Bull Mar Sci. 95(4):463–476. 2019
https://doi.org/10.5343/bms.2019.0043

introduction

Fishes and invertebrates of oil and gas platforms off California: an introduction and summary

Milton S Love

Marine Science Institute, University of California, Santa Barbara, California 93106.

Email: <love@lifesci.ucsb.edu>.

ABSTRACT.—This paper serves as an introduction to a symposium on the role that California oil and gas platforms serve as habitats for fishes and invertebrates. As of 2019, there are 27 platforms in state and federal waters off California, and the decommissioning of some of these platforms is imminent. Thus, consideration of whether to completely remove a platform or cut it off at some depth below the sea surface and retain the submerged portion as a reef is a decision that will occur in the near future. The objectives of the 10 papers in this dedicated issue of the *Bulletin of Marine Science* are to: (1) increase scientific understanding of the inter- and intrarelationships of fish and invertebrate populations at offshore oil and gas platforms and natural reefs within the Southern California Bight; (2) determine the extent of influence of platform assemblages on southern California and the Pacific coast populations of fishes and invertebrates; and (3) synthesize relevant reports, existing peer-reviewed literature, and new data analyses into a single peer-reviewed reference. This introductory paper contains a synopsis of all extant California platforms including information on: (1) the original operator, (2) the current operator of records, (3) the date the platform was installed, (4) the first production date, (5) the platform's distance from shore [including whether it is state or outer continental shelf (OCS) waters], (6) the bottom depth of the platform, (7) the number of well slots, (8) the number of conductors, (9) what the platform produces (oil and/or gas), (10) the platform jacket dimensions [generally at the seafloor (bottom)], (11) the platform's footprint, (12) the midwater surface area, (13) the total removal weight, (14) the platform location, (15) the shell mound size, (16) the shell mound volume, (17) the shell mound height, (18) the center of the shell mound location, and (19) the bottom slope. In addition, we present an overview of all previous research on the biology and ecology of California platform organisms.

Fishes and invertebrates of oil and gas platforms off California

Date Submitted: 21 March, 2019.
Date Accepted: 17 May, 2019.

With the construction of the first offshore oil and gas platforms off California in 1958, the ecology and assemblages of organisms living in association with these platforms has been of continuing interest. Beginning in 1958, state—and later federal—agencies invested both time and funds to conduct research on fishes and invertebrates

living in association with California platforms. In particular, the federal government, under the auspices of the Minerals Management Service [then the Bureau of Ocean Energy Management (BOEM)], has directed substantial resources into this research based on BOEM's mandate, summarized as "BOEM's Environmental Studies Program [began in 1973] develops, funds, and manages rigorous scientific research specifically to inform policy decisions on the development of energy and mineral resources on the Outer Continental Shelf (OCS). Research covers physical oceanography, atmospheric sciences, biology, protected species, social sciences and economics, submerged cultural resources and environmental fates and effects. Mandated by Section 20 of the Outer Continental Shelf Lands Act, the Environmental Studies Program is an indispensable requirement informing BOEM's decisions on offshore oil and gas, offshore renewable energy, and the marine minerals program for coastal restoration" (*see* https://www.boem.gov/Science-Informed-Decisions/).

This interest was given a greater urgency when, in 2010, Chairman of the State Assembly, John Perez, introduced Assembly Bill (AB) 2503. AB 2503 passed both houses by significant margins and then Governor Arnold Schwarzenegger signed it into law as the California Marine Resources Legacy Act (MRLA). MRLA establishes state policy to allow, on a case-by-case basis, "Rigs to Reefs," the partial decommissioning of offshore oil and gas platforms with the remaining submerged support structure staying in place and enduring as part of the California Artificial Reef Program. MRLA recognizes the multijurisdictional nature of platform decommissioning and the need for a viable Rigs to Reefs program to utilize the established expertise and authority of different state entities. With the passage of the MRLA, the State of California will allow consideration of the partial removal of decommissioned offshore oil platforms as an alternative to complete removal if specified criteria are met. The bill specifically requires an analysis and proof of a net environmental benefit to fisheries production by the California Ocean Science Trust. It also expands the scope of requirements for platform operators to share savings from partial rather than full platform removal with the state for marine conservation programs with savings deposited in an endowment (the California Endowment for Marine Preservation) whose moneys are to be used to the benefit of coastal marine resources (California Marine Resources Legacy Act 2010, Scarborough Bull and Love 2019).

The removal of oil and gas platforms offshore California is imminent. Consideration of whether to completely remove a platform or cut it off at some depth below the sea surface and retain the submerged portion as a reef is no longer a decision that will occur in the distant future. Among the platforms off California, Platform Holly in state waters and platforms Grace and Gail in federal waters are undergoing the initial steps for decommissioning as of 2019. The decommissioning process is expensive, complex, and lengthy. Due to the intricate planning and complex technical challenges that are involved, it is probable that more platforms will soon be considered for decommissioning.

