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Demersal fish assemblages in the Southern California Bight based on visual surveys in deep water

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Abstract Between 1995 and 2006, manned submersible fish surveys were conducted on the sea floor throughout the Southern California Bight. A total of 401 dives (comprising 1,015 transects and 14,373 habitat patches) were made in waters between 19 and 365 m deep. All natural habitat types were included, although both soft sea floors and rocky reefs were surveyed more than any other type. A total of 717,526 fishes, representing a minimum of 137 species and 47 families, were observed. Rockfishes (genus *Sebastes*), with a minimum of 50 species and 647,495 individuals (90.2% of all fishes observed), dominated most of the habitats. The most abundant species, squarespot (*Sebastes hopkinsi*), halfbanded (*Sebastes semicinctus*), shortbelly (*Sebastes jordani*), and pygmy rockfishes (*Sebastes wilsoni*), are dwarf taxa that either school or aggregate. The most abundant non-rockfish species was the benthic and territorial blackeye goby (*Rhinogobiops nicholsii*). Both species richness and overall fish densities were highest in the shallowest sites. Most of the fishes in all habitats were small (≤20 cm TL long) and economically important species were generally uncommon. Forty-four species were found to be characteristic of the study area (occurring in at least 5% of the transects) and these species formed three faunal associations centered around depths of 62, 105, and 168 m. Based on size frequency distributions, at least 18 of the characteristic species exhibited ontogenetic movements, with young-of-the-year and older juveniles living in relatively shallow waters and larger individuals generally in deeper depths. In this study, the abundance of juvenile widow rockfish (*Sebastes entomelas*), and the virtual absence of adults, in southern California waters may demonstrate an ontogenetic northward movement of this species. This research implies that substantial harvesting of larger species by commercial and recreational fishers has helped alter some fish assemblages, allowing small and "weedy" species to thrive.

Keywords *Delta* submersible · Rockfishes · Species assemblages · Scorpaenidae

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Introduction

The 78,000 km^2 Southern California Bight (SCB) is bounded by Pt. Conception on the north and the United States–Mexican border on the south (Fig. 1). Dotted with a number of islands, basins, banks, and submarine canyons, and with a borderland as wide as 300 km, the topography of the SCB is complex compared with much of the Pacific Coast of the United States. The SCB is further characterized by a dynamic mixture of cold water from the southward-flowing California Current and warmer, northward-flowing water ultimately derived from equatorial regions. Changes in the strength and location of the California Current, the intensity and timing of coastal upwelling, and the amount of warm water significantly influence the fish species assemblages in the SCB (Dailey et al. 1993; Hickey 1993; Bograd et al. 2000).

Rimmed by substantial urbanization, over 17 million people live within the five counties bordering the SCB (U. S. Census Bureau 2007[1]). Over the past 100 years, and particularly over the last 40 years, the waters of the SCB have been intensively fished by both commercial and recreational anglers to depths greater than 300 m (Love 2006). For instance, it is estimated that there are at least 2 million salt-water anglers in southern California, making over 6 million ocean fishing trips per year (M. Golden, National Marine Fisheries Service, personal communication). At least two species that were formerly abundant in the SCB (bocaccio, *Sebastes paucispinis*, and cowcod, *Sebastes levis*) have been declared over fished by the National Marine Fisheries Service.

Fish assemblages off southern California have been well described from visual surveys on rock outcrops in the shallow photic zone (30 m and less) (North and Hubbs 1968; Ebeling et al. 1980; Stephens et al. 1984) and on soft sediments in both shallow and deep (>30 m) water (Allen et al. 2002; Love and York 2005). However, neither scuba surveys (because of depth restrictions) nor bottom trawl surveys (due to gear restrictions over rocky areas) are effective at surveying deep rocky outcrops and banks. There have been no published comprehensive accounts of the fish communities that inhabit southern California rocky outcrops in waters deeper than 30 m, with the exception of a semi-quantitative survey of some fishes on Tanner and Cortes banks (Lissner and Dorsey 1986) and a description of fishes dwelling over one deep-photic zone outcrop area in 75–79 m of water (Love et al. 2006).

Beginning in 1995, using a manned submersible, we have conducted visual surveys of the fish assemblages on rock outcrops and soft sediments below scuba depths over much of the southern California continental shelf and upper slope. In this paper, we describe the demersal fish assemblages of this poorly characterized area.

Materials and methods

Field sampling

Surveys were conducted annually between 1995 and 2006 throughout much of the Southern California Bight (Fig. 1) aboard the research submersible *Delta*, which is 4.8 m in length, accommodates one scientific observer and one pilot, and has a maximum operating depth of 365 m. During a dive, a constant distance within 1 m of the seafloor and a constant speed between 0.5 and 1.0 knot was attempted. Dives were made between September and November, during daytime hours, and were documented with an externally mounted hi-8 video camera positioned above the middle viewing-porthole on the starboard side of the submersible. The scientific observer conducted a belt-transect survey through this same starboard viewing port, verbally recording the occurrence of all fishes onto the videotape. The observer estimated the total length of these fishes using reference light points from two parallel lasers installed 20 cm apart on either side of the external video camera. These lasers also helped delineate the width (2 m) of the transects. A personal dive sonar from inside the submersible was used to me assure distance underwater, thereby training the observers' eyes and verifying the swath width of the transect.

Between 1995 and 2002, transect length was estimated by measuring sub-samples of the transect using the 20-cm intervals from the parallel lasers. By viewing these lasers frame-by-frame in the video, and using a time code overlain onto the video screen, an observer counted the number of 20-cm segments that were included in a 15-s interval. This was repeated

[1] U. S. Census Bureau (2007) http://quickfacts.census.gov/qfd/index.html. Cited 7 Sep 2007

