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A COMPARISON OF THE FISH ASSEMBLAGES ASSOCIATED WITH AN OIL/GAS PIPELINE AND ADJACENT SEAFLOOR IN THE SANTA BARBARA CHANNEL, SOUTHERN CALIFORNIA BIGHT

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ABSTRACT

An oil pipeline and its surrounding seafloor, located in the Santa Barbara Channel, southern California, were surveyed for fishes using a manned research submersible. The parts of the pipeline and seafloor surveyed were situated in waters 95–235 m deep. Some sections of the surveyed pipe were covered with both sessile and motile invertebrates, such as sea anemones (*Metridium* cf. *farcimen*) and sea urchins (*Allocentrotus fragilis*), sea stars (particularly *Hippasteria* cf. *spinosa* and *Stylasterias* cf. *forreri*), basket stars (*Gorgonocephalus eucnemis*), spot prawns (*Pandalus platyceros*), and king crabs (*Paralithodes californiensis*). Based on differences in fish assemblages, four habitats (shallow and deep pipeline and shallow and deep seafloor) were categorized. Fish densities along the shallow portion of the pipeline were about seven times higher than on the adjacent seafloor and densities along the deep pipeline portion were nearly six times that of the deeper seafloor. Along the pipeline, rockfishes comprised 84% of the fishes and included 22 species. Unidentified sanddabs (probably most or all *Citharichthys sordidus*), forming 33.2%, and combfishes (*Zaniolepis frenata* and *Z. latipinnis*), comprising 19% of the total, were most often observed on the seafloor. Most of the fishes living on the pipeline were either juveniles of such larger taxa as blackgill (*Sebastes melanostomus*), flag (*S. rubrivinctus*), and vermilion (*S. miniatus*) rockfishes, cowcod (*S. levis*), and lingcod (*Ophiodon elongatus*), or diminutive species such as halfbanded (*S. semicinctus*) and stripetail (*S. saxicola*) rockfishes, combfishes (*Zaniolepis* spp.), and poachers (Family Agonidae). Higher densities of fishes were often noted in areas of the pipeline that had been undercut. Of particular interest were the relatively high densities of juvenile cowcod along the deeper parts of the pipeline, densities that were far higher than any seen at over 80 natural outcrops and at ten platforms. We suggest that, in the process leading to oil platform and pipeline decommissioning, it is important to understand the role that human-made structure plays as fish habitat.

Oil and gas platforms in southern and central California have finite economic life spans. Many of the structures off California have been in place for over 20 yrs (Love et al., 2003), and it is expected that some of these platforms will be decommissioned in the near future. One of the issues surrounding the decommissioning process involves the role that platforms play as fish habitat. Our research, carried out between 1995 and the present, strongly suggests that platforms, and their adjacent shell mounds, provide considerable hard structure to the marine ecosystem and may be important habitat for a variety of fishes, particularly rockfishes (*Sebastes* spp.) and lingcod (*Ophiodon elongatus*) (Love et al., 1999a,b, 2003).

However, the pipelines that carry oil, gas, and water from platforms to the mainland have been overlooked in most discussions regarding platform decommissioning (Culwell and McCarthy, 1998). And, despite their size (ranging from 10 to 60 cm in outer diameter) and the more than 298 km (185 nmi) of structure they provide in central and southern California (T. Roche, Divecon Inc., pers. comm.), no studies have been conducted on their potential role as fish habitat. In fact, with the exception of one qualitative study regarding fish and invertebrate assemblages on a Santa Monica Bay sewer line located near Los Angeles, California (Allen et al., 1976), there is no literature on the biota that lives on any pipeline off California. To address this data gap, we conducted a pilot study that compared the fish biota living around a southern California oil pipeline with that living on the adjacent seafloor.

Materials and Methods

Study Site.—We surveyed parts of the pipeline and adjacent seafloor located between platforms Gail and Grace and between Grace and the mainland (Fig. 1). Platforms Gail and Grace are situated in the eastern end of the Santa Barbara Channel; Gail stands in 224 m and Grace in 96 m of water and the structures are about 16 km (9.8 nmi) apart. The segment from the mainland to Grace was laid in 1979 and 1980 and that from Grace to Gail during 1987 and 1988. The pipe is 20 cm in diameter, and both sessile and motile invertebrates are associated with much of the structure (Fig. 2a). Particularly prominent are sea anemones (*Metridium* cf. *farcimen*) and sea urchins (*Allocentrotus fragilis*), as well as sea stars (particularly *Hippasteria* cf. *spinosa* and *Stylasterias* cf. *forreri*), basket stars (*Gorgonocephalus eucnemis*), spot prawns (*Pandalus platyceros*), and king crabs (*Paralithodes californiensis*). Along some sections, water motion has undercut the pipeline. Most of the adjacent seafloor is composed of soft, fine-grained sediments. However, near platform Grace our surveys included small areas containing cobblestones and small boulders (as defined in Greene et al., 1999).

Fish Surveys.—The seafloor in the immediate vicinity of both platforms is covered by a thick layer of mussel shells and other invertebrates (Love et al., 2003). Because we were comparing fish assemblages of pipes and adjacent, primarily soft, substrata, and because the shell mounds have their own unique fish assemblages (Love et al., 2003), we began both pipeline and seafloor surveys a minimum of 50 m away from the shell mound. To minimize the potential effect of the pipeline on seafloor fish assemblages, seafloor transects were made a minimum of 50 m away from the pipeline based on our observations that boundary layer effects from the pipelines on fish assemblages appeared to be undetectable within 10 m of the pipeline.

Our survey used the Delta research submersible, a 4.6-m, two-person vessel, operated by Delta Oceanographics of Oxnard, California. Two habitats, the pipeline and the soft sediment seafloor, were surveyed. Each belt transect was 15 min long and occurred about 2 m from the pipeline and, for the seafloor surveys, just above the sediment, while the submarine maintained a speed of about 0.5 kts. Surveys took place in October of 2001 and November of 2002 (Table 1).

Many years of experience along the Pacific Coast have shown that if the Delta is moving at a constant and slow rate of speed, as in these pipeline surveys, there is very little obvious effect on demersal rockfishes, as well as on a number of other benthic groups, such as greenlings, lingcod, and combfishes (Hexagrammidae), poachers (Agonidae), flatfishes (Paralichthyidae and Pleuronectidae), and eelpouts (Zoarcidae) (M. Love, pers. obs.; V. O'Connell, Alaska Department of Fish and Game, per. obs.; M. Yoklavich, NOAA Fisheries, pers. obs.). Certainly, we noticed virtually no movement at all from most of the fishes in this study as the research submersible passed by. Unless hidden in complex substrate, fishes as small as 5 cm in length are readily visible within 2 m of the submersible.

