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Ecological and political issues surrounding decommissioning of offshore oil facilities in the Southern California Bight

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Abstract

To aid legislators, resource managers, and the general public, this paper summarizes and clarifies some of the issues and options that the federal government and the state of California face in decommissioning offshore oil and gas production platforms, particularly as these relate to platform ecology. Both local marine ecology and political climate play a role in decommissioning offshore oil production platforms. Compared to the relatively supportive political climate in the Gulf of Mexico for "rigs-to-reefs" programs, conflicting social values among stakeholders in Southern California increases the need for understanding ecological impacts of various decommissioning alternatives (which range from total removal to allowing some or all of platform structure to remain in the ocean). Additional scientific needs in the decommissioning process include further assessment of platform habitat quality, estimation of regional impacts of decommissioning alternatives to marine populations, and determination of biological effects of any residual contaminants. The principal management need is a ranking of environmental priorities (e.g. species-of-interest and marine habitats). Because considerable numbers of economically important species reside near oil platforms, National Oceanic and Atmospheric Administration Fisheries should consider the consequences of decommissioning alternatives in their overall management plans. Management strategies could include designating reefed platforms as marine protected areas. The overarching conclusion from both ecological and political perspectives is that decommissioning decisions should be made on a case-by-case basis.

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1. Introduction

Worldwide, over 6000 large offshore platforms extract oil and gas from the continental shelf [1]. This ubiquity gives marine policy issues surrounding activities of the offshore oil industry a cosmopolitan significance. One such issue is the fate of obsolete oil facilities, a process known as decommissioning. Regulatory agencies decommission offshore oil platforms by choosing from a number of different alternatives. As examples, platform structure may be left completely or partially in the water (often called "reefing"), removed and then reused as a platform in another location, or hauled to shore for scrapping or recycling. Controversy often surrounds the decommissioning process because each alternative differs in costs, benefits, and risks to disparate stakeholder groups and the environment.

The fate of obsolete oil facilities has depended in part upon local marine ecology and political climate. In the Gulf of Mexico, approximately 85% of decommissioned platforms positioned in depths between 61 and 121 m (200 and 400 ft) were partially removed or toppled, and these decisions generally received support from local communities [2]. Conversely, in the North Sea, the decommissioning of Brent Spar, a large floating oil storage tank, made international headlines for its controversy. This controversy eventually led to the abandonment of the original plan, disposal in deepwater (forming a deep artificial reef), in favor of onshore disposal and recycling [3].

Decommissioning of deepwater structures appears to be more controversial than other decommissioning situations for two reasons. First, there are uncertainties regarding environmental consequences of disposal/reefing in deepwater, and second, these alternatives would greatly decrease the cost to the oil industry in the decommissioning process. These two factors in juxtaposition generate unease in the public mind.

In the United States, the next arena where decommissioning policy will play out is in the Southern California Bight, where several deepwater platforms (greater than 121 m or 400 ft) are expected to be decommissioned in the next 5–10 years. To aid legislators, resource managers, and the general public, this paper seeks to summarize and clarify some of the issues and options that the federal government and the state of California face in decommissioning offshore oil and gas production platforms, particularly as these relate to platform ecology. We also briefly review the history of platform decommissioning in the United States, focusing on the Gulf of Mexico.

2. Background information

2.1. Platform structure

Although Southern California platforms differ in size and detail, the general configuration is a steel structure supported on legs of steel tubing anchored in the seafloor (Fig. 1). The above-water structures, including oil and gas processing equipment, and crew living and working quarters are termed the *topside* or *topsides*

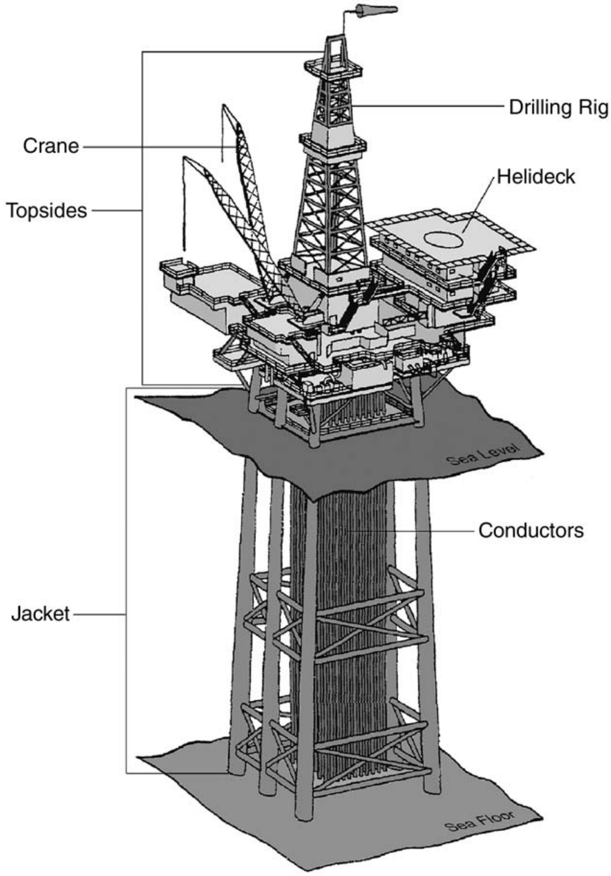

Fig. 1. A typical oil/gas production platform in the Southern California Bight. Adapted from Manago and Williams 1998.

(also *topside facilities* and *deck*). The vertical pipes that carry the oil and gas are the *conductors* and the parts of the structure that are anchored in the bottom and protrude through the surface to support the topside structural components (including the crossbeams, legs, and the piles inside the legs) are the *jacket*. Near the surface, horizontal crossbeams occur about every 15–20 m (50–66 ft), and deeper they occur every 30–40 m (99–132 ft). Horizontal, diagonal, and oblique crossbeams extend both around the perimeter of the jacket and reach inside and across the platform.

The surface area provided by a platform jacket creates a substantial amount of hard substrate to which sessile (fixed) invertebrates, including mussels, barnacles, and rock scallops, often attach. On oil platforms in the Southern California Bight, this biotic layer may become quite thick, over 0.5 m, extending from the intertidal to at least 30 m (99 ft) and deeper on other platforms [4]. When these encrusting animals are dislodged or die, perhaps by cleaning, storms, predation, or other causes, their remains fall to the seafloor. This rain of organic material creates a shell mound which covers the substrate surrounding the platform jacket. The matrix of the shell mound may incorporate rock cuttings and drilling muds produced during drilling operations and deposited near the platform structure. Height of these shell mounds may be 7 m (23 ft) or more above the seafloor, and cover over 6 km^2 (2.3 $mile^2$) in area, but depends upon age of platform, seafloor depth, and biogeographic area (which affects species composition of attached invertebrates) in which platforms are located [5].

2.2. General life history of marine species

The majority of fish and invertebrate species observed at both oil platforms and natural reefs do not reside in these habitats for their entire life history. Any stage of development (egg, larval, juvenile, or adult) may populate different depths or habitats, such as the oceanic or coastal water column, estuaries, seagrass beds, intertidal, or sand bottom environments. Therefore, organisms residing within a seemingly discrete habitat, such as an oil platform, are ecologically one part of a number of interconnected populations. Connectivity within and among populations will vary according to the life history of each species, oceanographic patterns, and distribution of hard bottom. One consequence of a spatially complex life history is that impacts of a reefed platform may propagate across regions and habitats and affect other populations. Therefore, some understanding of connectivity processes, both physical and biological, must precede predictions regarding the environmental consequences of platform decommissioning alternatives.

