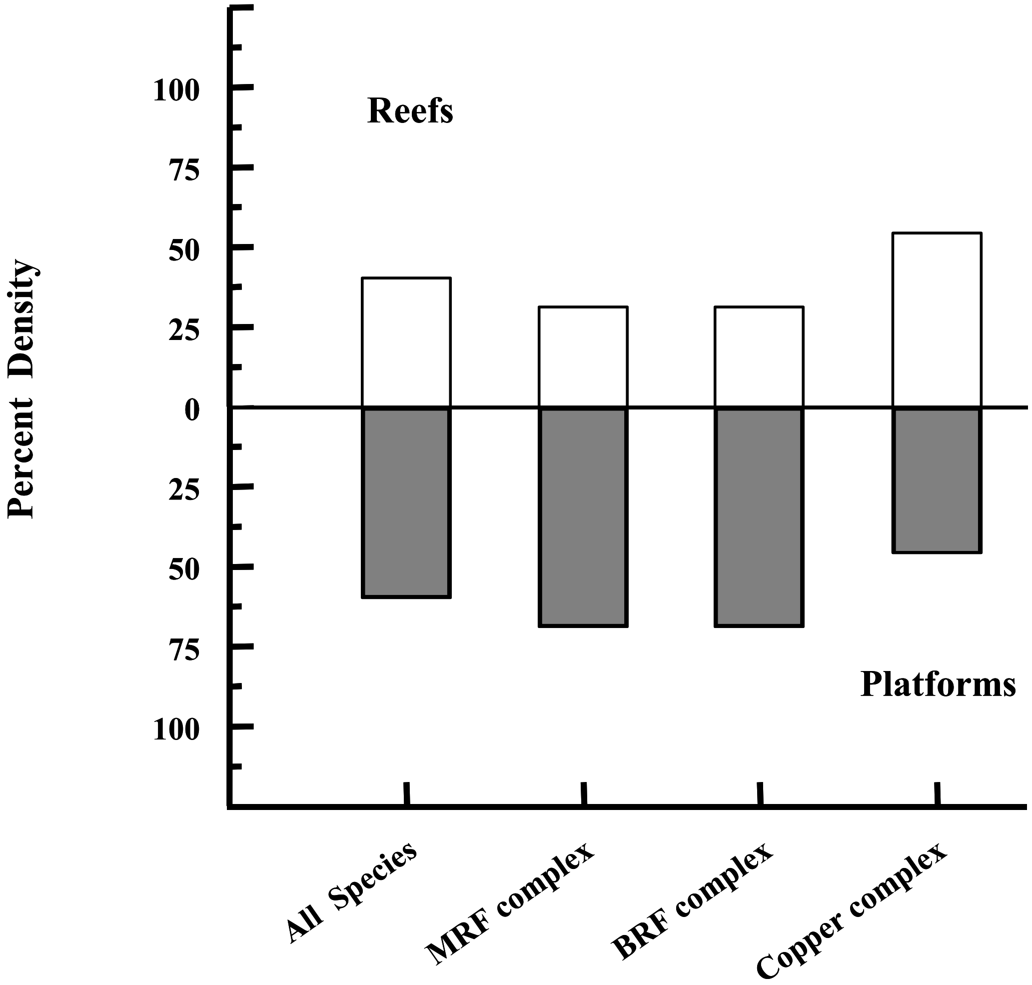


Table 7. Relationship between fish density and *Macrocystis* stipe density at Carpinteria reef from 1995 to 1997. All samples at the indicated depth level are included in analysis. C= Canopy, B= Bottom. Each sample is the mean of four 2 x 2 x 30 m transects, collected on the same day at the same depth level. Probabilities < 0.05 are shown in bold.

Common Name	Depth Level	No. Samples	Fish/Sample (mean ± s.d.)	R	R^2	F	d.f.	P	Spearman coefficient (r_s)	P (r_s)
topsmelt, jacksmelt	C	15	6.95 ± 11.4	0.06	0.00	0.04	1, 13	0.84	-0.09	> 0.5
kelp perch	C	15	3.2 ± 4.1	0.78	0.61	20.13	1, 13	**0.00**	0.67	**< 0.01**
giant kelpfish	C	15	0.22 ± 0.35	0.37	0.13	2.02	1, 13	0.18	0.60	**< 0.05**
blacksmith	C, B	30	0.57 ± 1.13	0.07	0.00	0.12	1, 28	0.73	0.03	> 0.5
kelp bass	C, B	30	4.44 ± 6.19	0.49	0.24	9.05	1, 28	**0.01**	0.58	**< 0.001**
senorita	C, B	30	3.67 ± 5.48	0.44	0.19	6.57	1, 28	**0.02**	0.57	**< 0.002**
rainbow surfperch	B	15	2.93 ± 6.55	0.10	0.01	0.14	1, 13	0.71	0.26	> 0.2
black surfperch	B	15	1.25 ± 1.13	0.54	0.29	5.43	1, 13	**0.04**	0.47	> 0.05
pile surfperch	B	15	1.95 ± 1.67	0.31	0.10	1.39	1, 13	0.26	0.30	> 0.2
white surfperch	B	15	0.90 ± 1.81	0.40	0.16	2.48	1, 13	0.14	0.70	**< 0.01**
rubberlip surfperch	B	15	0.13 ± 0.34	0.12	0.01	0.19	1, 13	0.67	-0.08	> 0.5
kelp rockfish	B	15	0.07 ± 0.20	0.09	0.01	0.12	1, 13	0.74	-0.16	> 0.5
gopher rockfish	B	15	0 ± 0	na	na	na	na	na	na	na
olive rockfish	B	15	0.03 ± 0.09	0.16	0.03	0.36	1, 13	0.56	0.18	> 0.5
California sheephead	B	15	0.18 ± 0.35	0.14	0.02	0.24	1, 13	0.63	-0.01	> 0.5
opaleye	B	15	0.20 ± 0.40	0.18	0.03	0.45	1, 13	0.51	-0.17	> 0.5

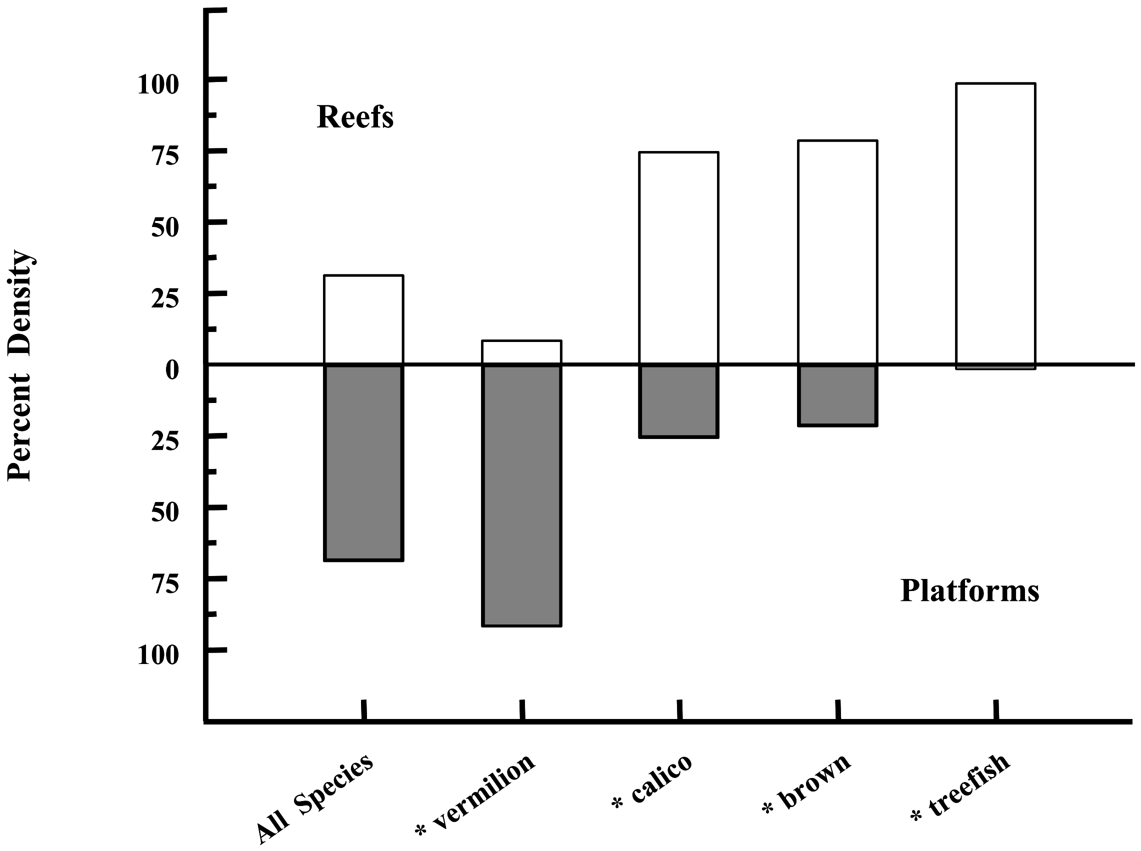
The many species of rockfishes observed over the study area also varied markedly in their relative density on platforms and natural reefs. Taken together, for all rockfishes combined, rockfishes on platforms constituted roughly 60% of the entire density of rockfishes sampled (Figure 6). This pattern of relative density between the two habitat types varied somewhat among the rockfish species complexes, and markedly for some species. Whereas the relative density of the midwater and benthic rockfish complexes was substantially greater on platforms than natural reefs (roughly 70% of the overall density), the relative density of the copper complex was only slightly higher on natural reefs (54%; Appendix 2b).

Figure 6. Relative density of **rockfish groups between platforms and natural reefs**. Species composition of each taxonomic group is described in Table 4. Data are combined across all size classes, all three years (1995-1997) and both sampling methods (divers and ROV) combined. Open bars are natural reefs, shaded bars are platforms. Relative density is explained in the Methods section text. Actual density values are presented in Appendix 2b.



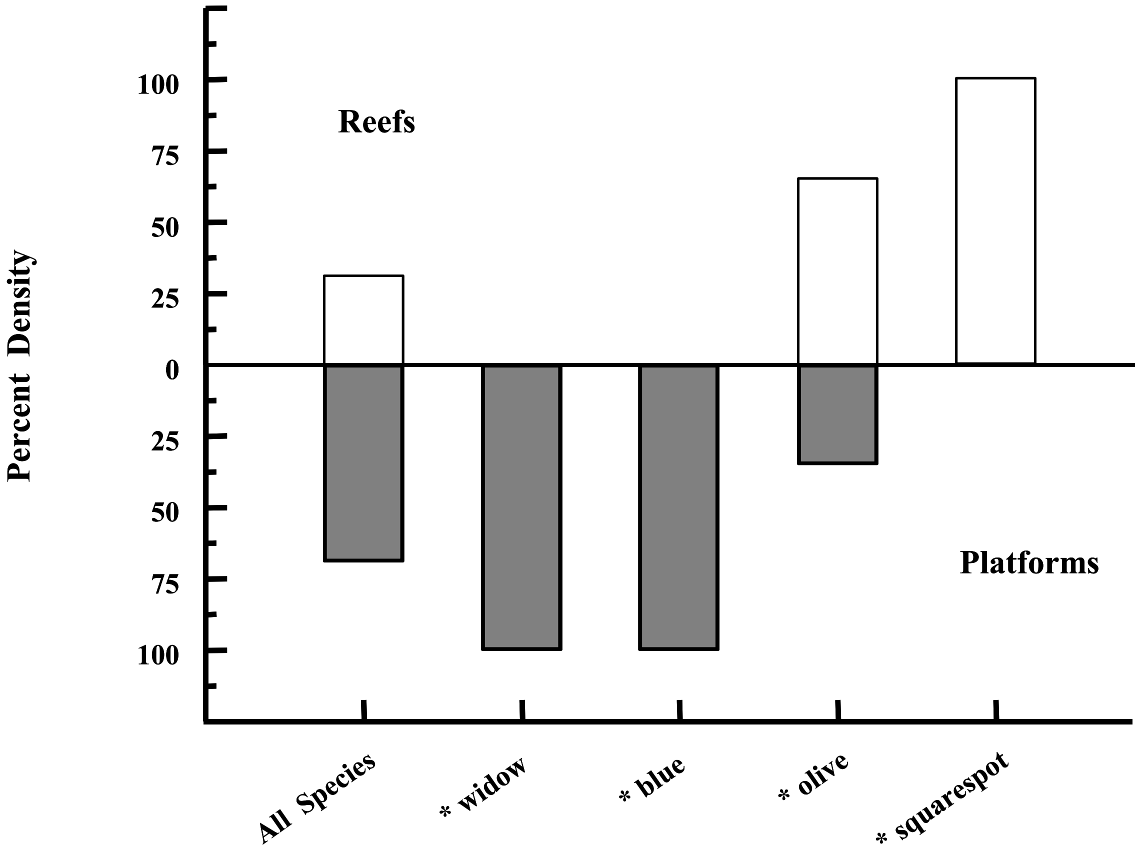
As indicated by the four most common species that constituted the benthic rockfish complex (which excludes the copper complex), some species occurred in relatively far greater density on natural reefs (75% or greater) than on the platforms (Figure 7). With the exception of treefish, these are species that occur on deeper reefs, sampled with the ROV. However, vermillion and the other benthic species (flag, halfbanded, and species that constitute the *Sebastomus* group; Table 4) occurred in relatively higher densities on platforms, contributing to the overall higher density of this group on platforms relative to natural reefs.

Figure 7. Relative density of the four most **common rockfish species in the shallow benthic group** (excluding "copper complex" species; see Figure 9) between platforms and natural reefs. Open bars are natural reefs, shaded bars are platforms. Data are combined across all three years (1995-1997) and both sampling methods (divers and ROV). Young-of-Year fish (YOYs) not included in species marked with *. "All Species" includes unidentified shallow benthic adults and YOYs. Relative density is explained in the Methods section text. Actual density values are presented in Appendix 2b.



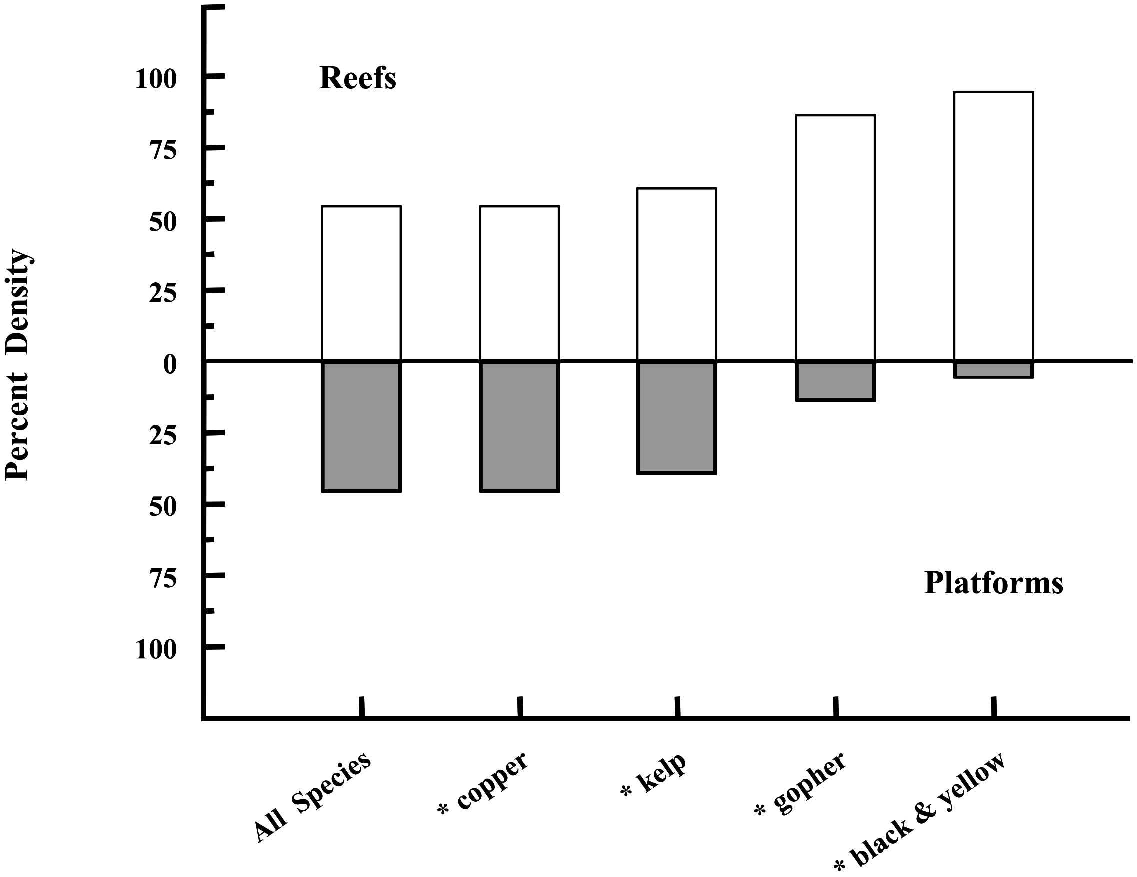
As indicated by the four most common species that constituted the midwater rockfish complex, the overall relative density of this group was far greater on platforms (70%) than natural reefs (Figure 8). But again, this pattern varied markedly among species. Whereas squarespot were observed only on natural reefs and 65% of the overall density of olive rockfish occurred on natural reefs, both widow and blue rockfish were observed only on platforms. While these differences cannot be interpreted as absolute, some species clearly occur in much greater density in one habitat relative to the other (e.g., blue and widow rockfish on platforms). Additional species that constituted this complex (boccacio, yellowtail) also contributed to the overall higher density of this group on platforms compared to natural reefs. Importantly, the behavior of species constituting this group to form large aggregations in the water column well above the bottom, allows them to occupy large areas of the water column, while maintaining proximity with the physical structure of the platform. This is a feature unique to platforms compared to natural reefs.

Figure 8. Relative density of the four most **common rockfish species in the midwater group** between platforms and natural reefs. Open bars are natural reefs, shaded bars are platforms. Data are combined across all three years (1995-1997) and both sampling methods (divers and ROV). Young-of-Year fish (YOYs) not included in species marked with *. "All Species" includes unidentified midwater adults and YOYs. Relative density is explained in the Methods section text. Actual density values are presented in Appendix 2b.



As indicated by the four species that constituted the copper rockfish complex, the overall relative density of this group was relatively similar between platforms and natural reefs (Figure 9). But again, this pattern varied markedly among species. Whereas the relative density of the shallow (< 30 m) dwelling gopher and black-and-yellow rockfish was substantially higher on natural reefs (> 80%), the relative density of kelp and copper rockfish was more equitable between habitat types. Importantly, the vast majority of kelp and copper rockfish encountered on platforms were at the bottom of the platforms. Thus, the difference in the relative density of the different species that constitute this complex may reflect the ability of species to exist at depth as adults. This may explain the absence of the shallow dwelling adults of the gopher and black-and-yellow rockfishes on platforms. This pattern does not appear to reflect differences in recruitment between platforms and natural reefs, based on patterns of recruitment described later in this section.

Figure 9. Relative density of all four **rockfish species in the copper complex group** between platforms and natural reefs. Open bars are natural reefs, shaded bars are platforms. Data are combined across all three years (1995-1997) and both sampling methods (divers and ROV). Young-of-Year fish (YOYs) not included in species marked with *. "All Species" includes unidentified copper complex adults and YOYs. Relative density is explained in the Methods section text. Actual density values are presented in Appendix 2b.



Distribution of life stages between platforms and natural reefs--Many species demonstrated marked differences in the relative density of young (< 1 year) and older life stages between platforms and natural reef habitats. For example, while older rockfish individuals occurred on both platforms and natural reefs, the relative density of young fish was far greater on platforms (Figure 10). Such was the case for the "copper", "midwater" and "shallow benthic" complexes (Figure 10). This pattern was even stronger for two non-rockfish species, the blacksmith and the California sheephead (Figure 11). Whereas recruitment of these two species was greater on platforms, the relative density of older stages was much greater on natural reefs.

Of the other non-rockfish species, the relative density of life stages between platforms and natural reefs varied among species. For example, the relative density of both young and older Garibaldi and halfmoon was vastly greater on platforms than natural reefs (Figure 11). In contrast, the relative density of both young and older senorita and kelp bass was far greater on natural reefs (Figure 11).

Comparison of size distributions on platforms and natural reefs--Overall, laser estimates of size distributions missed both the smaller, juvenile size classes as well as rare larger individuals when compared with visual estimates on either platforms or natural reefs. Therefore, we restricted our comparison of size distributions between platforms and natural reefs to individuals ≥ 9 cm Total Length. For that restricted size distribution, the two methods generally produced similar estimates of both mean size and size-frequency distributions (Appendix 4). Of the 19 species that we compared, lasers estimated larger mean adult sizes than visual estimates for only three species (blacksmith, pile surfperch and blue rockfish), and visual estimates were greater than laser estimates for four species (rubberlip surfperch, brown surfperch, barred sand bass and widow rockfish).

Of the 11 species whose adults (≥ 9 cm TL) co-occurred in both habitats in sufficient numbers to compare size distributions with either or both sampling methods, mean size of adults tended to be greater on platforms (pile perch, senorita, kelp bass, and copper, olive, kelp, gopher rockfishes). Sheephead and painted greenling adults tended to be larger on natural reefs. Mean size of adult halfmoon and blacksmith were similar on platforms and natural reefs (Appendix 4).

Figure 10. Relative density of **rockfish** size classes between natural reefs and platforms. Open bars are natural reefs, shaded bars are platforms. Data are combined across all three years (1995-1997) and both sampling methods (divers and ROV). "Older" fish are all fish ≥ 9 cm TL. Relative density is explained in the Methods section text.