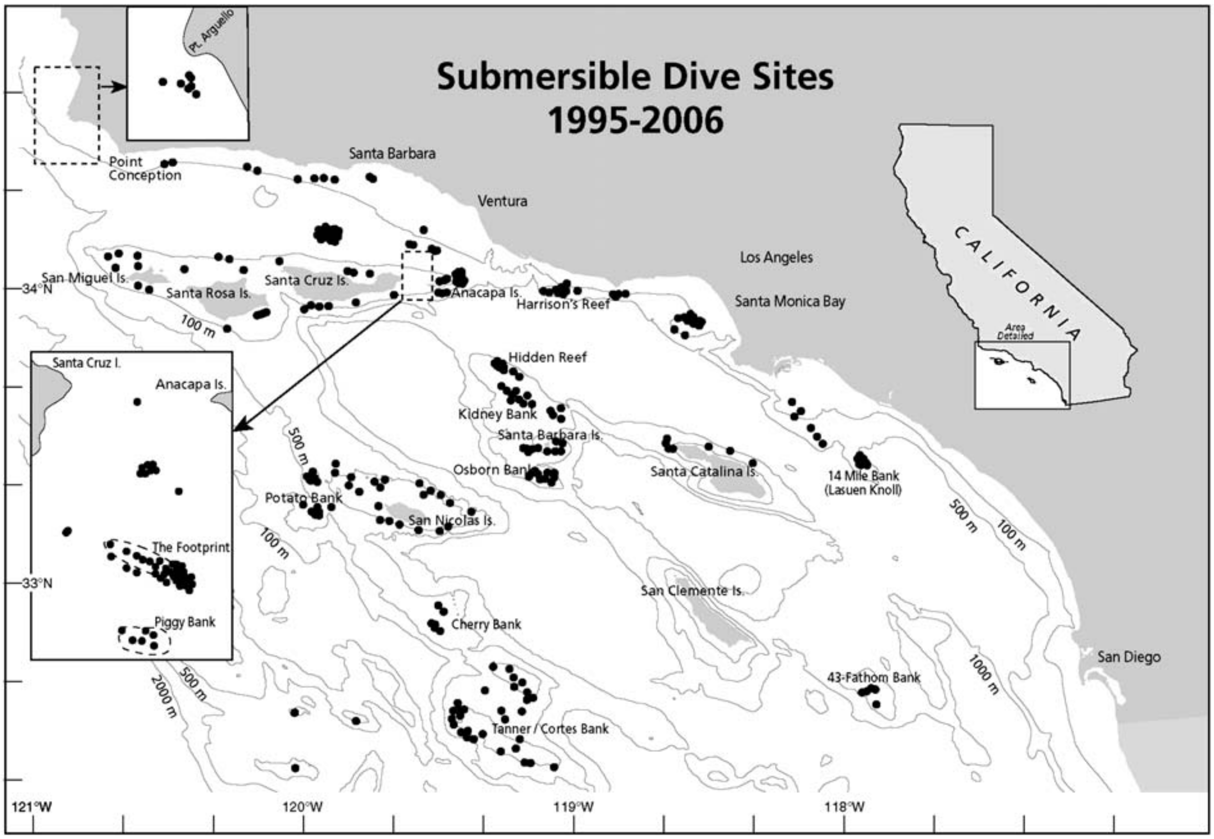

Fig. 1 Location of the 401 dive surveys conducted in southern California between 1995 and 2006 using the research submersible *Delta*. Note that some dots represent more than one dive made in the same general area

once per minute for the duration of the transect. If either laser beam was not visible for a portion of the interval, then that interval was rejected and the next usable interval was sampled. The speed of the submersible was estimated using the mean number of 20-cm segments per 15-s interval, and this mean speed was used to calculate the length of the transect as well as lengths of individual habitat patches.

From 2003 through 2006, navigation fixes (latitude and longitude coordinates) were received from a Thales GeoPacific Winfrog ORE Trackpoint 2 USBL system at 2-s intervals, and a Winfrog DAT file was generated for each dive. Distance and duration between fixes were calculated to obtain a point-to-point submersible speed; errant navigation fixes were removed when speed exceeded 2 m s^{-1}. The navigation fixes were then smoothed using a nine-point moving average, and transect length was estimated from the total distance between the smoothed points. Transect length was divided by transect duration to obtain an average transect speed. The length of individual habitat patches was estimated from average speed of the submersible during each transect. This method, direct observations of fish assemblages from the *Delta* submersible, has been used extensively to characterize both fish diversity and their ontogenetic movements (Yoklavich and O'Connell 2008).

This survey methodology underestimates the densities of some fish species. In particular, small and cryptic taxa, such as the bluebanded and zebra gobies (*Lythrypnus dalli* and *L. zebra*, respectively) are rarely observed and a number of flatfish species are difficult to visually identify. In addition, schools of benthopelagic forms, such as yellowtail rockfish (*Sebastes flavidus*), will occasionally aggregate in the water column above the *Delta* and are not counted.

Many years of experience along the Pacific Coast have shown that if the *Delta* or other manned submersibles are moving at a constant and slow rate of speed, as in these surveys, there is little obvious effect on the behavior of demersal fishes (Richards 1986; Murie et al. 1994; Love and York 2005; Love et al. 2006; Yoklavich et al. 2007).

Analyses

The analyses were restricted to 'characteristic' species, defined as those observed on at least 5% of all transects. In our database, young-of-the-year (YOY) rockfishes were defined as (1) any bank (*Sebastes rufus*), blue (*Sebastes mystinus*), darkblotched (*Sebastes crameri*), and speckled (*Sebastes ovalis*) rockfishes, bocaccio (*Sebastes paucispinis*), chilipepper (*Sebastes goodei*), and cowcod (*Sebastes levis*) that were ≤10 cm long, and (2) those halfbanded (*Sebastes semicinctus*), pygmy (*Sebastes wilsoni*), shortbelly (*Sebastes jordani*), and squarespot (*Sebastes hopkinsi*) rockfishes, fish of the subgenus *Sebastomus*, and 'unidentified rockfishes' that were ≤5 cm long.

In our analyses, substratum types (micro-scale habitats) were characterized within the 2-m swath along each dive track, based on images from the external video camera. Using the geological definitions of Greene et al. (1999), nine substratum types were initially characterized from the videotapes. These included mud (code M), sand (S), gravel (G), pebble (P), cobble (C), boulder (B), continuous flat rock (F), rock ridge (R), and pinnacle top (T), in order of increasing particle size or complexity. A two-character code was assigned each time a distinct change in substratum type was noted along the dive tract, thus delineating habitat patches of uniform type. The first character in this code represented the substratum that accounted for at least 50% of the patch, and the second character represented the substratum type that accounted for at least 20% of the patch (e.g., a patch designated as 'BC' comprised at least 50% boulders and at least 20% cobble). The area of each habitat patch was determined by multiplying length of the patch by the width of the swath (2 m). As this initial habitat classification created too many two-character categories for meaningful interpretation of preliminary analysis, we subsequently combined these substratum types into nine habitat categories based on high and low rock relief and on low relief soft sediments (Table 1, Fig. 2).

A cluster analysis of the densities of those species characteristic of the study area was performed and the densities for each of these species calculated by dividing the number observed by the transect area, where area equals two times the distance surveyed in meters. Densities for each species were standardized to a mean of zero and standard deviation of one. The procedure hclust of the statistical package R (R 2005) was used for the analysis, along with the average linkage option of the Unweighted Pair-Groups Method for performing the hierarchical agglomerative clustering. The Euclidean method was used for calculating distances. We computed the average water depth of each of the species clusters by first calculating a weighted average depth for each species in the clusters.