3. The process of decommissioning oil platforms in the United States

As aptly noted by Wiseman [6], “Decommissioning of platforms is not a project, but rather a process… What really differentiates a process from a project is the fact that the owner and the engineer/contractor do not make all of the decisions leading to the completion of the work. In the case of a process, regulatory agencies and the public have standing, and thus can demand a role in the decision-making process”. In this section, we provide an overview of decommissioning alternatives and some important elements in the decommissioning process.

3.1. Decommissioning alternatives

Within 1 year of an OCS lease termination, the Minerals Management Service (MMS) requires that the lessee remove the oil platform structure to a depth of 15 ft below the mud line, and the leased area must be cleared of obstructions (*see generally*, 30 C.F.R. Part 250, subpart Q, § 250.1700 et seq.). However, the MMS may waive these requirements to accommodate conversion of a platform structure to an artificial reef provided that (1) the remaining structure does not inhibit future oil or other mineral development, (2) the resulting artificial reef complies with the Army

Corps of Engineers permit requirements and procedures outlined in the National Artificial Reef Plan, and (3) a state fishing management agency accepts liability for the remaining structure (30 C.F.R. §§ 250.1703, 250.1730). In addition, the National Fishing Enhancement Act (NFEA) of 1984, which authorizes the Corps of Engineers' permit program and the National Artificial Reef Plan (33 USC. § 2101 et seq.), allows other organizations or agencies (such as the operator) to assume liability for the artificial reef, although MMS policy to date has required a state agency to accept liability. Proposed decommissioning activities are also subject to provisions in the National Environmental Protection Act (NEPA) and the California Environmental Quality Act (CEQA).

The timing of future decommissioning activities is not fixed. It depends on the length of the lease, the rate of reservoir depletion, the market value of oil or gas, and whether the platform might serve an extended use for the operator, such as a gathering system for the production of other platforms. There are three stages in the decommissioning process: planning, permitting, and implementation. Platform decommissioning alternatives fall into four general categories: total removal (the default option), partial removal, toppling, and leave-in-place (Fig. 2). The suite of decommissioning alternatives that proposes to leave part or all of the abandoned platform structure in the marine environment is often collectively referred to as "rigs-to-reefs". Deepwater disposal is often considered to be a separate alternative from a shallow-water reefing option, but from an ecological perspective, the functional impacts (addition of hard substrate into a marine environment) are the same.

Pipelines run from all platforms either to shore or to other platforms that collect the oil or gas and then ship it to shore, and the decommissioning process also considers the fate of obsolete pipelines. McGinnis et al. [7] note that "Both Federal and California regulations allow decommissioned OCS pipelines to be abandoned in place so long as they do not constitute a hazard to navigation, commercial fishing or

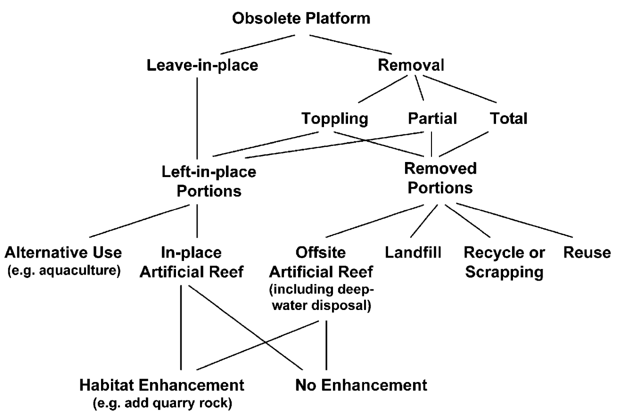

Fig. 2. Decommissioning alternatives for oil and gas production platforms.

unduly interfere with other uses of the OCS". In the Gulf of Mexico, few pipelines have been completely removed in the course of decommissioning [8].

Alternative 1: Total removal. A typical full-removal project begins with well abandonment in which the well bores are filled with cement. The conductors are then separated from below the seafloor by being pulled, cut off, or removed using explosives. Next the topsides, which contain the crew quarters and the oil and gas processing equipment, are cut from the jacket and removed. Finally, the piles that hold the jacket to the seabed are severed with explosives. Afterward, a derrick barge lifts the jacket, or pieces of the jacket, onto a cargo barge for transport. Alternatively, larger jacket structures may be moved by refloating or by "progressive transport". Progressive transport entails rigging the jacket between two barges and then winching the structure upward off the bottom. The barges then proceed inshore toward shallow water until the jacket legs touch bottom again; at this point the emergent pieces of the structure are removed, and the whole process begins again [9]. Other typical decommissioning requirements include the removal or abandonment of pipelines and electrical cables and the removal of any debris from the seafloor. As of 1999 in the Gulf of Mexico, about 1700 decommissioned oil and gas production platforms have been completely removed [10].

After deciding to totally remove a platform from the seafloor, operators have several options [11–14]. (1) The platform can be taken to shore, where it is disassembled and the components either recycled, sold as scrap, or discarded in landfills or other depositories. (2) The structure can be reconditioned and reused. As an example, in 1997 a platform was removed from the North Sea, taken to shore and cleaned, refurbished, shortened by 10 m (33 ft), and installed in another North Sea location. A few small platforms have also been reused in the Gulf of Mexico. (3) Platform structure can be towed to a site remote from the intact platform (in either shallow or deepwater) and reefed. Remote, shallow-water reefing has occurred a number of times in the Gulf of Mexico, with the most extreme example towing structures of two Tenneco platforms over 1480 km (920 mile) from offshore Louisiana to a site 2.4 km (1.5 mile) off Dade County, FL [15].

Alternative 2: Partial removal. In this scenario, the wells are abandoned, and the conductors and topsides are removed. Some portion of the jacket is removed, with the remaining structure and possibly the shell mound being left in place. If needed, navigation aids are emplaced.

Despite what has been implied in other reports, conductors need not be completely removed. Dauterive [10] notes "Recognizing the preservation of environmental values associated with the method of partial removal of the platform, the MMS in 1997 established a policy to allow the industry the option to partially remove the well conductors at the same depth below the water line (WL) at which the industry had proposed to remove the platform jacket". Retaining platform conductors has two consequences. First, it adds additional complexity to the remaining structure. Second, explosives are usually used to remove the conductors and retaining these pipes eliminates the need for explosives.

After cleaning, disposition of topsides may be handled in a couple of ways. It can be moved to a new platform and reinstalled, or it can be taken onshore, where the steel and other valuable components are recycled and other material sent to landfills. Certain parts of the topsides, such as the cleaned deck, have occasionally been used in forming artificial reefs.

Alternative 3: Toppling. As in partial removal, the wells are abandoned, and the conductor pipes and topsides are removed. Shell mounds may be removed or left in place. The primary difference between partial removal and toppling is that, in toppling, explosives are used to sever the jacket from the seabed and then a derrick barge or pull barge pulls the jacket over and it is allowed to settle to the seafloor [16]. Navigation aids, if necessary, are then installed.

This option was selected for a number of shallow-water platforms in the Gulf of Mexico, and has inadvertently occurred one time during a hurricane [17].

Alternative 4: No removal (leave-in-place). A platform and its associated shell mound could be left in its original location at the time of decommissioning. The topside would be stripped and cleaned and navigational aids installed.