The objectives of the present effort, based on BOEM funding, are to: (1) increase scientific understanding of the inter- and intrarelationships of fish and invertebrate populations at offshore oil and gas platforms and natural reefs within the Southern California Bight; (2) determine the extent of influence of platform assemblages on southern California and the Pacific coast populations of fish and invertebrates; and (3) synthesize relevant reports, existing peer-reviewed literature, and new data analyses into a single peer-reviewed reference.

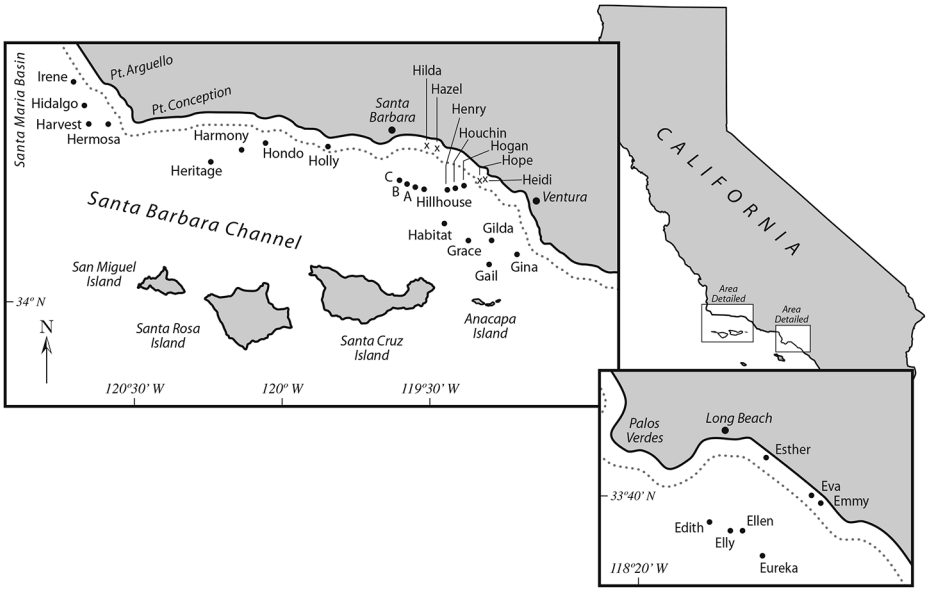

Figure 1. The location of all California oil and gas platforms. Current platforms (2019) are denoted by closed circles; structures that have been removed are denoted by "x".

Toward fulfillment of the broadest objective, a website (http://platformresearch.msi.ucsb.edu) has been established as an annotated repository for worldwide historic and new scientific research directed at organisms and organismal communities associated with offshore oil and gas platforms. The annotated bibliography contains (1) papers in referenced journals, (2) gray literature as research reports, (3) books and book chapters, and (4) theses and dissertations. To date, the repository contains nearly 1000 abstracts and full articles when available.

The purpose of this special *Bulletin of Marine Science* issue is to stand as a peer-reviewed publication that includes review articles and new data analyses, that synthesizes the scientific research focused on the organisms living in association with oil and gas platforms off California, and will act as a source of information for evaluating potential environmental effects of platform structures on regional marine ecology and consequences of their eventual removal. It is hoped that this collected material will help inform the public, policy makers, and regulators about their upcoming decisions. The locations of all California platforms are shown in Figure 1 and platform-specific information on these platforms are listed in Table 1.

An overview of previous research on the biology and ecology of California platform organisms is found in Online Supplementary Material 1.

Table 1. A synopsis of extant (as of 2019) California oil and gas platforms. The platforms are listed from the most northerly (Irene, off Point Arguello) to Emmy, the most southerly, off Huntington Beach. Wherever possible, we have included the following information on each platform: (1) the original operator; (2) the current operator of records; (3) the date the platform was installed; (4) the first production date; (5) the platform's distance from shore [including whether it is state or outer continental shelf (OCS) waters]; (6) the bottom depth of the platform; (7) the number of well slots; (8) the number of conductors; (9) what the platform produces (oil and/or gas); (10) the platform jacket dimensions [generally at the seafloor (bottom)]; (11) the platforms footprint; (12) the midwater surface area; (13) the total removal weight (US tons); (14) the platform location; (15) the shell mound size; (16) the shell mound volume; (17) the shell mound height; (18) the center of the shell mound location; (19) the bottom slope. These data was taken from California Resources Agency (1971), Manago and Williamson (1998), Holbrook et al. (2000), Sea Surveyor Inc. (2003), Love et al. (2003), Claisse et al. (2014), and TSB Offshore Inc. (2015). Note that the estimated platform removal weights include jacket, piles, conductors, and deck (TSB Offshore Inc. 2015).

