Recurrent Groups of Demersal Fishes on the Mainland Shelf of Southern California in 1994

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ABSTRACT

More than 100 species of demersal fishes inhabit the soft-bottom habitat of the mainland shelf of southern California. This study identifies and describes recurrent groups of demersal fishes based on a region-wide survey of the Southern California Bight (SCB). These groups are compared to recurrent groups described for the central part of the SCB for 1972-1973. During July and August 1994, trawl samples were collected at 114 stations selected at random from Point Conception, California, to the United States-Mexico international border at depths of 10 to 200 m. Recurrent groups (i.e., groups of frequently co-occurring species) were identified and described using Fager's recurrent group analysis. Of the 87 species of fish collected, only 28 formed recurrent groups or associates. Five recurrent groups of fish were described with two to eight species per group. Each group was characteristic of a different bathymetric zone. Major recurrent groups changed slightly by the addition or deletion of species between the early 1970s and 1994, probably as a result of oceanic warming beginning in the early 1980s. However, four core recurrent groups (representing the most characteristic and persistent species groups on the mainland shelf of the Bight) were found during both periods: (1) Inner/Middle Shelf Group; (2) Middle Shelf Group; (3) Middle/Outer Shelf Group; and (4) Outer Shelf Group.

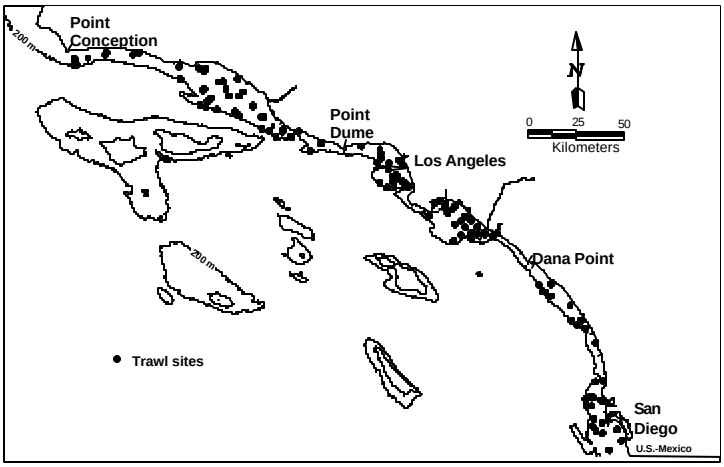
INTRODUCTION

The demersal fish fauna occupying the mainland shelf of southern California is diverse, consisting of more than a 100 species and 40 families (Allen 1982). Understanding whether these species are organized — and if so, how they are organized — is a prerequisite for determining community functional organization. Knowledge of species organization is also a prerequisite for assessing whether fish communities are affected by anthropogenic activities. One methodology that has been used to assess the consistency of assemblages is recurrent group analysis (Fager 1957, 1963).

Recurrent groups of demersal fish species have been identified and described for the central region of the mainland shelf of southern California from data collected in the period from 1972 to 1973 (Allen 1982). However, ocean waters in the SCB have warmed since the early 1980s (CSDLAC 1990, Stull 1995, Stull and Tang 1996); it is not known if this warming trend or other factors have caused changes in the demersal fish population. A region-wide trawl survey of the SCB in 1994 (Allen and Moore 1996) provided the opportunity to identify and describe recurrent groups from the entire mainland shelf of southern California and to determine if recurrent groups of demersal fishes had changed during the past two decades. Components of the groups that did not change during this period were also examined to establish the most reliable indicators of the presence of a community.

The objectives of this study are (1) to identify recurrent groups of soft-bottom fish on the mainland shelf of southern California in 1994; (2) to describe their bathymetric and geographic distribution; and (3) to determine if recurrent groups have changed since the early 1970s.

FIGURE 1. Stations sampled by trawl on the mainland shelf of southern California at depths of 10 to 200 m, July to August 1994.