Submersible surveys were conducted during daylight hours. During each transect, a researcher made observations from a viewing port on the starboard side of the submersible. An externally mounted hi-8 mm video camera with associated lights filmed the same viewing fields as seen by the observers. The observer identified, counted, and estimated the lengths of all fishes and verbally recorded those data on the video. All fishes within 2 m of the submarine were counted. Fish lengths were estimated using a pair of parallel lasers mounted on either

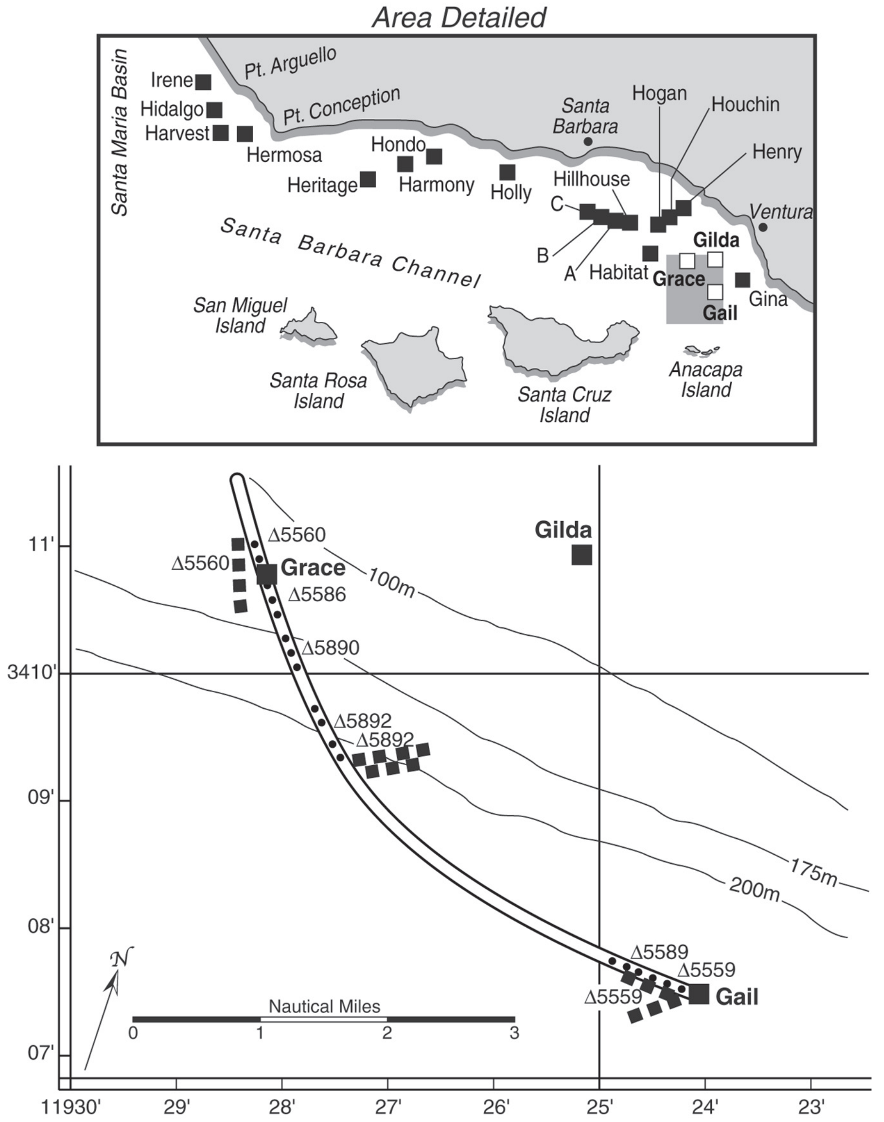


Figure 1. Location of the Gail-Grace pipeline in the Southern California Bight, including survey locations and seafloor isobaths. Pipeline transects are indicated by dots on pipeline, seafloor transects by squares.

side of the external video camera. The projected reference points were 20 cm apart and were visible both to the observer and the video camera. Transect lengths were computed by counting the number of 20 cm laser segments in 15 s subsamples (1 min^{-1}) throughout the transect, calculating speed based on those counts and averaging them over the whole transect, and multiplying that average speed by the transect duration. The 15 s subsamples were made during the first 15 s of each minute of the transect in which the laser points were visible.

An environmental monitoring system aboard the submarine continuously recorded date and time, depth, and altitude of the vessel above the sea floor. The environmental data were overlaid on the original videotape upon completion of each survey. Transect videos were reviewed aboard the research vessel or in the laboratory and observations transcribed into a database. For each fish, we recorded the: 1) species (if known); 2) estimated total length (TL);