Platform	Original operator	Current operator of record	Location	Distance from shore	Water depth	Date installed	Number of well slots	Number of conductors	Produces	Platform jacket dimensions	Total removal weight	Shell mound
A	Union Oil	DCOR	34°19′N, 119°36′W	9.3 km (5.8 mi) (OCS)	57 m (188 ft)	1968, first production: 1969	57	55	Oil and gas	40 × 48 m (133 × 158 ft) (bottom); platform footprint: 1,890 m^2; platform midwater surface area: 20,996 m^2	4,896	Size (ft) 140 × 260; volume (yds^3) 7,260; height (ft) 20; center location: centered; bottom slope (%) 1.02
B	Union Oil	DCOR	34°19′N, 119°37′W	9.2 km (5.7 mi) (OCS)	58 m (190 ft)	1968; first production: 1969	63	57	Oil and gas	40 × 48 m (133 × 158 ft) (bottom); platform footprint: 1,979 m^2; platform midwater surface area: 20,804 m^2	4,959	Size 160 × 210; volume (yds^3) 8,590; height (ft) 18; center location: centered; bottom slope (%) 1.03
C	Union Oil	DCOR	34°19′N, 119°37′W	9.2 km (5.7 mi) (OCS)	58 m (192 ft)	1977; first production: 1977	60	43	Oil and gas	40 × 48 m (133 × 158 ft) (bottom); platform footprint: 1,920 m^2	5,718	Size (ft) 160 × 235; volume (yds^3) 4,590; height (ft) 13; center location: southwest; bottom slope (%) 1.14
Edith	Standard Oil	DCOR	33°35′N, 118°08′W	13.7 km (8.5 mi) (OCS)	49 m (161 ft)	1983; first production: 1984	72	23	Oil and gas	58 × 50 m (190 × 165 ft) (bottom); platform footprint: 2,590 m^2; platform base surface area: 846 m^2; platform midwater surface area: 16,360 m^2	8,556	Unknown
Ellen	Shell Oil	Beta Operating Company	33°34′N, 118°07′W	13.8 km (8.6 mi) (OCS)	80 m (265 ft)	1980; first production: 1981	80	63	Oil and gas	45 × 56 m (147 × 186 ft) (bottom); platform footprint: 2,511 m^2	11,665	Unknown
Elly	Shell Oil	Beta Operating Company	33°35′N, 118°07′W	13.8 km (8.6 mi) (OCS)	77 m (255 ft)	1980	NA	NA	Processing facility for platforms Ellen and Eureka	48 × 61 m (159 × 202 ft) (bottom); platform footprint: 2,949 m^2	9,400	Unknown

Table 1. *Continued.*

Platform	Original operator	Current operator of record	Location	Distance from shore	Water depth	Date installed	Number of well slots	Number of conductors	Produces	Platform jacket dimensions	Total removal weight	Shell mound
Emmy	Signal Oil and Gas	California Resources Corporation	33°39′N, 118°02′W	1.9 km (1.2 mi) (state)	14 m (47 ft)	1963; first production: 1963	53	NA	Oil and gas	Unknown	Unknown	Unknown
Esther	Chevron	DCOR	NA	2.4 km (1.5 mi) (state)	9 m (30 ft)	1990	64	NA	Oil and gas	Unknown	Unknown	Unknown
Eureka	Shell Oil	Beta Operating Company	33°33′N, 118°06′W	14.5 km (9.0 mi) (OCS)	212 m (700 ft)	1984; first production: 1985	60	NA	Oil and gas	54 × 85 m (179 × 282 ft) (bottom); platform footprint: 4,635 m^2	33,377	Unknown
Eva	Union Oil	DCOR	33°39′N, 118°03′W	2.9 km (1.8 mi) (state)	17 m (57 ft)	1964; first production: 1966	39	NA	Oil and gas	Unknown	Unknown	Unknown
Gail	Standard Oil	Venoco	34°07′N, 119°24′W	15.9 km (9.9 mi) (OCS)	224 m (739 ft)	1987; first production: 1988	36	27	Oil and gas	21 × 52 m (70 × 170 ft) (surface), 21 × 52 m (70 × 170 ft) (bottom); platform footprint 5,390 m^2; platform base surface area: 1,675 m^2; platform midwater surface area: 104,752 m^2	37,057	Four small scattered small mounds; volume (yds^3) <500; height (ft) 3; center location; bottom slope (%) 3.6
Gilda	Union Oil	DCOR	34°10′N, 119°25′W	14.1 km (8.8 mi) (OCS)	62 m (205 ft)	1981; first production: 1981	96	64	Oil and gas	45 × 52 m (150 × 170 ft) (bottom); platform footprint: 2,081 m^2; platform base surface area: 862 m^2; platform midwater surface area: 18,626 m^2	11,293	Size (ft) 220 × 285. Shell mound volume (yds^3) 7,370; height (ft) 18; center location: north side; bottom slope (%) 1.1.
Gina	Union Oil	DCOR	34°07′N, 119°16′W	6.0 km (3.7 mi) (OCS)	29 m (95 ft)	1980; first production: 1982	15	12	Oil and gas	28 × 20 m (94 × 65 ft) (bottom); shell mound: 4 m (13 ft) high, oval, 45 × 64 m (150 × 210 ft), oriented in a northwest-southeast direction; platform footprint: 561 m^2	1,380	Size (ft) 150 × 210; volume (yds^3) 4,200; height (ft) 13; center location: north side; bottom slope (%) 1.01