MATERIALS AND METHODS

Trawl samples were collected at 114 randomly selected stations from Point Conception, California, to the United States-Mexico international border at depths of 10 to 200 m (Figure 1). A stratified random design was used with strata of the following depths: (1) inner shelf —10 to 25 m; (2) middle shelf — 25 to 100 m; and (3) outer shelf —100 to 200 m (Bergen 1996).

Samples were collected from July 12 to August 22, 1994, with 7.6-m head-rope semiballoon otter trawls with 1.25-cm cod-end mesh. Trawls were towed for 10 min at 1 m/sec (2 kt) along isobaths. Fish were identified to species, counted, examined for anomalies, and weighed by species to the nearest 0.1 kg. Fish lengths were reported by centimeter size class.

Recurrent groups were defined by calculating the index of affinity (IA) of Fager (1963) and Fager and McGowan (1963) for all species pairs. The index is based on the occurrence of each species and co-occurrence of the two species being compared, and is defined by the following equation:

$$IA = \frac{c}{\sqrt{ab}} - \frac{1}{2\sqrt{b}}$$

IA is the index of affinity, **a** is the number of samples in which species A occurred, **b** is the number of samples in which species B occurred, and **c** is the number of joint occurrences of species A and B. In this equation, **b** is always greater than or equal to **a**. The first term is the ratio of joint occurrences of both species to the geometric mean of their individual occurrences. The second term is a correction factor to give weight to values of the first term based upon high occurrences of the more frequently occurring species.

The index was calculated for all pairs of species. Pairs of species with a predetermined level of affinity (e.g., IA = 0.50) were grouped following rules described in Fager (1957). A recurrent group must satisfy the following criteria: (1) All species in a group must have positive affinities with all other members of the group; (2) The group must contain the largest possible number of species; (3) If several groups containing the same number of species can be formed, those are selected which give the largest number of groups without members in common; and (4) If two or more groups with the same number of species and with members in common can be formed, the group that occurs most frequently must be chosen.

Species were grouped by IA from 0.50 (a value that is commonly used in recurrent group analysis) to 0.80 at intervals of 0.05. Associates were defined as species that had positive affinities with one or more members of a recurrent group but not with all members of the group. The level of relationship of the groups to each other and to associate species is defined by a connex value. This number is the proportion of possible positive affinities (e.g., IA = 0.50 or greater) between members of two groups or between a group and an associate. The distribution of the 0.50-level groups in the SCB were mapped.