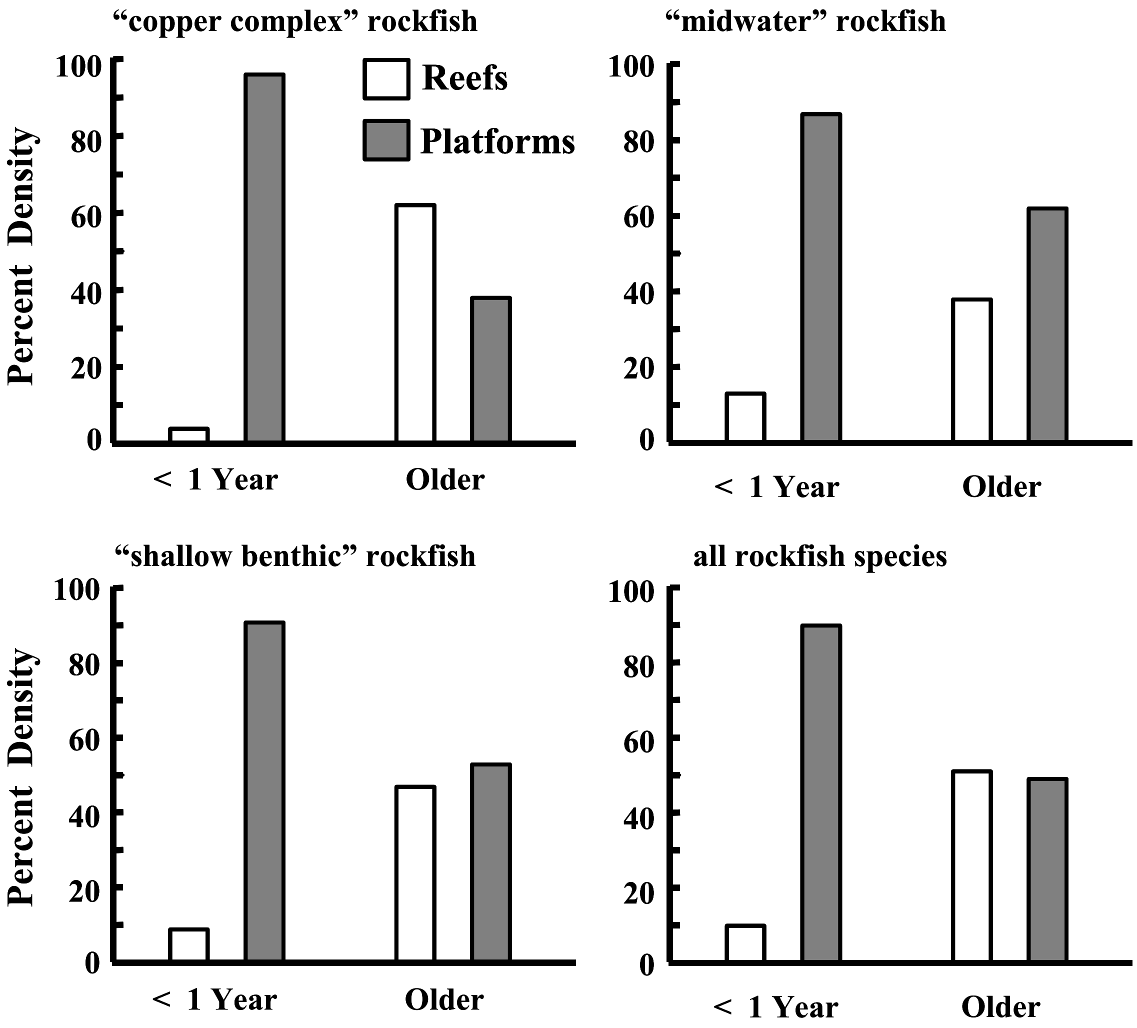
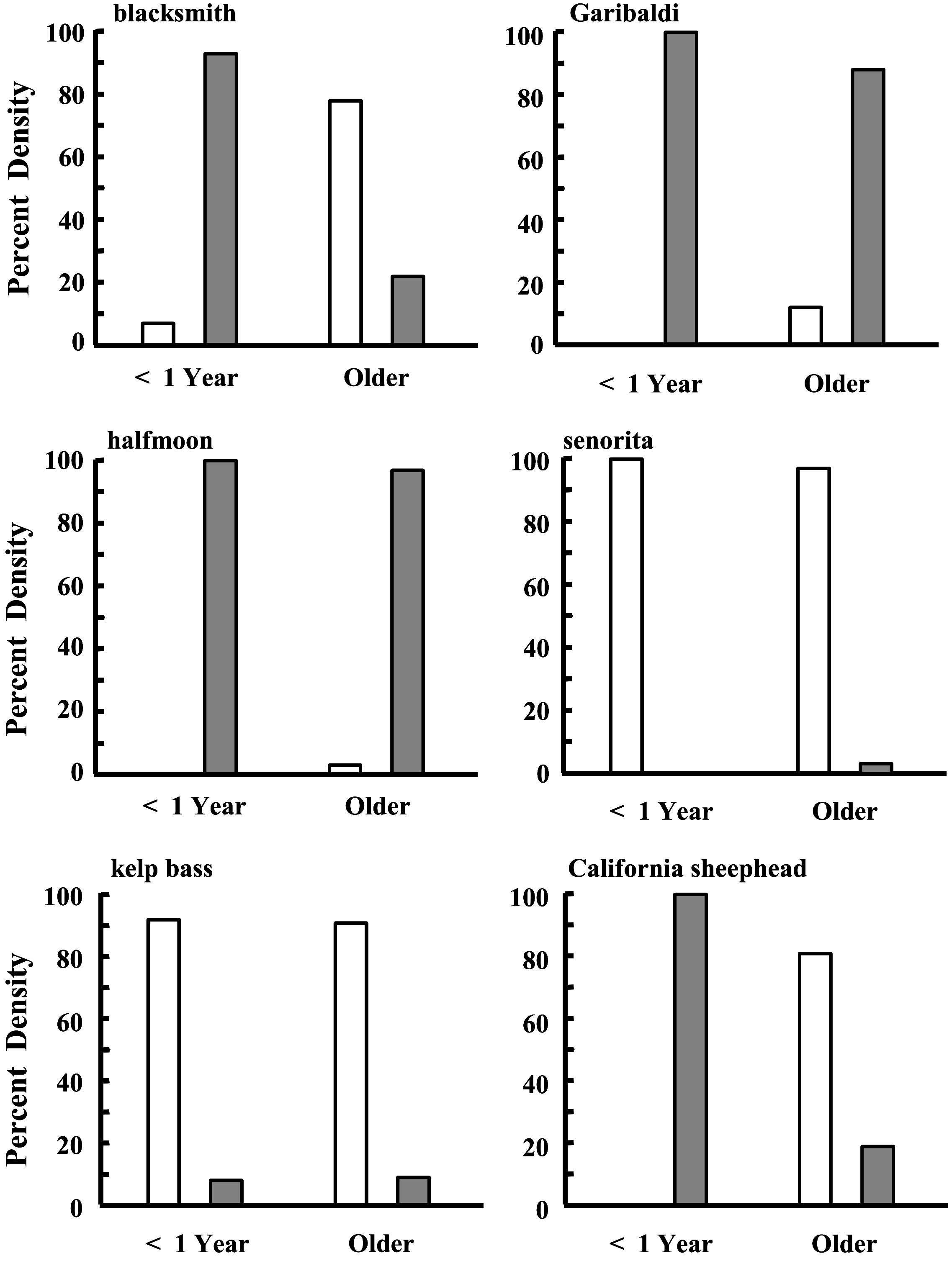
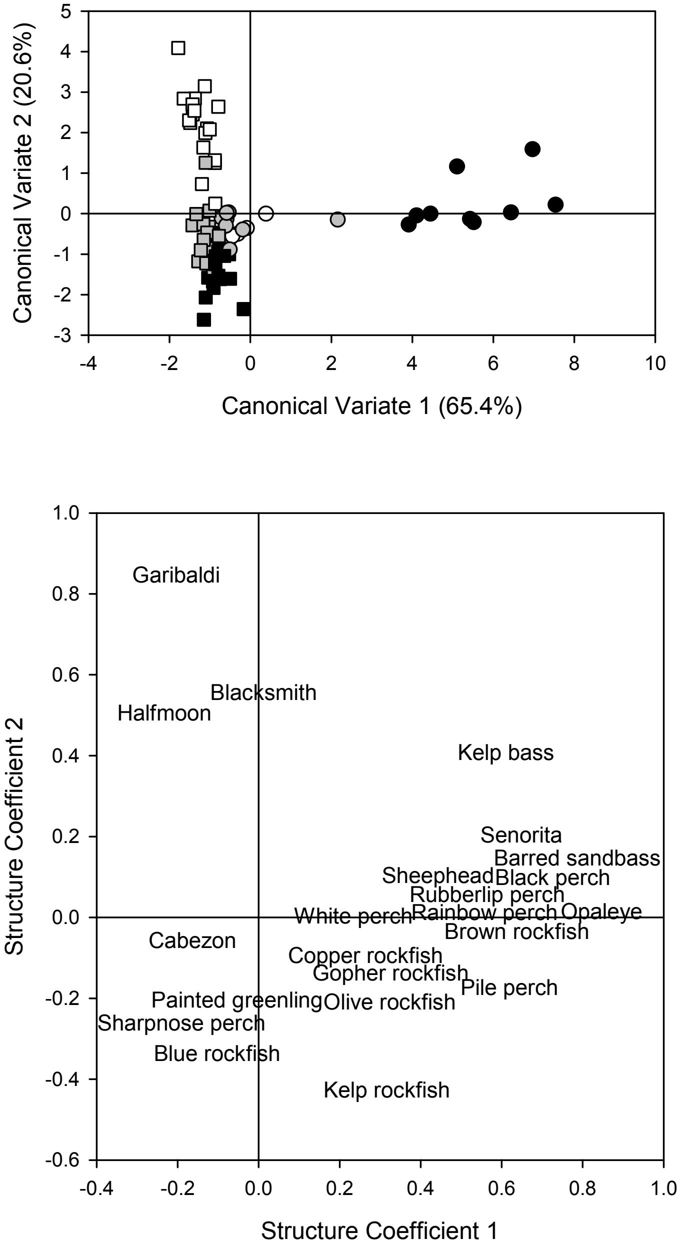


Figure 11. Relative density of **non-rockfish** size classes between natural reefs and platforms. Open bars are natural reefs, shaded bars are platforms. Data are combined across all three years (1995-1997) and both sampling methods (divers and ROV). "Older" fish are all fish ≥ 9 cm TL. Relative density is explained in the Methods section text.



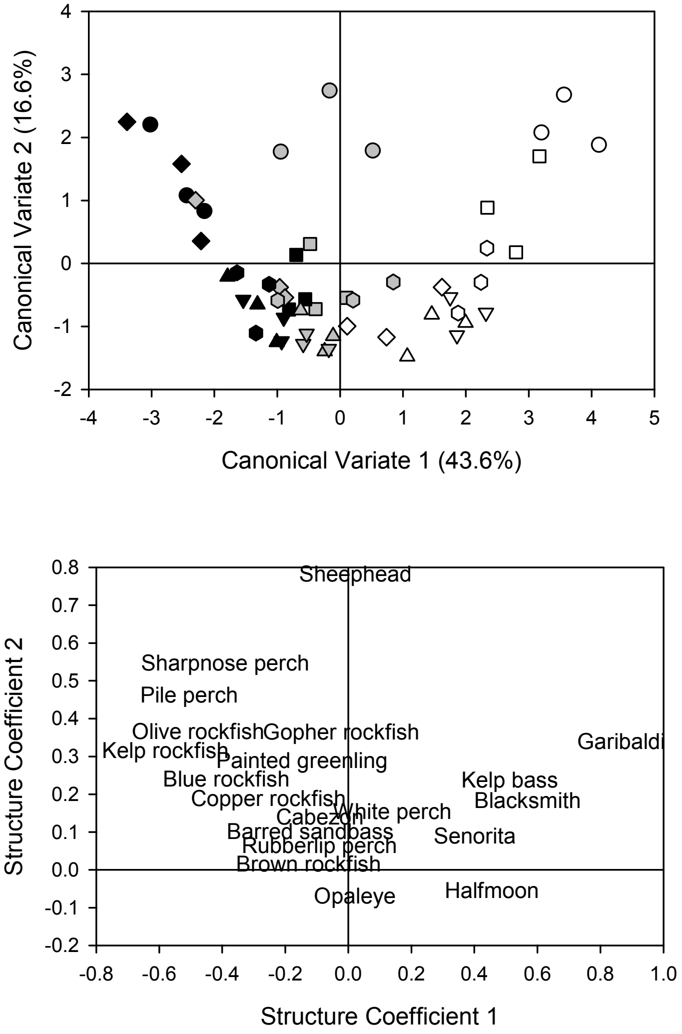
Comparison of assemblage structure--The many differences among species in their patterns of relative density between platforms and natural reefs are manifested in the composition and structure (i.e. relative abundance) of fish assemblages associated with the two habitat types. These differences are also manifested in the structure of fish assemblages across the depth strata sampled. For example, as indicated by the Canonical Discriminant Analysis (CDA) comparing the structure of the fish assemblages sampled by divers in the upper three depth strata (Figure 3: levels 1,2,3), roughly 65% of the variation in assemblage structure is explained by differences between platform and natural reefs (1st canonical variate) and another 20% of the variation is related to differences in fish assemblages across the three depth strata on the platforms (2nd canonical variate; Figure 12). In particular, the fish assemblage sampled by divers at the deepest stratum of natural reefs (level 3: many of the surfperches, opaleye, barred sandbass, brown rockfish, gopher rockfish) was distinctly different from all other habitats sampled (Figure 3). The fish assemblages occupying the shallow (Garibaldi, blacksmith, halfmoon) mid-depth (cabezon, copper, painted greenling, olive rockfish,) and deep (sharpnose perch, blue and kelp rockfish) strata of platforms sampled by divers were also distinctive (Figure 12). There was much overlap in the assemblages sampled at the middle stratum of the platforms with the shallow and middle strata of natural reefs (white perch, painted greenling, copper, olive and kelp rockfish) as indicated at the intersection of the two canonical variates (Figure 12).

Figure 12. Patterns of fish assemblages derived from the Canonical Discriminant Analysis of 1+ and older fishes sampled by **divers on platforms and natural reefs**. ○ Natural reef; □ Platform. Shading represents each of the three depth levels surveyed by divers from deep (black) to shallow (white). Each point represents the centroid of a fish assemblage of a given site-depth level combination for a given year.



Among the six study platforms, depth stratification was again the strongest correlate with variation in fish assemblages (Figure 13). Depth stratification explained 44% of the variation in fish assemblages (canonical variate 1). In addition, there was some variation among platforms, but this did not seem to correspond to any spatial pattern. Platforms A and B (offshore), and Hogan (the innermost platform) separatd from the other platforms based on a general higher density of fish (all species combined) relative to the other platforms. However, this was not a strong trend, given that it explained only an additional 17 of the variation in assemblage structures among platforms (Figure 13; canonical variate 2).

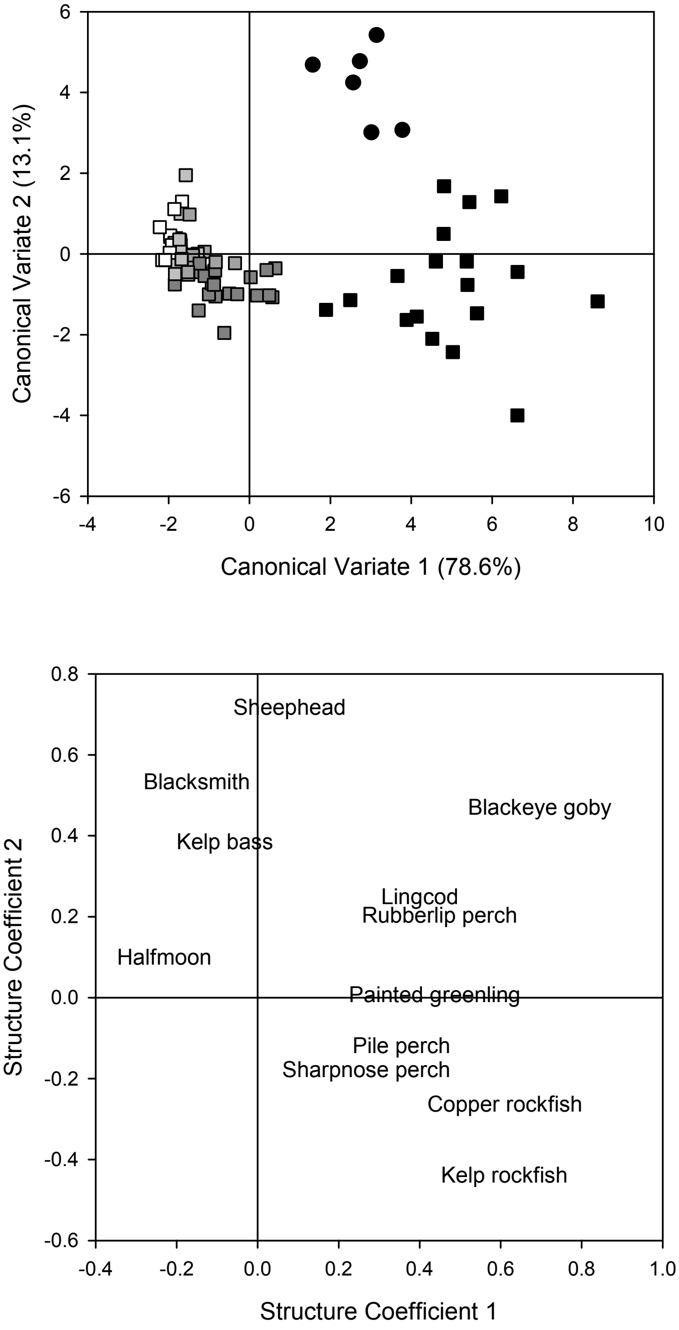
Figure 13. Patterns of fish assemblages derived from the Canonical Discriminant Analysis of 1+ and older fishes sampled by **divers on platforms** only. ○ Platform 'A'; □ Platform 'B'; △ Platform 'C'; ▽ Platform 'Henry'; ◇ Platform 'Hogan'; ⬡ Platform Houchin. Shading represents each of the three depth levels surveyed by divers from deep (black) to shallow (white). Each point represents the centroid of a fish assemblage of a given site-depth level combination for a given year.



Fish assemblages on the deepest natural reefs and the deepest portion of the platforms also varied by habitat (platform versus natural reef) and, especially, depth stratum. Most (79%) of the variation in assemblage structure among samples was related to whether samples were collected on the bottom of the platforms (or deepest reef) versus shallower depth strata above the bottom (Figure 14: canonical variate 1). The deepest natural reef sampled (36 m depth) was shallower than the bottom of the platforms (50-58 m) and this was reflected in the assemblage structure. The deepest natural reef (ROV) samples were comprised of more shallow dwelling species (sheephead, blackeye goby, blacksmith, kelp bass) than the bottom of the platforms (Figure 14).

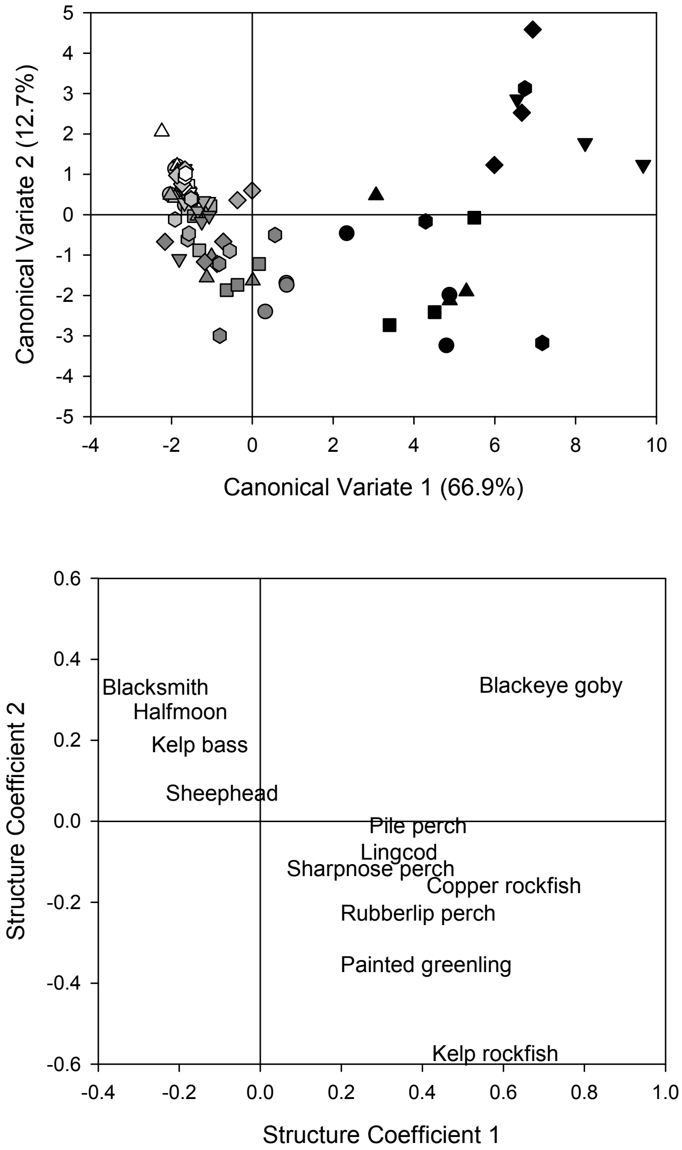
Above the bottom, platforms and natural reefs supported more similar fish assemblages within the lower depth strata sampled by the ROVs.