Table 1 Habitat categories surveyed from the Delta submersible, 1995–2006

Habitat categories	Substratum types
HH	BB, BR, BT, RR, RB, RT, TT, TB, TR
HL	BG, RG, BP, RP, BC, RC, TG, TP, TC, TF, BF, RF
HS	RS, RM, BS, BM, TS, TM
LH	CB, CR, GB, GR, PB, PR, FB, FR, FT
LL	CC, FC, FF, PP, GG, CF, CG, CP, FP, GC, GP, PC
LS	CS, CM, FS, FM, GS, GM, PS, PM
SH	SR, MR, SB, MB, ST, MT
SL	SC, MC, SG, MG, MF, SF, MP, SP
SS	SS, MM, SM, MS

The three habitat categories, H (high), L (low), and S (soft), are based on the following substratum types: soft sea floor=mud (M) and sand (S); low relief=gravel (G), pebble (P), cobble (C), and continuous flat rock; high relief=boulder (B), rock ridge (R), and pinnacle top (T)

Results

A total of 401 dives (comprising 1,015 transects and 14,373 habitat patches) were made in waters between 19 and 365 m deep and this totaled 794,079 m^2 (397,039.5 linear m) of sea floor. Among the nine habitat categories, more SS (soft–soft) and HH (high–high) habitats (194,935 m^2 and 131,461 m^2, respectively) were surveyed than any other type (Table 2). The survey sites were divided into 25 m depth bins and, overall, more habitat was surveyed in the shallower portions of our study sites than in deeper ones (Table 2). Habitat categories were also aggre-

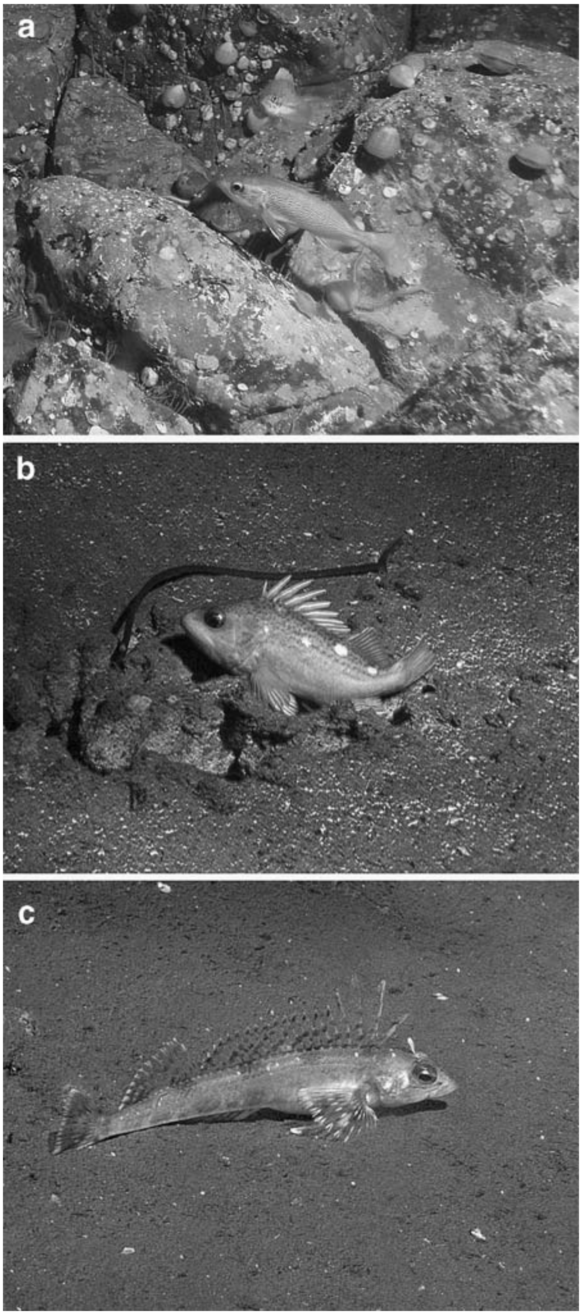

Fig. 2 Examples of the three habitat categories **a** high relief (with squarespot rockfish, *Sebastes hopkinsi* and whitespotted rockfish, *Sebastes moseri*), **b** low relief (with greenspotted rockfish, *Sebastes chlorostictus*), and **c** soft (with shortspine combfish, *Zaniolepis frenata*) used in this paper

gated into primarily high-relief rock (HH, HL, HS), primarily low-relief rock (LH, LL, LS), and primarily soft sediments (SH, SL, SS). More soft sediment habitats (338,022 m^2) were surveyed, than were primarily high-relief rock (282,902 m^2) or low-relief rock (173,155 m^2) (Table 2).

Species richness was characterized in two ways. First, we computed the number of species observed in each aggregated depth category (H, L, and S) and each 25 m zone (Fig. 3a) and found that species richness in each aggregated depth category peaked at depths of 50–125 m. However, equal amounts of habitat were not observed in all depths (Table 2) and this potentially influenced the number of species observed. To compensate for this, species richness was computed in terms of the number of species per unit area (species density). We used ln(area) because this transformation linearized the relationship between number of species and area surveyed. Similar to the first analysis, in all three aggregated habitat categories species densities peaked in relatively shallow water and then declined with increasing depth (Fig. 3b). Similar to species richness, fish density was highest in the shallower waters (except for the shallowest, 25 m, zone) and decreased with depth (Fig. 3c). Even when the very abundant young-of-the-year (YOY) rockfishes were deleted from the dataset, densities of fishes in shallow waters remained higher than those in the deeper habitats (Fig. 3c). Fishes also were larger in the deepest parts of the survey area, regardless of inclusion of YOY fishes (Fig. 3d).

A total of 717,526 fishes were observed representing a minimum of 137 species and 47 families (Appendix 1). Rockfishes (genus *Sebastes*) dominated most of the habitats. A minimum of 50 rockfish species, representing 647,495 individuals, or 90.2% of all fishes were documented. The most abundant species, squarespot, halfbanded, shortbelly, and pygmy rockfishes, are dwarf taxa that either school or aggregate. The most abundant non-rockfish species was the benthic and solitary blackeye goby (*Rhinogobiops nicholsii*). Most of the fishes were small, as individuals ≤20 cm long comprised 96.7% of all fishes (Fig. 4). At least 237,055 YOY rockfishes were observed, which represented 33.0% of all fishes.