RESULTS

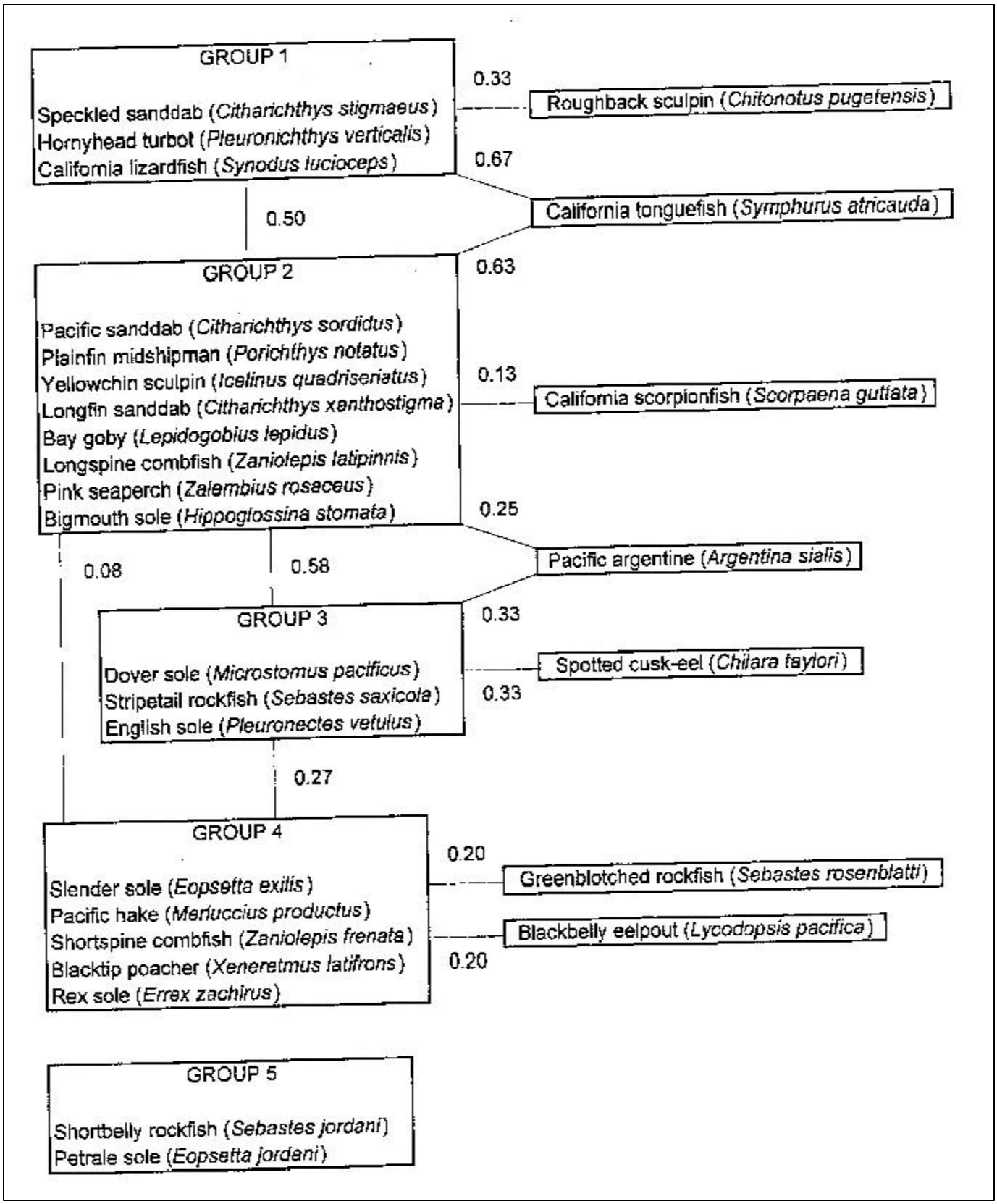
A total of 87 species of fish, representing 14 families and three classes, were collected in this survey. The catches were dominated by pleuronectiform species. Twenty-one species occurred in 20% or more of the stations on the mainland shelf (Table 1). The most frequently occurring species were Pacific sanddab (*Citharichthys sordidus*), Dover sole (*Microstomus pacificus*), and hornyhead turbot (*Pleuronichthys verticalis*), which occurred in 66, 57, and 53% of the stations, respectively (Table 1).

Recurrent group analysis identified five recurrent groups consisting of two to eight species per group with

TABLE 1. Demersal fish species occurring in 20% or more of the stations on the mainland shelf of southern California at depths of 10 to 200 m, July to August, 1994.

Scientific Name	Common Name	Number of Stations	% Stations (n=114)
Citharichthys sordidus	Pacific sanddab	75	66
Microstomus pacificus	Dover sole	65	57
Pleuronichthys verticalis	Hornyhead turbot	60	53
Synodus lucioceps	California lizardfish	58	51
Porichthys notatus	Plainfin midshipman	57	50
Hippoglossina stomata	Bigmouth sole	56	49
Citharichthys xanthostigma	Longfin sanddab	55	48
Icelinus quadriseriatus	Yellowchin sculpin	51	45
Pleuronectes vetulus	English sole	50	44
Sebastes saxicola	Stripetail rockfish	50	44
Symphurus atricauda	California tonguefish	49	43
Citharichthys stigmaeus	Speckled sanddab	47	41
Zalembius rosaceus	Pink seaperch	44	39
Zaniolepis latipinnis	Longspine combfish	44	39
Eopsetta exilis	Slender sole	37	33
Lepidogobius lepidus	Bay goby	36	32
Zaniolepis frenata	Shortspine combfish	32	28
Xystreurys liolepis	Fantail sole	27	24
Scorpaena guttata	California scorpionfish	26	23
Raja inornata	California skate	25	22
Paralichthys californicus	California halibut	23	20