In the Gulf of Mexico this scenario has been discussed on a number of occasions, although it has not been attempted. For instance, a platform in the Flower Garden Banks National Marine Sanctuary was studied as a possible research laboratory. However, the cost of maintaining cathodic protection and navigational aids (together running to $300,000/year) proved too high.[1] Other creative suggestions offered by stakeholders for decommissioned, left-in-place platforms include wind or aquaculture farms, meteorological stations, hospitals, hotels, gambling casinos, penal institutions, and water desalination plants.[2]

3.2. *Agencies responsible for the decommissioning process*

By law, various coastal states and the federal government share the administration of submerged lands, subsoils, and seabeds off the United States. Thus, depending on where platforms are positioned, responsibility for mineral extraction, including oil and gas development, is either under state or federal jurisdiction. Similarly, decisions regarding the decommissioning of platforms fall under either state or federal control, although the final decisions are based on consultation and mutual agreements among a number of agencies.

Responsibility for the fate of platforms in federal waters rests with the MMS (33 USC. § 1331 et seq.). Federal agencies that are consulted in the decommissioning process include the Environmental Protection Agency (33 USC. §§ 1311(a), 1342), Army Corps of Engineers (33 USC. §§ 403,1344), National Oceanic and Atmospheric Administration (NOAA) Fisheries (16 USC. § 1801 et seq.), and the Coast Guard (14 USC. § 85: 43 USC. § 1333(d)). State agencies, such as the California Department of Fish and Game, do not have jurisdiction in federal waters but may comment in the decision-making process. Under the federal Coastal Zone Management Act (16 USC. § 1451 et seq.), MMS decisions on platform decommissioning that potentially affect coastal resources are also reviewed by an appropriate state agency for

[1] Lester Dauterive, pers. comm., Minerals Management Service, New Orleans, LA.

[2] George Steinbach, pers. comm., Ojai, CA.

consistency with the state's coastal zone management program. In California, the California Coastal Commission conducts the review for consistency with the state program. In turn, state agency consistency decisions can be appealed to the Department of Commerce (16 USC. § 1456(c)(3)(A), (c)(3)(B)(iii); 15 C.F.R. Part 930, subpart H).

Decisions regarding the decommissioning of platforms in California state waters are the province of the State Lands Commission (Cal. Pub. Res. Code § 6216), along with such agencies as the California Coastal Commission (Cal. Pub. Res. Code § 30330), Department of Fish and Game (Cal. Fish & Game Code § 1602), local Air Pollution Control Districts (Cal. Health & Safety Code 40000), Army Corps of Engineers (33 USC. §§ 403, 1344), and the Coast Guard (14 USC. § 85).

Local Coast Guard districts are responsible for the safety of vessel traffic in their respective geographic areas and have the authority to dictate aids to navigation for obstacles in the water (14 USC. § 85; 43 USC. § 1333(d); 33 C.F.R. Part 67). Therefore, in instances where some part or all of a platform is to be reefed, the Coast Guard will specify the necessary navigational aids. Discussions regarding decommissioning of platforms off California have often erroneously assumed that the Coast Guard will require that the jacket be removed to about 26 m (85 ft) below the surface. Decommissioning experience in the Gulf of Mexico demonstrates that there is no set removal depth. Indeed, the Coast Guard decision-making process appears to be quite flexible; it reviews each decommissioning on a case-by-case basis. For instance, in the decommissioning of the mile-long Freeport–McMoRan sulfur mine platform and bridge off Louisiana, the Coast Guard required piles to be cut 9 m (30 ft) beneath the surface [18].

Generally, the requirements for aids to navigation become more restrictive (and therefore more expensive) the closer to the surface the obstacle lies. As an example, here is a generic set of conditions for decommissioned platforms in the Gulf of Mexico based on recent Coast Guard decisions (see footnote 2): if the obstacle is greater than 61 m (200 ft) in depth: no requirement for aids to navigation; if the obstacle is from 61 to 26 m (200–85 ft) in depth: unlighted buoys are required; if the obstacle is 26–11 m (85–35 ft) in depth: lighted buoys are required; if the obstacle is from 11 m (35 ft) to protruding through the surface: lights or lighted buoys and foghorns are required.

In rigs-to-reefs programs in the Gulf of Mexico, the states provide the required aids to navigation on reefed platforms. The costs of these aids are paid for from the funds created by the industry's donations. As a cost savings measure, these states generally have selected greater water clearances. The requirements for California waters may be different from those in the Gulf of Mexico. The local Coast Guard District will determine these requirements based on vessel traffic and other local conditions.

3.2.1. The question of liability

Liability, who retains responsibility for a reefed platform, is a major issue in the decommissioning process. MMS policy states that "The MMS supports and encourages the reuse of obsolete offshore petroleum structures as artificial reefs in US Waters'' [10]. Current MMS regulations provide that a platform operator may be released from removal obligations in the federal lease instrument if a state agency responsible for managing fisheries resources will accept liability (30 C.F.R. § 250.1730). However, in situations where reefs are not managed by a state agency, another organization or agency must assume liability, as provided in the NFEA of 1984. In such cases, liability could possibly be retained by the oil company, transferred to a private entity, or handled in some other manner as long as MMS approval is received (see footnote 2).

An extensive body of policy and research outlines proper procedures for siting and deploying artificial reefs, and this information bears upon liability of such structures. The National Artificial Reef Plan states ''When a reef has been properly located, marked on navigation charts if necessary, and any required surface markers affixed, there should be very little potential for liability'' [19]. Regarding accidents, which may occur during recreational activities near artificial reefs, the National Artificial Reef Plan further declares, ''Diving accidents may occur with use by recreational divers. In this respect, an artificial reef is like a public park—there are dangers in those parks, guardrails and fences cannot be placed everywhere, and everyone who visits the park assumes some risk of injury. A warning could be placed on nautical charts and posted in local dive shops to warn of these dangers. However, each case would probably involve determination of comparative negligence'' [19]. Parker [20] notes that no lawsuits have ever been filed against the California Department of Fish and Game with respect to their artificial reef program.

Regardless of which decommissioning alternative is selected, the federal government cannot be held liable. Regarding State liability, the National Artificial Reef Plan notes, ''If the permit holder is a State government, it may have sovereign immunity from liability. It is unclear whether the NFEA affects any State's claim of sovereign immunity'' [19].

3.3. Social values in platform decommissioning

Defining the social and ecological goals of decommissioned platforms as artificial reefs will be critical in evaluating the efficacy of any potential rigs-to-reefs program and the current and future performance of any artificial reef. Therefore, it is likely that various stakeholder groups will vie in defining the goals (and therefore the usefulness) of decommissioned platforms as artificial reefs. In this report, we sort the multitude of stakeholder viewpoints regarding a rigs-to-reefs program into three groups, each of which is primarily defined by one social concern: community membership, resource accessibility, and environmental (marine life) issues. Of course, an individual may be influenced by more than one social value, and others may use arguments from multiple categories to promote a desired decommissioning outcome.