Forty-four fish species were characteristic of the study area and of these, 29 species were rockfishes. Based on a cluster analysis of these species, three faunal associations centered on depths of 62 m ('Shallow Shelf'), 105 m ("Mid-Shelf"), and 168 m ('Deep Shelf') were identified (Fig. 5). One species, the pink seaperch (*Zalembius rosaceus*), belonged to both the Shallow and Mid-Shelf assemblages. With a

Table 2 Area surveyed (m^2) by habitat category and 25 m depth bins and area surveyed (m^2) by aggregated habitat categories and 25 m depth bins

a. Habitat Category

Depth	HH	HL	HS	LH	LL	LS	SH	SL	SS	Total
25	3372	636	1960	126	421	98	1712	261	2664	11251
50	31,478	8,490	12,705	2444	1332	4689	9895	6287	27,501	104,821
75	16414	6404	13,921	3272	1692	4186	8530	7942	27,712	90,073
100	28858	24952	14921	22,566	14,421	9699	8514	19,143	32,822	164,897
125	14,318	9868	5433	13,969	16,483	11,634	2363	16,000	15,531	105,600
150	10,409	7386	3684	6729	4921	10,462	2455	12,461	26,881	85,388
175	4667	2669	3796	2131	4410	5272	774	12,101	28,406	64,226
200	11,347	5198	7458	3991	7433	8373	2989	9910	17,116	73,816
225	2577	1662	3176	718	458	4672	1292	5735	5334	25,627
250	1631	3754	2181	837	1046	3421	210	1844	3439	18,363
275	3156	1295	3624	962	1092	3118	493	3106	3238	20,084
300	2392	1237	2529	1737	311	3202	954	3217	1934	17,513
325	363	408	792	100	42	410	802	3614	2189	8719
350	478	1195	103	236	215	823	70	412	168	3701
Total	131,461	75,156	76,285	48,818	54,278	70,059	41,054	102,033	194,935	794,079

b. Aggregated Habitat Category

Depth	H	L	S	Total
25	5968	646	4638	11,251
50	52,673	8465	43,683	104,821
75	36,739	9151	44,184	90,073
100	68,731	35,686	60,479	164,897
125	29,619	42,086	33,895	105,600
150	21,479	22,112	41,797	85,388
175	11,132	11,812	41,281	64,226
200	24,003	19,798	30,015	73,816
225	7418	5849	12,361	25,627
250	7566	5304	5493	18,363
275	8076	5172	6837	20,084
300	6158	5250	6105	17,513
325	1563	551	6605	8,719
350	1776	1274	650	3,701
Total	282,902	173,155	338,022	794,079

H High-relief dominated, *L* low-relief dominated, *S* soft-substrata dominated

few exceptions, the species that comprised the Shallow Assemblage lived in high or mixed high-low relief habitats (Fig. 5, Appendix 1). Exceptions included blackeye goby, pink seaperch, and deepwater kelpfish (*Cryptotrema corallinum*), which primarily lived on soft substrata, although often near rocks, and halfbanded rockfish, which occupied a wide range of habitats (Fig. 5, Appendix 1). All of the Mid-Shelf species (except pink seaperch) favored rock, mostly high relief, habitats. In the Deep Shelf Assemblage, species were more likely to favor soft or mixed soft and low relief habitats (Fig. 5, Appendix 1). In this assemblage, only bank rockfish and chilipepper were primarily high-relief species. Many of the species (50%—Shallow and 75%—Mid-Shelf) in the two shallower assemblages were schooling fish that would ascend at least a meter into the water column (Fig. 4). In contrast, most of the species (86%) in the Deep Shelf assemblage were solitary and benthic.

At least 18 of the characteristic species exhibited ontogenetic movements in which young individuals recruited from the plankton to bottom depths shallower than at least some of their larger conspecifics (Fig. 6a–c). In some instances, (e.g., shortspine combfish), YOYs recruited to shallow waters, but not all individuals moved deeper, as some of the largest fish were found in the shallowest depths. In many instances, once a fish had matured, there

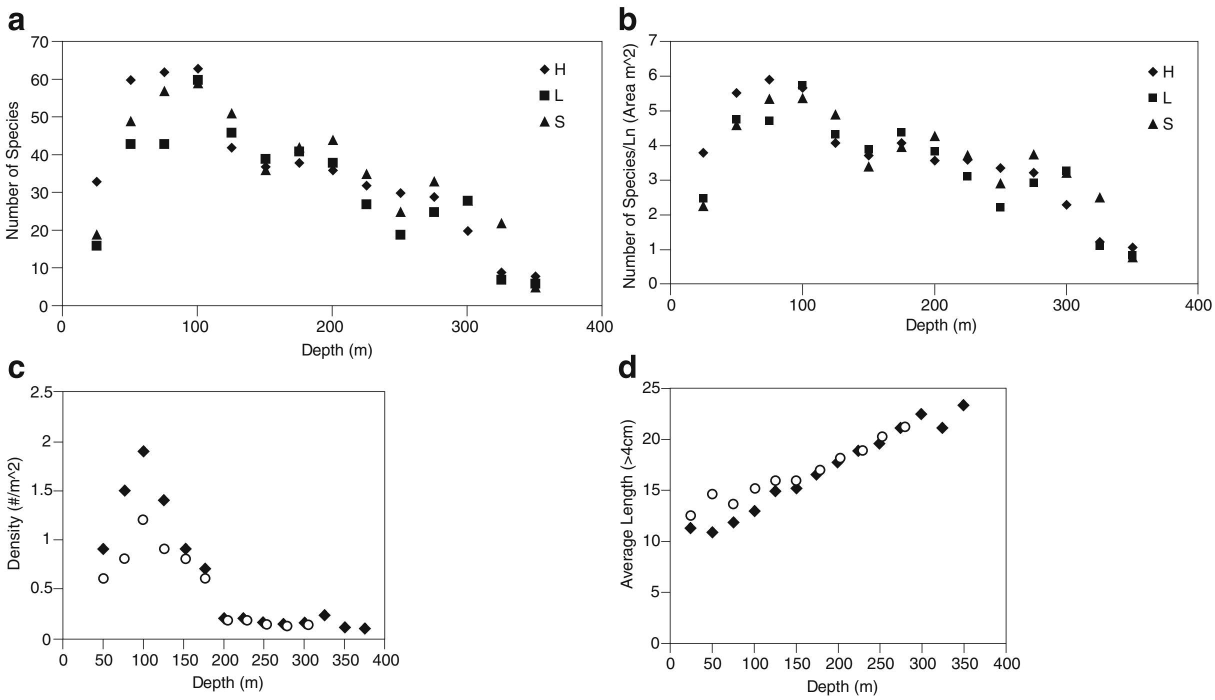

Fig. 3 **a** Number of species observed per 25 m depth bin and by habitat category (*H* high-relief rock, *L* low-relief rock, *S* soft bottom); **b** number of species observed per ln100 m^2 (=species density) per 25-m depth bin and by habitat category (*H* high-relief rock, *L* low-relief rock, *S* soft bottom); **c** Mean densities of all fishes observed per 25-m depth bin (*diamonds*) and mean densities of fishes, excluding young-of-the-year, observed per 25-m depth bin (*open circles*); **d** average length of all fishes observed per 25-m depth bin (*diamonds*), and average length of fishes, excluding young-of-the-year rockfishes, per 25 m depth bin (*open circles*)

appeared to be little additional directed bathymetric movements (Figs. 5 and 6c).

None of the approximately 56 economically important species, that is, those targeted or retained by recreational and commercial fishermen, were particularly common (Appendix 1). Only one of these species, the widow rockfish (*Sebastes entomelas*), was among the top ten most abundant species; 13,514 widow rockfish comprised 0.7% of all fishes. Despite the abundance of juvenile fish, adult widow rockfish (with 50% maturity at about 36 cm TL, Love et al. 2002) were almost absent throughout our study area, and there is a severe truncation in the size composition of widows at 30 cm TL (Fig. 6c).