FIGURE 2. Recurrent groups of demersal fishes on the mainland shelf of Southern California at depths of 10 to 200 m, July to August 1994. Index of affinity (IA) = 0.50. Species within a group are listed in order of abundance. Lines show relationships between groups and associates, with values indicating the proportion of possible pairs with IA = 0.50.



seven associate species at the 0.50 level of affinity (Figure 2). In all, the groups and associates included 28 (32%) of the 87 species. The groups differed in depth distribution, with each group occurring in one or two of the three predetermined depth zones (Figure 3). All but Group 5 were widely distributed along the mainland shelf from the Santa Barbara Channel to San Diego (Figure 4).

Group 1 (Inner/Middle Shelf Group) consisted of three species: speckled sanddab (*Citharichthys stigmaeus*); hornyhead turbot; and California lizardfish (*Synodus lucioceps*) (Figure 2). The group occurred at 29 stations (25% of the total) and was found mostly on the inner and middle shelf zones at depths of 14 to 66 m (Figure 3). Group 1 was found in the northern, central, and southern regions, ranging from Santa Barbara to the U.S.-Mexico international border (Figure 4A). Roughback sculpin (*Chitonotus pugetensis*) was an associate of this group, and California tonguefish (*Symphurus atricauda*) was an associate of this group and Group 2 (Figure 2). The group

FIGURE 3. Bathymetric distribution of demersal fish recurrent groups on the mainland shelf of southern California, July to August 1994.

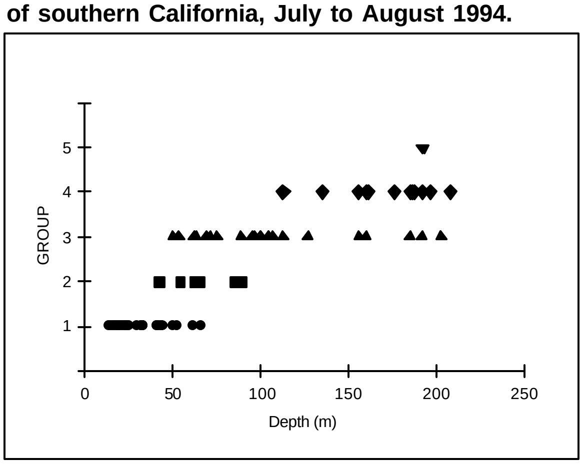
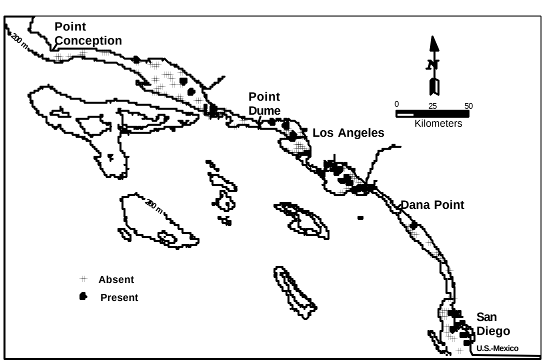
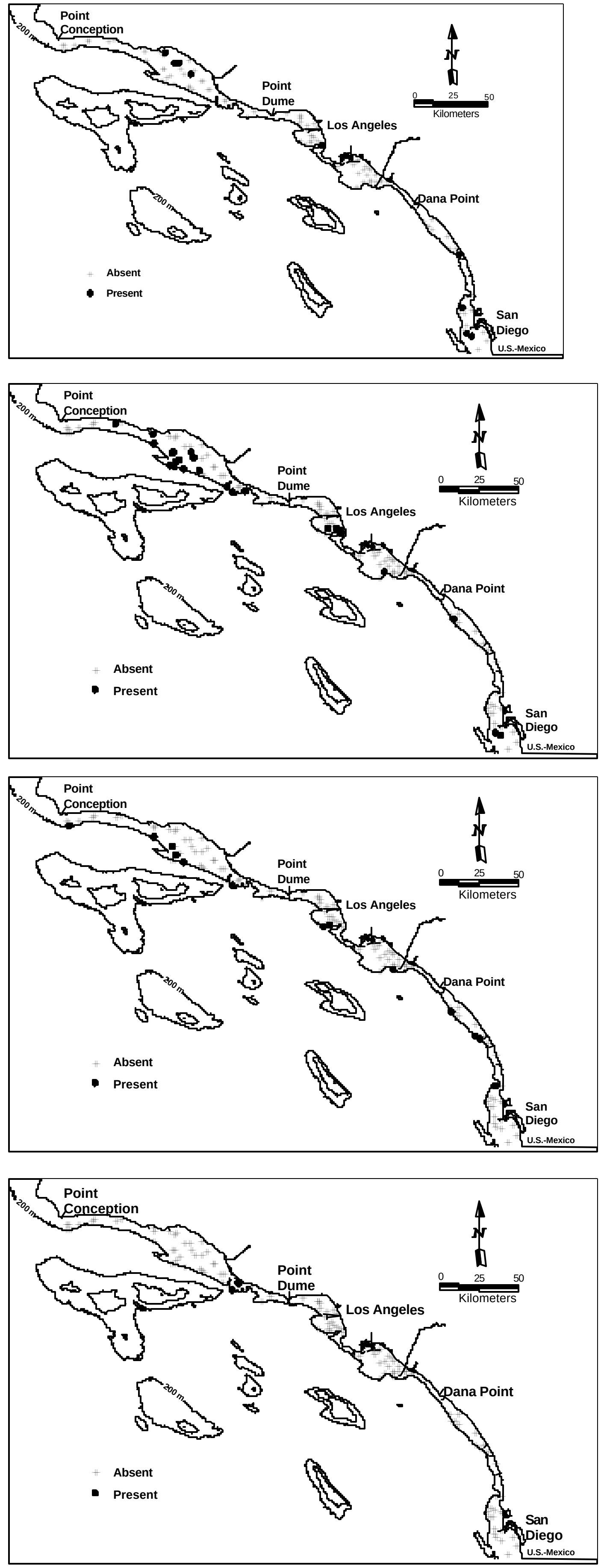