Table 1. *Continued.*

Platform	Original operator	Current operator of record	Location	Distance from shore	Water depth	Date installed	Number of well slots	Number of conductors	Produces	Platform jacket dimensions	Total removal weight	Shell mound
Grace	Standard Oil	Venoco	34°10′N, 119°28′W	16.9 km (10.5 mi) (OCS)	96 m (318 ft)	1979; first production: 1980	48	36	Oil and gas	27 × 44 m (90 × 145 ft) (surface), 48 × 65 m (158 × 213 ft); size of shell mound: 4 m(13 ft) high, oval, 61 × 118 m (200 × 390 ft), oriented in a northwest-southeast direction; platform footprint: 3,004 m^2; platform base surface area; 777 m^2; platform midwater surface area: 25,068 m^2	13,074	Size (ft) 200 × 390; volume (yds^3) 5,500; height (ft) 13; center location: northwest side; bottom slope (%) 0.38
Habitat	Texaco	DCOR	34°17′N, 119°35′W	12.6 km (7.8 mi) (OCS)	88 m (290 ft)	1981; first production: 1993	24	20	Gas	60 × 38 m (199 × 125 ft) (bottom); platform footprint: 2,242 m^2; platform midwater surface area: 2,242 m^2	9,611	Size (ft) 250 diameter; volume (yds^3) 6,840; height (ft) 19; center location: centered; bottom slope (%) 0.4
Harmony	Exxon	ExxonMobil	34°22′N, 120°10′W	10.3 km (6.4 mi) (OCS)	363 m (1,198 ft)	1989; first production: 1993	60	52	Oil and gas	91 × 117 m (300 × 385 ft) (bottom); platform footprint: 10,606 m^2	86,513	Unknown
Harvest	Texaco	Freeport McMoRan Oil & Gas	34°28′N, 120°40′W	10.8 km (6.7 mi) (OCS)	202 m (662 ft)	1985; first production: 1991	50	25	Oil and gas	61 × 97 m (200 × 319 ft) (bottom); platform footprint: 5,890 m^2; platform base surface area: 1,544 m^2; platform midwater surface area: 77,577 m^2	35,150	Unknown
Henry	NA	DCOR	34°19′N, 119°33′W	6.9 km (4.3 mi) (OCS)	52 m (173 ft)	1979; first production: 1980	24	24	Oil and gas	45 × 33 m (149 × 110 ft) (bottom); size of shell mound: 9 m (19 ft) high, circular and 76 m (250 ft) in diameter; platform footprint: 1,505 m^2	4,006	Size (ft) 250 diameter; volume (yds^3) 7,200; height (ft) 19; center location: centered; bottom slope (%) 0.67
Heritage	Exxon	ExxonMobil	34°21′N, 120°16′W	13.2 km (8.2 mi) (OCS)	326 m (1,075 ft)	1989; first production: 1993	60	49	Oil and gas	Unknown	69,192	Unknown

