Abstract.—Numerical classification techniques, recurrent group analysis, and a clustering analysis that uses the Bray-Curtis resemblance measure were used to identify rockfish (family Scorpaenidae) assemblages in the offshore waters of Oregon and Washington. Catch data from six multispecies groundfish assessment surveys conducted at three-year intervals (1977–92) by the National Marine Fisheries Service's Alaska Fisheries Science Center revealed three assemblages. The first, a deep-water assemblage, consisted of shortspine thornyhead, *Sebastolobus alascanus*, Pacific ocean perch, *Sebastes alutus*, darkblotched rockfish, *S. crameri*, and splitnose rockfish, *S. diploproa*. Redbanded rockfish, *S. babcocki*, and rougheye rockfish, *S. aleutianus*, were closely associated with this group. The second assemblage consisted of canary rockfish, *S. pinniger*, yellowtail rockfish, *S. flavidus*, and greenstriped rockfish, *S. elongatus*. This group was most abundant in areas over the middle shelf. The third assemblage, closely associated with the second, consisted of sharpchin, *S. zacentrus*, rosethorn, *S. helvomaculatus*, and redstripe, *S. proriger*, rockfish. While the three assemblages may be of particular interest to ecologists, managers faced with the division of the *Sebastes* complex management unit into groups that better reflect rockfish cooccurrence may only be able to manage the latter two assemblages as one shelf-rockfish unit.

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Rockfish assemblages of the middle shelf and upper slope off Oregon and Washington

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Over the last three decades, some stocks of the more than 30 species of rockfish (family Scorpaenidae) known to inhabit the offshore waters of Oregon and Washington (Eschmeyer and Herald, 1983) have been the target of intense foreign and domestic fishing pressure in a largely multispecies trawl fishery. In 1982 a groundfish fishery management plan was implemented by the Pacific Fisheries Management Council to address the reductions in groundfish populations, including serious declines of several rockfish species in some areas. This plan was based on an underlying single-species management philosophy.

In both the Columbia and the U.S. portion of the Vancouver (US-Vancouver) management areas instituted by the International North Pacific Fisheries Commission (INPFC), annual harvesting restrictions have been fashioned for Pacific ocean perch, *Sebastes alutus*, widow rockfish, *S. entomelas*, shortbelly rockfish, *S. jordani*, and thornyheads, *Sebastolobus* spp. The remaining rockfish species have been lumped into a single management unit, the *Sebastes* complex. In addition to individual trip limits, current restrictions for this large group involve an overall annual harvest guideline and harvest guidelines for two of its already stressed components, yellowtail, *Sebastes flavidus*, and canary, *S. pinniger*, rockfish (PFMC, 1992[1]). While efforts to prevent over-harvesting of yellowtail and canary rockfish continue, the fishing pressure on the minor rockfish in the management unit has escalated. Species, such as darkblotched rockfish, *S. crameri*, are becoming increasingly important to fishermen.

This research stems from a concern over the long-term effects of the trawl fishery on the condition of the rockfish community as a whole. Current reductions in some stocks along with present bycatch practices may precipitate the need for changes in management policies to conserve these stocks. One possible course of action involves multispecies management, whereby cooccurring species are managed as a species complex or assemblage. If needed, restrictions could be placed on the fishery for the assemblage when specific components become stressed. An effective assemblage management program requires knowledge of interspecific associations in addition to individual life histories, distribution, and abundance patterns.

Prior knowledge of offshore rockfish associations has largely been inferred from shoreside sampling of commercial catches. In recent years several investigations have been

[1] Pacific Fishery Management Council (PFMC). 1992. Status of the Pacific coast groundfish fishery through 1992 and recommended acceptable biological catches for 1993; stock assessment and fishery evaluation. Pacific Fishery Management Council, Metro Center, Suite 420, 2000 SW First Ave., Portland, OR 97201, 80 p.

conducted to identify assemblages using trawl data covering extensive geographic areas. Nagtegaal (1983) studied both annual and seasonal interrelationships of some rockfish species off British Columbia based on commercial catch data. However, these catch statistics do not allow a full description of the effects of selective harvest on the entire rockfish community, as the landed species are those of highest economic value allowed for harvest at the time and reflect only a portion of the overall rockfish community exposed to trawling. Rogers and Pikitch (1992) defined several groundfish assemblages based on prediscard data from the commercial trawl fishery off Oregon and Washington. That study included a variety of groundfish families, but only the most abundant rockfish species were considered. Similarly, Gabriel (1982) included a wide variety of groundfishes in a 1-year assemblage study that utilized 1977 survey data from California to Washington. All of these researchers recognized the value of fish assemblage identification as a tool for fisheries management and emphasized the need to verify assemblage persistence.