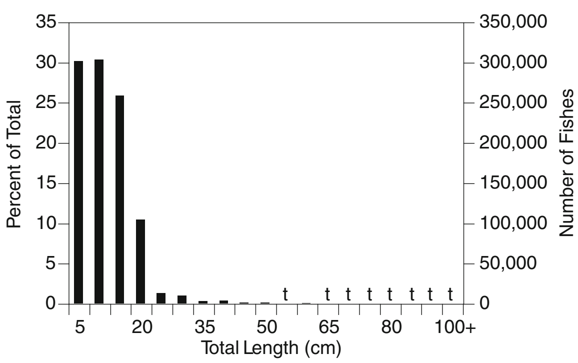

Fig. 4 Lengths of all fishes observed, 1995–2006. *T*=<0.1% of all fishes

Discussion

Rockfishes dominate both the high- and low-relief rock sea floor of our survey area. These data support previous research in the SCB around artificial structures (Love et al. 1999, 2000; Love and York 2005) and are similar to results from surveys along the Pacific Coast at least as far north as southeastern Alaska (Stein et al. 1992; Yoklavich et al. 2000, 2002;

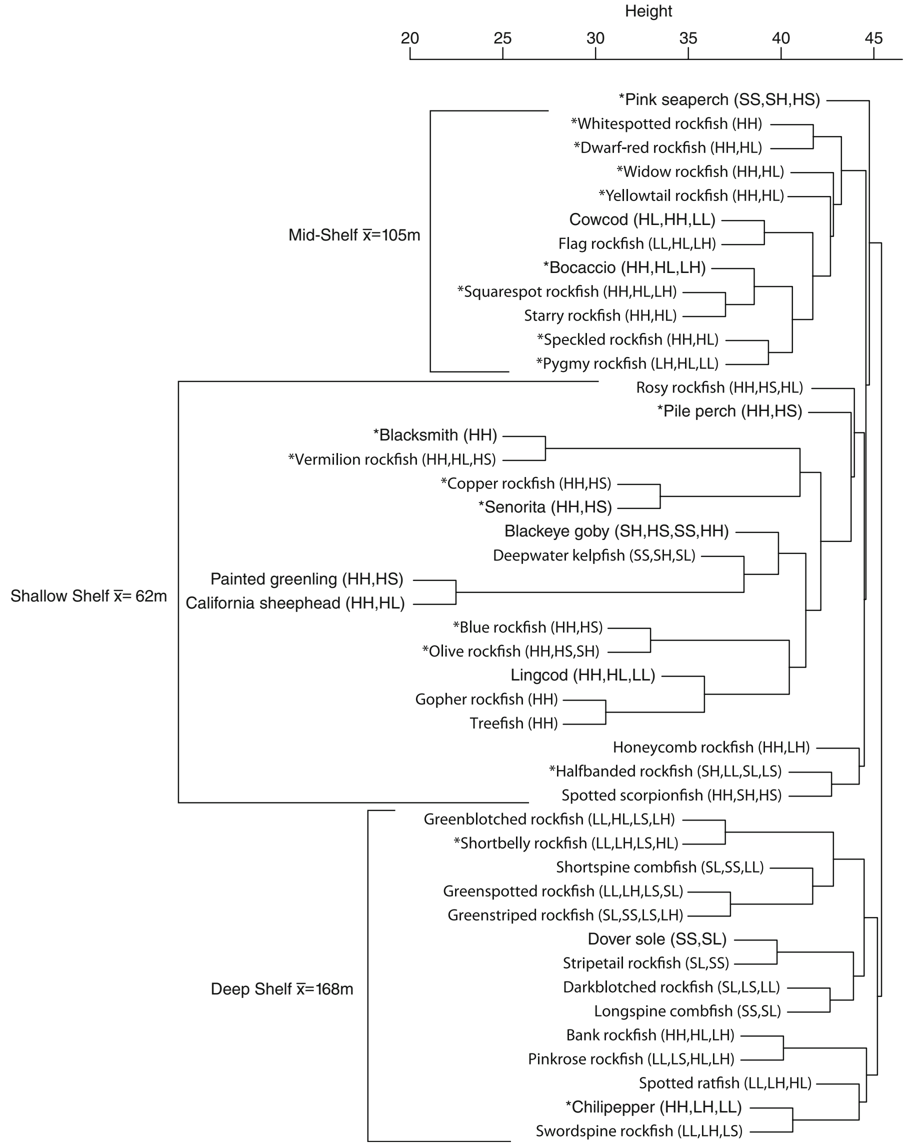

Fig. 5 A cluster analysis of 44 characteristic species (observed in at least 5% of the dives). *Asterisk* indicates species that form schools or aggregations. Most common habitats for each species are in *parenthesis*, *H* high-relief rock, *L* low-relief rock, *S* soft bottom

Wang 2005; L. Yamanaka, Fisheries and Ocean Canada, personal communication; Victoria O'Connell, Alaska Department of Fish and Game, personal communication). By comparison, in the shallow (<30 m), nearshore waters of the SCB, many members of the families Atherinidae, Clinidae, Cottidae, Embiotocidae, Kyphosidae, Labridae, Pomacentridae, and Serranidae actively compete with rockfishes (Quast 1968; Ebeling et al. 1980; Stephens et al. 1984). Based on the depth ranges of the 58 species of rockfishes that inhabit these waters (Love et al. 2002), the importance of this group to deep-water assemblages of the SCB likely begins to ebb at around 350 m.

Within the SCB, we distinguished three fish assemblages. The Shallow Shelf assemblage, centered within the deep photic zone, represents a transition between the fish communities found in southern California kelp beds and nearshore outcrops and those of deeper-water features. While rockfishes are among the most important group, a few members of the families Gobiidae, Hexagrammidae, Labridae, and Pomacentridae also are important. Most of these characteristic species are rock dwellers; only pink seaperch, blackeye goby (*Rhinogobiops nicholsii*), and deepwater kelpfish (*Alloclinus holderi*) commonly occupy the soft sea floor. In this assemblage, a