Table 1. *Continued.*

Platform	Original operator	Current operator of record	Location	Distance from shore	Water depth	Date installed	Number of well slots	Number of conductors	Produces	Platform jacket dimensions	Total removal weight	Shell mound
Hermosa	Chevron	Freeport McMoRan Oil & Gas	34°27′N, 120°38′W	10.9 km (6.8 mi) (OCS)	179 m (587 ft)	1985; first production: 1991	48	16	Oil and gas	61 × 85 m (200 × 280 ft) (bottom); platform footprint: 5,203 m^2; platform base surface area: 1,319 m^2; platform midwater surface area: 83,784 m^2	30,868	Size (ft) two mounds: 30 × 60 and 20 diameter; volume (yds^3) <500; height (ft) 2; center location; bottom slope (%) 5
Hidalgo	Chevron	Freeport McMoRan Oil & Gas	34°29′N, 120°42′W	9.5 km (5.9 mi) (OCS)	129 m (423 ft)	1986; first production: 1991	56	14	Oil and gas	78 × 53 m (257 × 176 ft) (bottom): platform footprint: 4,333 m^2; platform base surface area: 1,662 m^2; platform midwater surface area: 71,629 m^2	23,384	Size (ft) small and scattered; volume (yds^3) <500; height (ft) <2; center location; bottom slope (%) 4.3
Hillhouse	Sun Oil	DCOR	34°19′N, 119°36′W	8.9 km (5.5 mi) (OCS)	58 m (190 ft)	1969; first production: 1970	60	52	Oil and gas	49 × 40 m (163 × 133 ft) (bottom); platform footprint: 2,014 m^2	5,834	Size (ft) 180 × 270; volume (yds^3) 6,800; height (ft) 22; center location: western side; bottom slope (%) 0.88
Hogan	Phillips Petroleum/ Continental Oil/Cities Services Oil	Pacific Offshore Operators	34°20′N, 119°32′W	6.0 km (3.7 mi) (OCS)	47 m (154 ft)	1967; first production: 1968	66	39	Oil and gas	38 × 38 m (125 × 125 ft) (bottom); platform footprint: 1,444 m^2	5,098	Size (ft) 260 diameter; volume (yds^3) 12,500; height (ft) 26; center location: western side; bottom slope (%) 0.33
Holly	Atlantic Richfield	Quitclaimed by Venoco to the California State Lands Commission	34°22′N, 119°52′W	2.9 km (1.8 mi) (state)	60 m (197 ft)	1966; first production: 1966	30	NA	Oil and gas	18 × 30 m (60 × 100 ft) (surface); platform jacket dimensions: 36 × 48 m (119 × 158 ft) (bottom); platform footprint: 1,728 m^2	NA	Unknown
Hondo	Exxon	ExxonMobil	34°23′N, 120°07′W	8.2 km (5.1 mi) (OCS)	255 m (842 ft)	1976; first production: 1981	28	28	Oil and gas	68 × 68 m (225 × 225 ft) (bottom); platform footprint: 4,649 m^2	29,478	Size (ft) three mounds: 40 × 170, 60 × 130, 50 × 100; volume (yds^3)1,500; height (ft) 9; center location; bottom slope (%) 5.6

Table 1. *Continued.*

Platform	Original operator	Current operator of record	Location	Distance from shore	Water depth	Date installed	Number of well slots	Number of conductors	Produces	Platform jacket dimensions	Total removal weight	Shell mound
Houchin	Phillips Petroleum/ Continental Oil/Cities Services Oil	Pacific Offshore Operators	34°20′N, 119°33′W	6.6 km (4.1 mi) (OCS)	49 m (163 ft)	1968; first production: 1969	60	35	Oil and gas	38 × 38 m (125 × 125 ft) (bottom); platform footprint: 1,444 m^2	5,615	6 m (21 ft) high, circular and 85 m (280 ft) in diameter; size (ft) 280 diameter; volume (yds^3) 10,900; height (ft) 21; center location: centered; bottom slope (%) 0.38
Irene	Union	Freeport McMoRan Oil & Gas	34°36.37′N, 120°43.45′W	7.6 km (4.7 mi) (OCS)	72 m (236 ft)	1985; first production: 1987	72	26	Oil and gas	37 × 56 m (155 × 185 ft) (bottom); platform footprint: 2,664 m^2; platform base surface area: 621 m^2; platform midwater surface area: 14,243 m^2	8,762	Size (ft) 215 diameter; volume (yds^3) 3,720; height (ft) 9; center location; western side; bottom slope (%) 0.71

The papers in this special issue cover a broad range of topics:

Claisse JT, Love MS, Meyer-Gutbrod EL, Williams CM, Pondella DJ II. 2019. Fishes with high reproductive output potential on California oil and gas platforms.

One possible metric when assessing the potential "value" of a platform is the potential reproductive output of the fishes inhabiting these structures. In this study, the reproductive output (eggs m^{-2}) of 17 focal fish species (15 of which were rockfishes, genus *Sebastes*) were compared among 23 oil and gas platforms and 70 natural reefs. While the reproductive potential for almost all focal species was zero at the majority of surveyed sites, regardless of whether the habitat was on a platform or a natural reef, the highest reproductive output values were observed on platform habitats for all but two of the focal species.

Love MS, Claisse JT, Roeper A. 2019a. An analysis of the fish assemblages around 23 oil and gas platforms off California with comparisons with natural habitats.

This study gives an overview of the fish assemblages at those platforms and reefs sited in 49–363 m off California. It is based on manned submersible surveys conducted at 23 oil and gas platforms and 70 natural reefs in southern and central California between 1995 and 2013. Greater than 90% of the fishes observed were rockfishes (genus *Sebastes*). Fish densities were highest around platform bases, followed by platform midwaters, platform shell mounds, and natural habitats. Habitat depth had the most influence on assemblages; both habitat type and geographic location were also important. Generally, around platforms, fishes in the midwater assemblage formed one assemblage, while those of the bases and adjacent shell mounds formed a second. Throughout all of the habitats, most fishes were small (20 cm long or less) and many were juveniles. At all four habitats, most juveniles inhabited depths of ≤150 m. On average, densities of young-of-the-year fishes were highest in platform midwaters and bases and somewhat lower over natural habitats.