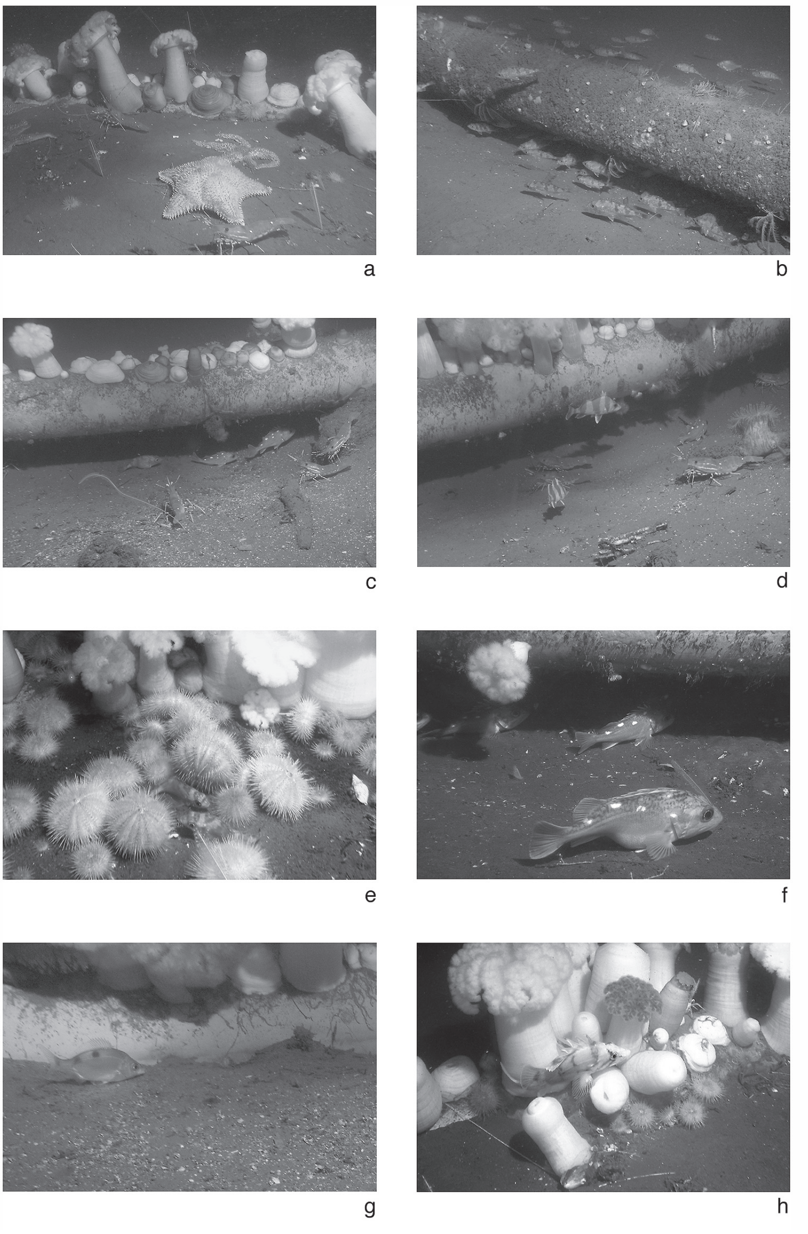


Figure 2. Representative fishes and invertebrates seen along the pipeline: a) sea anemones, *Metridium* cf. *farcimen*, seastars *Hippasteria* cf. *spinosa* and *Stylasterias* cf. *forreri*, and spot prawn (*Pandalus platyceros*); b) halfbanded rockfish; c) greenspotted rockfish; d) flag rockfish; e) stripetail rockfish and sea urchin (*Allocentrotus fragilis*); f) greenblotched rockfish; g) pink seaperch; and h) cowcod.

3) habitat it occupied (e.g., pipe or seafloor); and 4) degree to which the substrate under the pipe was undercut. Values for undercut were: 0, pipe completely buried; 1, pipe showing, but not undercut (pipe more than halfway buried); 2, pipe showing and touching bottom making a closed crevice (more than half of pipe is uncovered but there is no gap between the bottom of the pipe and the substrate); 3, underside of pipe not touching the bottom; and 4, pipe >

0.5 m above bottom (pipe is completely uncovered and the bottom of it is > 0.5 m above the substrate).

Analytical Methods.—The goals of our analyses were to compare species composition, fish density and size, and species richness (the number of species per unit area) between the seafloor and pipeline communities. Fish were identified to the smallest taxonomic unit possible. The number of species in a sample was defined as the total number of actual species identified plus the number of larger taxonomic units with no other species within that unit. We used Wilcoxin nonparametric statistical tests (Hollander and Wolf, 1973) to compare fish density and species richness over environmental factors. In cases where multiple tests were required, adjustments to the size of the test were made using the method of Holm (1979). All work was carried out using the statistical program R (Ihaka and Gentleman, 1996; R-Development Core Team, 2003).

Species communities were analyzed using ordination methods (Jongman et al., 1995). As our main goal was to compare communities over environmental factors, we used constrained correspondence analysis (ter Braak, 1995) to model the species community matrix on the environmental factors of interest. We used a permutation test to determine the statistical significance of variables used to model the community matrix (Legendre and Legendre, 1998). This work was also carried out in R using the community ecology package, vegan, (Oksanen, 2003). R and the package vegan are available from http://www.cran.R-project.org/mirrors.html. To minimize the effect of rare species, we followed the recommendation of ter Braak (1995) and fit the ordination model on the subset of species that were seen at least 20 times (approximately 95% of all observations).

Results

We conducted seven transects along the pipeline (in depths of 98–230 m) and eight over the adjacent seafloor (at 95–235 m) during the years 2001 and 2002 (Table 1). The pipeline survey covered a distance of 2909 m, and the seafloor survey 4612 m. The depth of the transects ranged between 95 and 230 m with natural groupings of 95–138 m and 172–235 m.

We counted 3931 fishes and a minimum of 35 fish species living on or near the pipeline, and 876 fishes, representing at least 29 species, over or on the seafloor (Tables 2, 3). Along the pipeline, rockfishes comprised 84% of the fishes, and included 22 species. Other common species included lingcod (*Ophiodon elongatus*), shortspine combfish (*Zaniolepis frenatus*), pink seaperch (*Zalembius rosaceus*), and unidentified poachers (Agonidae, most probably in the genus *Xeneretmus*). On the seafloor, the 10 species of rockfishes we observed were less important, comprising only 17% of the total. Unidentified sanddabs (probably most or all *Citharichthys sordidus*), forming 33.2%, and combfishes (*Zaniolepis frenata* and *Z. latipinnis*), comprising 19% of the total, were most often observed.

A constrained correspondence analysis (Table 4) delineated four habitat guilds: shallow and deep pipeline and shallow and deep seafloor (Fig. 3). Shallower habitats were more variable than deeper ones. Along the shallower pipeline, among the more characteristic species were halfbanded (*Sebastes semicinctus*) (Fig. 2b), vermilion (*Sebastes miniatus*), greenspotted (*Sebastes chlorostictus*) (Fig. 2c), flag (*Sebastes rubrivinctus*) (Fig. 2d), and squarespot (*Sebastes hopkinsi*) rockfishes, bocaccio (*Sebastes paucispinis*), lingcod, and shortspine combfish. Stripetail (*Sebastes saxicola*) (Fig. 2e), greenblotched (*Sebastes rosenblatti*) (Fig. 2f), blackgill (*Sebastes melanostomus*), and pinkrose (*Sebastes simulator*) rockfishes, pink seaperch (*Zalembius rosaceus*) (Fig. 2g), cowcod (*Sebastes levis*) (Fig. 2h), and poachers characterized the deeper

Table 1. Description of pipeline and seafloor transects, see also Figure 1. Maximum and minimum depths within a survey reflect beginning and ending depths.

Type	Date	Transect	Location	Depth (m)
Pipeline	19 Oct. 2001	1	34°07.46′ 119º24.17′ 34°07.47′ 119°24.60′	230–230
Pipeline	19 Oct. 2001	1	34°10.81′ 119°28.08′ 34°11.17′ 119°27.97′	100–95
Pipeline	25 Oct. 2001	1	33°10.76′ 119°28.12′ 33°10.34′ 119°28.05′	98–115
Pipeline	11 Nov. 2002	1	34°10.30′ 119°28.04′ 34°10.08′ 119°27.98′	115–138
Pipeline	12 Nov. 2002	1	34°09.28′ 119°27.83′ 34°09.52′ 119°27.88′	198–185
		2	34°09.58′ 119°27.89′ 34°09.73′ 119°27.93′	180–172
Seafloor	19 Oct. 2001	1	34°07.47′ 119°24.60′ 34°07.46′ 119°24.17′	235–230
		2	34°07.47′ 119°24.60′ 34°07.43′ 119°24.58′	230–235
Seafloor	19 Oct. 2001	1	34°11.20′ 119°27.99′ 34°10.88′ 119°28.33′	95–100
		2	34°18.81′ 119°28.35′ 34°10.67′ 119°28.39′	100–100
Seafloor	25 Oct. 2001	1	33°10.29′ 119°27.99′ 33°10.74′ 119°27.78′	104–97
Seafloor	12 Nov. 2002	1	34°09.32′ 119°27.32′ 34°09.24′ 119°27.30′	185–190
		2	34°09.23′ 119·27.35′ 34°09.18′ 119°27.66′	190–200
		3	34°09.22′ 119°27.72′ 34°09.26′ 119°27.82′	200–198

pipeline (Table 3, Figs. 4,5). Sanddabs, shortspine combfish, and halfbanded rockfish were most abundant on the shallow seafloor, and sanddabs, shortspine combfish, and eelpouts (such as the bearded eelpout, *Lyconema barbatum*) dominated the seafloor habitats (Table 3, Figs. 4,5).