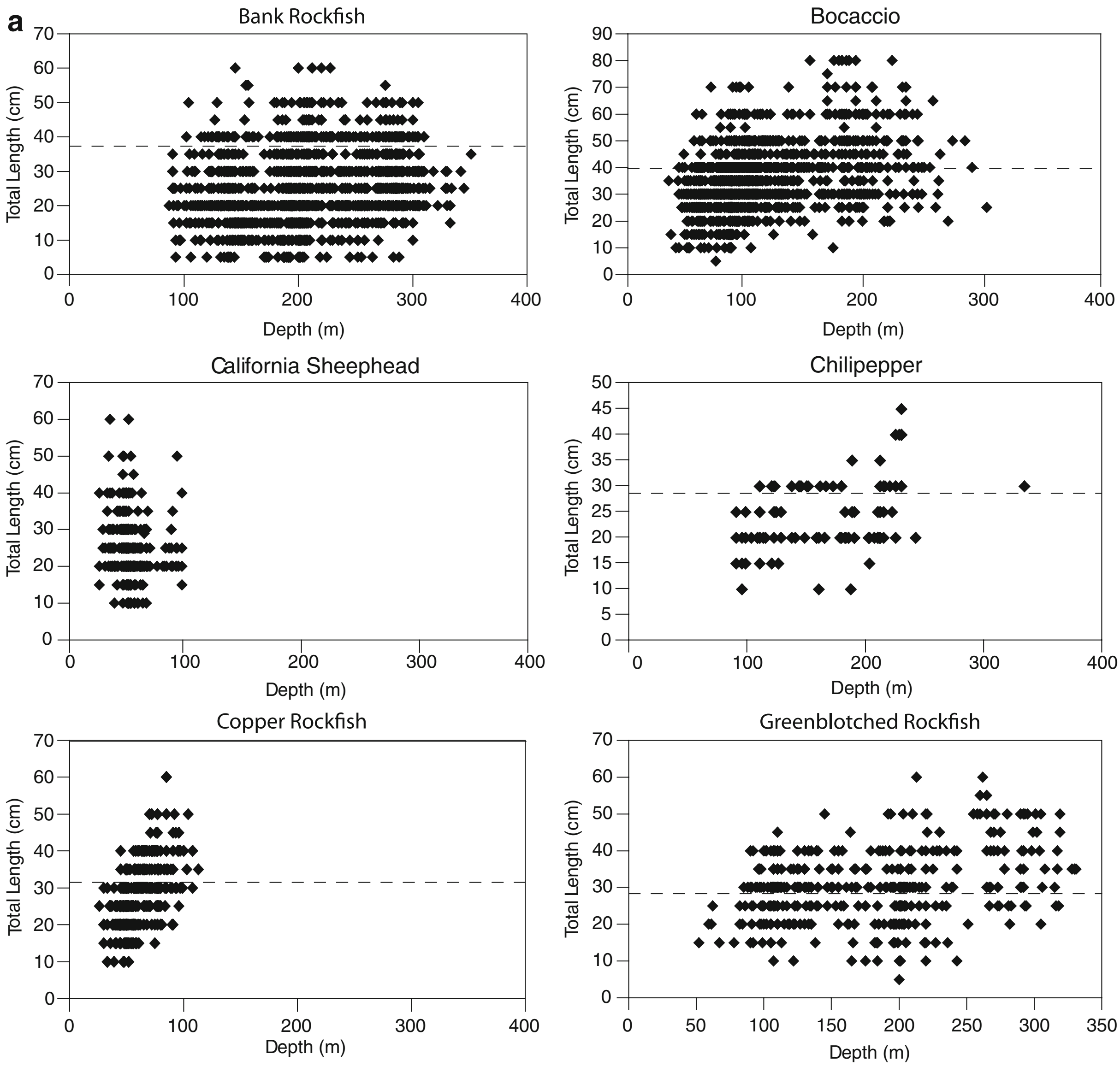

Fig. 6 a–c Fish occurrence (presence) by size class and depth for 18 species of fish. The *dotted lines* represent size at 50% maturity for rockfishes (Love et al. 2002) and pink seaperch (LaPlante 2006). The considerable between-sex differences in the lengths at 50% maturity for California sheephead and lingcod make meaningful comparisons difficult as sex was not differentiated in our surveys

number of characteristic species (e.g., pile perch (*Rhacochilus vacca*), blacksmith (*Chromis punctipinnis*), senorita (*Oxyjulis californica*), blackeye goby, painted greenling (*Oxylebius pictus*), California sheephead (*Semicossyphus pulcher*), blue, copper (*Sebastes caurinus*), olive (*Sebastes serranoides*), and gopher (*Sebastes carnatus*) rockfishes, lingcod (*Ophiodon elongatus*), treefish (*Sebastes serriceps*), and spotted scorpionfish (*Scorpaena guttata*)) also are abundant in shallower waters. Other species, such as halfbanded, honeycomb (*Sebastes umbrosus*), rosy, starry (*Sebastes constellatus*), and post-YOY vermilion (*Sebastes miniatus*) rockfishes, and deepwater kelpfish, rarely inhabit the nearshore environment. The Shallow Shelf Assemblage is composed both of species that recruit as YOY directly to this assemblage and by somewhat older individuals that settle from the plankton into shallower waters and immigrate into deeper waters. For instance, a majority of individuals of some species, such as halfbanded