Figure 14. Patterns of fish assemblages derived from the Canonical Discriminant Analysis of 1+ and older fishes sampled by **ROV on platforms and deep natural reefs**. ○ Natural reef; □ Platform. Shading represents each of four depth levels surveyed by ROVs on platforms from deep (black) to shallow (white), and the single depth level sampled on the two deep natural reefs. Each point represents the centroid of a fish assemblage of a given site-depth level combination for a given year.



This strong distinction between bottom and water column assemblages was again manifested among samples across the six study platforms (Figure 15). Bottom versus all samples shallower in the water column explained 67% of the variation in fish assemblage structure among samples across all six platforms (canonical variate 1). Actual depth explained only 13% more variation (canonical variate 2) because of the similarity of assemblages across the deeper strata above the bottom.

Figure 15. Patterns of fish assemblages derived from the Canonical Discriminant Analysis of 1+ and older fishes sampled by **ROV on platforms only**. ○ Platform 'A'; □ Platform 'B'; △ Platform 'C'; ▽ Platform 'Henry'; ◇ Platform 'Hogan'; ⬡ Platform Houchin. Shading represents each of four depth levels surveyed by ROVs on platforms from deep (black) to shallow (white). Each point represents the centroid of a fish assemblage of a given site-depth level combination for a given year.



Habitat type (platforms versus natural reefs) also explained a substantial amount of variation (51%) of the assemblage of young-of- year (less than 1 yr old fishes) fishes sampled (Figure 16; canonical variate 1). Deep portions of platforms harbored a number of rockfish species in much greater density than observed shallower on platforms or on any of the natural reefs sampled. Young of shallow dwelling species (Garibaldi, blacksmith) contributed more to the young-of-year assemblages on the shallower strata of platforms, and kelp-associated young (e.g., kelp bass) contributed more to assemblages of young on natural reefs (Figure 16). Thus, with respect to which species recruited as young from the plankton, the platforms and natural reefs differed substantially as recruitment habitat in the study area. As for assemblages of adult fishes, bottom versus above-bottom strata explained substantial variation (55%) in the assemblages of young-of-year recruits across the six study platforms (Figure 17; canonical variate 1). Variation across platforms was not strong.

Figure 16. Patterns of fish assemblages derived from the Canonical Discriminant Analysis of **YOY fishes sampled by divers on platforms and natural reefs**. ○ Natural reef; □ Platform. Shading represents each of the three depth levels surveyed by divers from deep (black) to shallow (white). Each point represents the centroid of a fish assemblage of a given site-depth level combination for a given year.

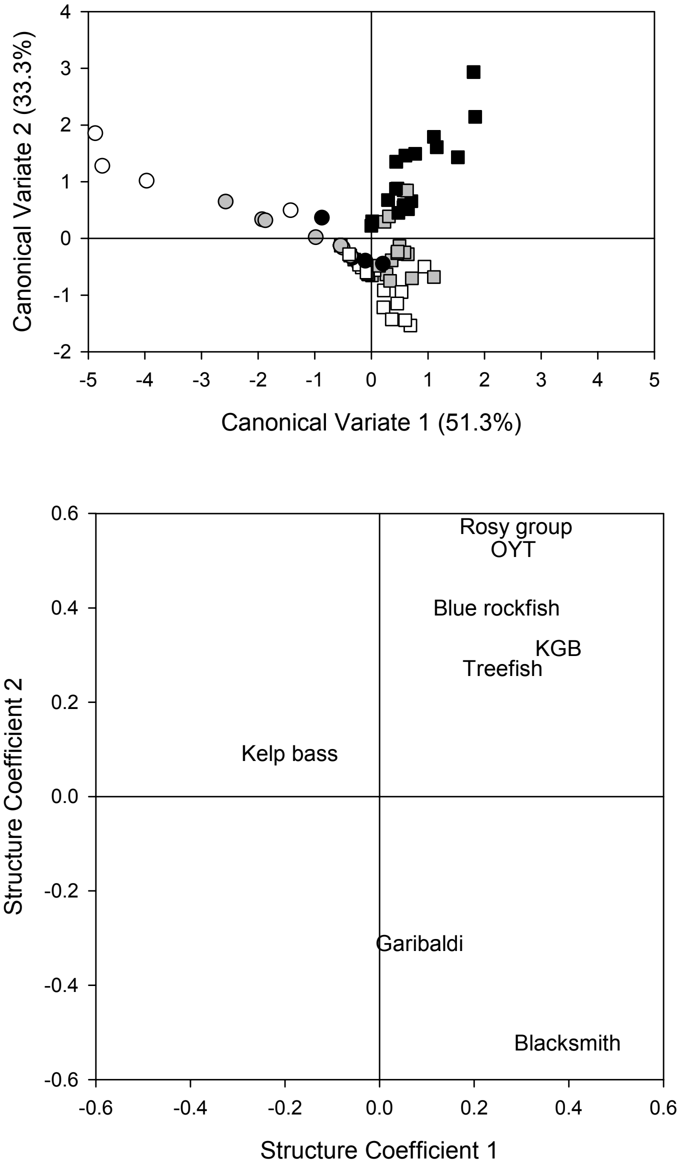
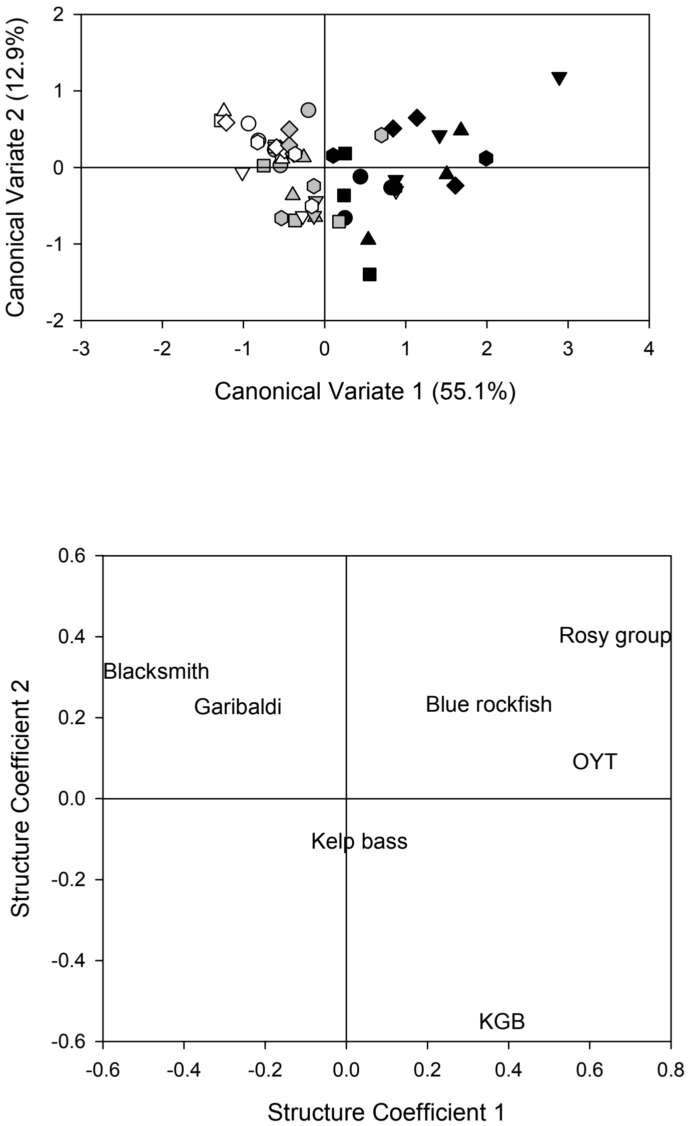


Figure 17. Patterns of fish assemblages derived from the Canonical Discriminant Analysis of **YOY fishes sampled by divers on platforms only**. ○ Platform 'A'; □ Platform 'B'; △ Platform 'C'; ▽ Platform 'Henry'; ◇ Platform 'Hogan'; ⬡ Platform Houchin. Shading represents each of the three depth levels surveyed by divers from deep (black) to shallow (white). Each point represents the centroid of a fish assemblage of a given site-depth level combination for a given year.



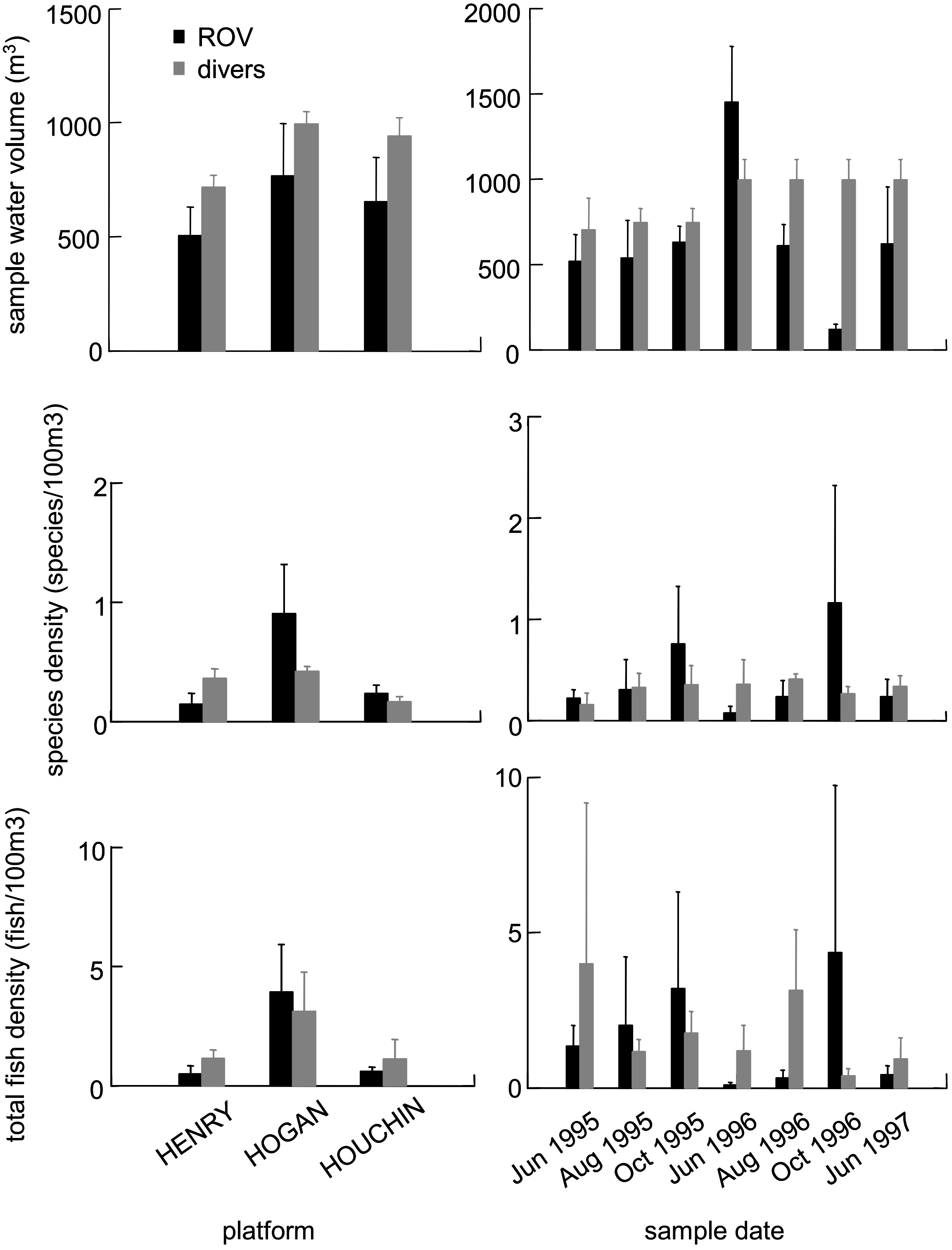
Vertical Stratification of Fish Species and Life Stages on Platforms

Comparison of Fish Density Estimates by ROV and Diver Surveys

Our characterization of fish assemblages on platforms and natural reefs indicated that much of the variation in fish assemblage structure between and within these two habitat types was related to water depth in two ways. First by the actual bottom depth, and secondly by position in the water column; i.e. the strong differences between assemblages on the bottom and all strata above the bottom. But our ability to describe this depth stratification across all 5 depth strata sampled was dependent, in part, on differences in sampling bias by the two methods we used to sample fish at different depth strata; divers and ROV. Because we are interested in both spatial and temporal variation among platforms, we compared the amount of habitat sampled (i.e. water volume), species density and total fish density sampled by divers and ROV between the three platforms (Hogan, Houchin and Henry) at which diver and ROV sampling overlapped with one another and across the 7seven ROV sampling dates. Diver and ROV samples overlapped along the outer perimeter cross members at the 36 m depth (level 3, Figure 3).

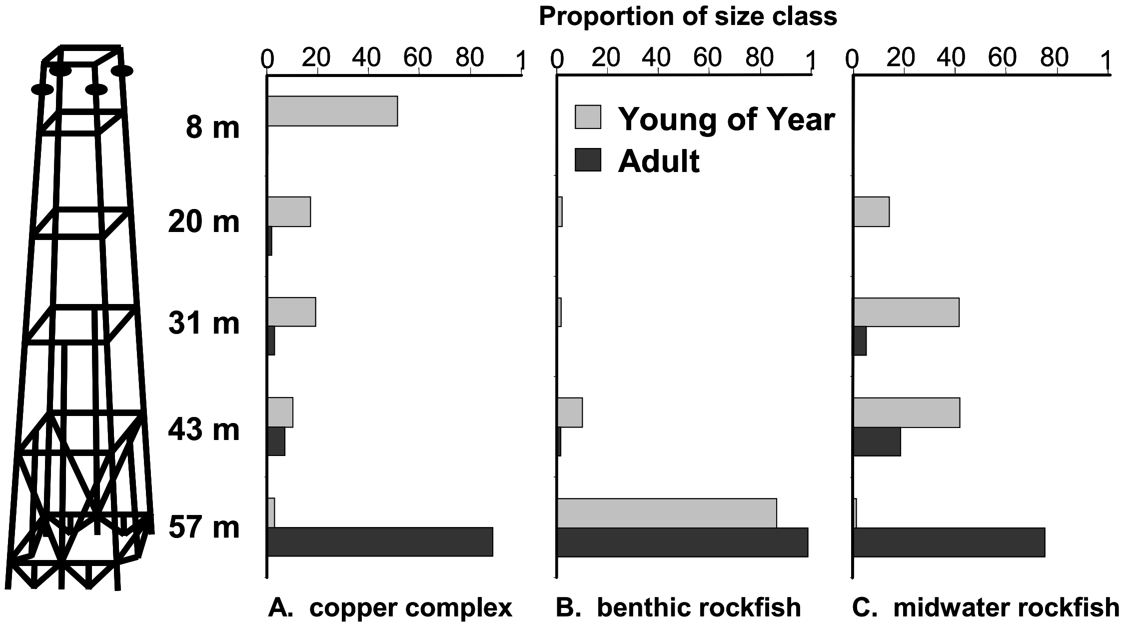
Water volume sampled by divers at level 3 tended to be somewhat greater (20-25%) than by the ROV with the exception of two sampling dates in which the ROV sampled substantially greater (25%) water volume and substantially less (10%) water volume sampled by divers (Figure 18). Although samples comparing species density (number of species per unit water volume) and total fish density were standardized per unit water volume, the greater volume sampled could contribute to greater likelihood of encountering rare species and bias species number estimates recorded by divers, which would lead to a greater species density in shallower water sampled by divers. However, at level 3, there was no clear difference in the density of species recorded by ROV than by divers across the three platforms sampled, nor was there any evidence of a consistent difference in species density across the 7 sampling dates (Figure 18). It is more likely that sampling with both methods was sufficient to pick up most of the conspicuous species on platforms, and the relatively lower volume sampled by ROV contributes to the greater number of species per unit water volume sampled by the ROV. Similarly, differences in total fish density between the two methods did not differ substantially or consistently across the three platforms and differences flip-flopped across sampling dates erratically (Figure 18). These patterns suggest that any strong depth-related differences in fish assemblages were more likely real differences, rather than differential bias in the sampling methods used at different depths of the platforms.

Figure 18. Comparison of the volume of water sampled, species density, and fish density (all species combined) by ROV and divers on each of the three study platforms where both methods sampled the perimeter cross members at level 3 (36 m depth). Plotted are the mean and standard error across the 7 sampling dates (n= 7) on the left-hand column, and across the 3 platforms (n=3) on the right-hand column.



Of particular importance with respect to depth is the degree to which the shallow portion of platforms provides recruitment habitat and is key to the replenishment of populations associated with platforms. This is particularly clear for those species whose juveniles and adults occur strictly in the upper portion of platforms (e.g., blacksmith, Garibaldi). It is less clear for the any rockfishes whose adults occupy deeper portions of platforms. The importance of the upper 20 m of platforms for recruitment varied markedly among the three major groups of rockfishes (copper, midwater, and benthic complexes). The vast majority of recruitment of the copper complex species occurred in the upper 20 m of the platforms (Figure 18). In contrast, recruitment of the benthic complex occurred near or on the bottom at the same depth stratum as adults. The midwater rockfishes exhibited recruitment patterns intermediate of these two extremes. Juveniles recruited at depths in the middle strata of the platforms (especially levels 3 and 4), but shallower than strata occupied by adults. Because of the numerical predominance of the midwater rockfishes, the vast majority of rockfish recruitment occurred in the middle strata of the platforms. Based on their small size (4-8 cm Total Length), it is clear that these recruits settled as pelagic juveniles from the plankton, rather than migrating from other habitats.

Figure 19. Relative depth distribution of young-of-year and older individuals of each of three rockfish complexes. Plotted is the percent of the total density of each size category across depth strata. Shaded bars are percent of total young-of-year within each depth stratum, solid bars are percent of total adults within each depth stratum. See Table 4 for species composition of the copper, benthic (BRF), and midwater (MRF) complexes. The benthic complex does not include the copper complex. Depth ranges included within each stratum are 8m= 0-9m, 20= 10-22m, 31= 23-36m, 43= 37-49m, 57= 50-57m.



Fish Movement Among Natural Reefs and Platforms

Of the 459 fish tagged in this study, 10% (48) were re-caught (Table 8). Recreational fishers were responsible for almost all recaptures. This relatively high return rate (10%) is not surprising for nearshore fishes. Of the fish re-caught, 67% (32 of 48) were caught where they were tagged, suggesting that many of the species tagged remain on the reefs where they were tagged. Most of the fish recaptured were kelp bass and rockfishes (38 and 44%, respectively). Collectively, kelp bass and brown rockfish accounted for 60 percent of all fish recaptured. For these two species, 61% (11 of 18) and 82% (9 of 11), respectively, were re-caught within 1 km of the tagging site. Of course, it is not clear how much movement occurs by the many fish that were not recaptured. But these data suggest that some individuals are generally residential, remaining on nearby reefs at least over the duration of the tagging study.

We made note of any tagged fish that were observed on diver surveys or on video footage recorded by divers or ROV on both natural reefs and platforms. We never observed tagged fish on platforms other than two brown rockfish at Platform Houchin, both of which were previously tagged there. Platform Houchin was the only platform we were able to tag fish at. Roughly 50 percent (254) of the 459 fish tagged in our study were tagged at one site, Horseshoe Reef. Horseshoe Reef lies roughly 8 km from the six study platforms (Figure 1). Divers recorded 17 re-sightings of tagged fishes, mostly benthic rockfishes. All 17 re-sightings were made on Horseshoe reef, all of which were tagged at that site. We never observed tagged fish on platforms that were tagged on natural reefs.

Table 8. Fish species tagged and recaptured on reefs and oil platforms in the area off Santa Barbara from 1996 to 1998. Distances moved correspond to movement between the following: *a* = 3-spot reef to Horseshoe reef, *b* = Horseshoe reef to 1-mile reef, *c* = Horseshoe reef to Carpinteria reef, d = 3-spot reef to Ventura flats, *e* = Carpinteria reef to Loginelle wreck (Ventura), *f* = Plat. Houchin to Plat. Hogan, *g* = Horseshoe reef to Campus Pt, *h* = 4-mile reef to 1-mile reef, *i*= Horseshoe reef to 3 miles of Summerland, *j* = Horseshoe reef in channel between Anacapa Island and Santa Cruz Isand, *k* = Horseshoe reef to 3-spot reef, *l* = location data missing.

								Distance from initial tagging location (km)					
Species	No. tagged	No. recaptured	% Return	Mean days between capture (± 1 sd)	Mean distance traveled (km) (± 1 sd)	Most days between capture	Maximum distance (km)	0	1-2	3-9	10-20	>20	?
kelp bass	163	18	11.0	97.8 ± 112.1	1.8 ± 3.4	350	9.5	11	2[a]	1	2[b]		2[l]
sand bass	52	5	9.6	109.2 ± 67.9	13.9 ± 18.6	197	40.9	2		1[c]		2[d,e]	
brown rockfish*s*	57	11	19.3	246.3 ± 126.4	2.4 ± 7.5	446	25.0	9	1[f]			1[g]	
gopher rockfish	33	2	6.1	182.5 ± 181.7	0	311	0.0	2					
treefish	26	4	15.4	365.5 ± 283.5	12.71 ± 19.4	772	41.6	1		2[h,i]		1[j]	
squarespot rockfish	15	1	6.7	84.0	0	84	0.0	1					
copper rockfish	7	1	14.3	54.0	0	54	0.0	1					
olive rockfish	8	2	25.0	33.0 ± 18.4	0.8 ± 1.1	46	1.6	1	1[k]				
blacksmith	40	2	5.0	59.5 ± 7.8	0.0 ± 0.0	65	0.0	2					
ling cod	1	1	100.0	44.0	0.0	44	0.0	1					
California scorpion fish	5	1	20.0	54.0	0.0	54	0.0	1					
All other species	52	0	0.0										
Total	459	48	10.5										

Relative Performance of Fishes on Platforms and Natural Reefs

Unfortunately, species that recruited in sufficient abundance to platforms (e.g., blacksmith or rockfish) or natural reefs (senorita, kelp bass) recruited in insufficient numbers to the other habitat type (Figures 10 and 11). This precluded our ability to make this very important comparison from the surveys we conducted at the different study platforms and natural reefs.