Compared to the seafloor habitats, overall fish numbers and densities were highest at the two pipeline habitats (Table 3). Fish densities along the shallow portion of the pipeline were about seven times higher than on the adjacent seafloor and densities along the deep pipeline portion were nearly six times that of the deeper seafloor. Based on a Wilcoxin non-parametric test, the number of fish m^{-2} in the pipe habitat was greater ($W = 12$, $n = 23$, $P = 0.001$) than on the seafloor. Within the pipe habitat, areas that were less undercut (undercut values 1 and 2 combined) had fewer fish m^{-2} than did those pipeline lengths that were more undercut (values 3 and 4 combined; $W = 8$, $n = 15$, $P = 0.04$). Similarly, species richness (defined as the number of species/area surveyed) was greater in the pipeline habitat ($W = 13$, $n = 23$, $P = 0.001$) than on the seafloor. Within the pipe habitat, there was no significant difference in the number of species according to the degree of undercut ($W = 19$, $n=15$, $P = 0.5$).

Table 2. Common and scientific names of species observed in this study and the habitats in which they were observed.

Common name	Scientific name	Habitat
Bank rockfish	*Sebastes rufus* (Eigenmann and Eigenmann, 1890)	P, S
Bearded eelpout	*Lyconema barbatum* Gilbert, 1896	S
Blackbelly eelpout	*Lycodes pacificus* Collett, 1879	S
Blackgill rockfish	*Sebastes melanostomus* (Eigenmann and Eigenmann, 1890)	P
Blue rockfish	*Sebastes mystinus* (Jordan and Gilbert, 1881)	P
Bocaccio	*Sebastes paucispinis* Ayres, 1854	P, S
California halibut	*Paralichthys californicus* (Ayres, 1859)	P, S
California smoothtongue	*Leuroglossus stilbius* (Gilbert, 1890)	P, S
Canary rockfish	*Sebastes pinniger* (Gill, 1864)	S
Copper rockfish	*Sebastes caurinus* Richardson, 1845	P, S
Cowcod	*Sebastes levis* (Eigenmann and Eigenmann, 1889)	P, S
Dover sole	*Microstomus pacificus* (Lockington, 1879)	P, S
English sole	*Parophrys vetulus* Girard, 1854	S
Flag rockfish	*Sebastes rubrivinctus* (Jordan and Gilbert, 1880)	P, S
Greenblotched rockfish	*Sebastes rosenblatti* Chen, 1971	P
Greenspotted rockfish	*Sebastes chlorostictus* (Jordan and Gilbert, 1880)	P, S
Greenstriped rockfish	*Sebastes elongatus* Ayres, 1859	P
Halfbanded rockfish	*Sebastes semicinctus* (Gilbert, 1897)	P, S
Hornyhead turbot	*Pleuronichthys verticalis* Jordan and Gilbert, 1880	S
Kelp greenling	*Hexagrammos decagrammus* (Pallas, 1810)	P
Lingcod	*Ophiodon elongatus* Girard, 1854	P, S
Longspine combfish	*Zaniolepis latipinnis* Girard, 1858	P, S
Olive rockfish	*Sebastes serranoides* (Eigenmann and Eigenmann, 1890)	P
Pacific hake	*Merluccius productus* (Ayres, 1855)	P, S
Pacific sanddab	*Citharichthys sordidus* (Girard, 1854)	S
Painted greenling	*Oxylebius pictus* Gill, 1862	P
Pink seaperch	*Zalembius rosaceus* (Jordan and Gilbert, 1880)	P, S
Pinkrose rockfish	*Sebastes simulator* Chen, 1971	P
Shortbelly rockfish	*Sebastes jordani* (Gilbert, 1896)	P
Shortspine combfish	*Zaniolepis frenatus* Eigenmann and Eigenmann, 1889	P, S
Slender sole	*Lyopsetta exilis* (Jordan and Gilbert, 1880)	S
Speckled rockfish	*Sebastes ovalis* (Ayres, 1862)	P
Splitnose rockfish	*Sebastes diploproa* (Gilbert, 1890)	P, S
Spotted cusk-eel	*Chilara taylori* (Girard, 1858)	P, S
Spotted ratfish	*Hydrolagus colliei* (Lay and Bennett, 1839)	S
Squarespot rockfish	*Sebastes hopkinsi* (Cramer, 1895)	P, S
Stripetail rockfish	*Sebastes saxicola* (Gilbert, 1890)	P, S
Swordspine rockfish	*Sebastes ensifer* Chen, 1971	P
Vermilion rockfish	*Sebastes miniatus* (Jordan and Gilbert, 1880)	P, S
Unidentified combfish[1]	*Zaniolepis* spp.	P, S
Unidentified cusk-eel	Family Ophidiidae	P, S
Unidentified eelpout	Family Zoarcidae	S
Unidentified flatfish		P, S
Unidentified poacher	Family Agonidae	P, S
Unidentified prickleback	Family Stichaeidae	S
Unidentified rockfish	*Sebastes* spp.	P, S
Unidentified ronquil	Family Bathymasteridae	P, S
Unidentified sanddab[2]	*Citharichthys* spp.	P, S
Unidentified *Sebastomus*[3]		P
Unidentified sculpin	Family Cottidae	P, S
Unidentified skate	Family Arhynchobatidae or Rajidae	P, S

Minimum number of species on pipeline = 35, on seafloor = 29; [1]Either *Zaniolepis frenatus* or *Z. latipinnis*. [2]All or nearly all of these were *C. sordidus*. [3]Most likely *Sebastes chlorostictus* , *S. ensifer*, *S. rosenblatti*, or *S. simulator*.

Table 3. Number and density (per 100 m^2) of all species observed at four habitats (shallow and deep pipeline, shallow and deep seafloor) in the Santa Barbara Channel, Southern California Bight.