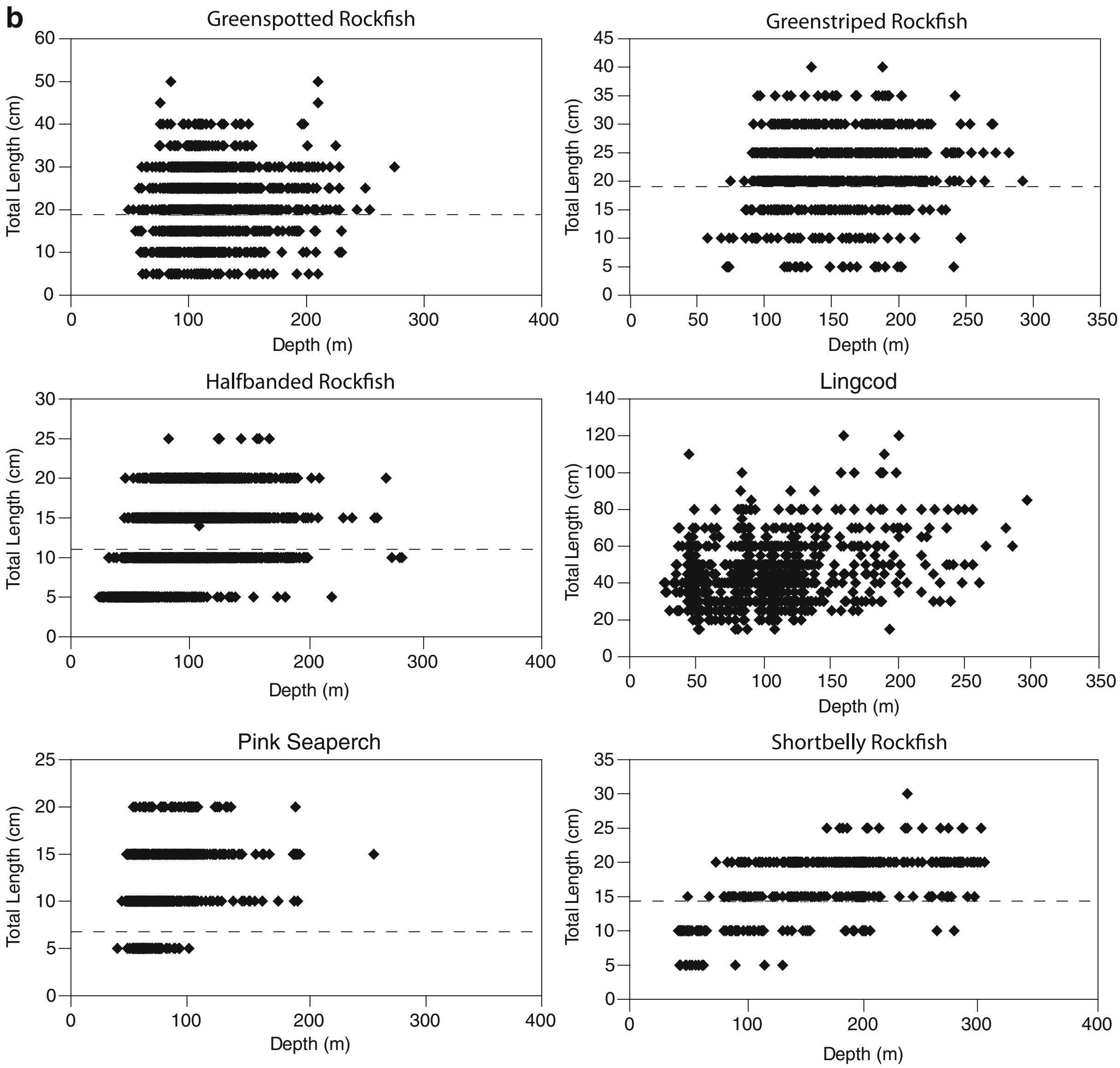

Fig. 6 (continued)

rockfish and blackeye goby, recruit as YOY directly to this assemblage (Fig. 6b; Love and Schroeder 2007). Other species either always (e.g., vermilion rockfish) or most often (e.g., blacksmith and blue rockfish) settle into shallower waters and migrate to this assemblage (Love et al. 2002; Love and Schroeder 2007). Thus, there is likely a strong relationship between the Shallow Shelf Assemblage and more nearshore waters.

In contrast (with the exception of pink seaperch), the Mid-Shelf Assemblage is composed entirely of rockfish species. And while the YOYs of at least three Mid-Shelf taxa (e.g., bocaccio (*Sebastes paucispinis*) and widow and yellowtail (*Sebastes flavidus*) rockfishes) may recruit to kelp beds and inshore rocky areas, the other species have no direct connection to shallower waters (Fig. 6a; Love et al. 2002; Love and Yoklavich 2008; Appendix 1). All of the species in this assemblage (with the exception of pink seaperch) are rock-associates and most are schooling or aggregating species Love et al. 2002).

As with the other assemblages, most of the characteristic species of the Deep Shelf assemblage are rockfishes. However, members of the Pleuro-

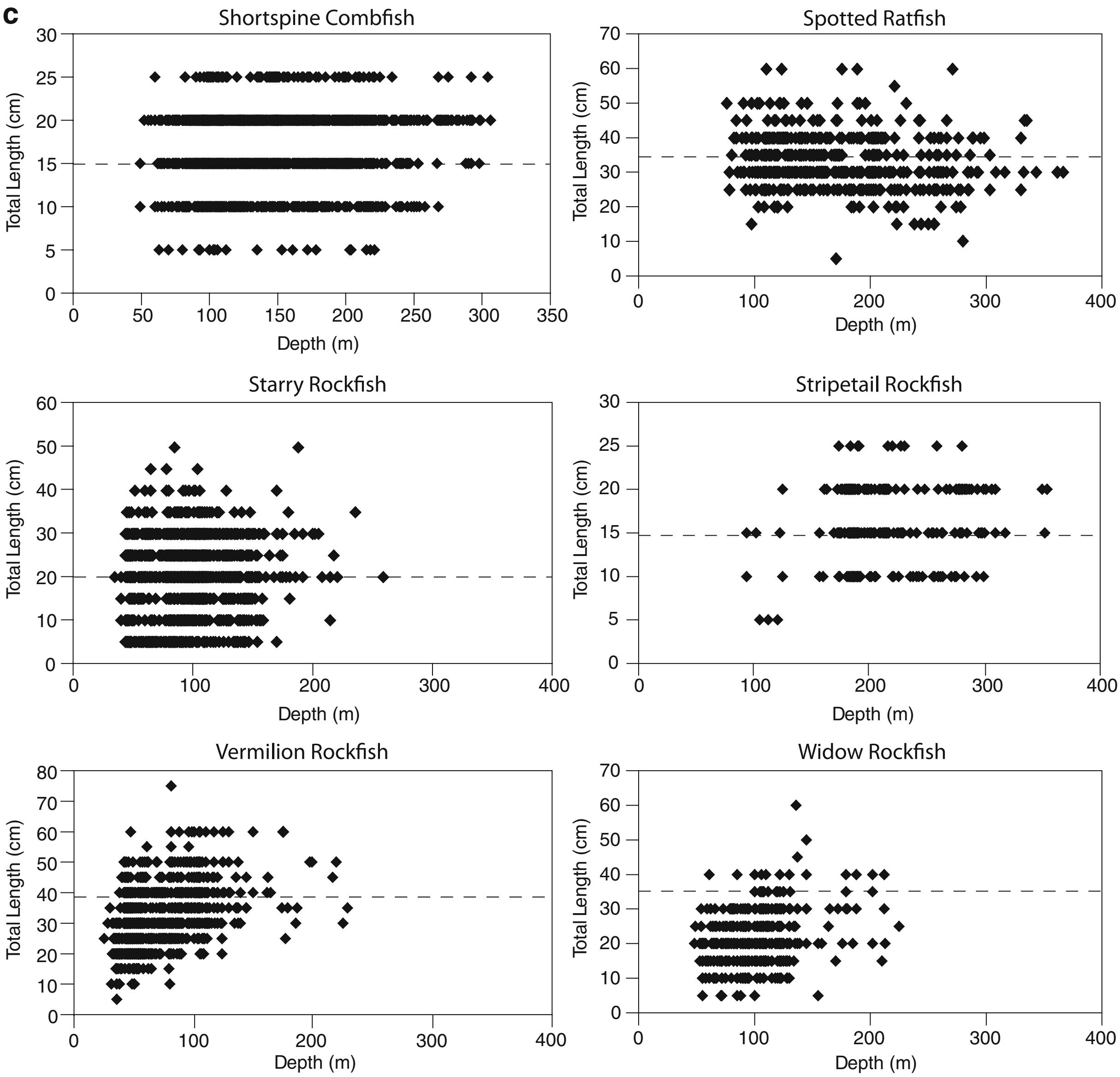

Fig. 6 (continued)

nectidae, Hexagrammidae, and Chimaeridae also are represented. Species in this assemblage are more likely to be associated with soft substrata or rock margins than those in the other two assemblages (Appendix 1; Love et al. 2002). In addition, most of the species are solitary forms, and only shortbelly rockfish and chilipepper form large aggregations (Love et al. 2002; Love, unpublished data).