Contribution of Platforms to the Abundance of Regional Reef Structure

All available maps and images were of insufficient resolution to estimate in any quantitative way the amount of rocky habitat in the region.

Discussion

Several offshore oil and gas production facilities in the Pacific Outer Continental Shelf (POCS) region are nearing the end of, or have ended, their economic lives. Present legislation requires complete removal of decommissioned platforms. However, alternative decommissioning options including partial removal in place or relocation have been implemented in other areas of the country. The removal of four offshore platforms in the Santa Barbara Channel during the summer of 1995 created interest by some user groups in pursuing such alternatives on the West coast (MMS-CSLC Abandonment Workshop 1994, MMS 1998). Critical to formulation of appropriate decommissioning policy is an understanding of the ecological, economic and social consequences of different decommissioning options and identification of the mechanisms by which such information is incorporated, or not, into legislation and public policy.

Central to understanding the ecological role of anthropogenic structures on regional fish production is knowledge of their relationship with fish assemblages on natural reefs (Alevizon and Gorham 1989, Ambrose and Swarbrick 1989, Ambrose 1994, Beets and. Hixon 1994, Carr and Hixon 1997, Osenberg et al 2002). It is difficult to conclude to what extent species associated with a structure influence regional production without distinguishing local production from the redistribution of individuals (i.e., “attraction”) from natural habitat. Also critical to the development of decommissioning is an understanding of how the local environment (i.e., oceanographic conditions and proximity to natural reef habitat) and structural characteristics of decommissioned structures influence the kinds and numbers of species associated with it. Thus, our multi-year investigation of the ecological role of offshore structures had three primary objectives. One objective of this study was to quantify the species and sizes of fishes associated with platforms and natural reefs. Such information is required to determine what species and life stages might be influenced by the various decommissioning options. Because several of the various options for platform decommissioning alter the vertical height of the remaining structure (e.g., “topping”, “toppling”, moving to different water depths), a second objective of our study was to quantify the vertical distribution of each species from the surface to the bottom of the platforms to estimate the potential consequences of these options. Fundamental to understanding the net contribution of local populations to regional production is information on the size-specific rate of migration of fishes among local, reef-associated populations. In the context of platform decommissioning, knowledge of the net direction and rate of transfer of biomass between platforms and natural reefs is crucial. Therefore, a third objective was to determine how much and what direction fish move (from platforms to reefs or vice versa), the rate of that movement, and net direction of exchange.

Fish Assemblages on Natural Reefs and Production Platforms

Several key results were generated from our comparisons of fish population and assemblages between natural reefs and productions platforms in the eastern Santa Barbara Channel. Clearly, platforms create a different kind of reef environment than is characteristic of nearby natural reefs. Three habitat characteristics are particularly relevant. Most conspicuous is the unique occurrence of physical structure high in the water column in deep water. This provides structure for the young of species that recruit to reef-associated populations after surviving a dispersive planktonic larval phase. Many species that occupy platforms clearly recruited to platforms this way (e.g., Garibaldi, blacksmith, cabezon and several species that constitute the midwater rockfish complex). These species were far less abundant as recruits on the natural reefs we sampled. The presence of physical structure high in the water column also allowed large numbers of midwater rockfishes (including blue, widow, olive, yellowtail, and boccacio) to aggregate well above the bottom and forage on planktonic prey (especially blue rockfish and the juveniles of all of these species). A second habitat distinction is the absence of large macroalgae (kelps) on platforms. The absence of kelp, especially the giant kelp, *Macrocystis pyrifera*, contributed to the paucity of species that associate closely with this alga on natural reefs (e.g., senoritas, kelp bass, kelp fishes, opaleye). A third habitat feature is the apparent lower rugosity (cracks and crevices) of the platform structure compared to natural reefs. Although this did not contribute to a reduction in the relative density of several species closely associated with the reef substratum (e.g., Garibaldi, cabezon, painted greenlings), it may have contributed to the relatively lower density of some (e.g., sheephead, lingcod, gopher and black-and-yellow rockfishes). Taken together, these three differences in structural aspects of platforms and natural reefs contributed to the population and assemblage differences we detected between the two habitat types.

Another important cause for differences in fish assemblages between platforms and natural reefs were broader landscape scale differences. Platforms are isolated in deeper water from the shallow reefs along the coast. For species whose young do not disperse in the plankton, this isolation is a barrier to colonization and replenishment. This probably explains the lower relative density of the many surfperch species whose young are not dispersed in the plankton and primarily replenish populations where they are born. In addition, the location of platforms offshore in deeper water appears to expose them to recruitment of species whose young (larvae and pelagic juveniles) are delivered in far fewer numbers to shallower natural reefs closer to shore. This may explain the higher density of species (especially juveniles) of blacksmith and several rockfish species constituting the copper and midwater rockfish complexes. In fact, it is surprising that relative densities of young and adults of some of the other rockfishes (e.g., calico, brown, and treefish) were not greater on platforms. This may reflect the episodic recruitment characteristic of rockfishes and it is possible that recruitment of these species may be greater on platforms when recruitment events occur.

Taken together, these surveys indicate that some species are likely to be more strongly influenced by decommissioning decisions than others and the patterns presented in this study identify those species for the area we sampled. For those species with much greater relative densities on platforms, or were altogether absent from the natural reefs we sampled, platforms may be not just represent “extra” habitat that is interchangeable with natural reef habitat. Platforms would add or enhance populations that are otherwise sparse in the study region. But two notes of caution are required in interpreting these patterns. First, our study area was rather small, limited to the eastern portion of the Santa Barbara Channel and only those natural reefs adjacent to the mainland. We restricted our focus on natural reefs in that area because (1) of the limited logistical scope of the study, (2) natural reefs near the platforms probably provide the best direct comparison of the role of these habitat types exposed to similar oceanographic conditions and larval supply, and (3) these natural reefs are the most likely to be influenced by the presence of the study platforms and future decommissioning activities, thereby providing a baseline for future studies of their response to such activities and for the evaluating the consequences of decommissioning activities. However, the limited spatial scope of our study is far smaller than the region-wide collection of fish populations that likely share larvae, and perhaps adults. Decommissioning of the platforms in our study area might influence natural reefs in other areas of the Channel and those reefs may support different fish assemblages than the natural reefs we studied. Recognizing this, our study was conducted in collaboration with studies funded jointly by the Minerals Management Service and the United States Geologic Survey’s Biological Research Division (Love et al. 1999, 2001) designed collaboratively with very similar sampling protocols but over a much broader (Channel-wide) area. Thus, a more thorough comparison of the platform and natural reef fish assemblages would benefit greatly from analyses that include the combined datasets from these two studies. Indeed, recognizing the importance of such a comparison, the two studies were designed for this purpose.

Also key to interpreting the results of our study is an explicit identification of the purpose of decommissioning activities and the creation of artificial reefs (Ambrose 1994, Carr and Hixon 1997). One aim of decommissioning might be to produce more habitat similar to natural reefs, in order to expand spatial coverage and increase abundance of the overall natural fish assemblages in an area. Key to this purpose is identifying the area of the natural fish assemblage of interest. Different conclusions would be drawn for an area the size of our study versus the Channel-wide fish populations and assemblages that are likely to share larval recruitment with one another. For this purpose, managers and policy makers can use the results of our study to ascertain the extent to which the different decommissioning options would contribute to this purpose. If, on the other hand the aim is to enhance local or regional populations of economically or endangered species, regardless of their natural occurrence or abundance in the study area, our results have identified those species that inhabit platforms over the period of our study. Another important caveat for all these comparisons is the well-documented changes in region-wide populations and assemblages of fishes in response to large-scale climatic conditions (Stephens et al. 1986, Ebeling and Hixon 1991, Holbrook et al. 1997, Love et al 1998, Brooks et al. 2002). Thus, differences in fish assemblages on platforms and natural reefs may diminish the time period over which comparisons are made increases. Another critical aspect of this comparison is the effect of fishing on local population and assemblage structure, which is now confounded with these two habitat types. Fishing effort is strong on the natural reefs that we studied and the influence of this mortality on the size/age structure and density of targeted populations (as well as indirect effects on non-targeted species) may be pronounced as well. In contrast very little, if any, recreational and live-fish fishing has been allowed for many years on the platforms we studied.

Thus, some of the differences we detected in population size structure, density and assemblage structure may simply reflect the effects of both the recreational and commercial live-fish fishery, rather than differences between habitat types. This is most likely for those species targeted by these two fisheries (e.g., kelp bass, sheephead, all rockfishes).

Vertical Stratification of Fish Species and Life Stages on Platforms

Our analyses of assemblage structure indicated time and again that the structure of fish assemblages on platforms and differences between these and assemblages on nearby natural reefs was strongly influenced by the vertical structure of the platforms. The abundance of many species varied markedly with depth along the height of platforms, and especially between the bottom and all shallower depth strata. Often, these depth-related differences were also related to the age/size of individuals. For example, the young of many shallow dwelling rockfish occurred only at the shallower depths sampled, whereas older stages (juveniles and adults) occurred more frequently at greater depths. These results have critical implications for the consequence of decommissioning options with respect to the subsequent occurrence or abundance of species and the structure of the fish assemblages on decommissioned platforms. Removal of the upper (20-30 m) portion of platforms is likely to reduce the abundance of many species whose depth range was restricted to that portion of platforms. Moreover, to the extent that young fish that settle to the upper portion of platforms constitute an important prey source to the remainder of the fish assemblage (especially the midwater rockfish complex), reduced recruitment may translate into lower productivity of the fish assemblages associated with decommissioned platforms. In contrast, both the young and older stages of other species (many midwater rockfishes including olives, widows, bocaccio) occurred at depth, suggesting that recruitment and adult abundance of these species may not be reduced by the removal of the upper portions of platforms. Another consideration is the ecological role of sea mussel (*Mytilus* species) production on platforms and the restricted depth range of mussel beds (surface to 20 m depth). If platforms are decommissioned in a manner that eliminates structure in the upper 20-30 m of the water column, mussel production will be eliminated. To the extent that mussel beds provide habitat for fishes on platforms, and the mounds of mussel shell litter provide habitat for small fishes on the bottom beneath platforms, the survival and density of species reliant on such structure would be diminished if an alternative source of structure was not provided. Our observations and others (Love et al. 1999, 2000, 2001) suggest that the litter mounds beneath platforms are important sources of habitat structure for many juvenile rockfishes and other small fishes. These implications for changes in fish assemblages and overall fish density associated with platforms have been manifested on toppled platforms in the Gulf of Mexico. To fulfill Louisiana state monitoring requirement, hydroacoustic surveys are taken yearly to monitor fish populations at standing platforms versus toppled platforms (Kasprzak 2000). Results from these surveys have shown higher fish biomass associated with standing platforms relative to toppled platforms (Kasprzak, 2000).

The robustness of our conclusions about the vertical stratification of fishes along platforms is supported in two ways. Firstly because many of the depth restrictions we detected were within the depth range sampled by divers. Thus, there was no confounding of different sampling methods used at different depths over the depth range that restricted distributions were recorded. Furthermore, the physical habitat (e.g., cross members) sampled at each depth stratum was similar. Secondly, our comparison of the effectiveness of sampling between the ROV and the divers both with respect to species composition and total fish density suggested, to our amazement, that the effectiveness of these two methods were sufficiently similar so as not to be a substantial source of bias. It is more likely that the depth-related differences we detected are due to real differences in species occurrence or abundance across the entire vertical extent of the platforms. Where sampling method was very likely to contribute to a bias in these species composition and density, is by underestimating the species at the bottom of the platforms. Here, reduced visibility and the very limited spatial coverage of sampling may have biased our estimates to underestimate either species or total fish density.

Fish Movement Among Natural Reefs and Platforms

Our limited re-capture data suggest rather limited movement for most species sampled. Indirect evidence, based on differences in the relative distribution of life stages, supports this pattern of restricted movement for both the Garibaldi and halfmoon. The relative density of both young and older Garibaldi and halfmoon was far greater on platforms than natural reefs. This was also the case for the many kelp-associated species (e.g. senorita, kelp bass) whose young and adults occurred only on natural reefs. However, indirect evidence, based on differences in the relative distribution of life stages, and movement data from other studies, suggests that some species do move between natural reefs and platforms. In particular, the greater relative density of young rockfishes on platforms, and more equitable density of adults between habitats, suggests either greater recruitment and subsequent emigration from platforms to natural reefs, or greater relative mortality of juveniles on platforms. Similar patterns exist for blacksmith and California sheephead. One possible example of recruitment to natural reefs and subsequent migration to platforms, though not strongly supported by our data, includes kelp bass. Small kelp bass (< 15 cm) were rarely observed on our study platforms, but were present with older life stages on natural reefs (Figure 11). Large (> 15 cm) kelp bass, though relatively sparse on platforms, occurred there despite the paucity of young recruits. Combined with some evidence for limited movement in our study and greater movement observed by others (Love et al. 2001), these data suggest that platforms may not be suitable settlement habitat for larval kelp bass, but that juveniles, and adults especially, migrate in low numbers onto platforms after first recruiting elsewhere. Such equivocal results from our movement study, in which differential movement and differential mortality may both contribute to differences in the size structure of populations between habitat types, emphasizes the importance of assessing both relative survival and emigration of fishes on platforms and natural reefs.

Relative Performance of Fishes on Platforms and Natural Reefs

In addition to comparing the relative density and structure of fish populations and assemblages on platforms and natural reefs, ascertaining the relative performance (survival, growth and reproductive success) of a species in these two habitat types was the next most important ecological objective of our study. The ultimate objective of the ecological studies currently being conducted is to provide information that will inform predictions on the regional consequences of leaving, removing or relocating (i.e. adding) artificial structures. Unfortunately, no information exists on the state of fish populations or assemblages on natural reefs prior to the presence of the platforms. Therefore, analytical approaches based upon time series, such as

Before-After-Control-Impact (BACI; Stewart-Oaten et al. 1986, Stewart-Oaten 1996), are not applicable for either estimating the influence of the existing platforms or predicting responses to changes in their location or structure. Instead, information on the density and performance of fishes inhabiting each habitat type, seem the most logistically feasible approach to estimating region-wide platform effects and predicting the regional response to changes in these structures (see Alevizon and Gorham 1989, Ambrose and Swarbrick 1989, and Beets and Hixon 1994 for similar approaches). But it is critical to recognize the limitation of this approach as well. Because density is a critical response variable and is likely to have some effect on individual performance (growth, survival, reproduction), any estimate of performance must account for density. Performance, standardized by density, can be greater, equivalent, or lower on platforms relative to natural reefs. If performance on platforms is greater, than the presence of platforms (in their present configuration) are more likely to have a net benefit to a regional population. Even if fish have simply been redistributed from the natural to the artificial habitat, their greater performance there is likely to translate into a positive regional effect. This, of course, assumes that the fate of larvae and contribution to replenishment of the regional population is comparable to that of populations on natural reefs. If density-specific individual performance of a species on platforms is equivalent to that on natural reefs, then the regional effect is unlikely to be negative (at most, fishes have been redistributed but still performing as well) and may have a net positive effect (larvae that recruit to a platform may not have survived to recruit to a natural reef, thereby enhancing region-wide recruitment). Critical to this result is whether or not performance on natural reefs is resource limited and, therefore, density-dependent. If however, performance on platforms is less than natural reefs, the results are equivocal and potentially negative. The unknown balance between an unknown enhancement of regional recruitment (by intercepting larval recruits that would have otherwise no survived to recruit to natural habitat), and the poorer post-settlement performance in terms of survival, growth and reproduction, make it very difficult to estimate the net regional consequence of the presence of platforms.

Two approaches are recommended for future progress in understanding the consequences of decommissioning options. First is the implementation of the comparative density-specific performance approach that we hoped to conduct in our study. Second, is an adaptive management approach based on observations of the response of regional populations to an experimental decommissioning. If monitoring of species composition, density and performance was conducted before and after the removal or relocation (i.e. addition) of a platform, much could be learned about the consequence of these activities. Such comparative time series approaches, most likely to be unreplicated (i.e. a single platform at a time) could employ analytical approaches such as BACI. A critical design constraint with this approach is identifying single or multiple natural “control” reefs similar to natural “impact” reefs, but also independent of the effects of the putative “impact” (i.e. addition or removal of a platform; Osenberg et. al. 2002). This design constraint is no different to that of identifying control reefs or control areas for assessing the effect of establishing marine reserves, plagued by the long dispersal potential of marine larvae, the openness of marine populations, and the great spatial scale over which marine populations potentially interact.

Contribution of Platforms to the Abundance of Regional Reef Structure

To our surprise, and after extensive and repeated efforts (see list of contacts in Methods section), we were unable to obtain geological maps of the resolution and coverage necessary to make our simple estimate of the relative contribution of platforms to the hard substratum throughout the Santa Barbara Channel region. Three aspects of this question are important considerations. First, and most simple, is what proportion of the total hard substratum (i.e. rocky reef) in the Channel platforms constitute. Based on the general amount of hard substratum in shallow regions of the Channel, including the Santa Barbara Channel Islands, this contribution is very small (Holbrook et. al. 2000). However, relative to the amount of hard substratum at the depths that platforms occur, this contribution may increase markedly. Moreover, there are no natural reefs with the physical relief comparable to platforms, especially at bottom depths that platforms occur. As such, these platform habitats are very unique. Thus, depending on the overall intent of creating artificial reef habitat, the relative contribution varies from miniscule if the purpose is to simply contribute to the overall natural reef habitat in the region, to 100% if the interest is for the unique habitat created by platforms.

Future Recommendations

We strongly recommend that studies be pursued to conduct those aspects of our proposed research that we were not able to complete. **Most importantly**, this should entail a study of the relative performance (survival, growth, reproduction) of species on platforms and natural reefs. We believe that this is the most direct line of evidence for assessing the contribution of platforms to the regional fish populations in the Santa Barbara Channel. **Secondly**, a comprehensive analysis of the type and amount of natural reef habitat throughout the Channel is critical to understanding the potential magnitude of decommissioning effects on the region-wide fish assemblage. Means to identify, collect and analyze existing maps, identify gaps in mapping data applicable to such an analysis, including coverage and resolution need to be developed and the appropriate analyses need to be conducted. **Third**, a more thorough and comprehensive comparison of the fishes that inhabit our study platforms and natural reefs throughout a broader area of the Channel should be conducted in collaboration with the Love et al. (2001) study designed for this purpose. **Fourth**, our study of fish movement would have benefited greatly by greater tagging effort and success at the platforms themselves. This was not accomplished for two critical reasons. We were not allowed to anchor and fish in close proximity to the platforms. This was because of the potential danger and costs of entangling an anchor in debris and cabling on the bottom around the platforms. Also, only smaller vessels could conduct such sampling in close proximity to the platforms and this would be too time and labor intensive for the scope of our study. If fishers could use the platforms themselves as platforms for collecting and tagging fishes to better estimate movement away from or retention on platforms, we would have a better understanding of the interaction and relationships between these platforms and nearby natural reefs.

Section III: Ecological Information and the Development of Decommissioning Policy

This section's focus is on the role of science and the scientific community in the development of offshore platform decommissioning policy. While we show that science and the scientific community are factors that contribute to the development of platform decommissioning policy, it is important to recognize that social, economic and perceptual factors associated with the Gulf states and California shape the politics and history of oil exploration, development and decommissioning policy (Freudenberg and Gramling 1994; Gramling 1996; McGinnis 1998). The social science literature shows that the history and politics of offshore oil development in southern California is very different from the Gulf experience. While this section does not provide a detailed overview of the diverse social, economic and political factors shaping decommissioning policy, McGinnis et al. (2001) show that environmental organizations and alliances played an important role in defeating policy initiatives for a rigs-to-reefs option to complete removal of offshore platforms in California while in the Gulf states, environmental groups have not taken a stand against state rigs-to-reefs program development.

Methods

Documentary Analysis

The study included documentary analysis of technical, scientific, and government reports produced by policymakers, scientists and members of resource agencies on the subject of decommissioning of platforms and the rigs-to-reefs alternative to complete removal. For the Gulf of Mexico, material was collected from V.C. Reggio, Jr. of the Minerals Management Service (MMS) in 1998, who provided documents and technical reports on the historical development of the rigs-to-reefs alternative to the region. For the California OCS, material was collected in 1998 from Sacramento on state oil and gas activities. Material was also gathered at the MMS Pacific Region office in Ventura County, California and at the Santa Barbara County Energy Division.

Analytical Framework: the “Revised Garbage Can” Model

Kingdon (1995) provides a useful framework to characterize policy development. Kingdon (1995) uses a revised version of a classic essay by Cohen-March-Olsen (1972) on the “garbage can model of organizational choice” to explain the politics of agenda setting and policy generation.

Kingdon (1995) describes the policy making process as chaotic and turbulent. Public choices are not always based on scientific understanding. This type of political process operates on the basis of “trial and error”, “learning from accidents of past experiences, “ or on the basis of “inventions of necessity” (Cohen, March and Olsen 1972: 1). Choices are based on a variety of “inconsistent and ill-defined preferences”, according to Cohen, March and Olsen (1972: 1-2), “To understand processes … one can view a choice opportunity as in a garbage can into which various kinds of problems and solutions are dumped by participants as they are generated.”