	Shallow pipeline		Shallow seafloor		Deep pipeline		Deep seafloor	
Species	Number	Density	Number	Density	Number	Density	Number	Density
Bank rockfish			2	<0.1	1	<0.1		
Bearded eelpout							33	1.5
Blackbelly eelpout							1	<0.1
Blackgill rockfish					23	0.8		
Blue rockfish	4	0.1						
Bocaccio	15	0.5	7	0.1				
California halibut					1	<0.1	4	0.2
California smoothtongue			4	0.1	4	0.1	3	0.1
Canary rockfish			2	<0.1				
Copper rockfish	3	0.1	1	<0.1				
Cowcod			1	<0.1	41	1.4		
Dover sole			18	0.3	10	0.3		
English sole							12	0.6
Flag rockfish	20	0.7	3	0.1	12	0.4		
Greenblotched rockfish					167	5.5		
Greenspotted rockfish	70	2.5	5	0.1	30	1.0		
Greenstriped rockfish	3	0.1			15	0.5		
Halfbanded rockfish	1,175	42.6	63	1.1				
Hornyhead turbot			4	0.1				
Kelp greenling	1	<0.1						
Lingcod	79	2.8	4	0.1				
Longspine combfish	1	<0.1	31	0.5	4	0.1		
Olive rockfish	1	<0.1						
Pacific hake					35	1.2	4	0.2
Pacific sanddab			2	<0.1				
Painted greenling	1	<0.1						
Pink seaperch	30	1.1	8	0.1	76	2.5	5	0.2
Pinkrose rockfish					25	0.8		
Shortbelly rockfish					1	<0.1		
Shortspine combfish	64	2.3	88	1.5	5	0.2	34	1.6
Slender sole							8	0.4
Speckled rockfish	7	0.3						
Splitnose rockfish			5	0.1	23	0.8		
Spotted cusk-eel			14	0.2	19	0.6		
Spotted ratfish			1	<0.1			14	0.6
Squarespot rockfish	41	1.4	7	0.1				
Stripetail rockfish	6	0.2	7	0.1	1,099	36.4	12	0.6
Swordspine rockfish	7	0.3			1	<0.1		
Unidentified combfish	2	<0.1	10	0.2	82	2.7	4	0.2
Unidentified cusk-eel			4	0.1	3	0.1		
Unidentified eelpout			3	0.1			28	1.3
Unidentified flatfish	1	<0.1	21	0.4	21	0.7	20	0.9
Unidentified poacher	2	<0.1	40	0.7	169	6.0	7	0.3
Unidentified prickleback							1	<0.1
Unidentified rockfish	38	1.4	1	<0.1	4	0.1		
Unidentified ronquil			2	<0.1	8	0.3		
Unidentified sanddab	7	0.3	235	4.1	4	0.1	54	2.5
Unidentified sculpin			1	<0.1				
Unidentified *Sebastomus*	15	0.5			20	0.7		
Unidentified skate			3	0.1	1	<0.1	3	0.1
Vermilion rockfish	434	15.7	32	0.6				
Total	2,027	73.6	629	10.0	1,904	63.0	247	11.4
Minimum number of species	20		27		23		14	

Table 4. Degrees of freedom (df), chi-square, and the "pseudo F" statistic for a constrained correspondence analysis of the species community matrix on depth (< 150 m or > = 150 m) and habitat type (pipeline and bottom). The pseudo-F statistic is F-like, but is not guaranteed to be distributed as F; thus permutation tests (based on 2,000 permutations of the data) were conducted to approximate the significance level of each pseudo F. The P-value was estimated as the proportion of times that the statistic arising from a random permutation of the data exceeds the pseudo F. (See Legendre and Legendre, 1998 for details).

Factor	df	ChiSq	Pseudo F	P
Depth	1	0.8301	6.5999	< 0.0001
Habitat|depth	1	0.5251	4.9632	< 0.0005
Depth × habitat	1	0.2660	2.7316	0.0177
Residual	19	1.8502		

Both pipeline and seafloor habitats were inhabited almost entirely by small fishes, with the exception of a few large lingcod (Fig. 6). Few fishes were larger than 30 cm. These assemblages were composed both of diminutive species (e.g., combfishes, poachers, sanddabs, eelpouts, and halfbanded and squarespot rockfishes) and juveniles of larger taxa (e.g., cowcod, flag, greenspotted, splitnose, *Sebastes diploproa*, stripetail, and vermilion rockfishes, and lingcod) (Fig. 6).

Most of the pipeline-dwelling species were found within about 1 m of the structure. The major exception was halfbanded rockfish, which is a highly mobile, schooling species that ventured as much as 5 m away from the pipeline. Almost all of the pipe-

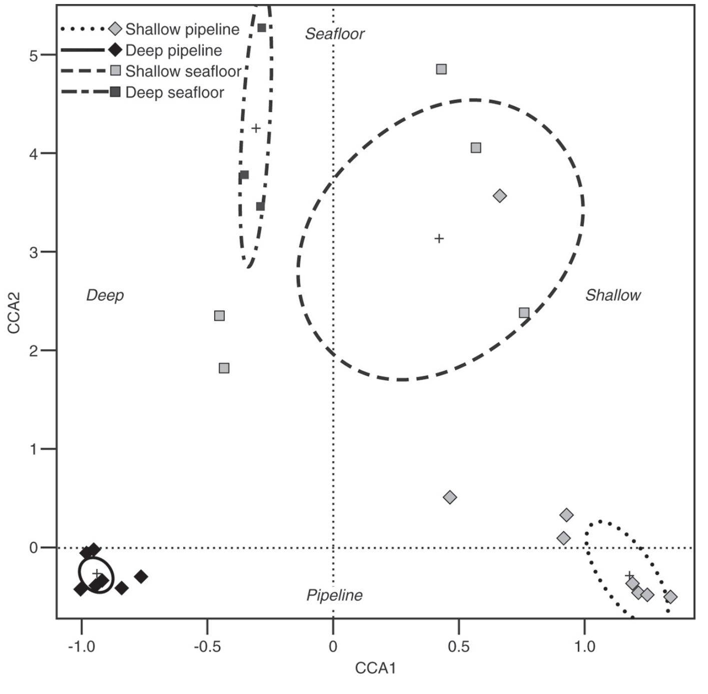


Figure 3. Canonical scores based on a constrained correspondence analysis model (ter Braak, 1995; Okasanen, 2003) in which the community matrix of number of fish per unit area was modeled on depth and habitat type. To avoid the effect of rare species, the model was fit for those species with at least 20 fish sighted, and included about 95% of all fish recorded. We present scores for each sample, the centroid for each depth-habitat type (+), and a 95% confidence ellipses for each centroid.