The first group consists of stakeholders who are concerned about community membership, and either oppose or support local presence of the oil industry. Those who wish to promote a community without the oil industry often view reefing alternatives as bundled together with all oil industry activities (e.g. continued exploration and production), the whole of which should be locally opposed (although they may not be opposed to remote oil industry activities in the Gulf of Mexico). For example, Camozzi [21] states that total removal should be the preferred alternative in decommissioning because, after decades of fighting oil development on the California Coast, it serves as a "catharsis" for the local community. A representative of a local Surfrider Foundation has stated that "We're not convinced that the alleged scientific benefit to habitat is worth the sort of *larger social encouragement* it gives the oil companies" (italics added; [22]). Individuals who wish to encourage or maintain the presence of the oil industry in the local community, presumably for economic reasons, favor some sort of reefing option because reefing is less expensive than total removal [23]. Further information regarding local community views concerning California's oil industry can be found elsewhere [24–27].

The second group of stakeholders is primarily concerned with resource accessibility. A heterogeneous group, these citizens will either favor or oppose decommissioning alternatives depending on how these alternatives aid or inhibit their ability to access a particular resource. For example, commercial trawlers in the Southern California Bight favor total removal because fishing gear may snag on platform structure or shell mounds [28,29]. Other commercial fishers benefit from oil industry activities. Shrimp trawlers in the Gulf of Mexico drag within 0.4 km (0.25 mile) of platform structures, reporting that these fishing grounds tend to be more productive [15]. The rocky habitat associated with the Rincon Oil Island in California provides excellent lobster fishing grounds and trap fishers would oppose seeing this habitat removed [30]. Recreational fishers often dominant the debate surrounding platform decommissioning, and they have driven the formation of artificial reef policy at both state and federal levels [15,19,31]. Many recreational fishers favor a reefing alternative in decommissioning because catch per unit effort is often high at offshore platforms for targeted fish species such as kelp bass [32,33]. In the Gulf of Mexico, Reggio [34] estimates that 70% of Louisiana fishing excursions target oil platform habitats. Citizens who participate in non-consumptive activities also hold a variety of viewpoints regarding decommissioning alternatives. Many scuba divers find that underwater portions of oil platforms provide outstanding diving and underwater photographic opportunities, and favor decommissioning alternatives that preserve such opportunities [35,36]. Other members of the public may view the topside structure of platforms as denying them access to unobstructed, scenic ocean views, and consequently they oppose the leave-in-place decommissioning option [6].

The third stakeholder group makes decisions regarding decommissioning based on their perception of how certain marine populations or environmental ideals fare under the various decommissioning alternatives. It is this last group which is most likely to use ecological information in making decisions regarding platform decommissioning. A decommissioning option that involves reefing may be supported if a substantial net benefit to the marine environment can be demonstrated [37,38]. Others support total removal because this option is the only one which promotes a wilderness ideal, that is, a marine environment which fails to retain a visible mark of human activities. If there is a lack of scientific evidence regarding ecological consequences, or if they are unaware of such consequences, these stakeholders may use another social value, such as community membership, in choosing a preferred decommissioning alternative [37].

Economic incentives interact and overlap with social values. In past rigs-to-reefs activities in the Gulf of Mexico, industry and state entities have equally shared the cost savings resulting from partial removal or toppling alternatives. Partial removal of large, deepwater platforms will generate cost savings much greater than the amount saved in partially removing smaller platforms. The cost of maintaining navigational equipment (if needed) at these reefed platforms will not increase in the same proportion as the increase in cost savings, and may actually decrease. These additional financial resources may be used to develop or enhance projects important to stakeholders, and may be a sufficient incentive to alter the preferred decommissioning option for some groups. Finally, social values will also be important in directing how potential cost savings will be used.

3.3.1. The interaction of science, scale, and social values

In the face of strongly conflicting viewpoints among stakeholder groups, resource managers may try to convert a controversial issue into a technical or scientific question. For instance, they may give preference to the protection of marine life resources, thereby avoiding the appearance of favoring one group's economic concerns over another's. Additionally, legislation such as the Endangered Species Act and the Marine Mammal Protection Act, among others, often give environmental concerns priority over social and economic concerns. In combination, these issues give ecological information a prominent role in decommissioning oil and gas production platforms in the Southern California Bight.

As examples, at a public workshop on the decommissioning process [39], a representative for Secretary for Resources for the State of California stated "We have to base this as much as possible on science". The executive officer of the State Lands Commission said "We need to bring science into the process to figure out really what the effect of the reef is on the environment and then make logical decisions from that". However, local agency representatives responded with less enthusiasm regarding the usefulness of science in selecting decommissioning alternatives; a spokesperson from Santa Barbara County thought that the most important issues regarding decommissioning relate to social values and that he remained "a science skeptic".

Impacts to the environment may be measured at short or long time scales, or within a local or regional context. As time and space scales increase, so does scientific uncertainty about predicting consequences of various management alternatives (due to an increasing number of unknown variables, and propagation of error associated with imprecise assumptions or model parameters). When there is greater scientific uncertainty, social values and political or economic factors often become more important in the decision-making process. This phenomenon may result in stakeholders advocating that ecological performance of reefed platforms be evaluated at scales which enhance the possibility of their preferred decommissioning alternative, even if ecological data are irrelevant to their concerns.

For example, proponents of regional ecological assessment at long time intervals are often individuals who oppose the local presence of the oil industry. Since regional assessment is difficult and expensive to accomplish, social values (e.g. antagonistic views of oil industry) will increase in importance. Significantly, these same individuals have not stipulated that other artificial reefs which are similar to reefed platforms, such as steel hulled ships, undergo the same rigorous ecological assessment. Further, the assured instantaneous and lethal effects of explosives are not considered in arguments about marine life effects.

Proponents of small-scale ecological assessment tend to be recreational anglers, who often state their support for rigs-to-reefs programs in terms of benefits to the environment. They maintain that the local presence of abundant marine life at a platform is sufficient evidence of satisfactory ecological performance. But this support for a rigs-to-reefs alternative often fades if these artificial reefs are designated no-take areas, as was proposed in California's SB 1 legislation in 2001.

Ecological information can greatly aid the decision-making process if explicit management goals are specified. The rebuilding of depleted fish stocks might be one goal, the preservation and expansion of marine wilderness might be another. Determination and ranking of ecological goals necessarily reflects cultural values. Thus, even if large amounts of ecological data regarding decommissioning consequences were available, controversies surrounding platform decommissioning will still arise because there is no formal ranking of which species or habitats have management priority. Further, there is no agreement on the space and time scales in which ecological impacts should be measured. To date, state and federal regulatory agencies have not supplied such specific management priorities in the decommissioning process.

4. Decommissioning activities in the Gulf of Mexico

The majority of platform decommissioning and reefing in the world has occurred in the Gulf of Mexico. Currently, there are approximately 5000 platforms in the Gulf of Mexico in both state and federal waters, ranging in depth from about 3 m (10 ft) to over 1830 m (6000 ft) [40], Because large-scale offshore drilling first took place in the Gulf of Mexico, it was in this region that the issue of what to do with obsolete platforms first arose. Below, we give a brief summary of the history of decommissioning in the Gulf of Mexico; details are found in Lukens [41], Kasprzak [42], and Dauterive [10].

Kerr-McGee erected the first offshore oil and gas platform in the Gulf of Mexico off Louisiana in 1947. Despite its primitive structure and placement in waters only 5.5 m (18 ft) deep, oil was struck 22 days after drilling began, presaging a veritable tidal wave of offshore drilling. The vast majority of offshore structures occur off Louisiana, followed by Texas, Mississippi, and Alabama [10,18,41–43]. Platforms provide a considerable amount of the hard substrate in the Gulf of Mexico and surveys indicate that fish density is 20–50% higher around platforms than on surrounding soft seabeds [44,45]. Because recreational and commercial fishers target fish residing near these structures, they are of considerable economic value [34,42,46].