The three assemblages are linked through the ontogenetic movements of many species. Ontogenetic movements appear to be common among fishes in the SCB, particularly among the rockfishes (Love et al. 1991). Among these species, YOYs settle out in relatively shallow waters and at least a portion of the population moves into deeper waters as the fishes mature (Love et al. 2002). The YOYs of some species (e.g., pink seaperch, shortbelly and vermilion rockfishes) recruit from the plankton to a relatively narrow depth range in shallow waters, while others (e.g., bank (*Sebastes rufus*), greenspotted (*Sebastes chlorostictus*), halfbanded, and greenstriped (*Sebastes elongatus*) rockfishes) may settle over a very broad range of depths (as much as 200 m) (Fig. 6a–c). Copper and greenblotched (*Sebastes rosenblatti*) rockfishes move substantially deeper with age (Fig. 6a), while for other species (e.g., pink seaperch) there is only limited bathymetric movements by some individuals (Fig. 6b). Allen et al. (2007) have noted similar recruitment and migration patterns for a number of species, including shortbelly rockfish and shortspine combfish, collected in trawl surveys in the SCB. While our data tell us little about seasonal movements of fishes, one species, the viviparous pink seaperch, must migrate into shallow waters to release its fully formed and non-pelagic young, as young fishes were only observed in the shallower parts of the species' depth range.

Young-of-the-year rockfishes and dwarf, schooling planktivorous rockfishes comprise most of the fishes living on rock outcrops in depths of about 100 m. Despite some differences in species composition, this also has been noted off central California (Yoklavich et al. 2002) and Oregon (Pearcy et al. 1989). Depth-related food limitations are likely responsible for this pattern. In the SCB, the photic zone reaches to about 60 m and relatively high densities of invertebrate zooplankton and larval fishes do not extend much below 100 m (Allen 1945; Ahlstrom 1959; Dawson and Pieper 1993). It is noteworthy that shortbelly rockfish is the only schooling deep-water planktivore associated with rock outcrops and banks in the SCB that vertically migrates. During the day, this species aggregates at depth and then ascends at night into shallower and more productive waters to feed, indicative of the relative scarcity of food in their deeper habitats.

While small aggregating planktivores are numerous over SCB rocky areas, conspicuously absent are high densities of larger, schooling planktivorous species such as canary (*Sebastes pinniger*), widow, and yellowtail rockfishes. These are characteristic of rocky outcrops and banks from central or northern California northwards (Miller and Gotshall 1965; Stein et al. 1992; Shaw et al. 2000). This, too, is likely related to geographic differences in food availability, as overall productivity and zooplankton density are higher to the north of the SCB (Ware and Thomson 2005; S. Ralston, National Marine Fisheries Service, personal communication) and thus can support higher densities of their predators. It is noteworthy that the partially planktivorous adult Pacific hake (*Merluccius productus*), which are very abundant in the SCB during the spawning season, migrate northwards to feed outside of the SCB (Bailey et al. 1982).

One of the more interesting phenomena we observed was the paucity of adult widow rockfish in the SCB, although juveniles are relatively abundant. There are three possible explanations for this phenomenon. First, while the adults might live in the SCB, we may not have observed them due to their avoidance of the submersible or because we did not sample their adult habitat. Adult widow rockfish have been observed by *Delta* researchers off central California (Yoklavich et al. 2000), Oregon (Stein et al. 1992), and British Columbia (L. Yamanaka, Fisheries and Ocean Canada, personal communication), thus it is unlikely that the paucity of adults is a sampling artifact. Second, adult widow rockfish might have been historically abundant in the SCB, but have been removed through fishing. There is no evidence that there ever were large numbers of adult widow rockfish in the SCB (or further southwards along the Baja California coast), as catches of adults in both the commercial and recreational fisheries historically have been small (Ralston and Lenarz 2001; RecFin 2007; M. Love, unpublished data). Lastly, as they mature, widow rockfish may migrate northwards to more productive waters. Similar behavior (of larger adults) also has been hypothesized for shortbelly rockfishes (B. Lenarz, personal communication).

There is general agreement that the deep-shelf and shallow-slope fishes of the Pacific Coast are partitioned into a number of habitat-associated groups (Yoklavich et al. 2000, 2002; Anderson and Yoklavich 2007). These have been defined by Anderson and Yoklavich (2007) as 'rock-boulder', 'cobble-mud', and 'soft-sediment' associates, and 'generalists.' However, partitioning exists within these groups at finer spatial scales. Anderson and Yoklavich (2007) demonstrated that portions of habitat patches are used differently by various species on a spatial scale <1 m (e.g., two species associated with the same cobble-mud habitat patch actually use the cobbles and mud differentially). Also, Love et al. (2006), determined that certain rock-boulder species, for instance flag (*Sebastes rubrivinctus*) and vermilion rockfish, and bocaccio, were members of the 'sheltering guild' that seek caves and crevices to the exclusion of other high relief habitat. In general, the habitat associations of the characteristic species in the SCB were very similar to those determined from central California by Anderson and Yoklavich (2007).

Several of the observed trends were also noted in a trawl study conducted in the SCB at depths between 5 and 500 m (Allen et al. 2007). Similar to our findings, the trawl survey found that overall fish densities and species richness on soft sediments also were highest in 31–120 m water depth. Also noteworthy were the recurrent groups of soft-sediment demersal species centered at depths of 49, 86–88, and 163 m, similar to our three assemblages at 62, 105, and 168 m. Because the Allen et al. (2007) survey focused on fishes occurring on soft sediments, many of their important species were different from those in our study. However, these similarities in diversity at specific depths imply that there may be forcing factors, such as food availability, light levels, or temperature patterns that broadly act on fishes with a wide range of life history traits.

Intensive commercial and recreational fishing and perhaps environmental factors have altered the fish species assemblages of the SCB (Love et al. 1998; Love and Yoklavich 2008). In particular, harvesting has removed most of the larger fishes (e.g., bocaccio, cowcod (*Sebastes levis*), lingcod) from rocky areas, making their habitats available to smaller, adventitious species. A possible effect of this predator eradication, along with good recruitment events, appears to be an increase in numbers of these small, 'weedy' rock species (e.g., dwarf-red (*Sebastes rufianus*), pygmy (*Sebastes wilsoni*), squarespot, and whitespotted rockfishes). A similar response by the diminutive Puget Sound rockfish (*Sebastes emphaeus*) to overfishing of its predators occurred in Puget Sound (Coates et al. 2007). Another result of this release from predation may be that ecotonal species, such as greenstriped rockfish, that evolved to occupy the soft sediment-rock margins, now exploit more of the rock outcrop habitats. However, the diminution of larger predators need not alter the species assemblage. That is, while total biomass of many species will change, the species composition may remain mostly intact.

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