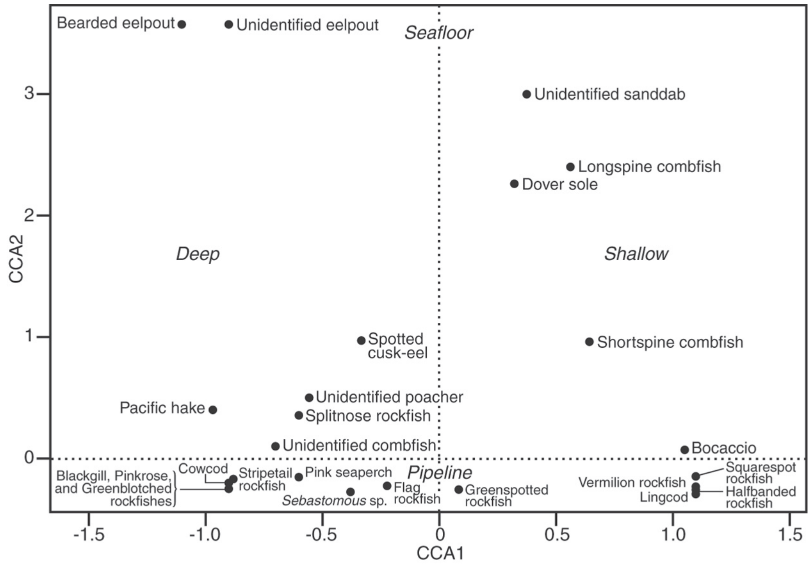


Figure 4. Canonical scores for each species from a constrained correspondence analysis model (ter Braak, 1995; Okasanen, 2003) in which the community matrix of number of fish observed per unit area was modeled on depth and habitat type. The model was fit for those species with at least 20 fish sighted, and included about 95% of all fish recorded. Points represent the centroid for each species in the canonical space determined by the model.

line fishes were found either along the sides of the pipe or underneath it in undercut areas (Fig. 2), while few species were commonly found on or above the structure. The exceptions were juvenile cowcod and blackgill rockfishes, which were usually observed close to or tucked into sea anemones. Stripetail rockfish, poachers, and combfishes were most often seen resting on the sea bottom < 1 m away from the pipe.

Discussion

Generally, the pipeline fish assemblages are similar to those that occupy such low-relief habitats as cobble and small boulders (Yoklavich et al., 2000) and the shell mounds that surround California offshore platforms (Love et al., 2003). With the exception of a few adult-sized lingcod, most of the fishes are either diminutive species such as halfbanded and stripetail rockfishes, combfishes, and poachers, or juveniles of such larger taxa as blackgill, flag, and vermilion rockfishes, cowcod, and lingcod. Many of the species found on pipelines, particularly most of the rockfishes, are absent from the seafloor. The dominant seafloor species, such as Pacific sanddab, and the two species of combfishes, are ones that characterize soft substrata throughout southern California (Allen et al., 2002). Some species, such as combfishes and poachers, are found on both soft sediment and the low relief provided by the pipe and attached invertebrates. The relatively small numbers of halfbanded and vermilion rockfishes observed over the seafloor were associated with small cobble and boulder fields.

The pipeline species assemblage is composed of two groups of fishes. Some species, such as poachers, combfishes, and stripetail rockfish, appear to require minimal or no sheltering sites, and tend to rest on soft substratum while orienting to hard material. On the contrary, the young of many rockfish species, such as cowcod,

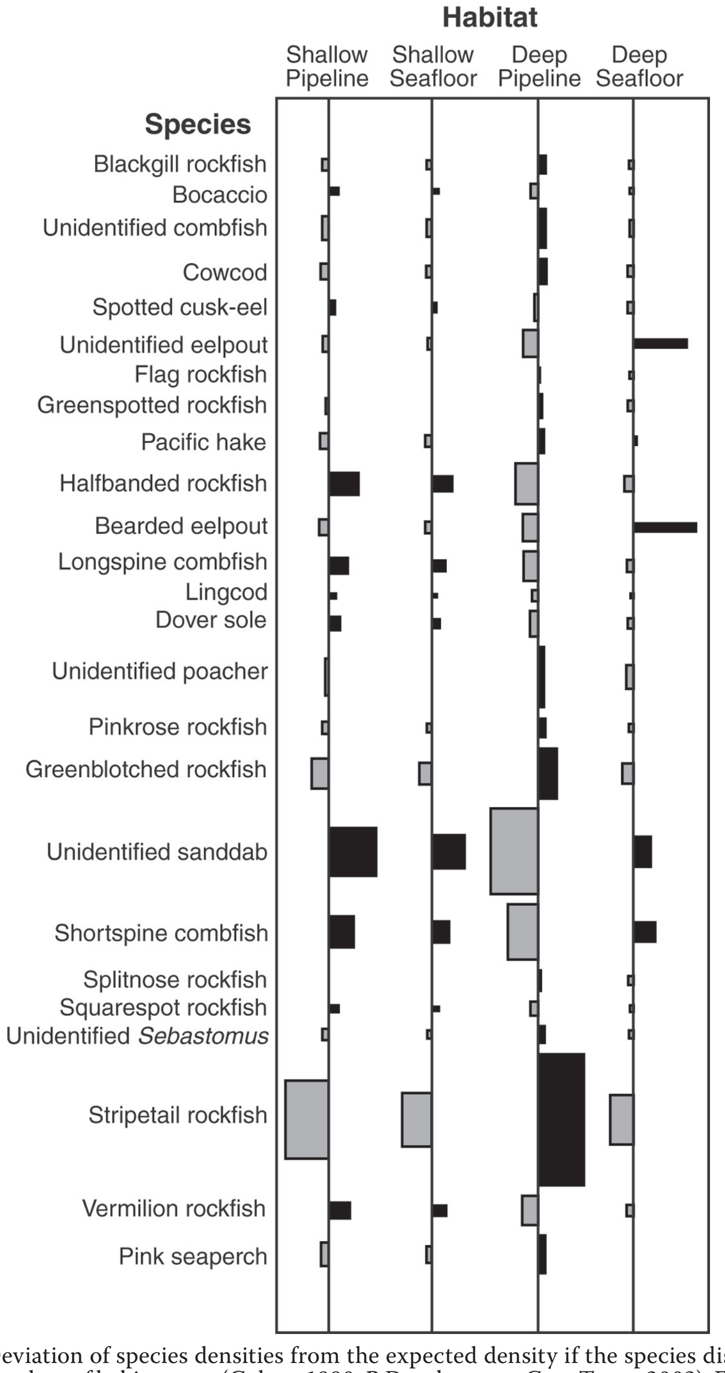


Figure 5. Deviation of species densities from the expected density if the species distribution were independent of habitat type (Cohen, 1980; R Development Core Team, 2003). Each cell is represented by a rectangle with height proportional to the difference between the observation and its expected value and the width proportional to the square root of the expected value. All species with at least 20 observations are included. Gray boxes to the left mean that that species is underrepresented (if distribution were independent of habitat type), dark boxes to the right mean the species is over represented.