FIGURE 4. Spatial distribution of major demersal fish recurrent groups on the mainland shelf of southern California at depths of 10 to 200 m, July to August 1994: (A) Group 1 — Inner/Middle Shelf Group; (B) Group 2 — Middle Shelf Group; (C) Group 3 — Middle/Outer Shelf Group; (D) Group 4 (Outer Shelf Group); and (E) Group 5 (Hueneme Canyon Group).





also had affinities with Group 2. Group 1 was most strongly associated with California tonguefish, followed by Group 2, and then roughback sculpin.

Group 2 (Middle Shelf Group), the largest and most diverse group, was comprised of eight species: Pacific sanddab; plainfin midshipman (*Porichthys notatus*); yellowchin sculpin (*Icelinus quadriseriatus*); longfin sanddab (*Citharichthys xanthostigma*); bay goby (*Lepidogobius lepidus*); longspine combfish (*Zaniolepis latipinnis*); pink seaperch (*Zalembius rosaceus*); and bigmouth sole (*Hippoglossina stomata*) (Figure 2). The group was found only on the middle shelf, ranging in depth from 42 to 89 m (Figure 3). Group 2 occurred at nine stations (8% of the total); it was found in all three regions, extending from Santa Barbara to San Diego (Figure 4B). California scorpionfish (*Scorpaena guttata*) was an associate of this group. California tonguefish was an associate of this group and Group 1. Pacific argentine (*Argentina sialis*) was an associate of this group and Group 3 (Figure 2). The group also had affinities with Groups 3 and 4. Group 2 was most strongly associated with California tonguefish, followed by Group 3, Pacific argentine, California scorpionfish, and Group 4 (in order of decreasing strength of association).