Love MS, Kui L, Claisse JT. 2019b. The role of jacket complexity in structuring fish assemblages in the midwaters of two California oil and gas platforms.

Off California, habitat complexity is one of the drivers that helps characterize fish species assemblages at both platforms and natural reefs. This study demonstrates that, even when a series of environmental parameters are held constant, the fish assemblages at two platforms differ primarily because of the differences in the complexity of their jackets. The study compared the assemblages throughout the water column of platforms Gail and Eureka. The jacket of Gail is relatively simple, with rounded crossbeams and pilings, while that of Eureka is more complex. Compared to Gail, Eureka: (1) exhibited higher densities of all species combined and of most species in common, (2) had more mature individuals of most species, (3) exhibited greater species richness, and (4) had higher densities of species typical of complex high relief habitat.

Love MS, Nishimoto MM, Snook L, Kui L. 2019c. An analysis of the sessile, structure-forming invertebrates living on California oil and gas platforms.

Studies on the invertebrate fauna inhabiting California platforms had previously focused on either the fauna dwelling within the shallowest 30 m of water or on the platform legs, i.e., platform crossbeams in the deeper parts of the jacket had not been surveyed. Using video transects, this study examined the structure-forming sessile invertebrates living on the crossbeams of 23 oil and gas platforms at depths of between 20 and 363 m. At least 15 species or species groups were documented, and the anemone *Metridium farcimen* was by far the most commonly observed taxon. Of the corals, the alcyonacean *Leptogorgia chilensis* and the scleractinian *Desmophyllum pertusum* were the most abundant, while among sponges, an unidentified white vase sponge predominated. The species richness of these taxa varied among platforms and depth was the most important environmental parameter driving their occurrences.

Meyer-Gutbrod EL, Love MS, Claisse JT, Page HM, Schroeder DM, Miller RJ. 2019a. Decommissioning impacts on biotic assemblages associated with shell mounds beneath southern California offshore oil and gas platforms.

Shell mounds, composed primarily of mussel shells dislodged from shallow parts of jackets, are found in varying amounts below California oil and gas platforms. It is likely that part of the decommissioning planning for any platform will be an assessment of the ecological value of these shell mounds. In this study, the biomass, density, species composition, and similarity of fish assemblages at 22 platforms were documented. There was a wide variation in fish density, species composition, and the areal extent of the mounds among platforms. Bottom depth was the most important factor in structuring shell mound fish assemblages.

Meyer-Gutbrod EL, Kui L, Nishimoto MM, Love MS, Schroeder DM, Miller RJ. 2019b. Fish densities associated with structural elements of oil and gas platforms in southern California.

Studies have demonstrated that, during some years and at some platforms, high densities of both young-of-the-year and older fishes inhabit the relatively shallow parts of California platforms. Are all parts of the platform jacket equally attractive to these fishes? This study examined fish densities at three depths with scuba range (shallow <16.8 m, midwater, and deep >26 m) at 11 platforms in relation to platform exterior or interiors, and in relation to horizontal or vertical beams. Fish densities tended to be greatest along the horizontal interior beam compared to any exterior beams, implying that habitat position, rather than orientation or other small-scale characteristics, may be most important.

Mireles C, Martin CJB, Lowe CG. 2019. Site fidelity, vertical movement, and habitat use of nearshore reef fishes on offshore petroleum platforms in southern California.

Fish movements, both vertical along the platform jacket and away from platforms, are the subject of this study, which focused on four reef-associated species: *Scorpaenichthys marmoratus*, *Semicossyphus pulcher*, *Sebastes rastrelliger*, and *Sebastes atrovirens*. A majority of the individuals remained at their platforms at the end of 1.5 yrs. All species shifted depths seasonally, although all often inhabited the

shallowest 24 m of the structure. The paper posits that platform decommissioning might remove this heavily-utilized shallow habitat.

Nishimoto MM, Simons RD, Love MS. 2019a. Offshore oil production platforms as potential sources of larvae to coastal shelf regions off southern California.

It is likely that at many platforms there is substantial production of fish eggs and larvae. But where are these reproductive products carried? This study used the Regional Ocean Modeling System to model the dispersal and ultimate destination of fish larvae (here in the form of passively transported particles) from three platforms, A and Gail in the Santa Barbara Channel, and Eureka, southwards farther into the Southern California Bight. The study demonstrated that (1) larvae produced by fishes at all three platforms tended to travel northwards, although this varied somewhat by season; (2) larvae were often entrained or partially entrained in the Santa Barbara Channel; and (3) these patterns were consistent across years.

Nishimoto MM, Washburn L, Love MS, Schroeder DM, Emery BM, Kui L. 2019b. Timing of juvenile fish settlement at offshore oil platforms coincides with water mass advection into the Santa Barbara Channel, California.