Since 1977, the Alaska Fisheries Science Center (AFSC) of the National Marine Fisheries Service (NMFS) has been conducting controlled bottom trawl surveys aimed at assessing and monitoring groundfish resources off the west coast of the United States. Now that several of these surveys have been performed, a unique opportunity exists to monitor persistence in fish assemblages. In this paper I describe and summarize these surveys and their rockfish samples and use standard numerical classification techniques to identify the major rockfish assemblages.

Methods

This study utilizes rockfish catch data from six AFSC multispecies groundfish assessment surveys conducted triennially over a 16-year period from 1977 to 1992. Only data from bottom trawling in the Columbia and U.S.-Vancouver INPFC areas (43°00'N to the U.S.-Canada border) were examined. Trawling occurred during August and September between the depths of 55 and 366 m. All surveys employed stratified random sampling designs, apportioning towing sites according to various geographic strata and depth intervals. While the overall multispecies assessment goal remained unchanged from one survey to the next, many of the specific objectives did not. Objectives of the 1977 survey included determining the distribution and abundance of several commercially important rockfishes (Gunderson and Sample, 1980) and the on-bottom component of Pacific hake, *Merluccius productus*. The survey design was patterned after rockfish distributions, determined by fisheries catch data and the results of a pilot rockfish survey (Gunderson and Nelson[2]). The 1980 survey was specifically redesigned to better assess the canary and yellowtail rockfish populations, in addition to Pacific hake (Coleman, 1986). Thus, the sampling effort was divided among three depth strata: 55–183 m, 184–220 m, and 221–366 m. The 1983 survey repeated the work conducted in 1980 with the addition of some stations in the northern U.S.-Vancouver area (Weinberg et al., 1984). Based on the results of the previous surveys and in an attempt to further reduce the variance of canary and yellowtail rockfish catch rates, station allocation was changed again in 1986 (Coleman, 1988). In that year, sampling was apportioned among four depth strata: 55–91 m, 92–183 m, 184–219 m, and 220–366 m. Almost three times the effort was applied in the U.S.-Vancouver area, most of which was off northern Washington (lat. 48°00'–42°23'N). However, having not been able to improve rockfish estimates significantly, the 1989 and 1992 AFSC surveys shifted away from rockfish concerns of past surveys and concentrated on abundance estimation of Pacific hake and young sablefish, *Anoplopoma fimbria*. Consequently, the high density rockfish strata were abandoned and sampling was allocated within only two depth strata, 55–183 m and 184–366 m (Weinberg et al., 1994).

Samples were collected with standardized Nor'eastern high-opening rockfish bottom trawls rigged with roller gear. In general the gear's horizontal and vertical openings measured 13 and 9 m, respectively. Towing was controlled by fishing along depth contours for one-half hour at about three knots. Catches were sorted by species, weighed, and counted.

Assemblage analyses

I examined rockfish associations using two techniques: recurrent group analysis and cluster analysis. These two methods provide somewhat different characterizations of species distribution and cooccurrence and, when used together, can enhance our understanding of rockfish communities.

Recurrent group analysis (RGA), a nonhierarchical technique, addresses the question of which rockfish are likely to be caught together, thus reflecting their

[2] Gunderson, D. R., and M. O. Nelson. 1977. Preliminary report on an experimental rockfish survey conducted off Monterey, California, and in Queen Charlotte Sound, British Columbia, during August-September 1976. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Northwest and Alaska Fish. Cent., 2725 Montlake Blvd. E., Seattle, WA 98112. Unpubl. manuscr., 82 p.

spatial distribution patterns (Fager and McGowan, 1963). Species were included in a group based solely on their presence or absence in catches. Fixed groups were defined as the greatest number of members having affinities with one another based on a 40% affinity threshold.