By the late 1970s, it was apparent that the economic life span of many of these structures was nearing an end. During this decade, about 150 platforms were removed to shore and scrapped. The first reefing of an oil and gas structure occurred in 1979 when a subsea production system was towed from Louisiana to an artificial reef site off western Florida. In 1982, an obsolete platform jacket was moved from Louisiana to a Florida site and over the next few years several additional structures were moved to various artificial reef sites [10].

Responding to this new activity, Congress passed the NFEA of 1984, which mandated the creation of a "long-term plan for siting, constructing, permitting, installing, monitoring, managing, and maintaining artificial reefs within and seaward of state jurisdictions" [19]. This document, later called the National Artificial Reef Plan, was published in 1985. Several Gulf of Mexico states also passed laws (for instance, the Louisiana Fishing Enhancement Act of 1986 [Act 100] and the Texas Artificial Reef Act of 1989) that take advantage of platform decommissioning to help preserve platform habitat in the northern Gulf of Mexico. As an example, Act 100 created a process by which ownership of and liability for uneconomical platforms could be transferred from operators to the state of Louisiana. As noted by Kasprzak [42], "Act 100 established the state of Louisiana as the permittee for artificial reefs developed under the program's jurisdiction and appointed the Department of Wildlife and Fisheries as agent for the state. The state assumes responsibility for the reefs upon placement within the established reef permit area… Act 100 does not authorize state general funds for the artificial reef program but does establish the Louisiana Artificial Reef Trust Fund. Oil and gas companies that donate structures to the program are asked to contribute half of the disposal savings realized through program participation to the trust fund". A similar program exists in Texas [47].

A significant amount of money has been collected in rigs-to-reef programs in both Louisiana and Texas. As of 2001, there was about $15 million in the Louisiana fund and at least $4 million in Texas. Contrary to what has been reported in other studies, major artificial reef programs of several states, including Louisiana and Texas, receive neither state nor federal funding; they are fully underwritten by the interest paid on their respective rigs-to-reef accounts.[3]

Since 1947, 188 Gulf of Mexico platforms have been reefed, primarily off Louisiana and Texas, representing about 8.4% of all decommissioned platforms.[4] The reasons for this early low reefing rate were economic. Most of the platforms thus far decommissioned were in shallow water, and it was more cost effective to haul them onshore for salvage or reuse rather than tow them to reefing sites. As larger

[3] Jan Culbertson, pers. comm., Texas Department of Park and Wildlife, Houston, TX; and Rick Kasprzak, pers. comm., Louisiana Department of Wildlife and Fisheries, Baton Rouge, LA.

[4] Lester Dauterive, pers. comm., Minerals Management Service, New Orleans, LA.

platforms in deeper waters are decommissioned, Dauterive (see footnote 4) has noted a trend toward partial removal, rather than towing or toppling.

Compared to the Southern California Bight, assessment of potential ecological impacts from decommissioning alternatives has been rather low in the Gulf of Mexico. Since there has been general support from the community for rigs-to-reefs programs, the lack of controversy probably decreased the social need for scientific information.

5. Decommissioning activities in the Southern California Bight

As of 2003, there are 27 platforms in the Southern California Bight, 24 in federal waters (Pacific Outer Continental Shelf) and three in state waters (Fig. 3). These platforms lie between 1.9 and 16.9 km (1.2–10.5 mile) from shore and are in bottom depths ranging from 11 to 363 m (35–1198 ft). Details regarding location, depth and other features of these platforms are found in [48], and details about the history of the oil industry in Santa Barbara and Ventura counties can be found in [26,27].

Compared to the Gulf states, California has limited experience and limited infrastructure in decommissioning obsolete oil production facilities. However, it is likely to be the first region where deepwater platforms will be decommissioned, and unlike the Gulf of Mexico, California stakeholder views are highly polarized; it

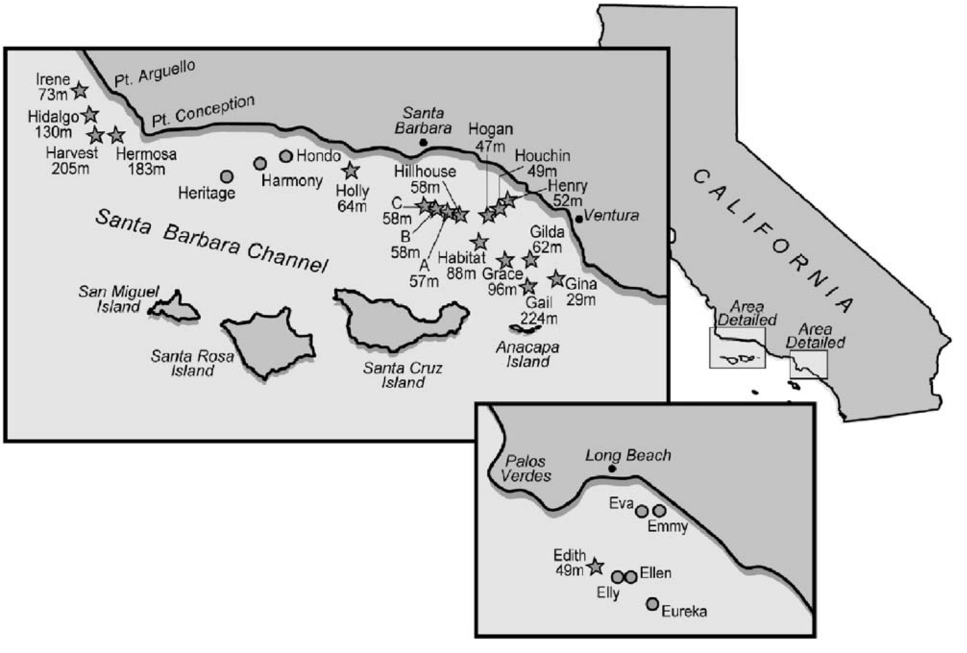

Fig. 3. Location of oil and gas production platforms in the Southern California Bight. Platforms surveyed at least once are indicated by stars. Depth (m) of platforms surveyed are also included.

appears certain that future decommissioning of California platforms will be controversial.

To date, most decommissioning of obsolete oil facilities has occurred in state waters. Three platforms, Harry (in 1974), Helen (in 1988), and Herman (in 1988) were totally removal without a great deal of controversy. However, late in the planning for the removal of the "4H" platforms Hilda, Hazel, Hope, and Heidi, a recreational angler's group began to lobby for their retention. Ultimately, the platforms were removed in 1996. Other types of oil industry facilities decommissioned in state waters include a number of oil piers, an offshore treatment and storage facility (the Exxon SALM, similar in design to the Brent Spar of the North Sea), and the Belmont Oil Island. With a few exceptions, most of the material from these decommissioning activities were reused, recycled or deposited in landfills. The California Department of Fish and Game used rocks from the decommissioned Belmont Oil Island to enhance the Bolsa Chica Artificial Reef. A number of power cables and intrafield and field-to-shore pipelines as well as parts of Platform Hazel, a gravity base structure, have been decommissioned in-place [9].

Anticipating future decommissioning activities in the Southern California Bight, a bill creating a mechanism to allow the Sate of California to receive a portion of the cost-savings from any reefing alternative was introduced in the state legislature, first as SB 241, and later as SB 1. The bill was passed by both the state senate and the assembly, but was vetoed by Governor Davis in 2001.