While California platforms experience substantial recruitment of young-of-the-year fishes during at least some years, the origin of these young fishes is unclear. To investigate this, frequent scuba-based fish surveys and continuous oceanographic monitoring was conducted around two platforms, Gail and Gilda, in the Santa Barbara Channel during the primary recruitment season (May–August) of 2004. Most of the recruits were either rockfishes (genus *Sebastes*) or *Chromis punctipinnis*. Almost all of the rockfishes recruited to the deepest part (26–31 m) of the survey depths, while most *C. punctipinnis* recruited in shallower waters. Based on an analysis of water mass dynamics during the recruitment pulses, it was demonstrated that larvae came from south of the Santa Barbara Channel (deep into the Southern California Bight) rather than from central California.

Page HM, Zaleski SF, Miller RJ, Dugan JE, Schroeder DM, Doheny B. 2019. Regional patterns in shallow water invertebrate assemblages on offshore oil platforms along the Pacific continental shelf.

This paper summarizes both published and more recent data to examine possible patterns in the invertebrate assemblage inhabiting the shallower water (≤18 m depth) parts of jackets of 23 offshore oil and gas platforms. In general, mussels and other encrusting bivalves, barnacles, sponges, anemones, and bryozoans dominated all of the platforms. There were regional differences (reflective of sea surface temperatures) in assemblages. These were partly attributable to the relative abundances of the anemones, *Metridium senile* and *Corynactis californica,* and the bryozoan, *Watersipora subatra*. Within each region, platform assemblages tended to be similar; however, each platform assemblage was unique. This even extended to significant differences even between platforms Ellen and Elly, despite these two structures being next to each other and connected by a causeway.

The above studies, and those noted in Online Supplementary Material 1, demonstrate that the platforms off California harbor a diverse assemblage of both fishes

and invertebrates. These assemblages are primarily structured by water depth, platform geography, platform jacket complexity, and position on or around the platform relative to the sea floor. In general terms, and with some overlap, assemblages can be characterized as those occupying platform midwaters, bottoms, or shell mounds (these formed primarily by mussels and associated invertebrates dislodged during platform cleaning or during storms).

In relatively shallow waters along each platform, the jackets are covered by mussels and sea anemones, and by such associated taxa as sea stars, barnacles, brittle stars, and rock scallops. Mussels become rarer with depth, essentially disappearing at about 30 m, and are replaced by sea anemones, sponges, and corals. The shell mounds surrounding most platforms (they form diffuse patches around some structures) often harbor substantial densities of such invertebrates as sea anemones, sea stars, crabs, and brittle stars, and may serve as a nursery ground for a variety of invertebrates.

Regarding fishes, midwater assemblages often differ from those at both bottoms and shell mounds, and bottoms and shell mounds tend to harbor similar species. Most California platforms act as nursery grounds for a range of fishes, primarily rockfishes (genus *Sebastes*), but also including various damselfishes, greenlings, and other taxa. Rockfishes tend to recruit to platforms in waters at least 25 m deep, while some other taxa, such as damselfishes, recruit shallower. Densities of juvenile fishes (particularly rockfishes) around most platforms tend to be higher than those at most natural reefs. In at least some instances, densities of juveniles of some taxa at some platforms are large enough that they may substantially increase the number of adults in the total population. Studies of the movement of fishes at platforms support the hypothesis that many individuals remain at a specific platform for extended periods and that some will return to a home platform after being displaced.

If juvenile fishes tend to characterize the platform midwaters, the bases (and to a certain extent the shell mounds) tend to harbor larger individuals. This reflects (1) an ontogenetic shift of juveniles from shallow midwaters to deeper bases and shell mounds; and (2) the adaptations of many reef species to living in complex habitats as adults, which are habitats present at platform bases but usually absent from midwaters. Densities of larger individuals of at least some economically important species, such as bocaccio and cowcod, tend to be higher at some platforms than at many or all natural reefs, at least partially reflecting the relatively low fishing pressure at most California platforms. This density disparity means that reproductive output of some species may be substantially higher at some platforms than at all or most natural reefs.

Platform architecture (for instance the occurrence of undercut bottom cross beams or the placement of flanges on cross beams) affects the densities of many platform fish taxa. In general, the more complex that architecture, the higher the density of (1) large fishes or (2) species that are adapted to living in caves and crevices. Location around a platform also influences fish densities. As an example, juvenile fishes tend to be found along horizontal cross beams spanning the jacket interior, rather than any structures along the jacket exterior.

Overall, while it is clear that there are great similarities in the fish and invertebrate assemblages among California platforms, the substantial variability in these assemblages make any generalization among platforms problematic. Rather, any

assessments of the biota of a platform made during the decommissioning process will require each structure be assessed independently.

Acknowledgments

This research was funded by the US Department of the Interior, Bureau of Ocean Energy Management (BOEM) Environmental Studies Program (ESP) through Award M15AC00014, and by the National Aeronautics and Space Administration Biodiversity and Ecological Forecasting program (NASA Grant NNX14AR62A) and the BOEM ESP (Award M15AC00006) in support of the Santa Barbara Channel Biodiversity Observation Network.