Group 3 (Middle/Outer Shelf Group) consisted of three species: Dover sole; stripetail rockfish (*Sebastes saxicola*); and English sole (*Pleuronectes vetulus*) (Figure 2). This group occurred at 24 stations (21% of the total) on the middle and outer shelf zones, ranging in depth from 50 to 203 m (Figure 3). Group 3 was found in all three regions, occurring from Gaviota (northwest of Santa Barbara) to San Diego (Figure 4C). Spotted cusk-eel (*Chilara taylori*) was an associate of this group (Figure 2). Pacific argentine was an associate of this group and Group 2. The group also had affinities with Groups 2 and 4. Group 3 was most strongly associated with Group 2, equally associated with Pacific argentine and spotted cusk-eel, and less associated with Group 4.

Group 4 (Outer Shelf Group) was composed of five species: slender sole (*Eopsetta exilis*); Pacific hake (*Merluccius productus*); shortspine combfish (*Zaniolepis frenata*); blacktip poacher (*Xeneretmus latifrons*); and rex sole (*Errex zachirus*) (Figure 2). The group occurred at 12 stations (11% of the total) on the outer shelf at depths of 113 to 208 m (Figure 3). Group 4 occurred in all three regions from Point Conception to La Jolla (north of San Diego) (Figure 4D). Greenblotched rockfish (*Sebastes rosenblatti*) and blackbelly eelpout (*Lycodopsis pacifica*) were associates of this group (Figure 2). The group had affinities with Groups 2 and 3. Group 4 was most strongly associated with Group 3, followed by greenblotched rockfish and blackbelly eelpout, and then by Group 2.

Group 5 (Hueneme Canyon Group) consisted of two species: shortbelly rockfish (*Sebastes jordani*) and petrale sole (*Eopsetta jordani*). This group occurred at two stations (2% of the total) on the outer shelf at depths of 192 to 193 m (Figure 3). Group 5 only occurred in the northern region in Hueneme Submarine Canyon (west of Point Dume) (Figure 4E). The group had no affinities with other groups (Figure 2).

DISCUSSION

The primary objective of this study was to determine if recurrent groups of fishes on the mainland shelf of southern California had changed between the cool-water period before the 1982 to 1983 El Niño and the subsequent warm-water period (Smith 1995). Allen (1982) described recurrent groups of fishes based on 342 samples collected from 1972 to 1973 during the cool-water period. These samples were collected from the central region (Point Dume to Dana Point) of the mainland shelf at depths of 10 to 190 m. The recurrent groups described in the present study, identified from 114 samples collected in 1994 throughout the SCB over approximately the same depth range, represent the warm post-El Niño period.

At the 0.50 affinity level, Allen (1982) identified nine recurrent groups with two to seven species per group and seven closely associated nongroup species. These groups and associates comprised 34 (27%) of the 126 species collected in the survey. Three groups represented important depth-related communities on the inner/middle, middle/outer, and outer shelf zones (Table 2). With some alterations, these three recurrent groups also appear in the 1994 survey described here.

The core species of the Inner/Middle Shelf Group (Group 1 in 1994) consisted of the speckled sanddab and hornyhead turbot. These species occurred together in both periods. However, in the 1972 to 1973 survey, the group also included California tonguefish whereas in the 1994 survey, it included California lizardfish. In 1994, California tonguefish was an associate of both the Inner/Middle and Middle Shelf Groups.

The core of the Middle Shelf Group (Group 2 of 1994) consisted of yellowchin sculpin, Pacific sanddab, plainfin midshipman, and pink seaperch. Three species (English sole, stripetail rockfish, and Dover sole) of the Middle Shelf Group of 1972 to 1973 formed a new Middle/Outer Shelf Group (Group 3) in 1994. Thus, during the cool-water period, the deeper living Middle/Outer Shelf Group of 1994 coalesced with the core Middle Shelf Group of 1994 when the middle-outer shelf species were more common on the middle shelf. In 1994, the Middle Shelf Group gained four

TABLE 2. Comparison of recurrent groups of demersal fishes on the southern California shelf in the 1970s and in 1994.[a]