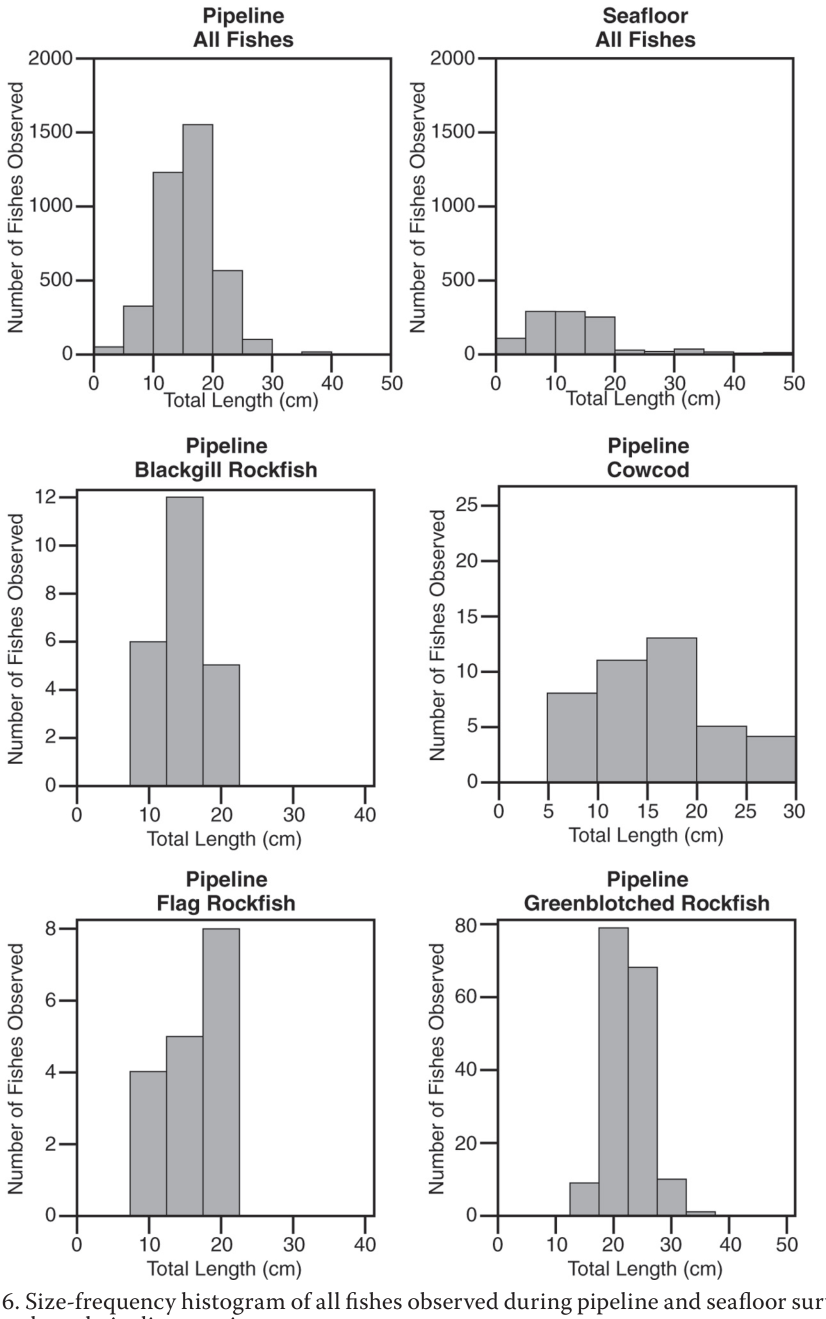
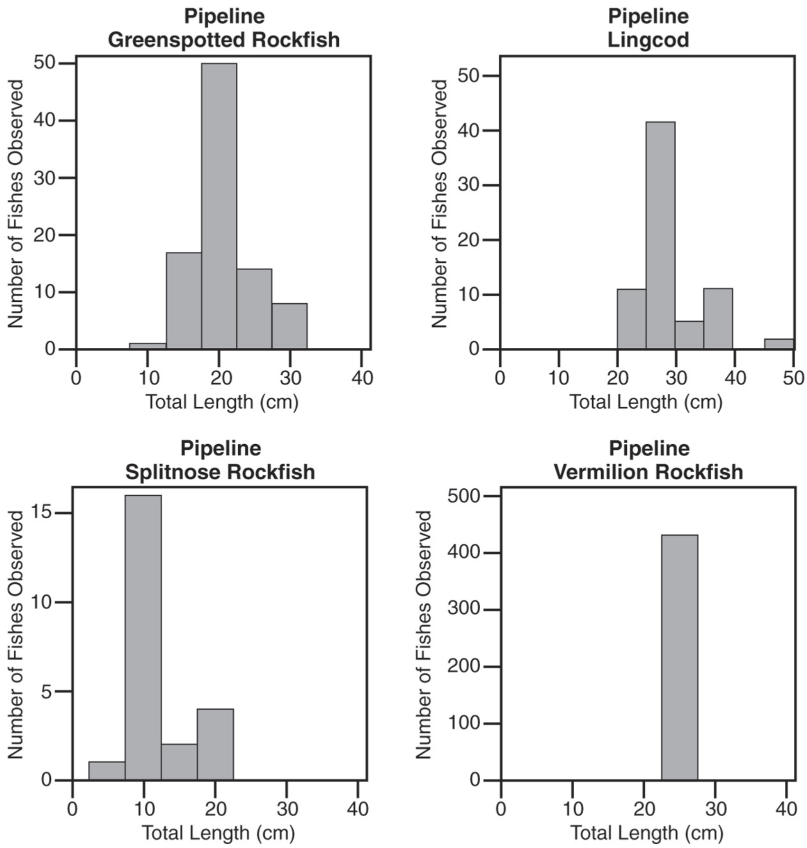


Figure 6. Size-frequency histogram of all fishes observed during pipeline and seafloor surveys and for selected pipeline species.

blackgill, and vermilion, and diminutive species such as halfbanded, require refuge sites, whether composed of rocks, habitat-forming invertebrates such as sea anemones, undercut pipelines or, in the case of the platform shell mounds, mussel shells. In general, species (or size classes of some species) most characteristic of high relief substrata (e.g., rosy, *Sebastes rosaceus*, and starry, *Sebastes constellatus*, rockfishes



in shallower water, and adult bocaccio, cowcod, and bank rockfish, *Sebastes rufus*, in deeper waters) were absent from the pipeline habitat.