5.1. *California's Artificial Reef Plan*

The state of California possesses an Artificial Reef Plan [31], but this plan does not include any policy, for or against, a rigs-to-reefs program. However, in response to interest in oil platform reefing during the 1980s, the Department issued a set of guidelines regarding rigs-to-reefs. "These guidelines stipulate that platforms as artificial reefs (1) benefit living marine resources, habitat, and user groups; (2) may not be used to dispose of contaminated materials; (3) endeavor to leave the subsurface structure of the platform in place and where possible subsurface structure that must be removed could be relocated to the base of the rig or other appropriate sites; and that the remaining structure be augmented by rocks or other materials to assure that the site functions as a diverse and productive reef habitat. To replace the biotic productivity from that part of the platform removed for navigational purposes, rock or concrete reefs should be placed in nearshore locations. A rigs-to-reef project sponsor must provide sufficient funds to the Department to evaluate the benefits to biotic productivity, user groups, and the overall management of fishery resources" (cited in [49]). The Department may reconsider these guidelines on the basis of new information.[5]

[5] David Parker and Dennis Bedford, pers. comm., California Department of Fish and Game, Los Alamitos.

6. The biological setting

6.1. Marine life associated with oil and gas production platforms in the Southern California Bight

The extensive variability in marine life observed around oil and gas production platforms prohibits a generic set of predictions regarding the ecological consequences of different decommissioning alternatives; it is clear that decisions regarding platform decommissioning should be done on a case-by-case basis. Below we identify three important factors that influence the observed variation in the marine life at platform habitats using data from numerous studies [4,48–51 and references therein].

Depth zonation. Natural variation in depth, temperature, and exposure creates a density gradient of species in all marine environments, including platform habitats. This zonation pattern is observed in both fish and invertebrate communities and also in the distribution of life history stages where juvenile stages tend to reside in shallower habitats than their adult counterparts. The absolute depth of the seafloor over which a platform is anchored also plays a role in determining biodiversity because deeper platforms possess a greater range of habitats. For example, all platforms have intertidal and shallow midwater habitats, but only those structures positioned in water depths that exceed 100 m (330 ft) have deep benthic habitat.

Biogeographic and oceanographic influences. Species composition at both platforms and natural reefs exhibit regional patterns related to biogeography, where northerly platforms show the influence of the Oregonian province (a suite of cool water species) and southerly platforms show the influence of the Californian or San Diegan province (a suite of warm water species). These biogeographic patterns are more conspicuous in shallow water. The large interannual variation observed in the density of juveniles of many species may be generated by the large interannual variability in oceanographic conditions (e.g. upwelling intensity, El Niño/Southern Oscillation events). Again, this variability is more conspicuous in shallow water.

Offshore position. The offshore and exposed position of some oil platforms results in a high delivery rate of plankton to platform habitats. This in turn sustains large numbers of filter-feeding animals (mussels, anemones), and planktivorous fishes. Pelagic fishes aggregate to a variety of offshore structures, and they compose a significant part of the fish community at oil platforms compared to natural reefs. Platforms located furthest offshore have a lower diversity of shallow-water fishes compared to those located nearshore.

6.2. Ecological performance of oil and gas production platforms as artificial reefs and the attraction or production issue

Predictions about decommissioning alternatives depend upon the ecological performance of an oil platform as an artificial reef. In other words, does the removal of platform structure benefit or degrade the marine environment for species-of-interest? Because marine populations are often interconnected (see Section 2.2), many ecologists call for regional-scale assessment of impacts in artificial reef formation and management (e.g. [52,53]). Regional-scale impacts can be determined by first estimating the abundance and connectivity of habitats for species-of-interest, and second, by comparing important parameters such as growth or survivorship (the ‘‘ecological performance’’) of species at a platform with those of natural reefs within the region. However, no federal or state Artificial Reef Plan mandates regional assessment, and evaluation of artificial reefs of all types has only occurred at local scales, if at all [54,55].

A concern in artificial reef management appears in political and scientific discourse as the ‘‘attraction or production debate’’, especially in regard to exploited fish populations. The phrase is misleading because the two processes, attraction and production, are not exclusive. When resources such as food or habitat are abundant, the addition of an artificial reef may simply attract fish from a natural habitat into an artificial one, without increasing regional abundance or biomass. In this case, assuming survivorship and reproduction rates are equivalent among sites, an artificial reef has a neutral effect on regional production—a zero sum game. Negative effects from attraction occur if an artificial reef lures fish or invertebrates into an unfavorable environment, perhaps where mortality is high (say from fishing pressure) or habitat quality is poor compared to natural reefs. Such negative effects have been documented in California waters and other places where artificial reefs concentrated previously depleted fishing stocks, making them easier to catch by recreational fishers [56]. Positive effects from attraction occur if an artificial reef provides habitat that enhances fish growth, survivorship, or reproduction compared to natural reefs. Production may occur independently of attraction when a species spends its entire life at platform, and enjoys a higher rate reproduction or survivorship.

Only a few studies have begun to address the comparative ecological performance of oil and gas platforms and natural habitats. Platforms, like natural reefs, attract some species. Since many platforms in the Southern California Bight may act as de facto marine protected areas (see Section 7.5.2), adult mortality may be much lower at platform habitats compared to natural ones, thus providing substantial benefits to fish populations that have been overfished. A few studies have shown that animals which feed on plankton have faster growth on platforms compared to natural reefs, suggesting that platforms provide production benefits for some species. There have been no studies that show lower ecological performance of platform habitat compared to natural habitats, but much more work remains to be done in this area.

Scientists have begun describing the distribution, abundance, and connectivity of natural and artificial habitats in the Southern California Bight in order to understand the regional ecological impacts of various decommissioning alternatives (among other goals). Conventional wisdom once assumed that large amounts of hard substrate exist in the Southern California Bight and that local marine populations are strongly interconnected over a large area. Recent work has failed to confirm either of these assumptions, suggesting that platform structure may affect local marine populations more that previously supposed [48].

6.3. Local pollution levels near oil and gas production platforms

Questions about local pollution levels interact with the attraction issue, as attraction into a polluted environment from an unpolluted one may have negative impacts on marine populations. We know of one field study that addresses these questions in California waters. Bascom et al. [57] provide data regarding pollution levels at Santa Barbara Channel oil platforms and the surrounding environment. Liver, muscle, kidney, gonad, and whole soft tissues were extracted from rockfishes, crabs, and mussels from rocky reef control sites and impact sites of Platforms Hazel and Hilda. Two hundred thirty-two samples were analyzed for trace metals (cadmium, chromium, copper, lead, mobedium, nickel, silver, vanadium, and zinc). Concentrations of trace metals were not different between control and impact sites with the exception of vanadium in rockfishes which was significantly higher. Vanadium levels were not toxic at measured levels. Concentrations of hexane-extractable materials, volatile solids, copper, and zinc showed no obvious anomalies near the platforms. Regarding hydrocarbon levels, Bascom et al. [57] state that there were "no detectable hydrocarbons in the mussels or crabs regardless of collection site, but very high levels in the rockfish. However, the gas chromatographic fingerprints show no indication of any petroleum hydrocarbons in the rockfish. All the peaks can be reasonably attributed to biogenic hydrocarbons. Since mussels are generally good accumulators of petroleum hydrocarbons and no detectable amounts of hydrocarbons were found in the mussels, it is unlikely that the rockfish found at the same site would contain significant amounts of petroleum hydrocarbons".