Common Name	Scientific Name	Trawl Data Set[b] 1972-73 (n=342)	1994 (n=114)	Group Interpretation
Walleye surfperch	*Hyperprosopon argenteum*	**A**	**-**	Shallow Surfperch
Black perch	*Embiotoca jacksoni*	**A**	**-**	Shallow Surfperch
Shiner perch	*Cymatogaster aggregata*	**B**	**-**	Nearshore Schoolers
White croaker	*Genyonemus lineatus*	**B**	**-**	Nearshore Schoolers
California lizardfish	*Synodus lucioceps*	**-**	**C**	Inner/Middle Shelf
Speckled sanddab	***Citharichthys stigmaeus***	**C**	**C**	**Inner/Middle Shelf**
Hornyhead turbot	***Pleuronichthys verticalis***	**C**	**C**	**Inner/Middle Shelf**
California tonguefish	*Symphurus atricauda*	**C**	**CE1**	Inner/Middle Shelf
Pygmy poacher	*Odontopyxis trispinosa*	**CE1**	**-**	
Roughback sculpin	*Chitonotus pugetensis*	**E1**	**C1**	
Curlfin sole	*Pleuronichthys decurrens*	**D**	**-**	Palos Verdes Benthic
California scorpionfish	*Scorpaena guttata*	**D**	**E1**	Palos Verdes Benthic
Longspine combfish	*Zaniolepis latipinnis*	**CE1**	**E**	Middle Shelf
Bigmouth sole	*Hippoglossina stomata*	**CE1**	**E**	Middle Shelf
Longfin sanddab	*Citharichthys xanthostigma*	**-**	**E**	Middle Shelf
Bay goby	*Lepidogobius lepidus*	**-**	**E**	Middle Shelf
Yellowchin sculpin	***Icelinus quadriseriatus***	**E**	**E**	**Middle Shelf**
Pacific sanddab	***Citharichthys sordidus***	**E**	**E**	**Middle Shelf**
Plainfin midshipman	***Porichthys notatus***	**E**	**E**	**Middle Shelf**
Pink seaperch	***Zalembius rosaceus***	**E**	**E**	**Middle Shelf**
English sole	***Pleuronectes vetulus***	**E**	**F**	**Middle/Outer Shelf**
Stripetail rockfish	***Sebastes saxicola***	**E**	**F**	**Middle/Outer Shelf**
Dover sole	***Microstomus pacificus***	**E**	**F**	**Middle/Outer Shelf**
Cowcod	*Sebastes levis*	**E1**	**-**	
Pacific argentine	*Argentina sialis*	**-**	**EF1**	
Spotted cusk-eel	*Chilara taylori*	**-**	**F1**	
Pacific hake	*Merluccius productus*	**-**	**G**	Outer Shelf
Shortspine combfish	***Zaniolepis frenata***	**G**	**G**	**Outer Shelf**
Slender sole	***Eopsetta exilis***	**G**	**G**	**Outer Shelf**
Rex sole	***Errex zachirus***	**G**	**G**	**Outer Shelf**
Blacktip poacher	***Xeneretmus latifrons***	**G**	**G**	**Outer Shelf**
Blackbelly eelpout	*Lycodopsis pacifica*	**G**	**G1**	Outer Shelf
Greenblotched rockfish	*Sebastes rosenblatti*	**G1**	**G1**	
Greenstriped rockfish	*Sebastes elongatus*	**G1**	**-**	
Splitnose rockfish	*Sebastes diploproa*	**H**	**-**	Upper Slope Benthopelagic
Sablefish	*Anoplopoma fimbria*	**H**	**-**	Upper Slope Benthopelagic

[a] Recurrent groups occurring at less than three stations not included.
[b] 1972-1973 = Allen (1982); 1994 = present study, July-August 1994
A, B, C, D, E, F, G, H designate recurrent groups; C1, CE1, E1, EF1, F1, G1 designate associates of recurrent groups or combinations of recurrent groups. Core group species are in bold and boxed together.

species: longspine combfish; bigmouth sole; bay goby; and longfin sanddab. In the 1970s, longspine combfish and bigmouth sole were associates of the Inner/Middle and Middle/Outer Shelf Groups. However, bay goby and longfin sanddab were not frequently occurring species in the 1970s. The addition of these four species to the Middle Shelf Group probably reflects the more successful recruitment of these species during the warm period (CSDLAC 1990, Stull and Tang 1996). The expansion of the sampling area may also have had some influence on the results (particularly by including the more southerly longfin sanddab).