Ideas are generated by policy "entrepreneurs", specialists, techno-experts in government, industry or non-government organization. Kingdon (1995) and other social scientists (such as Anton 1989 among others) describe the policy entrepreneur as an advocate who plays the fundamental role in "opening" a policy window by offering a solution to a perceived problem. These solutions are not only based on some level of scientific information but perceptions and values as well. This process of exchange of information, partisan mutual adjustment, and communication is dynamic and fluid. Political elites and other participants in the process can act as policy entrepreneurs.

The specialist, technocrat, bureaucrat, policy elite, and expert play the role of policy entrepreneur. "Many ideas are possible in principle," notes Kingdon (1995: 19), "and float around in a primeval soup in which specialists try out their ideas in a variety of ways – bill introductions, speeches, testimony, papers and conversation." The policy entrepreneur *identifies* the problem and *offers* solutions. Without the entrepreneur, the idea will remain floating in the "primeval soup". Experts, specialists, and policy elites *couple solutions to problems* and couple "problems and solutions to politics" (Kingdon 1995: 20).

The capability of the entrepreneur to open "policy windows" and set government agendas depends on three separate, but interrelated, processes:

- <u>Problems</u>: the set of issues in particular public policy areas that come to capture the attention of those in and around government at any one time;
- <u>Policy articulation</u>: a process involving gradual accumulation of knowledge and perspectives among specialists in a policy area, and the resulting generation of policy proposals by those specialists;
- <u>Politics</u>: trends and events in the overall political environments, such as interest group campaigns and administrative changes.

Kingdon metaphorically refers to these processes as separate "streams" -- the political, problem and policy stream.[2] Policy change can occur when the streams join to form a "policy window of opportunity". The window opens when the political climate is ripe for policy change, when a problem is recognized by political elites, and when a solution is successfully developed and proposed by policy "entrepreneurs". Kingdon's model and framework are used here to show that there is a political ecology to decommissioning policymaking in the Gulf and California OCS.

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[2] Kingdon's model is based on the earlier work of Michael Cohen, James March and Johan Olsen, "A Garbage Can Model of Organizational Choice, " *Administrative Science Quarterly* 17 (March 1972): 1-25. Cohen et al. argue that "…organizations can be viewed for some purposes as collections of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be an answer, and decision makers looking for work." The Cohen et al. "garbage can model" is the foundation for Kingdon's framework to study agenda setting. For a critique of the "garbage can model" see Gary Mucciaroni, "The Garbage Can Model and the Study of Policy Making: A Critique," *Polity*, Vol. 24, 3 (Spring 1992): 459-482.

Results

Work on this section of the report contributed to and therefore draws upon the analysis of McGinnis et al. (2001) that compares the Gulf States and the West Coast decommissioning policy.

Political Ecology of Decommissioning Policy Development in the Gulf of Mexico

This section describes how and why the policy of decommissioning platforms at sea as artificial reefs evolved in the distinct political, intergovernmental, regional and ecological context of the Gulf of Mexico. It describes how each of the political, problem and policy streams met to form a window of opportunity for the development of such a policy. Various policy entrepreneurs from the MMS, oil and fishing industries, and others advocated the idea of what became known as a "rigs-to-reefs" alternative to complete removal of Gulf Outer Continental Shelf (OCS) oil platforms (Reggio 1987a, b, Reggio and Kasprzak 1991, Murray 1994). Reggio, from the Gulf Region of the Minerals Management Service (MMS), and Kasprzak, from the Louisiana State University, (1991: 15) explain:

> [T]here are ever increasing demands on marine fish and restrictions on fishing. Through state and industry leadership, we have an unprecedented opportunity in the Gulf of Mexico to create artificial reefs with oil and gas structures, which will concentrate marine life and enhance fishing.

The Gulf's commercial and recreational fisheries are the largest in the United States. Fishing activity in the region is supported by a history of large-scale OCS oil and gas activity in the Gulf. This has led to "over-adaptation" to these platforms as fishery enhancement structures. There are currently approximately 4,000 platforms in the Gulf of Mexico, and it is estimated that 150 per year will be decommissioned. This significant development of offshore oil on the Texas-Louisiana OCS has led to a network of artificial habitats or "organic machines" that either attract or produce species that are harvested by the commercial and recreational fisheries. In the Gulf OCS, removal of offshore platforms would have associated economic impacts (and potential ecological impacts) to these fisheries. Removal of a platform would mean the removal of a "fishing hole", such as the removal of the "best snapper fishery in the world" offshore Alabama (a state with very little natural habitat for reef fishes).

Why was complete removal of offshore platforms a "perceived problem"? There are many reasons, some of which are introduced below:

- Field studies show the lack of "natural" habitat for fish in the Gulf region. Field studies also show the link between offshore platforms and marine life, including commercially and recreationally valuable finfishes and oysters.

- Social scientists show the link (in terms of recreation days and levels of use) between offshore platforms and sportfishing. State, regional and local economies benefit from offshore oil and gas activity, and artificial reef building (in Florida, Alabama, Louisiana, Mississippi, and Texas).

- In the Gulf, commercial and recreational fishing groups have been receptive to the oil industry (Freudenberg and Grambling 1994; Grambling 1996). Special interests in the Gulf sought out a OCS policy that could provide guidance, coordinate local, state, and federals efforts as well as streamline the permitting process for the rigs-to-reefs alternative.

- Gulf state governments had artificial reef programs in place, many of which were operated by local and regional administrators on a part-time basis or as volunteers. There was no major state-based funding or private source to develop and implement artificial reef programs. Alabama established the first program in the Gulf of Mexico in 1954. Alabama's program started with the sinking of 250 car bodies and now includes several thousand individual artificial reefs in state waters (Harrison 2000).

- A number of policy entrepreneurs and advocates campaigned for the rigs-to-reefs alternative, basing their preferences on available scientific information, and fishery values associated with offshore structures.

This section shows that the passage of the National Fisheries Enhancement Act (NFEA) was followed by the creation of formal state artificial reef programs in Louisiana (1986), Texas (1989), Florida (1990), and Mississippi (1999).

The Problem Stream: The Perceived Lack of Reef Habitat

The reliance of commercial and recreational fishers on OCS oil and gas structures contributed to a perceived problem --- complete removal of structures would have significant economic impacts on the fisheries of species associated with these structures. Policy entrepreneurs defined the problem based on the perceived lack of natural fishery habitat in the Gulf, and the link between the development of offshore oil and commercial and recreational fishing. As Reggio (1987a: 2) writes, "Since the inception of the federal offshore leasing program in 1954, the Gulf of Mexico OCS Region has led the nation in offshore energy production and has retained its pre-eminence in offshore fishery production." The ecology of the Gulf, the history of Gulf OCS oil development, the relationship between offshore oil development and fishing (such as commercial hook-and-line fishing) and scuba diving were also factors associated with the problem stream.

Within the Gulf, accumulation of sedimentary layers since the beginning of the Tertiary period created a continental slope (0 to 200 m) that now makes up nearly 35% of the bottom habitat, with 25% being very deep water (>3000 m) and reaching a maximum depth of 3850 meters (Darnell & Defenbaugh 1990). The northern shelf and slope offshore Texas and Louisiana receive extensive accumulations of sediment from stream, estuarine, and river discharges. River-borne sediments composed of silt, sand, clay and anthropogenic pollutants create a soft bottom habitat that stretches from the coastline to the middle and outer shelf off most of Louisiana and Texas (Darnell & Defenbaugh 1990). Although occasional small shoals and rocky ridges occur throughout the Gulf OCS, the broad and vast area lacks hard-bottom habitat. Only one-third of the estimated natural reef habitat is located offshore Texas and Louisiana where more than 95% of the platforms stand. The nearest natural hard-bottom habitat is located approximately 92 km offshore Louisiana (Sonnier et al. 1976). Nearly 4,000 offshore production platforms and 22,000 miles of oil and gas pipelines exist within the Gulf of Mexico (MMS 2000). Ranging in size and structure, the average depth of these platforms is 100 to 300 feet in state and federal waters.

Most of the oil and gas structures are set in the soft, sandy bottom of the Gulf where there exists very little hard substrate for natural reefs (Sonnier et al. 1976). The platforms of the Texas-Louisiana OCS have created a web of artificial habitats for some marine life. There is some indication that platform development increases the amount of habitat available for marine species that depend on hard bottom substrates (Sonnier et al. 1976, Continental Shelf Associates 1982, Gallaway and Lewbel 1982). Filter feeding organisms proliferate on the platform structures, providing food and shelter for economically valuable and commercially and recreationally sought fish species (Sonnier et al. 1976, Wolf et al. 1979, Gallaway & Lewbel 1982, Gallaway et al. 1988). Underwater platforms structures serve as a point of concentration for many biofouling organisms (Wolf et al. 1979). Marine studies describe the biofouling community associated with platforms as rich and diverse (Sonnier et al. 1976, Gallaway and Lewbel 1982, Gallaway et al. 1988). The colonial species provide additional habitat for small and motile, cryptic organisms such as ophioroids and caprellid and gammarind amphipods who feed on the abundant food supply and in turn are consumed by fishes (Gallaway et al. 1988, Gallaway and Lewbel 1982).

The increased biological activity associated with platforms attracts a wide variety of fish species from the sea surface to the bottom of the platforms (Continental Shelf Associates 1982, Gallaway and Lewbel 1982, Gallaway et al. 1988, LGL and SAIC 1988, Sonnier et al. 1976). Following the installation of a new platform, fish colonization can occur in as little as 15 months (Lukens 1983) in search of food and/or shelter (Gallaway 1982). Dressen (1989) estimates that nearly 20-50% more fish occur beneath or adjacent to platforms compared to nearby soft bottom areas in the Gulf. Fish assemblages vary from a few hundred individuals to a few thousand, depending on platform, size, location and season (Continental Shelf Associates 1982). Stanley and Wilson (1990) surveyed catch records from recreational and charter boat anglers in the northern Gulf and found that the fish species and number caught varied with season, platform size and structural complexity, and water depth.

The Perceived Problem--More than one-quarter of the remaining platforms in the Gulf are over 25 years old, and may be removed within the next ten years (MMS 2000). This means that nearly one thousand structures may be removed in the next ten years. But offshore oil and gas activity over the past fifty years has contributed to the development of commercial and recreational fishing. For this reason, a number of government and non-government organizations began to “campaign for changes in public attitudes and existing laws to facilitate use of petroleum platforms as artificial reefs for fish concentration” (Harville 1983: 5). The oil and gas industry was also anxious to cooperate with responsible reef developers willing and able to accept future responsibility and liability for rigs-to-reefs projects (DuBose 1984, Reggio 1987a). A strong coalition of fishery and oil interest groups had emerged during a long history of oil development in the Gulf OCS region (Freudenberg & Grambling 1994, Grambling 1996). In addition, many coastal inhabitants of the Gulf regularly fish coastal and marine waters for recreation, sport, commerce, and subsistence.

The southeastern recreational fisheries are the largest in the nation. Between 1955 and 1980, participation in saltwater recreational fishing increased 2.7 times and related expenditures grew sevenfold. In 1998, 5.8 million anglers took 53 million trips and caught 284 million fish, nationwide (NMFS 1998). The increased interest in sportfishing is attributed to advances in technological design of recreational motorboats, outboard motors, navigational equipment and gear (NMFS 1999). Recreational fishermen operate from private boats, charter boats, head boats and shore using fish traps, hooks and lines, longlines, spears, trammel nets, bang sticks and barrier nets (NMFS 1999).

As the number of platforms dominated the Texas-Louisiana shelf, commercial and recreational harvest efforts became more concentrated around the structures. Studies document the levels of fishing activity near or around platforms. During the 1960s, Gulf newspapers and magazines featured the "fabulous" sites associated with rig structures (Reggio and Kasprzak 1991). Gunter (1955) describes the area between Pascagoula, Mississippi and Port Arthur, Texas as the "Fertile Fisheries Crescent" claiming it contains the most productive waters on earth. Oil platforms became a principal fishing destination for many local recreational fishermen (Ditton & Graefe 1978, Dugas, et al. 1979). In Louisiana, over 70% of all recreational angling trips occur near the platforms in Federal waters (Reggio 1987).

Ditton and Graefe (1978) showed that 87% of registered sport-fishing boats from Galveston, Texas target the platforms for fishing. One half of the 66,924 offshore fishing trips by resident boat owners in Galveston and eight adjacent counties, were primarily to the platforms (Ditton and Graefe 1978). One MMS survey (conducted in 1980) of offshore platform personnel on 300 platform structures offshore Texas and Louisiana shows that employees also fish off the structures. Stanley and Wilson (1989) found that the average distance traveled by recreational users was at least 62 km to the platform, and the distance increased from east to west and from anglers to divers.

Commercial fisheries harvest in the Gulf of Mexico lead the nation. From 1950 to 1998, commercial landings totaled more than 34 million metric tons and generated more than $1.8 billion in dockside revenues (NMFS 1999). Louisiana accounted for nearly 65 percent (22 million metric tons) of the landings and 38 percent ($22 million) of the revenues (NMFS 2000). Texas holds the second largest fishery, contributing 2.7 million metric tons of commercial landings and generating $5 million in dockside revenues (NMFS 1999).

Overall, the recreational fishing industry has grown significantly since the first platform was placed in Louisiana waters in 1947 (GSMFC 1997, Howe 1985). Fishers have benefited from the increased biological activity associated with offshore platforms. As the number of removals increased from one year to the next, fishers became alarmed by the loss of habitat and reduction in fishing opportunities (Kasprzak 2000). The reduction in available habitat from the removal of platforms has unknown consequences to fish populations. At the very least, a huge amount of reef fish biomass is lost and fishes move to other places. As regular users of offshore platform structures, the sport fishing clubs, local artificial reef committees and dive clubs actively advocated the benefits of converting obsolete platforms into artificial reefs for fishery enhancement.

The Political Stream

The Gulf of Mexico contains approximately two-thirds of the world's offshore oil and gas structures, and 95% of the production platforms in waters off the coast of the Unites States (Reggio and Kasprzak 1991: 11). A coalition of oil and fishery interest groups, federal and state resource agency personnel, and other individuals, such as Congressional representatives, favored a platforms-to-artificial reef alternative to complete removal of Gulf OCS oil and gas facilities. For example, in 1979, the Sport Fishing Institute initiated action by urging a resolution to the Secretary of Commerce and the Secretary of the Interior to develop policies, procedures and guidelines to convert platforms to artificial reefs. The Sports Fishing Institute also pointed out the importance of existing artificial reefs in the Gulf to fisheries.

Early Artificial Reef Program Development -- Local governments, private parties and individuals have carried out artificial reef programs in the Gulf of Mexico since the 1940s and 1950s. In 1954, Alabama initiated the first artificial reef program in the Gulf. Natural reefs are virtually nonexistent in Alabama waters. As a result of artificial reef building, the state is now referred to as the "Red Snapper Capital of the World", because Alabama waters provide the highest catch of red snapper in the Gulf (Harrison 2000). Since the late 1940s, the Texas Parks and Wildlife Department has also been involved in artificial reef activities, such as the development of oyster reefs in Texas bays since 1947 (Joyce 1981, Osburn & Culbertson 1993). Some of the materials used during the 1940s and 1950s were not durable enough to withstand the shifting currents and eventually dissolved or moved to an unknown location. Used cars and vessels have also been used (Joyce 1981, Osburn & Culbertson 1993). In Louisiana, local fishermen created small artificial reef sites in an effort to increase their personal fish catch (Kasprzak 2000). Early artificial reef development in this state was not part of a state artificial reef program. Unwanted materials such as old automobiles, large appliances, and concrete rubble were dumped in secret locations in estuaries and coastal waters to create personal fishing areas (Kasprzak 2000).

Since 1978, several divisions with the Florida Department of Natural Resources have been involved with artificial reef activities to enhance fishery habitat (Joyce 1981). In 1980, the State of Florida set the precedent and made an important step toward the development of a rigs-to-reefs alternative. Through the cooperative effort between the Southeastern Fisheries Association, the Gulf and South Atlantic Fisheries Development Foundation, Exxon Corporation and the State of Florida, an oil production template was removed and transported from Louisiana waters to Florida offshore waters for use at an artificial reef site (Joyce 1981, Wilson & Van Sickle 1987). The oil industry has also contributed offshore structures to fishery enhancement projects. In 1980, a joint effort between Exxon and Florida's Department of Natural Resources permitted the towing of a 2,200 ton submerged production system from Louisiana waters to a pre-selected site in Florida (Wilson and Van Sickle 1987). The structure was placed without an underwater survey of the site before placement (Mathews 1985). Two years after the Exxon project, Tenneco Oil donated a production platform removed from offshore Louisiana. The structure was towed 275 miles and placed offshore Pensacola, Florida (Frishman 1982, Bohnsack and Sutherland 1985). The following year, the Alabama Department of Conservation and Natural Resources permitted Marathon Oil Company to tow a 1,650 ton oil platform 220 miles from Louisiana waters to southeast Mobile, Alabama (Wilson and Van Sickle 1987).[3]

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[3] On October 2, 1985, two more Tenneco structures were towed 920 miles from Louisiana to 1.5 miles off Dade

By the end of 2000, many materials such as used automobiles, refrigerators, derelict ships, concrete rubble and other structures (such as military tanks and oil structures) have been used to construct over 150 permitted artificial reefs off Florida, Alabama, Mississippi, and Texas (Reggio personal communication, 2000). Three-fourths of all the existing, dedicated, or permitted reef sites in the Gulf are off the west coast of Florida and the Florida Keys (Reggio and Kasprzak 1991). Advocacy of artificial reef building has a long history in the Gulf. In 1979, the American Fisheries Society and Sport Fishing Institute supported artificial reef building in the Gulf (Harville 1983).

Since the late 1970s, the National Marine Fisheries Service (NMFS) has supported artificial reef research through technical and financial assistance to states, counties, and private interests (Harville 1983). NMFS has participated in artificial reef planning, design, permitting, construction, monitoring and evaluation (GSMFC 1993). The MMS also supported converting obsolete oil and gas structures to artificial reefs. MMS sponsored "Information Transfer Meetings" in 1982, 1984, 1985, 1986, and 1987, which included sessions on present and potential fishery uses of oil and gas structures. Reflecting on these public forums and information transfer meetings, Reggio and Kasprzak (1991: 10-11) write:

> Public forums organized and sponsored by the MMS in a series of annual information transfer meetings during the 1980s elicited additional information on the present and potential fishery uses of oil and gas structures. Federal and state conservation officials, private conservation groups, fishing organizations, oil and gas companies, university researchers, and others encouraged the conversion and use of oil and gas structures as artificial reefs. Workshops included a review of data available and information on Gulf fisheries, and explored the economic, social, political, biological and technical benefits of a rigs-to-reefs alternative.

In August 1983, Secretary of Interior, James Watt created the Recreation, Environmental Enhancement and Fishing in the Sea (REEFS) task force to "pave the way for aggressive movement towards a national rigs-to-reefs program which will enhance fishery resources and improve recreational and sport fishing opportunities within America's offshore marine environments." (DuBose 1985). The primary agenda of the REEF task force was to assess the use of obsolete platforms as artificial reefs as a means to enhance local fisheries and to develop policy that set national standards for artificial reef building.

The Policy Stream

Most ideas never find the light of day. Ideas that survive to shape public policy in a dynamic intergovernmental process must meet several criteria, including their scientific merit, their fit with dominant values, and the political support or opposition that ideas may experience.

The Role of the Scientific Community--As the number of platforms increased in the Gulf, the number of scientific studies on the economic benefits of offshore platforms also increased. Since the 1950s, a number of field studies have described the invertebrate species, fish species and the

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County, Florida (Wilson and Van Sickle, 1987).

impact of potential pollutants on waters and biota associated with offshore platforms. The Offshore Ecological Investigation (1972 to 1974) by the Gulf Universities Research Consortium (GURC) investigated the sedimentology, hydrography, microbiology, plankton, benthos, bio-fouling communities, trace metals, and hydrocarbons associated with platforms sited in Louisiana bays and inner shelf. Sonnier, et al. (1976) compared natural reef fish assemblages to fish fauna associated with offshore platforms in the Gulf of Mexico.

Interest spread to government agencies, particularly the MMS, who funded a number of large-scale, multi-year scientific projects. For example, MMS sponsored a $4.4 million study in cooperation with Texas A&M University and the oil industry to assess the environmental impacts on the benthos surrounding oil platforms. The study, known as the Gulf of Mexico Offshore Monitoring Experiment (GOOMEX), was intended to provide detailed information on the biological, geological, and chemical impacts of discharged effluents on the surrounding marine biota.

The Move to the Federal Level: Congressional Activity--The heightened awareness of converting rigs-to-reefs for fisheries enhancement among commercial and recreational user groups and the need to coordinate state and local efforts initiated hearings before the Congressional Subcommittee on Fisheries and Wildlife Conservation and the Environment on September 11, 1981. State representatives from Louisiana (John Breaux), New Jersey (William Hughes and Edwin Forsythe) and Rhode Island (Claudine Schneider) introduced two bills, H.R. 1041 and H.R. 1897, to: (1) develop marine artificial reefs in U.S. waters and, (2) provide funds to develop, maintain, and monitor offshore artificial reef sites.

The two bills, H.R. 1041 and H.R. 1897, designated the NMFS the primary responsibility to fund, develop, and monitor Gulf state artificial reef activities. The two bills stipulated that any construction of a “fishery conservation zone” (3 to 200 nautical miles) could only be constructed by the NMFS. Despite the fact that both of these bills were defeated, the bills demonstrate the idea for the need of federal backing for an artificial reef plan. One important policy entrepreneur Congressman John Breaux expressed his support for the development of a comprehensive artificial reef program for the Gulf as follows:

> “We are missing a golden opportunity. There is, for example an oil and gas industry out there that has thousands of platforms that are going to have to be dismantled and towed in and broken up at a great deal of expense. It would be cheaper to be able to cut those and use them as artificial reefs. I think a coordinated policy could be greatly beneficial to both the fishing industry and the people who own those structures. If we need to change, or draft new legislation that would allow them to do that, I believe we should.”