One indirect source of information about potential contamination comes from the California Department of Health Services. For over a decade, various toxin levels have been measured in platform mussels because tons of these organisms are harvested and sold to southern California restaurants for human consumption. A state health official has stated that mussels residing on platforms in the Southern California Bight have "probably the highest quality of shellfish meat sold in California and maybe the entire country" [58]. This high quality may result from the offshore position of platforms, away from agricultural and urban runoff that pollutes nearshore environments.

The above examples focus on rockfishes and shellfish which feed primarily on organisms in the water column. Additional studies should include fish species which feed on organisms living in the sediments, such as sanddabs, which are more likely to show a response to local levels of pollutants.

7. Potential ecological consequences of offshore platform decommissioning in the Southern California Bight

In this section, we outline potential ecological response to four general decommissioning alternatives: total removal, partial removal, toppling, and leave-in-place. In general, detailed predictions about ecological responses to decommissioning alternatives must be done on a case-by-case basis. However, we present here two kinds of generalized and local ecological responses to decommissioning: shifts in species diversity and dominance, and changes in the distribution and abundance of key species. Regional impacts of decommissioning alternatives can be better estimated once seafloor mapping and models of population connectivity are completed, and thus are not discussed in this section.

7.1. Alternative 1: Total removal

Total removal of platform structure will kill the majority of organisms associated with oil and gas production platforms, causing a dramatic reduction in local species diversity and abundance. Depending on the specific site or time of year of decommissioning, considerable numbers of federally managed or endangered species may be lethally impacted. In general, all fishes residing on the seafloor adjacent to the platform and many fishes in the water column will be killed by shock waves generated by underwater explosions used to separate platform structure from the seafloor (see Section 7.1.1). Fishes and mobile invertebrates that survive blasts must relocate to suitable habitats. Fish survivors are likely to be those species without swimbladders, such as mussel blennies, and will likely suffer a considerable chance of mortality during their exodus. Marine mammals, seabirds, and sea turtles may also be killed, injured, or their behavior altered by underwater blasts.

Contaminated sediments are likely to be resuspended into the water column during removal of structures embedded in the seafloor. Damage to soft-sediment communities will occur from anchors and associated ground tackle, and from dragging platform legs if the jacket is removed using progressive transport. Air emissions from derrick barges and other support vessels used to remove the platform structure will negatively impact local air quality.

Deposition of platform structure to land fills will cause complete mortality for all remaining attached invertebrates that were not dislodged by detonations. The small invertebrates which hide in the attached mussel matrix (e.g. crabs, brittlestars) will also die. If part of the platform structure is hauled to a reef area and replaced in the water, some of these organisms may survive, depending on water depth and the length of time the structure is exposed to the air. The invertebrate biomass removed from the marine environment will vary according to the size of the platform and the factors affecting the fouling community before decommissioning began. Approximately 900 metric tons of attached invertebrates from Platforms Helen and Harry and over 2500 metric tons of attached invertebrates from the 4H platforms (Hazel, Heidi, Hilda, and Hope) went into landfills after decommissioning [9]. Trawling the area to remove residual debris will negatively impact epifauna compared to the use of remotely operated vehicles and divers.

After the completion of decommission activities, local species composition will shift toward a soft-sediment community (if the shell mound is removed) or to a community similar to one inhabiting areas with low-relief cobble (if the shell mound is left in place). For soft-sediment communities, recovery will naturally depend on such factors as natural and human-caused disturbance rates (e.g. severe storms or trawling), species' migration rates (at both larval and benthic stages) and the degree of sediment contamination. Recovery is defined here as the point at which the community of organisms at the site of impact is indistinguishable (using standard statistical analyses) from communities in similar substrates that are distant from the impact site. One study estimated that the soft-sediment community at platform Hazel would recover after 10 years [4]. Initially, shell mound communities will have a higher diversity of species than surrounding sediment communities, including many juveniles of exploited marine species [48]. Persistence of the shell mound community depends on a number of factors including shell mound burial rate, local currents and sedimentation patterns. An intact shell mound at the base of a platform provides a natural "cap" to local contaminants. If a platform's shell mound is removed, these contaminants will be resuspended into the water column and cause an undetermined amount of environmental damage.

7.1.1. Underwater explosions

Underwater explosions used to separate platform steel legs from the seafloor generate intense shock waves that cause instantaneous lethal impacts for marine life residing on and near the oil platform structure, particularly for fishes with swimbladders [17,59]. There will be two major zones of injury from blasts. The first is a roughly spherical zone centered on the explosion. Virtually, all fishes and many invertebrates associated with platform structure next to the seafloor will die from this first zone of injury. The second zone of injury is in the shape of a shallow disk, also centered on the explosion, but located near the surface of the water. Fishes in this zone will die from rapid swimbladder expansion or explosion as the initial shock wave (which is traveling as a compression wave) reflects off the surface of the water and transforms into a decompression wave. Fishes without swimbladders will not experience expansion problems, but may experience auditory damage or debilitating physiological stress. Fish size or developmental stage play a role in mortality risk, since small fishes are more susceptible to lethal concussion compared to larger fishes [59]. Explosive shock waves may adversely affect marine mammals, sea turtles, and diving seabirds close to the blast by killing them, damaging their auditory system, or causing other types of trauma or stress [60]. Marine mammals are sensitive to noise pollution and may alter migration patterns or other behaviors in response to underwater noise. Few studies have examined the effects of explosives on invertebrate populations, but it is expected they will have lower mortality than fishes due to the lack of air inside their bodies.

Some shallow-water platforms can be removed without explosives. However, "The oil and gas industry has attempted to find alternatives to the use of explosives, such as cryogenic cutting, hydraulic abrasive cutting, mechanical cutting, and torch cutting. Most of these techniques either have proven to be ineffective or are successful only in limited situations. At present, the industry maintains that the use of explosives is by far the safest, most reliable, and most cost-effective method of platform removal" [42]. An assessment of techniques for removing platforms found that it is unlikely that any techniques or devices now known will significantly reduce fish kills during removal operations that use explosives [61].

7.2. Alternative 2: Partial removal

Since partial removal reduces or eliminates a portion of the shallow-water habitat from the marine environment, this alternative would likely result in lower abundance and species richness than was present at the start of the decommissioning process. Since partial removal does not require the use of explosives, there is relatively little mortality or injury to fishes and invertebrates, and virtually no negative impact to marine mammals, sea turtles, and seabirds. Fish and invertebrate communities associated with the remaining platform structure are assumed to be minimally affected. As in the total removal alternative, there will be some harm to soft-sediment communities from anchors and ground tackle. Deleterious air emissions from derrick barges and other support vessels used to remove the platform structure are expected.

After decommission activities are completed, the remaining structure will continue to function as an artificial reef, hosting a greater abundance and diversity of large fishes and invertebrates compared to the surrounding mud habitat. Response of platform communities to partial removal will depend upon how much of the upper portion is removed. Fishes and invertebrates that only reside or recruit to shallow-water habitat would be absent. Since the majority of mussels are located at shallow depths, replenishment of shell mound habitat will be reduced or absent; this will affect the persistence of shell mound community.