The core of the Outer Shelf Group (Group 4 in 1994) consisted of shortspine combfish, slender sole, rex sole, and blacktip poacher. The Outer Shelf Group also included blackbelly eelpout in the 1970s and Pacific hake in 1994. In 1994, blackbelly eelpout was an associate of the group.

In addition, several minor groups identified in the 1970s (Allen 1982) were not present in 1994 (Table 2). These groups consisted of deep, shallow-water, and outfall-associated species. Two groups (Shallow Surfperch and Upper Slope Benthopelagic) represent species that are typically shallower or deeper, respectively, than the depth range sampled in both surveys. Hence, they may not have been present in 1994 survey due to chance. Two other groups (Nearshore Schoolers and Palos Verdes Benthic) occurred on the Palos Verdes Shelf in the 1970s (which was heavily contaminated at the time) (Stull 1995, Stull and Tang 1996). Although only two trawl samples were collected on the Palos Verdes Shelf in 1994, previous studies (CSDLAC 1990, Stull 1995, Stull and Tang 1996) have shown that shiner perch (*Cymatogaster aggregata*) and curlfin sole (*Pleuronichthys decurrens*) disappeared from the Palos Verdes Shelf in the late 1970s. This event preceded the oceanic warming of the 1980s and coincided with the changed environmental conditions resulting from changes in wastewater treatment. However, the disappearance of these species may be attributable to changes in the trophic environment on the Palos Verdes Shelf. Curlfin sole feeds primarily on spoonworm (*Listriolobus pelodes*) (Allen 1982), which decreased in abundance on the Palos Verdes Shelf in the early 1970s (Stull 1995). Shiner perch feeds on zooplankton (particularly, calanoid copepods) (Allen 1982). Zooplankton biomass in southern California decreased by 80% between 1951 and 1993, with most of the decline occurring since the 1970s (Roemmich and McGowan 1995).

Allen (1982) described ecological segregation within the fish recurrent groups from the 1970s. That study showed that, species occurring together in recurrent groups were generally ecologically and morphologically different. The most ecologically similar species were found in different recurrent groups at different depths. In 1994 and in the early 1970s, the morphologically similar speckled sanddab, Pacific sanddab, and slender sole were important members of the Inner/Middle Shelf, Middle Shelf, and Outer Shelf Groups, respectively. In the 1994 group, the pattern was repeated, except that longfin sanddab (a warm-temperate/tropical species; Eschmeyer *et al.* 1983) was included with Pacific sanddab (a temperate species; Allen and Smith 1988) in the Middle Shelf Group. Polychaete-feeding flatfishes are only found in the Inner/Middle Shelf Group and Middle/Outer Shelf Group. This dispersion reflects the general distribution of the species, with hornyhead turbot dominant on the inner shelf and Dover sole and English sole performing this role on both the middle and outer shelf zones (Allen 1982).

Generally, the most diverse recurrent groups were not widely represented. The likelihood of finding all members of a group at a site with an increased number of species was limited. This does not mean that the species comprising the groups (or combinations of species comprising the groups) were not widespread. Nevertheless, if core recurrent groups represent core biogeographic communities, the relative development of the group at a site may be useful in identifying the best areas for the community.

Allen (1982) found that a high proportion of the species occupying the soft-bottom habitat of the mainland shelf of southern California were either incidental to the habitat or region, or were inadequately sampled by trawl. Of 126 fish species collected in the early 1970s, 26% formed recurrent groups, 68% were incidental (being more commonly found in other habitats or biogeographic zones), and 6% were characteristic of the area but ineffectively sampled by trawl. A similar distribution probably applied in 1994 as only 32% of the 87 species formed recurrent groups.

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