Two years later, on July 18, 1983 Congressman John Breaux of Louisiana along with 17 other members of Congress introduced H.R. 3474 in an effort to establish a national artificial reef policy. Testimony from federal, state and local agencies as well as user groups and environmental organizations supported the establishment of a comprehensive federal artificial reef program that included the rigs-to-reefs option. Some portions of the bill were amended and it was reintroduced as H.R. 5474. The amendments were approved and passed on April 12, 1984.

The political stream included Congressional representatives, federal and state resource agency personnel, members of the oil and fishery industries who supported the idea of the rigs-to-reefs alternative to complete removal of offshore oil structures in the Gulf. Various studies of the marine ecology and socio-economic uses associated with commercial and sports fishing also supported the idea of the platforms to reefs alternative. MMS personnel (such as Villere Reggio) and other resource managers and scientists played a major role in promoting the use of platforms as artificial reefs to enhance fisheries. These individuals acted as policy entrepreneurs, pushing and advocating their particular proposals and ideas in the intergovernmental policymaking process.

The rigs-to-reefs "idea" was less an invention and more a mutation of an old idea. The rigs-to-reefs idea represented the coupling of an already familiar activity of building artificial reefs in the Gulf. The use of familiar ideas, such as the idea of artificial reef building in the Gulf, by policy entrepreneurs and experts is referred to by Kingdon (1995: 201) as the "act of recombination". The rigs-to-reef policy idea represented a recombination of an old solution (the reliance on artificial reefs to enhance fisheries) to a perceived new problem (the lack of natural habitat and potential economic impacts associated with complete removal of OCS oil and gas structures).

The Window of Opportunity: Passage of the National Fisheries Enhancement Act of 1984--The National Fishing Enhancement Act (NFEA) of 1984 (Title II of Public Law 98-623) was passed by Congress and signed into law by President Reagan on November 8, 1984. The NFEA defines an artificial reef as "a structure which is constructed or placed…for the purpose of enhancing fishery resources and commercial and recreational opportunities." The NFEA states the following:

> Properly designed, constructed, and located artificial reefs…can enhance the habitat and diversity of fishery resources; enhance recreational and commercial fishing opportunities; increase the production of fishery products in the United States; increase the energy efficiency of recreational and commercial fisheries; and contribute to the United States coastal economies.

The NFEA consolidated several decades of localized and state laws to maximize the potential benefits of artificial reefs *as fishery enhancement mechanisms*. State governments are responsible for carrying out the general goals of the NFEA in federal and state waters by funding, promoting, and maintaining artificial reefs. The NFEA provides a foundation for the establishment of a national artificial reef program based on the following goals: to (1) enhance fishery resources; (2) facilitate access for recreation and commercial fishing; (3) lessen conflicts between users of marine resources; (4) minimize environmental risks; (5) follow principles of international law; (6) prevent unreasonable obstruction to navigation; and (7) promote consistency with the National Artificial Reef Plan. The NFEA directed the NMFS to develop the National Artificial Reef Plan within one year. The Plan was published one year later through the combined efforts of fishermen, divers, scientists, state and federal resource agencies (Stone 1985; Harrison 2000). The Plan serves three purposes:

1. To provide guidance to individuals, organizations, and government agencies on technical aspects of artificial reef planning, design, siting, construction, and management for effective artificial reef development;

2. To serve as a reference for federal and state resource agencies involved in artificial reef permitting; and

3. To ensure that the national standards and objectives established by the NFEA are met. The Plan serves as one guide to develop state artificial reef programs. It includes information on design criteria, permit compliance, management methods, and ideas for increasing artificial reef development. In addition, the Plan emphasizes the need for research and monitoring of artificial reef activity.

Federal Guidance and Assistance[4]--Since the NMFS developed and published the Plan, they have continued to support regional, state, and local artificial reef development activities. The NMFS provides technical consultation, resources, and contributes to various regional artificial reef management committees established by interstate marine fisheries commissions.

The U.S. Fish and Wildlife Service administers the Federal Aid in Sport Fish Restoration Program (U.S.C. Sec 777), which provides funding for important recreational fisheries work. Coastal states in Region 4 (North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana) and Region 2 (Texas) of the Service can apply for funds from the Federal Aid for sport fish restoration and boating projects. Money for this program is collected from taxes placed on fishing tackle and motorboat fuel. In 1984, the Wallop Breaux amendment to the Sport Fish Restoration Act allocated funds for use in artificial reef programs.

MMS amended its guidelines on the “Disposal of Oil Platforms” to reflect the goals of the NFEA. MMS’s new policy statement encourages the “reuse of obsolete offshore petroleum structures as artificial reefs in US waters” so long as the structures do not “pose an unreasonable impediment to future mineral development”. MMS also provides information to state programs, such a geophysical data, offshore area/lease block maps, bathymetric maps, pipeline and platform location maps, numerous technical reports and environmental impact statements, and

visuals (maps that illustrate bottom sediment types, oceanographic currents, shrimp trawling areas, etc.; MMS 2000).

The Permits and Evaluation Branch of the Corps of Engineers (COE) regulates planning and development activities in OCS under the jurisdiction of the Rivers and Harbors Act of 1899, the National Environmental Protection Act of 1969, the Clean Water Act of 1972, and the Marine Protection Research and Sanctuaries Act of 1972. It is the lead federal agency that permits and monitors artificial reef development under NFEA. All state natural resource agencies must obtain a COE permit before any construction of an artificial reef site. The COE reviews the

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[4] A comprehensive review of policy and regulatory issues associated with decommissioning of OCS oil and gas structures is found in County of Santa Barbara Energy Division (July 2000). This information will not be reviewed in this section.

permit, inspects the materials and then issues the appropriate permit or makes recommendations to improve the permit application.

Gulf State Artificial Reef Programs[5] *in the era of NFEA*--In the Gulf, the primary purpose of the platforms to reefs policy is to enhance fisheries (Murray 1994). Since the implementation of the Plan of 1985, most state marine fisheries agencies have assumed the lead in developing artificial reefs through state developed programs. State natural resources agencies currently direct or coordinate with local agencies in obtaining permits, maintaining liability, financing, constructing, researching and monitoring marine artificial reefs. Many coastal states have adopted state-specific plans based on the guidance of NFEA.

Louisiana was the first among the Gulf states to create a formal artificial reef program. Passed in 1986, the Louisiana Fishing Enhancement Act (Act 100) is the most comprehensive reefing policy and program in the Gulf (Murray 1994). The Act provides for: 1) establishment of the artificial reef program, 2) creation of the Louisiana Artificial Reef Council, 3) establishment of a Louisiana Artificial Reef Development Fund, 4) development of a reef plan, 5) establishment of the state as the permittee for artificial reefs developed under the plan, and 6) relief from liability (Wilson and Van Sickle 1987). The Louisiana Act sets up a means to transfer the ownership and liability of the platforms from the oil and gas companies to the State when the platform ceases its production. The Plan established an Artificial Reef Trust Fund for funding costs associated with each artificial reef project (Kasprzak 2000). When oil and gas companies donate platform structures, they are asked to donate half of the cost savings for participation directly into the trust fund. As of 2000, the Artificial Reef Trust Fund has accrued $13 million and uses the 5% interest to fund the artificial reef program (Kasprzak 2000). Since 1987, the Louisiana Artificial Reef Program has created 25 artificial reef sites that utilize 85 obsolete platform jackets and/or parts. Approximately 7-10 platforms are donated per year as platforms become available (Kasprzak 2000). Most of the reef development spans between 30 to 70 miles offshore and extends down a minimum of 50 feet from the surface to satisfy Coast Guard navigational guidelines. A discussion of the other Gulf state programs is found in McGinnis and Navaro (2001), and will not be summarized in this section.

Political Ecology of Decommissioning Policy in the Southern California Bight

The California experience with the rigs-to-reefs option to complete removal of offshore oil platforms is very different from the political ecology that has shaped program development in the Gulf of Mexico (McGinnis 1998). The political debate is shaped by the ecological setting of the Southern California Bight, which is a marine area between Point Conception and Punta Banda in Baja California, Mexico.

The politics of California decommissioning policy includes such issues as the question of "attraction versus production", liability considerations, and funding to administer a potential rigs-to-reefs program. These are similar issues that are also found in the Gulf of Mexico states artificial reef programs. As in the case of the Gulf of Mexico, there are recreational fishing

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[5] This report and section is not intended to provide a comprehensive review of state artificial reef programs but rather a characterization of the historical development of the rigs-to-reefs alternative. In addition to the state programs that are described in this section, Alabama and Mississippi have artificial reef programs.

interests who support the use of offshore oil platforms as artificial reefs in southern California. For example, in California rockfish represent $3 billion in sports fishing values and between $200 to 300 million annually in commercial landings. Like the ecological surveys presented in this report, other studies suggests that the vast majority of fishes near some platforms are rockfishes (Love and Westphal 1990, Love et al. 1999a,b, 2000, 2001). Populations of rockfish off southern California -- an area within the Southern California Bight that includes about 70 species of fish harvested by both recreational and commercial fisherman -- have dropped to 8% of their 1960 populations (Love et al 1998). The significant decline of several rockfish species reflects the combined effects of long-term (decades) climatic conditions of low productivity (which began in 1977) and fishing mortality by recreational and commercial fishers (McGinnis 2001, Schroeder and Love 2002). Field studies show that some platforms in the Santa Barbara Channel include juvenile and adult bocaccio, *Sebastes paucispinis*, (Love et al. 2000). This species has been listed as a threatened fishery (Pacific Marine Conservation Council 1999).[6] Despite the recreational fishing values associated with offshore platforms, the California experience with the rigs-to-reefs initiative represents a departure from the federal and Gulf states program development. Recent evidence in the decline of several marine species during the warm water regime of the Southern California Bight led State Senator Alpert on behalf of the recreational fishing and oil industry to support a rigs-to-reefs alternative to complete removal (McGinnis et al. 2001).[7] Pomeroy, in McGinnis et al. (2001), characterizes the major actors and interest groups that have been involved in the California debate over the rigs-to-reefs option. Albert's SB 241 (2000) failed in the California Legislature while SB 1 was vetoed by the Governor in 2001. Pomeroy writes:

> The growth in public concern for the marine environment between the time of its introduction in early 1998 and its re-introduction in 1999 (and 2000) led to the clear identification of the problems a rig-to-reef program could help to address. During that time, the proposal was re-shaped to address some of its deficiencies, and over its two-year course through the legislature as SB 241, it underwent further
>
> refinement to address critical issues including program funding, scientific merit and liability. Moreover, it was reshaped to mesh with state and federal fishery (and other marine) management resource management, especially recent policy changes and new concepts pertaining to marine resource restoration, marine reserves, and essential fish habitat.

Yet the rig-to-reef policy proposal embodied in SB 241 has fallen short in meeting these and other myriad concerns. Uncertainties regarding liability issues, start-up and ongoing

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[6] In February 2001, the Center for Marine Conservation, the National Resources Defense Council and the Center for Biodiversity sued the National Marine Fisheries Service for failing to list the bocaccio as a threatened species in accordance to the U.S. Endangered Species Act. show that the abundance of Bocaccio is less than 5% of their historical population in the northern Channel Islands. The Bocaccio is one species among several species of rockfish that are showing serious signs of decline in abundance and distribution in the Bight.

[7] A complete characterization of the rigs-to-reefs debate and the various policy initiatives in California are beyond the scope of this section. Please refer to Pomeroy (2001) for a historical treatment of the California artificial reef program and the rigs-to-reefs debate. Pomeroy uses Kingdon's analytical model to characterize the major political actors and interest groups in the California debate.

funding, and the scientific merits of such a policy, together with strong opposition from certain interests proved insurmountable. The increased attention to problems in the marine environment and rigs-to-reefs as a policy solution, and the active debate of liability, funding and ecological impact concerns, however, have likely prompted policy entrepreneurs to seek solutions to those issues, and incorporate them into a revised policy proposal, ready for the next window of opportunity.

In addition, Murray (1994: 960) shows in an analysis of the National Artificial Reef Plan, "The Plan of 1985 suggested that states should play a major role in the development of guidelines for artificial reefs. However, most coastal states have not established clear artificial reef development plans that consider social, economic, environmental and biological factors associated with artificial reef programs." In contrast to the Gulf experience, these political and ecological factors have carried more weight in the California context.

California's unique Political Ecology

There are currently 27 platforms in the Bight and approximately 200 miles of associated pipelines. Both the installation date and platform depth should be recognized as important factors related to decommissioning (Fernandez, in McGinnis et al. 2001). For example, decommissioning costs vary by water depth (MMS 1999). A few of the offshore structures are over 1,000 feet deep. California OCS oil and gas production has occurred since the mid-1960s (Lima 1994). These oil platforms have a finite economic lifespan; several platforms are nearing the end of the economic operation.

To date, only seven relatively small structures have been decommissioned; all were located in State waters. The most recent project occurred in 1996 when Chevron removed Platforms Hope, Heidi, Hilda and Hazel. These platforms were in water depths ranging from 100 to 140 feet. One hundred and thirty-four wells were plugged and abandoned on these platforms. In order to remove the platforms to be brought ashore for recycling and disposal, explosives and heavy machinery were used to tear the platforms from their foundations. The biomass that accumulated around these OCS oil and gas structures was destroyed during the decommissioning activity (MMS 1997).

California OCS oil and gas production is expected to decline by the year 2015. International, federal and California laws require the complete removal of offshore oil and gas structures (California Coastal Commission 1999). As a brief overview, the regulatory compliance requirements are as follows:

- US Minerals Management Service: Federal law (30 CFR 250) requires the plugging and decommissioningof wells; full removal of well conductors and platform jackets to 15 feet below the mudline; decommissioning and full removal of platform decks; decommissioning and removal of pipelines and power cables as appropriate; and site clearance.

- California Department of Conservation, Division of Oil, Gas and Geothermal Resources: The basic plugging requirements are found in the California Code of Regulations Title 14 Division 2, Chapter 4, Section 1745.

- California State Lands Commission: The basic plugging requirements are found in the California Code of Regulations Title 2 Section 2128(q).

There are also lease and permit requirements that must be met during decommissioning of California offshore oil and gas structures. Provisions of federal and state oil leases and MMS regulations can be changed by the state and federal government to allow the federal government to consider and approve methods of rig decommissioning other than complete removal, as evidenced in the Gulf of Mexico. With respect to California, Kallaur (1998), the Associate Director for Offshore Minerals Management with the U.S. Department of the Interior, MMS writes, "MMS does not have a position one way or the other as to the rigs-to-reefs program here in California. We believe that is an issue that falls primarily within the regulatory jurisdiction of the California Department of Fish and Game, Army Corps of Engineers, and the California Coastal Commission." California's Department of Fish and Game (CDFG), the agency with oversight over the state's artificial reef program, has policy guidelines in place for artificial reefs with a preference for those structures that provide "good" habitat.

The fundamental issue in California is whether or not offshore oil platform provide "good habitat" for marine life. The economics of platform removal, and the uncertainty over the potential "fishery-related values" that may be associated with particular platforms in the Santa Barbara Channel are additional factors that are contributing to the policy debate.

One factor is the scientific uncertainty associated with the offshore platforms. A Scientific Advisory Committee on Decommissioning from the University of California (Holbrook et al. 2000: 3-5) wrote:

> 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 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 (such as 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...*Thus, in light of the strong evidence of the 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"* [my emphasis].

The ecology associated with California offshore platforms and associated structures often depends on the relationship between the location of the structure and the oceanographic setting. This is a dynamic setting influenced by changing ecological patterns, oceanographic currents, and climate-related events, such as El Niño or La Niña. Life around a platform should not be thought of as a "steady state". As the University of California's Scientific Advisory Committee on Decommissioning (Holbrook, et al. 2000: 4) note, "The particular species present at any given platform depend on the biogeographic setting of the platform and its depth, as well as other factors." The biogeographic setting of each platform can also change over time. Marine life around a platform may change in response to ocean-climate variability.[8]

The marine environment of southern California is one of the most studied marine systems in the world (Hickey 1993). Members of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) have studied the SCB since 1950 (Scheiber 1995). These studies have described large-scale (i.e. Bight-wide), long-term (i.e. several decades) changes, or what is referred to as a *regime shifts*, in physical and biological processes that have contributed to changes in the distribution and abundance of some marine species, such as several species of rockfish..

McGowan, et al. (1998) state that the last regime shift occurred in 1977. Based on an analysis of CalCOFI data,[9] Roemmich and McGowan (1995a, b) document large-scale changes in primary and secondary productivity throughout the SCB between 1951 and 1993. Hayward et al. (1996) and McGowan, et al. (1998) show that large-scale biological responses in marine ecology due to climatic variations in the atmosphere has resulted in changes in geographical ranges and spatial patterns of species and in community structure. This evidence suggests that the maintenance of community structure and patterns of species diversity has changed in accordance to hydrographic perturbations and climate-ocean variability. The ecology of particular platforms *may* change with future regime shifts and ocean-climate variability.

Offshore platforms are part of a dynamic ecological system. The reduction in biomass and significant decline in the abundance of a number of species of rockfish and other marine animals and habitats sets the current ecological stage or context for the debate over the utility of the rigs-to-reefs option. Each offshore rig is situated in a particular ecological setting. There are wide differences between platforms in the numbers or biomass of various species (Love et al. 2001). There may also be differences in fish communities inhabiting platforms and nearby natural reefs (Section II). What is certain is that policymakers may need to make trans-scientific decisions that involve the intermingling of scientific information, values and interests.

With respect to the California debate over the future of platforms, Pomeroy (in McGinnis et al. 2001) notes that:

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[8] McGinnis (1998) has proposed the idea of a "living permit" as one response to variability.

[9] CalCOFI has compiled several spatially and temporally comprehensive data sets for the SCB from strategically located offshore stations (Hickey 1993: 21-25).

> Throughout, attention has focused upon a number of scientific, technical and institutional issues. These include: 1) whether platforms actually enhance, or simply attract reef fishes; 2) the net ecological benefits or costs of removal and of reefing; 3) the practicality of removal and of reefing, especially involving platforms in very deep waters; 4) concerns for navigational safety; 5) interference with other ocean uses; 6) funding to support maintenance and monitoring as well as initial reefing; and 7) liability, among others. Recent rig-to-reef policy proposals manifest in legislation first introduced in 1998, then re-introduced in 1999 and 2000, have sought to address many of these issues. And this is where the state's artificial reef program and the rig-to-reef concept have become intertwined.

In contrast to the experience in the Gulf states, concerns associated with the use of platforms as artificial reefs in California ultimately led to a veto of SB1 by Governor Davis. In an analysis of interviews with state artificial reef managers, Murray (1994) describes the current status of artificial reef programs in relation to administration, budget, siting, promotion, education, evaluation, future trends and major concerns. The major issues and concerns that state artificial reef managers raise are as follows (Murray 1994):

(1) *The Liability Issue*. Since the publication of the National Artificial Reef Plan, which recommended that the US Army Corps of Engineers develop specific permit standards and conditions, the issue of liability remains vague and unclear. The Corps has developed a policy requiring the permit holder of an artificial reef to prove adequate liability coverage. States with reefing programs have assumed the role of the permittee. This has necessitated a close review of the role of the states and localities in implementing the NFEA (Murray 1994). As Murray (1994: 965) writes in an analysis of the interviews with state artificial reef managers:

> Because most private fishing associations cannot afford the insurance premium, many states have assumed the role of the permittee. Although many state managers welcomed this as a way of gaining control of artificial reef activities, it has necessitated a closer inspection of each state's liability. The level of concern varied widely, but the general consensus was that clarification is needed from the state's attorney general's office. Most reef managers felt that even this would be vague and subject to interpretation until a case comes before a court. Clarification of this issue would improve operational procedures and potentially reduce uncertainty about exposure on the part of state artificial reef managers (Murray 1994: 968).

(2) *Scientific Uncertainty: Production versus Aggregation*. State artificial reef managers remain concerned about the production versus aggregation question. It remains unclear if platforms attract or produce fishes. As Murray (1994: 966) writes, "One troublesome issue is related to the inability of artificial reefs to assist fishery production at all stages of the life cycle." Artificial reef managers are concerned that too much emphasis has been placed on adult fishery enhancement activity and not enough on restoring essential coastal processes, such as estuarine habitats and wetland ecosystems (the "nurseries of the sea").

(3) *Limited Funding*. State artificial reef program funding remains a major concern of administrators and managers. In 1988, the average reported annual budget for reef programs was $139,000, with a range of 0$ to $400,000 (Murray 1994: 962). Most funds are generated from either state appropriations or Wallop-Breaux funds, which refer to the 1984 Wallop-Breaux Amendment to the Federal Aid in Sport Fish Restoration Act (16 U.S.C. sec. 777 (1988)).

Oil companies that "donate" structures are asked to contribute half of the disposal savings realized to the Fund. In a description of this process, Reggio and Kasprzak (1991: 15) write:

> Negotiations to obtain platforms and to determine the amount of donation are done on a case-by-case basis between the oil and gas operator and the state. The size, location, distance from shore, water depth, resale value, and proximity of the platform to the permitted reef site all affect the cost of converting a rig into a reef; thus, it is not always cost-effective for operators to participate.

State artificial reef programs maintain an average staff size of 1 full-time employee. In addition, monitoring of existing artificial reefs and regulatory compliance issues remain important concerns of state artificial reef managers in the Gulf. State artificial reef programs have not received adequate funding (Murray 1994: 967).