Both fish and invertebrate shallow-water communities are sensitive to biogeographic, oceanographic, and offshore position. We, therefore, can expect a considerable amount of variability in ecological response among platforms to partial removal. For example, because deepwater platforms have fewer species than nearshore platforms, the decrease in diversity with partial removal will be less as one proceeds offshore.

7.2.1. The estimated life span of a reefed platform

How long can a decommissioned steel platform survive in the marine environment before rusting away? Operating steel platforms are protected by sacrificial anodes, often made of aluminum or zinc, which preferentially corrode before steel, thus preserving the jackets' integrity. This cathodic protection lasts as long as the anodes are intact, usually for a number of decades. It is assumed that, once a platform is reefed, there will be no additional replacement of the sacrificial anodes, although the issue has yet to be addressed for platforms off California. While corrosion rates vary in seawater, depending on water temperature, biofouling and other factors, it is estimated that the life span of a cathodically unprotected platform will range from a minimum of 100 to more than 300 years [62–64].

7.3. Alternative 3: Toppling

Toppling would produce artificial reefs with somewhat different fish communities than what has been observed around intact platforms, although there should be a few similarities. First, explosives would greatly reduce the abundance and species richness by killing virtually the entire fish population present at the time of decommissioning (see Section 7.1.1). After toppling, there would be a certain amount of empty habitat suitable for colonization by other species. In this respect, toppled platform structure would function as a newly emplaced artificial reef. Shallow-water habitat and perhaps some midwater habitat would be removed from a toppled platform, decreasing the potential diversity of fish and invertebrates. Depending on the characteristics of the platform, a toppled structure, with twisted and deformed pilings and beams, might have more complexity than an upright one. This might increase the diversity of habitats compared to an intact or partially removed platform jacket. There will be damage to soft-sediment communities and a decrease in air quality generated by support vessels during the removal and toppling process.

7.4. Alternative 4: No removal (leave-in-place)

The no-removal option would allow the platform and shell mound to continue to function as they had before decommissioning. No or minor mortality impacts to resident marine populations would occur.

A no-removal option may involve using the remaining platform structure for another purpose, such as aquaculture. These new activities will also impact the marine environment.

7.5. Resource management options associated with decommissioning

A number of other management options exist relating to platform decommissioning. We discuss two of these options below.

7.5.1. Habitat enhancement of reefed platform structure

The California Department of Fish and Game has issued guidelines for rigs-to-reef projects that call for enhancing the remaining structure using quarry rocks or other material. Adding such material would increase the variety of habitats and therefore an increase in the species richness would almost certainly follow. The degree of response will depend on type of habitat enhancement and has not been examined.

7.5.2. Marine protected areas

To a certain extent, some platforms in the Santa Barbara Channel region currently act as de facto marine protected areas, especially for deep benthic habitats [65]. Fishing pressure around many of these platforms is relatively low because (1) some platforms are relatively far from harbors and thus from fishing vessels, (2) four platforms (Irene, Hidalgo, Harvest, and Hermosa) are located in waters that are extremely rough for much of the year, (3) it is difficult to fish near operating platforms as tying up to these structures is discouraged by platform operators, and (4) strong offshore currents make it difficult to deploy and retrieve fishing gear from the seafloor.

Ecological consequences discussed in previous sections assume that very little fishing would occur around any reefed platform. If fishing is allowed or promoted at reefed platforms, some platforms that would potentially produce fishes could turn into aggregation devices, imparting an early death to many fishes whose populations are already over-exploited. Clearly, many reefed platforms would be a target for recreational anglers or commercial fishermen because platforms often host sizable local populations of exploited fish species. This pattern is not limited to the Southern California Bight. In Florida waters, Shinn and Wicklund [66] suggest that observed patterns of large fishes at reefed Tenneco platforms may be in part determined by patterns of fishing activity.

7.6. Decommissioning alternatives in relation to NOAA fisheries

Instances where explosives are used to remove or topple a platform may compromise fishery-rebuilding programs. Cowcod (*Sebastes levis*) provides one example. This species has been declared overfished by the National Marine Fisheries Service and is the subject of a federal rebuilding plan. The Pacific Fisheries Management Council has approved a cowcod rebuilding plan that limits fishery impacts to 1%/year (about 2.4 metric tons for 2001), as part of a 95-year rebuilding period, and the use of spatial closures south of Pt. Conception to reduce bycatch mortality. Observations by Love et al. [48] record that Platform Gail has the highest density of adult cowcod of any natural or artificial structure surveyed. We can make an estimate of the number of cowcod at the bottom of Gail by multiplying the density of cowcod observed by the area of the platform's footprint (the area underneath the platform). For instance, in the last 2 years of the survey, 1999 and 2000, observed cowcod densities were 0.015 and 0.0183 fish/m^2, respectively. As Gail's footprint is 5327 m^2 [49], extrapolation for 1999 and 2000 gives estimates of 79 and 97 individuals, respectively. This conservative estimate does not include juveniles, we have observed living on the shell mound or on the adjacent pipeline. The current rebuilding plan calls for both a quota on commercial and recreational fisheries combined of 2.4 metric tons, equal to about 600 fish.[6] Assuming that Platform Gail has 75 or more cowcod living under it, and if, as seems likely from all known research, explosives used to remove or topple a platform removal will kill them all, that loss may be sufficiently large to complicate the rebuilding plan (see footnote 6).

8. Conclusions

We reviewed the political and ecological issues surrounding oil platform decommissioning in the Southern California Bight. The overarching conclusion from ecological studies is that decisions regarding decommissioning alternatives should be made on a case-by-case basis. We now suggest future directions regarding environmental issues in two areas: science and management.

[6] Thomas Barnes, pers. comm., California Department of Fish and Game, La Jolla, CA.

Scientific needs. Multiple studies have identified the following research needs: assessment of quality of platforms as reef habitat (“comparative ecological performance”), estimation of regional impacts of decommissioning alternatives to marine populations, and determination of biological effects of any residual contaminants on local marine populations. Ideally, experimental manipulation of platform structure would give managers the best information. Post-decommissioning monitoring is necessary in order to ground-truth initial predictions about ecological consequences, and to improve the information base for future decisions.

Management needs. Because the decommissioning process is complex and because it will be impossible to satisfy all stakeholder groups, regulatory agencies must rank their priorities. Regarding environmental issues, an easy first step is to identify any potential “deal-breakers”, say a large negative impact to an endangered species, associated with a particular decommissioning alternative. Policy statements too vague to be useful are those that require artificial habitat to “enhance marine species or produce net benefits to the environment” [67], because benefits for one marine species will naturally be adverse for its competitor. Likewise, you cannot simultaneously promote both reef and mud bottom environments, as one excludes the other.

Extensive surveys have shown that considerable numbers of economically important fishes and invertebrates reside near oil platforms, the structure often acting as refugia for spawners and nurseries for juveniles. Thus, NOAA Fisheries should incorporate the ecological consequences of a selected decommissioning alternative, either the protection or destruction of these species, as part of their overall management strategy. This is particularly important for those species subject to federal fishery-rebuilding plans. Post-decommissioning monitoring for any reefing option will encourage adaptive management of marine resources. Fishing greatly affects the ecological outcome of decommissioning alternatives. Therefore, managers should explicitly state whether reefing alternatives will be designated as marine protected areas. Finally, to increase the efficiency of ecological studies, managers should provide to researchers a list of species-of-interest and a statement regarding the scale at which decommissioning alternatives will be assessed (local or regional).

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