Literature Cited

California Resources Agency. 1971. The offshore petroleum resource. California Department of Conservation.

Claisse JT, Love MS, Meyer-Gutbrod EL, Williams CM, Pondella DJ II. 2019. Fishes with high reproductive output potential on California oil and gas platforms. Bull Mar Sci. 95(4):515–534. https://doi.org/10.5343/bms.2019.0016

Claisse JT, Pondella DJ II, Love MS, Zahn LA, Williams CM, Williams JP, Bull AS. 2014. Oil platforms off California are among the most productive marine fish habitats globally. Proc Natl Acad Sci USA. 111:15462–15467. https://doi.org/10.1073/pnas.1411477111

Holbrook SJ, Ambrose RF, Botsford L, Carr MH, Raimondi PT, Tegner MJ. 2000. Ecological issues related to decommissioning of California's offshore production platforms. Report to the University of California Marine Council by the Select Scientific Advisory Committee on Decommissioning, University of California.

Love MS, Schroeder DM, Nishimoto MM. 2003. The ecological role of oil and gas production platforms and natural outcrops on fishes in southern and central California: a synthesis of information. US Dep Int, US Geol Survey, Biol Res Div, Seattle, Washington, 98104, OCS Study MMS 2003-032.

Love MS, Claisse JT, Roeper A. 2019. An analysis of the fish assemblages around 23 oil and gas platforms off California with comparisons with natural habitats. Bull Mar Sci. 95(4):477–514. https://doi.org/10.5343/bms.2018.0061

Love MS, Kui L, Claisse JT. 2019. The role of jacket complexity in structuring fish assemblages in the midwaters of two California oil and gas platforms. Bull Mar Sci. 95(4):597–615. https://doi.org/10.5343/bms.2017.1131

Love MS, Nishimoto MM, Snook L, Kui L. 2019. An analysis of the sessile, structure-forming invertebrates living on California oil and gas platforms. Bull Mar Sci. 95(4):583–596. https://doi.org/10.5343/bms.2017.1042

Manago F, Williamson B, editors. 1998. Proceedings: public workshop, decommissioning and removal of oil and gas facilities offshore California: recent experiences and future deepwater challenges, September 1997. MMS OCS Study 90-0023.

Meyer-Gutbrod EL, Love MS, Claisse JT, Page HM, Schroeder DM, Miller RJ. Decommissioning impacts on biotic assemblages associated with shell mounds beneath southern California offshore oil and gas platforms. Bull Mar Sci. 95(4):683–701. https://doi.org/10.5343/bms.2018.0077

Meyer-Gutbrod EL, Kui L, Nishimoto MM, Love MS, Schroeder DM, Miller RJ. 2019. Fish densities associated with structural elements of oil and gas platforms in southern California. Bull Mar Sci. 95(4):639–656. https://doi.org/10.5343/bms.2018.0078

Mireles C, Martin CJB, Lowe CG. 2019. Site fidelity, vertical movement, and habitat use of nearshore reef fishes on offshore petroleum platforms in southern California. Bull Mar Sci. 95(4):657–681. https://doi.org/10.5343/bms.2018.0009

Nishimoto MM, Simons RD, Love MS. 2019. Offshore oil production platforms as potential sources of larvae to coastal shelf regions off southern California. Bull Mar Sci. 95(4):535–558. https://doi.org/10.5343/bms.2019.0033

Nishimoto MM, Washburn L, Love MS, Schroeder DM, Emery BM, Kui L. 2019. Timing of juvenile fish settlement at offshore oil platforms coincides with water mass advection into the Santa Barbara Channel, California. Bull Mar Sci. 95(4):559–582. https://doi.org/10.5343/bms.2018.0068

Page HM, Zaleski SF, Miller RJ, Dugan JE, Schroeder DM, Doheny B. 2019. Regional patterns in shallow water invertebrate assemblages on offshore oil platforms along the Pacific continental shelf. Bull Mar Sci. 95(4):617–638. https://doi.org/10.5343/bms.2017.1155

Scarborough Bull A, Love MS. 2019. Worldwide oil and gas platform decommissioning: a review of practices and reefing options. Ocean Coast Manage. 168:274–306. https://doi.org/10.1016/j.ocecoaman.2018.10.024

Sea Surveyor Inc. 2003. Final report. An assessment and physical characterization of shell mounds associated with outer continental shelf platforms located in the Santa Barbra Channel and Santa Maria Basin, California. Prepared for Minerals Management Service by MEC Analytical Systems Inc. and Sea Surveyor, Inc. MMS Contract No. 1435-01-02-CT-85136.

TSB Offshore Inc. 2015. Decommissioning cost update for Pacific OCS region facilities. Final Report. Vol 1. The Woodlands, Texas: TSB Offshore Inc. Project No. 139681.