In addition to these general administrative concerns associated with artificial reef program development, Governor Davis vetoed California SB 1 because of the scientific uncertainties associated with the rigs-to-reefs alternative.

Conclusion

This section described the political, problem and policy streams that met to form a policy window of opportunity for the platforms to reefs alternative in the Gulf. In the case of the Gulf, an advocacy coalition that combined the interests of the oil industry, recreation and commercial fishing, scientists, and resource managers supported the use of offshore platforms as artificial reefs. The development of oil and gas in the Gulf OCS led to an increase in commercial and sports fishing activity. Scientific reports and workshops spoke to the benefit of artificial reefs in the Gulf. States and local artificial reef programs had been established before the passage of the NFEA. In passing the NFEA, the federal government granted discretionary authority to states to create their respective platforms to artificial reef program. Many of these programs were based on existing artificial reef programs.

Despite the passage of the NFEA, there remain a number of management issues and concerns that have not been clearly addressed by federal and state resource policymakers who are interested in artificial reef development and building. In contrast to the Gulf experience, marine scientists raised serious questions with respect to the utility of a rigs-to-reefs alternative in California (McGinnis et al. 2001). Moreover, a strong coalition of environmentalists and commercial fishing interests have been successful in blocking a rigs-to-reefs policy initiative in California.

Acknowledgements

We thank the Minerals Management Service, US Department of the Interior, under MMS agreement no. 14-35-0001-30758 for supporting this research. This work could not have been completed without the stellar efforts of technicians, Jeff Harding, Arnold Ammann, Laird MacDonald, William Golden, Rebecca Frodsham, and Amy McClean Findlay, responsible for the management and implementation of the diving, data collection and data management. Jeff Harding and Arnold Amman also contributed to the analysis and interpretation of data and results. Several dedicated volunteers, including Bryon Banks, David Chan, Bryn Evans, Neil Grider, Melissa Meeker and Lise Schickel contributed to many hours of underwater work. ROV sampling was only possible through our collaboration with the Santa Barbara City College Technical Diving Program, especially Don Barthelmess and our ROV drivers, Jeff Browning, Ryan Cummings and Jim Hayward. Fish tagging was accomplished with the help of Bernard Friedman and Martin Lee, and in collaboration with the Channel Islands National Marine Sanctuary, especially Superintendent Edward, who provided and captained the R.V. Ballena. Approximately 50 volunteer sportfishers contributed to the tagging effort, without whose efforts we could not have accomplished the sample size we achieved. Approximately 30 volunteer undergraduates contributed countless hours of watching ROV and diver video and recording species, number and sizes of fishes. Many discussions with Donna Schroeder and Dr. Richard Ambrose (UCLA) contributed to the design and development of the study and report. Dr. Craig Syms advised on and conducted the multivariate analyses. Bonnie Williamson provided us extraordinary administrative support throughout this project. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either express or implied, of the US Government.

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Appendix 1

Appendix 1. Taxonomic categories of fish species used in analyses. Additional categories include ND= no data available; no census conducted; NF= no fish present; census conducted, no fish seen.

Common Name	**Family**	**Genus**	**Species**	**Code**
smelt, unidentified sp.	ATHERINIDAE			ATHE
giant kelpfish	CLINIDAE	Heterostichus	rostratus	HROS
cabezon	COTTIDAE	Scorpaenichthys	marmoratus	SMAR
kelp surfperch	EMBIOTOCIDAE	Brachyistius	frenatus	BFRE
pile surfperch	EMBIOTOCIDAE	Damalichthys	vacca	DVAC
black surfperch	EMBIOTOCIDAE	Embiotoca	jacksoni	EJAC
surfperch, unidentified sp.	EMBIOTOCIDAE			EMBI
rainbow surfperch	EMBIOTOCIDAE	Hypsurus	caryi	HCAR
sharpnose surfperch	EMBIOTOCIDAE	Phanerodon	atripes	PATR
white surfperch	EMBIOTOCIDAE	Phanerodon	furcatus	PFUR
rubberlip surfperch	EMBIOTOCIDAE	Rhacochilus	toxotes	RTOX
blackeye goby	GOBIIDAE	Coryphopterus	nicholsii	CNIC
kelp goby	GOBIIDAE	Lethops	connectens	LCON
sargo	HAEMULIDAE	Anisotremus	davidsonii	ADAV
lingcod	HEXAGRAMMIDAE	Ophiodon	elongatus	OELO
painted greenling	HEXAGRAMMIDAE	Oxylebius	pictus	OPIC
opaleye	KYPHOSIDAE	Girella	nigricans	GNIG
halfmoon	KYPHOSIDAE	Medialuna	californiensis	MCAL
rock wrasse	LABRIDAE	Halicoeres	semicinctus	HSEM
senorita	LABRIDAE	Oxyjulis	californica	OCAL
california sheephead	LABRIDAE	Semicossyphus	pulcher	SPUL
blacksmith	POMACENTRIDAE	Chromis	punctipinnis	CPUN
garibaldi	POMACENTRIDAE	Hypsypops	rubicundus	HRUB
rockfish, blackspot YOY	SCORPAENIDAE	Sebastes	sp	BKSP
rockfish, shallow benthic unidentified	SCORPAENIDAE	Sebastes	sp	BRF
rockfish, copper complex YOY	SCORPAENIDAE	Sebastes	sp	KGB
rockfish, midwater complex, unidentified sp.	SCORPAENIDAE	Sebastes	sp	MRF
rockfish, *Sebastomus* unidentified YOY	SCORPAENIDAE	Sebastes	sp	ROS
kelp rockfish	SCORPAENIDAE	Sebastes	atrovirens	SATR
brown rockfish	SCORPAENIDAE	Sebastes	auriculatus	SAUR
gopher rockfish	SCORPAENIDAE	Sebastes	carnatus	SCAR
copper rockfish	SCORPAENIDAE	Sebastes	caurinus	SCAU
black and yellow rockfish	SCORPAENIDAE	Sebastes	chrysomelas	SCHR
rockfish, unidentified sp.	SCORPAENIDAE	Sebastes	sp	SCOR
calico rockfish	SCORPAENIDAE	Sebastes	dalli	SDAL
widow rockfish	SCORPAENIDAE	Sebastes	entomelas	SENT
california scorpionfish	SCORPAENIDAE	Scorpaena	guttata	SGUT

Appendix 1 cont'd. Taxonomic categories of fish species used in analyses. Additional categories include ND= no data available; no census conducted; NF= no fish present; census conducted, no fish seen.

Common Name	**Family**	**Genus**	**Species**	**Code**
squarespot rockfish	SCORPAENIDAE	Sebastes	hopkinsi	SHOP
vermilion rockfish	SCORPAENIDAE	Sebastes	miniatus	SMIN
blue rockfish	SCORPAENIDAE	Sebastes	mystinus	SMYS
bocaccio	SCORPAENIDAE	Sebastes	paucispinis	SPAU
rosy rockfish	SCORPAENIDAE	Sebastes	rosaceus	SROS
flag rockfish	SCORPAENIDAE	Sebastes	rubrivinctus	SRUB
halfbanded rockfish	SCORPAENIDAE	Sebastes	semicinctus	SSEM
olive rockfish	SCORPAENIDAE	Sebastes	serranoides	SSER
treefish	SCORPAENIDAE	Sebastes	serriceps	STRE
widow/blue rockfish	SCORPAENIDAE	Sebastes	sp	WB
kelp bass	SERRANIDAE	Paralabrax	clathratus	PCLA
barred sandbass	SERRANIDAE	Paralabrax	nebulifer	PNEB

Appendix 2a. Total number of individuals, density, and percent density of each **non-rockfish** species in each habitat type across all sampling sites and years. Also summarized is the total water volume sampled by each method in each habitat type. Platforms abbreviated as "rigs".

		ROV	divers	ROV	divers - natural reefs				density (fish / 1,000 m3)		percent density	
species	category	rigs	rigs	reefs	canopy	midwater	bottom	total	rigs	reefs	rigs	reefs
cabezon	benthic	4	75	0	0	0	2	2	0.17	0.03	86	14
blacksmith	midwater	556	56742	5275	15	627	1642	2284	121.36	100.94	55	45
lingcod	benthic	18	1	9	0	0	4	4	0.04	0.17	19	81
sheephead	benthic	9	194	22	0	0	111	111	0.43	1.78	19	81
kelp bass	midwater	20	1299	19	96	252	1669	2017	2.79	27.19	9	91
barred sand bass	benthic	0	1	3	0	2	253	255	0.00	3.45	0	100
giant kelpfish	canopy	0	0	0	13	5	2	20	0.00	0.27	0	100
garibaldi	benthic	12	211	0	0	0	4	4	0.47	0.05	90	10
halfmoon	midwater	219	1989	0	1	7	2	10	4.68	0.13	97	3
senorita	midwater	3	400	5	312	376	1237	1925	0.85	25.77	3	97
opaleye	midwater	0	2	0	14	2	103	119	0.00	1.59	0	100
painted greenling	benthic	119	315	12	0	0	32	32	0.92	0.59	61	39
sharpnose surfperch	midwater	107	1160	1	0	0	1	1	2.68	0.03	99	1
pile surfperch	benthic	69	340	4	2	20	278	300	0.87	4.06	18	82
rubberlip surfperch	benthic	63	1	25	0	0	79	79	0.14	1.39	9	91
black surfperch	benthic	0	0	0	0	3	366	369	0.00	4.93	0	100
kelp surfperch	canopy	0	0	0	231	95	0	326	0.00	4.35	0	100
white surfperch	midwater	0	1	0	14	92	55	161	0.00	2.15	0	100
rainbow surfperch	benthic	0	0	0	0	2	302	304	0.00	4.06	0	100

sample method, location	water volume sampled (m3)
ROV, platforms	92524
ROV, natural reefs	5764
divers, platforms	379613
divers, natural reefs, canopy only	12000
divers, natural reefs, midwater only	28320
divers, natural reefs, bottom only	28800
divers, natural reefs, all	69120

Appendix 2b. Total number of individuals, density, and percent density of each **rockfish** species in each habitat type across all sampling sites and years. Also summarized is the total water volume sampled by each method in each habitat type. Platforms abbreviated as "rigs".

		ROV	divers	ROV	divers - natural reefs				density (fish / 1,000 m3)		percent density	
species	category	rigs	rigs	reefs	canopy	midwater	bottom	total	rigs	reefs	rigs	reefs
rockfish: copper complex	all	1021	1444	12	3	5	448	456	5.22	6.25	46	54
rockfish: midwater	midwater	1845	1616	102	4	34	107	145	7.33	3.30	69	31
rockfish: shallow benthic (excluding copper complex)	benthic	1790	396	106	0	0	47	47	4.63	2.04	69	31
rockfish: all species	all	4704	3456	220	7	39	602	648	17.28	11.59	60	40
**kelp rockfish	mid, benthi	910	727	5	0	4	386	390	3.47	5.27	40	60
**copper rockfish	benthic	85	16	1	0	0	18	18	0.21	0.25	46	54
**gopher rockfish	benthic	0	42	5	0	0	37	37	0.09	0.56	14	86
**black and yellow rockfish	benthic	0	3	1	0	0	6	6	0.01	0.09	6	94
**olive rockfish	midwater	370	97	25	0	31	82	113	0.99	1.84	35	65
**blue rockfish	midwater	334	246	0	0	0	0	0	1.23	0.00	100	0
**widow rockfish	midwater	553	350	0	0	0	0	0	1.91	0.00	100	0
**squarespot rockfish	midwater	0	1	63	0	0	0	0	0.00	0.84	0	100
**brown rockfish	benthic	75	5	13	0	0	31	31	0.17	0.59	22	78
**calico rockfish	benthic	75	0	32	0	0	1	1	0.16	0.44	26	74
**vermilion rockfish	benthic	595	0	5	0	0	3	3	1.26	0.11	92	8
**treefish	benthic	0	2	8	0	0	8	8	0.00	0.21	2	98

**only individuals >= 9 cm TL. Smaller individuals were less easily classified to species, especially in ROV samples, and were usually placed in broader multi-species groups such as copper complex, MRF, or BRF.

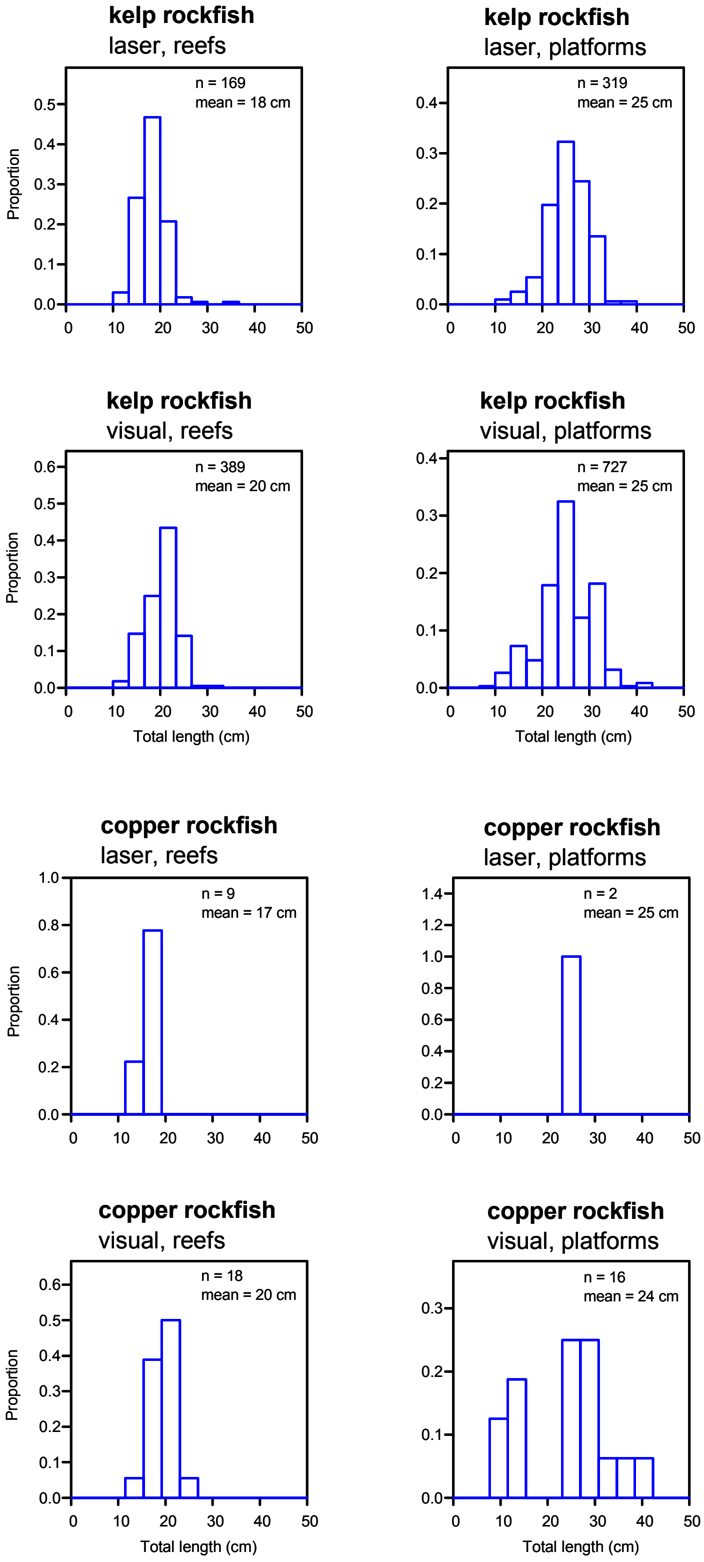
Appendix 3

Appendix 3. Comparison of species composition of samples by diver and ROV on oil platforms Henry, Houchin, and Hogan at level 3 (36m) horizontal crossmembers (excluding interior zone samples). See Appendix 1 for codes and species common names.

	sample	DIVER		ROV	
platform	period	species	quantity	species	quantity
Henry	Jun-95	no fish		RYOY	16
Henry	Aug-95	KGB	2	no fish	
		SPAU	8		
		SGUT	1		
Henry	Oct-95	CPUN	11	PATR	1
		OYT	2	OPIC	3
Henry	Jun-96	COTT	2	no fish	
		DVAC	1		
		SPAU	6		
		OPIC	2		
		ROS	1		
Henry	Aug-96	OYT	1	no fish	
		OPIC	1		
		SMAR	1		
		PCLA	1		
Henry	Oct-96	CPUN	1	OPIC	1
		SMAR	1		
Henry	Jun-97	OYT	13	no fish	
		KGB	1		
		SMYS	2		
Houchin	Jun-95	SGUT	1	RYOY	6
Houchin	Aug-95	SSER	7	RYOY	4
Houchin	Oct-95	KGB	6	SATR	5
				OPIC	1
Houchin	Jun-96	no fish		SATR	1
Houchin	Aug-96	SPAU	50	SATR	3
		CPUN	1	SSER	1
		SATR	6	OPIC	1
		SSER	4		
Houchin	Oct-96	OPIC	1	no fish	
		SATR	1		
Houchin	Jun-97	CPUN	2	OPIC	1
		OYT	1	SSER	2
Hogan	Jun-95	SSER	12	SSER	2
		SMYS	4		
		OYT	100		
Hogan	Aug-95	RYOY	5	RYOY	8
		KGB	1	SPAU	24
		SSER	1	SSER	2
				PATR	7
				OPIC	1
				STRE	1
Hogan	Oct-95	PATR	1	PATR	11
		DVAC	2	DVAC	2
		KGB	6	RTOX	1
		OPIC	1	SSER	20
		RYOY	10	SPAU	10
				EMBI	1
				RYOY	1
				SATR	1
				SMYS	1
				OPIC	1
Hogan	Jun-96	CPUN	17	EMBI	2
		PCLA	2	SSER	1
		SSER	1	DVAC	1
		SCAU	1		
		RYOY	2		
Hogan	Aug-96	ROS	1	SSER	1
		PATR	31	OPIC	1
		DVAC	3		
		OPIC	1		
Hogan	Oct-96	CPUN	4	DVAC	3
		RYOY	1	PATR	5
		SSER	1	EMBI	5
		ROS	2		
Hogan	Jun-97	CPUN	1	OPIC	1
		STRE	1	SATR	1
		SATR	1	DVAC	5
		SMAR	1		
		DVAC	2		

Appendix 4

Appendix 4. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.