The pipeline appears to act as a nursery for a number of fishes. Based on their size frequencies (Fig. 6), some species (including blackgill, flag, greenspotted, and splitnose rockfishes, and cowcod) recruit directly from the plankton to the pipeline as young-of-the-year (YOY). Others, such as vermilion rockfish, bocaccio, and lingcod are known to recruit to waters shallower than we surveyed; they migrate into deeper waters as they mature (Hart, 1973; Love et al., 2002). While the settlement locations of these species is unknown, YOY bocaccio recruit at platforms Grace and Gail (Love et al., 2003) and may move to the pipeline from these structures. Alternatively, some individuals of these species may recruit to more inshore areas of the pipeline or to nearshore natural outcrops. We found few large fishes around pipelines and thus predation on juveniles is likely to be low.

Because juveniles comprise many typical pipeline species, and because the abundance of these juveniles is dependent on interannual differences in juvenile recruitment success, it is likely that there will be some variation in species assemblages over time. As an example, based on their lengths, most or all of the bocaccio, lingcod, and vermilion rockfish we observed came from the strong 1999 year-class. Thus, compared to assemblages based on adult fishes, this partial dependence on variable oceanographic conditions implies that the pipeline fish assemblages are somewhat unpredictable over time.

Table 5. The top ten locations, based on fish density per transect, for cowcod juveniles (≤ 30 cm TL), 1995–2002. Transects from a total of 199 research dives at eight platforms and about 120 natural outcrops.

Density (per 100 m^2)	Year	Location
2.5	2001	Platforms Gail-Grace pipeline
1.2	2002	Platforms Gail-Grace pipeline
0.9	1999	Platform Hermosa, bottom
0.8	2000	Platform Hermosa, midwater
0.7	2002	Platforms Gail-Grace pipeline
0.7	2001	Platform Hidaldgo, shellmound
0.5	2000	Osborn Bank
0.6	1999	Platform Hermosa, shellmound
0.6	2000	Platform Hidalgo, bottom
0.5	1999	Platform Grace, bottom

Many of our observations are similar to those made by Allen et al. (1976) at two sewer pipelines in Santa Monica Bay. Although the Allen study sites were in generally shallower waters (10–100 m), their assemblages were also composed of small fishes, both juveniles and diminutive species. And, as in our study, among the dominant taxa were juvenile flag and vermilion rockfishes, bocaccio, and cowcod lending credence to the idea that the young of these species are characteristic of this low-relief habitat. However, our observations were made in what may have been the first years of a cool water period (Venrick et al., 2003) and it is interesting to note that the Allen study was made in the waning years of the previous cool regime. Thus, it is difficult to know to what extent the species found in both studies are dominant throughout all oceanographic regimes or only reflect cooler water conditions.

Because cowcod are officially characterized as overfished, and relatively little is known regarding their early life history (Johnson et al., 2001; Love et al., 2002), it is important to note the unusually high densities of juvenile cowcod found during several pipeline transects. We compared pipeline densities to those found in underwater surveys conducted between 1995 and 2002, at ten platforms and over 80 natural outcrops off central and southern California, at depths between 30 and 360 m (detailed in Love et al., 2003). Of the ten highest densities, nine were associated in some way with oil and gas platforms (Table 5). Three of the five highest densities were found on the pipeline surveys nearest platform Gail. However, juveniles were also found on platform shell mounds, around the jacket bottom, and even on the jacket midwaters. On natural habitats, juvenile cowcod appear to be most often associated with low relief, such as cobble or low ridges, but also with isolated anemones and other small features on soft substrata (M. Love and M. Yoklavich, unpubl. data). The pipeline and its associated invertebrates, which create a vertical structure of no more than about 1 m, appears to have a similar attraction to these young fishes. In the vicinity of platform Gail, we believe there are few or no natural outcrops to compete for cowcod juvenile recruitment and this may also account for the relatively high density of young fish. Platform Gail also has the highest density of adult cowcod of any area we have surveyed (Love et al., 2003) and, although we have noted some YOY cowcod recruitment to Gail's shell mounds, it is likely that juveniles that settle on the pipeline eventually swim to the platform.

Not all sections of the pipeline, even within a narrow depth range, are of equal value as fish habitat. In particular, those portions where the seafloor has been scoured away, leaving undercut areas, tend to harbor higher fish densities. We also have the sense, although we have not tested this hypothesis, that fish are more abundant in the presence of sea anemones. It is likely that pipeline undercuts and the presence of such structure-forming invertebrates as anemones lead to greater habitat complexity and a concomitant greater fish density. We lack information on the stability of these platform subhabitats; that is, how dynamic the oceanographic conditions in this environment are. One observer has noted significant interannual differences in the amount of undercut along a span of pipe located at a depth of about 180 m in the Santa Maria Basin, off Point Conception (C. Artopoeus, Plains Exploration and Production Company, pers. comm.). Perhaps one indication that some or all of the Gail-Grace pipeline may be subject to sediment movement is the rarity of sponges on the structure. All of the invertebrates we noted, including sea anemones, crinoids, and sea urchins, are motile and can avoid being buried by deposition. Sponges, which live on the platforms and on natural outcrops in the Santa Barbara Channel, cannot relocate and perhaps are killed during periods of intense seafloor sediment transport.

Various currents, including those induced by tides, storms, and ocean circulation, impinge on a pipeline. As water is forced past the pipe, vortices are set up, and these can move soft seafloor sediment in a variety of ways (de Groot, 1982; Haldane et al., 1992). However, the possible effects of pipelines on both sediment transport and seafloor organisms are very poorly understood. Pipeline deployment over soft sediments appears to have relatively local, and transitory, effects on benthic and infaunal organisms (Watson et al., 1997; Lewis et al., 2002), while coral reef disturbance may be more long lasting (Rezai et al., 1999). However, we are in no way suggesting that additional pipelines be deployed to add hard structure to southern California seafloors. Rather, our intent is to highlight the importance of understanding the potential role of any marine habitat before that habitat is altered either purposefully or unintentionally.

Southern and central California pipelines vary in diameter, bottom depth, and in the water mass they occupy. Given these variables, it would be premature to judge the importance of all of these structures as fish habitat. However, the Gail-Grace pipeline is an important habitat for a number of juvenile and diminutive fish species. It is quite possible that for some exploited species, such as cowcod, blackgill, and vermilion rockfishes, pipelines are of regional significance as nursery grounds. The extent of this significance will play an important component in determining the preferred option in future decommissioning activities (removal or leave-in-place of pipelines) once oil production ceases (Schroeder and Love, 2004). Additional biological surveys combined with seafloor mapping (to characterize the amount of natural habitat in the area) will aid managers in determining the ecological consequence of various policy alternatives, including impacts to overfished species.

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