kelp rockfish
laser, reefs

kelp rockfish
laser, platforms

kelp rockfish
visual, reefs

kelp rockfish
visual, platforms

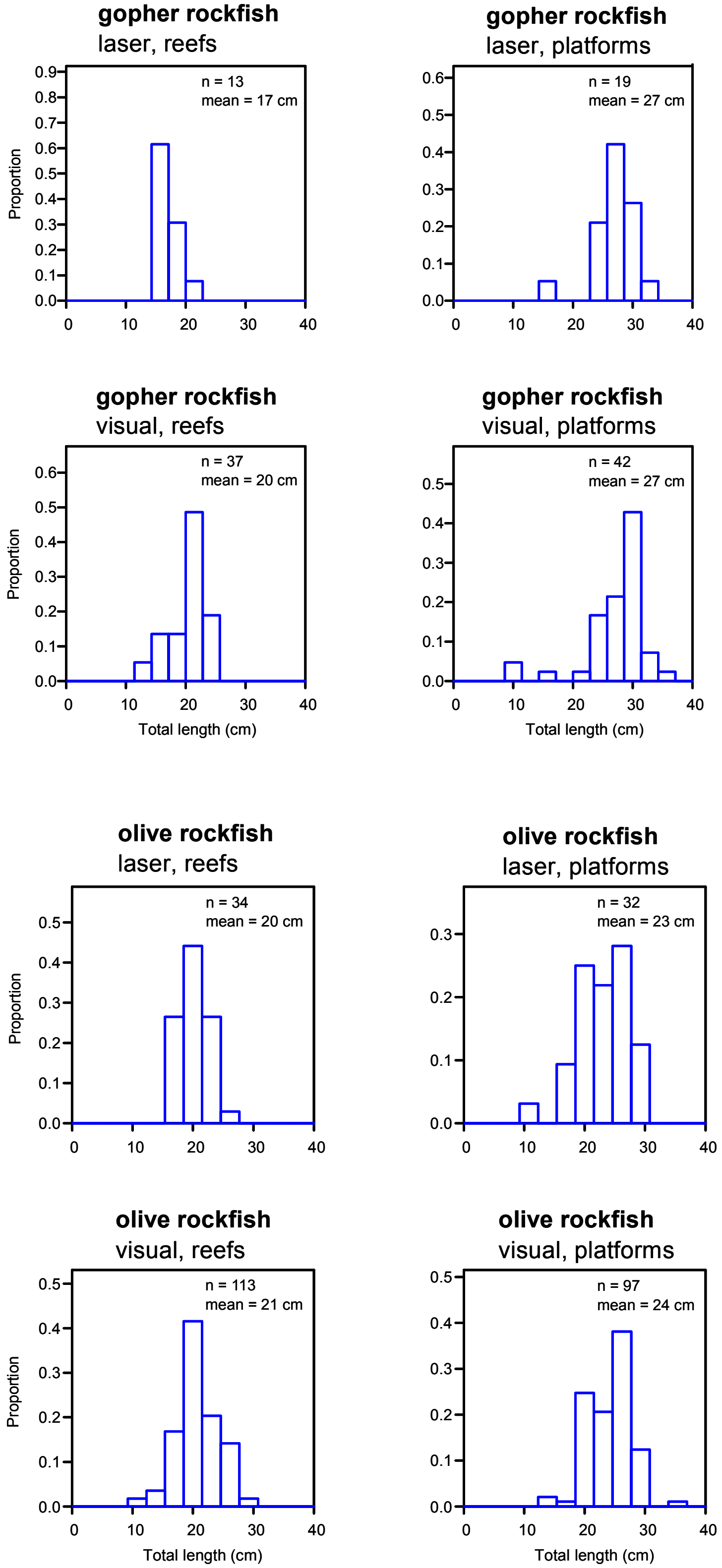
copper rockfish
laser, reefs

copper rockfish
laser, platforms

copper rockfish
visual, reefs

copper rockfish
visual, platforms

Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

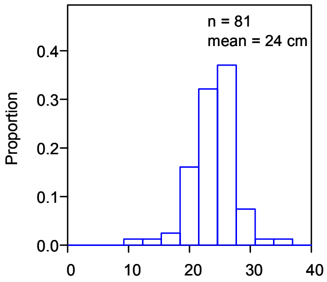


Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

blue rockfish
laser, reefs

no data

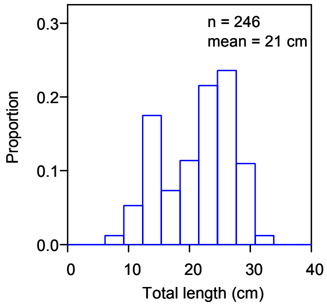
blue rockfish
laser, platforms



blue rockfish
visual, reefs

no data

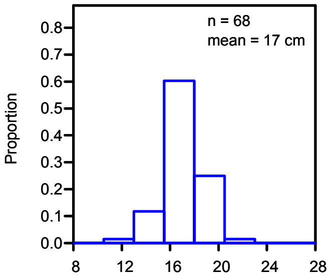
blue rockfish
visual, platforms



widow rockfish
laser, reefs

no data

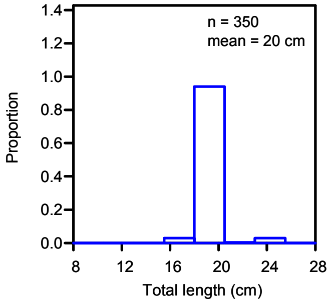
widow rockfish
laser, platforms



widow rockfish
visual, reefs

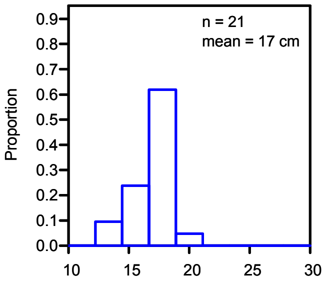
no data

widow rockfish
visual, platforms



Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

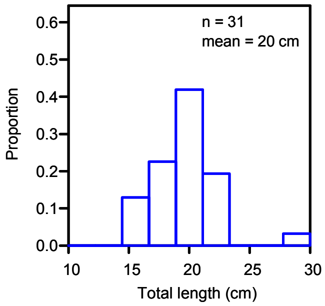
brown rockfish
laser, reefs



brown rockfish
laser, platforms

no data

brown rockfish
visual, reefs



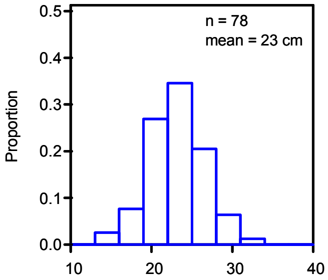
brown rockfish
visual, platforms

no data

sharpnose surfperch
laser, reefs

no data

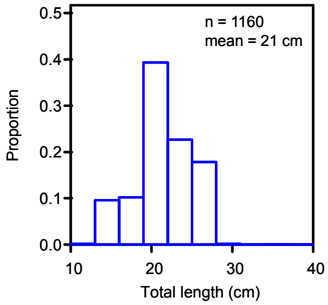
sharpnose surfperch
laser, platforms



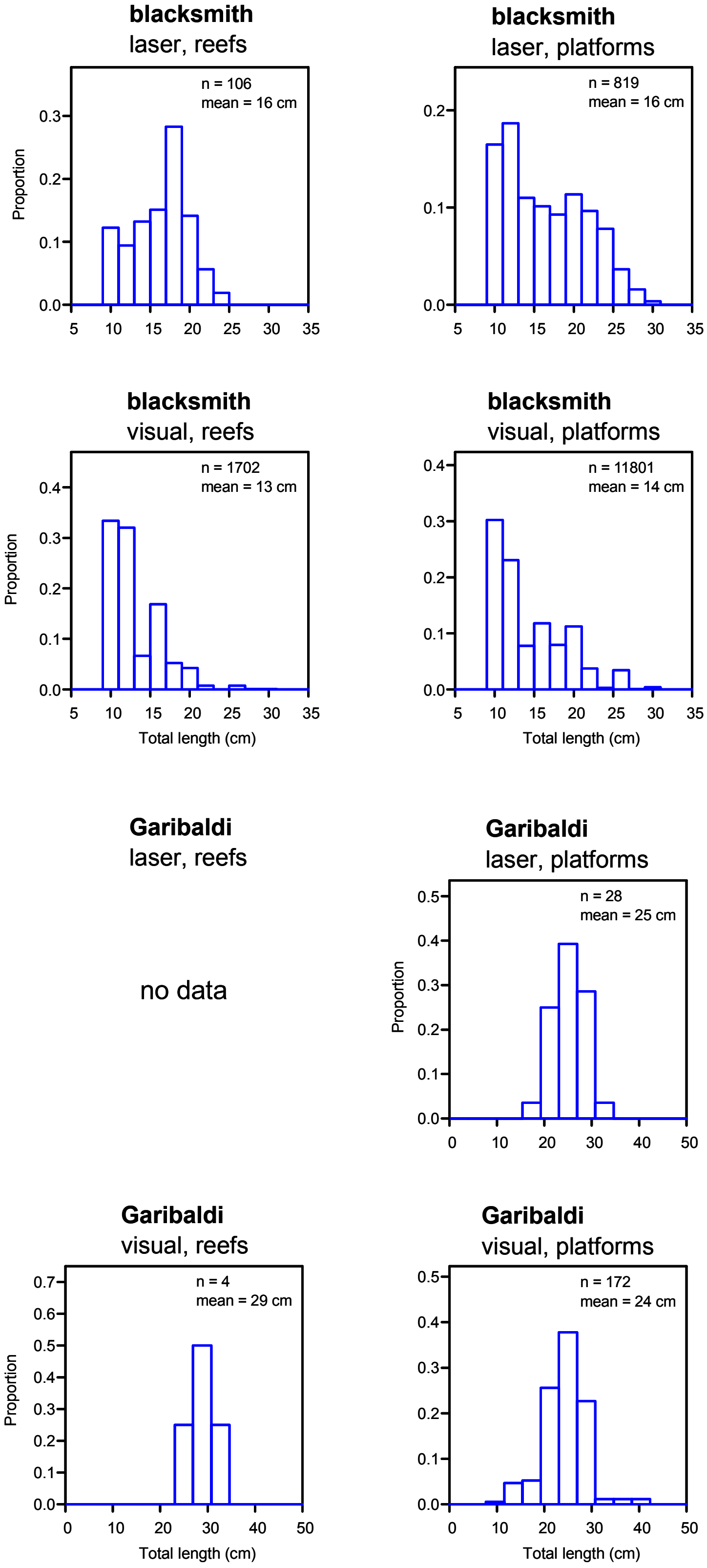
sharpnose surfperch
visual, reefs

no data

sharpnose surfperch
visual, platforms

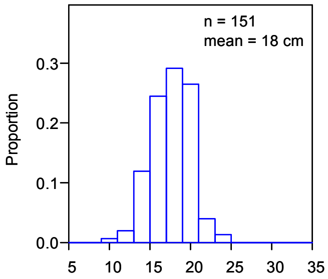


Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

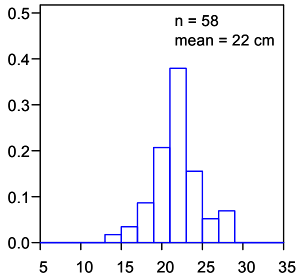


Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

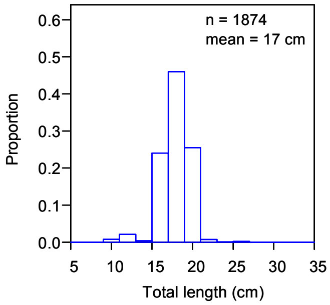
senorita
laser, reefs



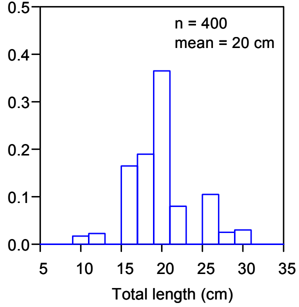
senorita
laser, platforms



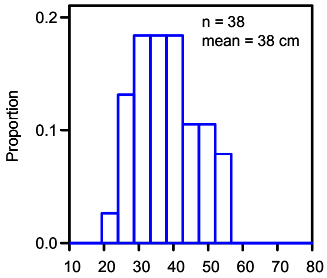
senorita
visual, reefs



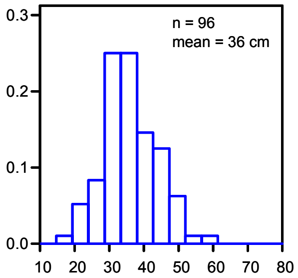
senorita
visual, platforms



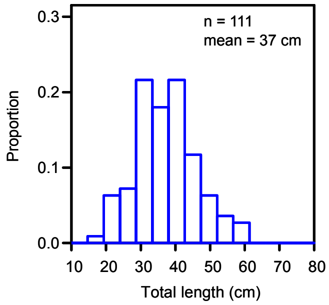
Calif. sheephead
laser, reefs



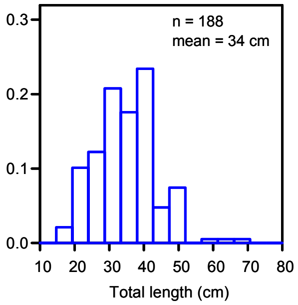
Calif. sheephead
laser, platforms



Calif. sheephead
visual, reefs

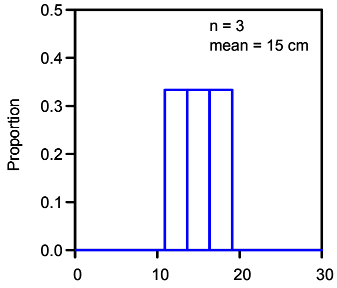


Calif. sheephead
visual, platforms

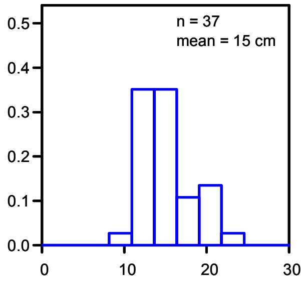


Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

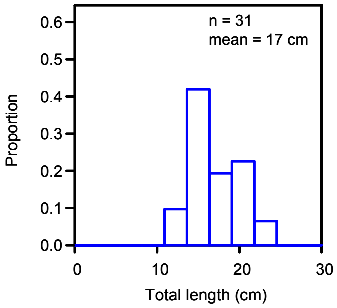
painted greenling
laser, reefs



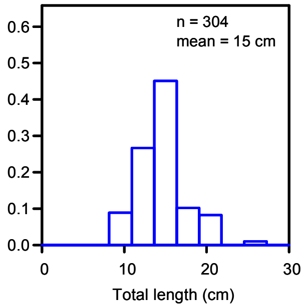
painted greenling
laser, platforms



painted greenling
visual, reefs



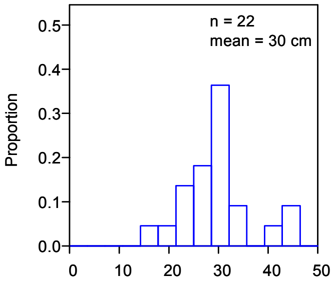
painted greenling
visual, platforms



cabezon
laser, reefs

no data

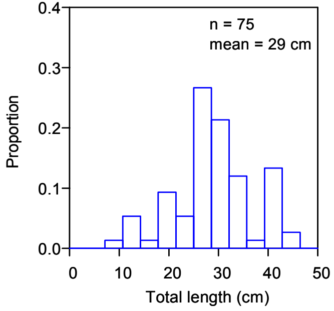
cabezon
laser, platforms



cabezon
visual, reefs

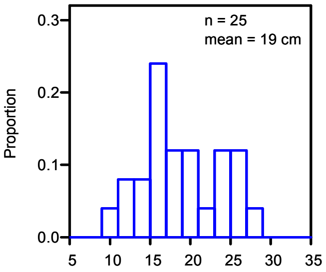
no data

cabezon
visual, platforms



Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

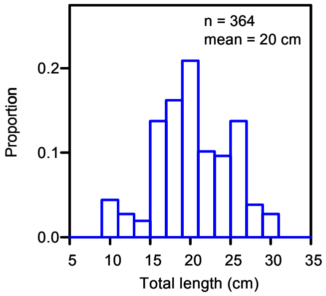
black surfperch
laser, reefs



black surfperch
laser, platforms

no data

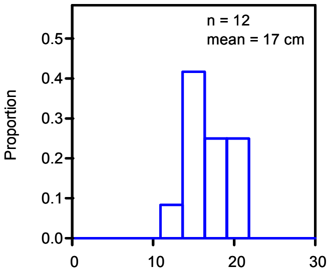
black surfperch
visual, reefs



black surfperch
visual, platforms

no data

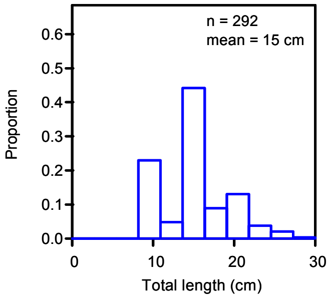
rainbow surfperch
laser, reefs



rainbow surfperch
laser, platforms

no data

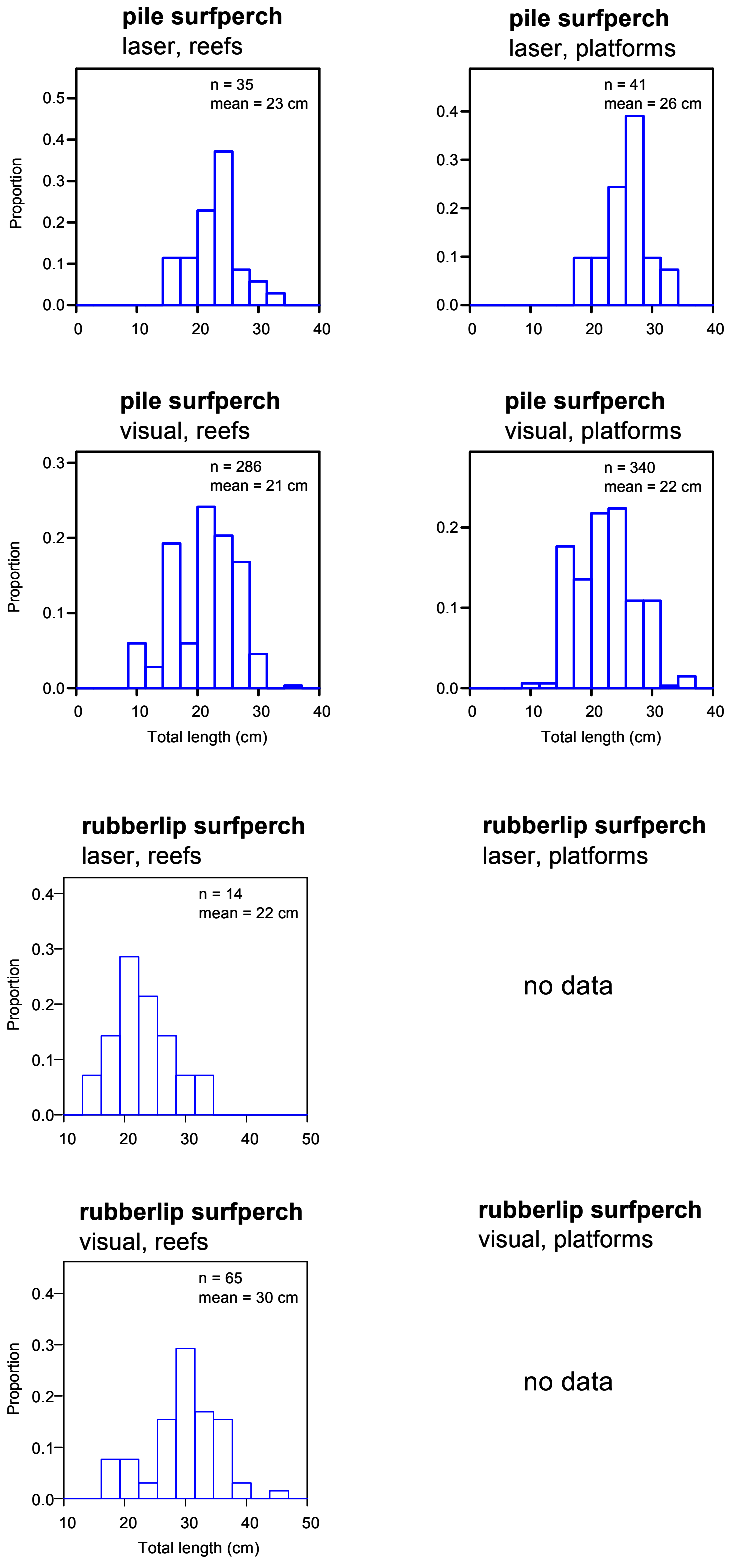
rainbow surfperch
visual, reefs



rainbow surfperch
visual, platforms

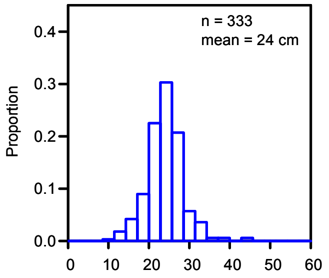
no data

Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

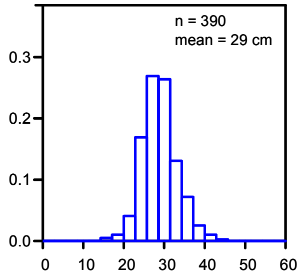


Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.

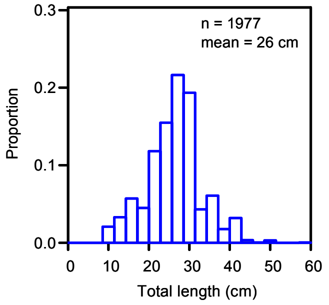
kelp bass
laser, reefs



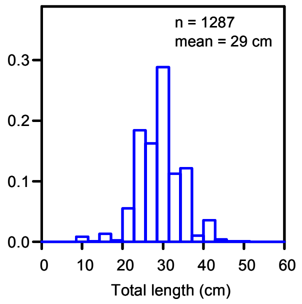
kelp bass
laser, platforms



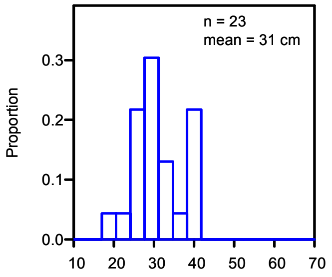
kelp bass
visual, reefs



kelp bass
visual, platforms



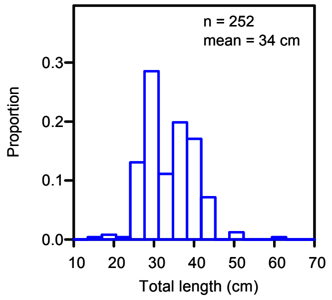
barred sand bass
laser, reefs



barred sand bass
laser, platforms

no data

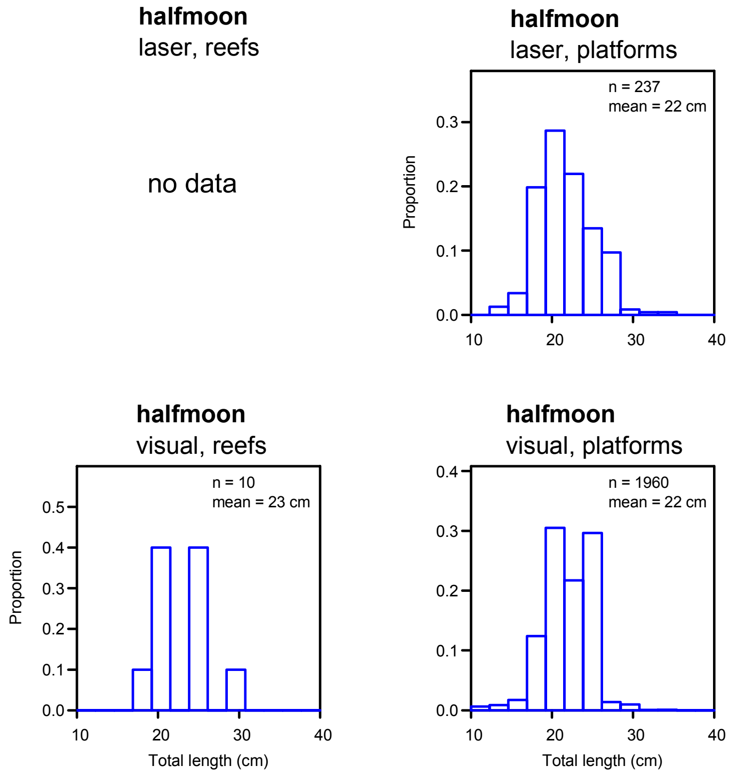
barred sand bass
visual, reefs



barred sand bass
visual, platforms

no data

Appendix 4 continued. Size distributions of reef fishes (> 9 cm TL) on platforms and natural reefs estimated visually by divers and by video with parallel lasers. Distributions are based upon all platforms and natural reefs combined across 3 years. N= total number of fish.



MARCH 3, 1849

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.