However, because fishermen are concerned primarily with abundance in terms of biomass, the findings of RGA were supplemented by cluster analysis (CA), a method that incorporates sample catch weights into the grouping process. CA calculates resemblance measures using the Bray-Curtis dissimilarity coefficient (Bray and Curtis, 1957) and then clusters agglomeratively, using a flexible sort fusion strategy with an assigned clustering coefficient value (beta) equal to –0.25 (Lance and Williams, 1967). The flexible strategy was selected over other clustering methods because of its tendency to reduce the chaining effect often seen in dendrograms. Dendrograms display the similarities among species and groups in hierarchical form, permitting greater flexibility in the interpretation of associations than the RGA technique which produces set groups (Clifford and Stephenson, 1975). Relative groupings can be distinguished at varying levels of dissimilarity where the number 0 indicates greatest resemblance.

Prior to classifying assemblages, steps were taken to reduce "noise" in the data. First, groundfish species other than scorpaenids were eliminated, since the objective of the study was to identify rockfish assemblages without the masking effect caused by the presence of other species. Next, the least frequent rockfishes, defined as those taken at fewer than three stations in each of the groundfish surveys, were omitted. Knowledge of the path width of our survey gear facilitated the standardization of catch data as catch per unit of effort (CPUE), i.e. kilograms per hectare towed (kg/ha)[3], or roughly equivalent to towing our gear for 0.8 km. Finally, CPUE's were log transformed ($\log_{10}(x+1)$) to reduce the influence of high CPUE's (Boesch[4]).

Results

Over the six surveys, a total of 1,874 successful hauls were made in the Columbia and U.S.-Vancouver INPFC areas (Fig. 1). Rockfish were present in 79% (1,476) of the tows. Sampling effort was greatest in 1986 and considerably lower during 1977, 1989, and 1992. Most of the effort was applied between the depths of 101 and 200 m (Fig. 2). Sampling at greater depths was proportionally higher in 1977 than during the other surveys.

Catch composition and species diversity

Thirty three rockfish species (shortspine thornyhead *Sebastolobus alascanus* and 32 species of *Sebastes*) were identified. Among these, 20 were commonly caught in 1,468 hauls and included in the assemblage analysis (Table 1).

Catches of rockfish varied widely in size and composition. Many of the catches were small: 25% had CPUE's under 1.1 kg/ha and 50% had CPUE's under 4.8 kg/ha. In contrast, 8% were greater than 100 kg/ha while only 1% were greater than 500 kg/ha. Maximum rockfish CPUE's reached 4,126, 564, 1,253, 759, 2,303, and 828 kg/ha during the six respective surveys. The average CPUE for each survey was 50, 16, 34, 21, 34, and 27 kg/ha, respectively. On average, abundance levels increased in deeper water, peaking in the 151–250 m depth interval (Fig. 3).

Species diversity in survey catches depicts the multispecies nature of the rockfish community vulnerable to the bottom trawl. Eighty three percent of rockfish samples contained more than one species. Of these, approximately 50% contained 2–5 species, 29% contained 6–10 species, and 4% contained 10–16 species. Of the single-species catches, 78% were under 1 kg/ha. In contrast, the two largest single-species catches (canary rockfish) exceeded 100 kg/ha. Eighty five percent of the single-species samples were either shortspine thornyhead (7%), canary (26%), darkblotched (21%), yellowtail (18%), or greenstriped, *Sebastes elongatus* (14%), rockfish. Silvergray, *S. brevispinis*, rosethorn, *S. helvomaculatus*, redbanded, *S. babcocki*, and yellowmouth, *S. reedi*, rockfish were never caught alone.

Species diversity, like abundance, increased with depth (Fig. 4). Hauls made at the shallowest sampling sites (~55 m) demonstrated little variety. As sampling depth increased, nearshore species, such as black, *S. melanops*, and quillback, *S. maliger*, rockfish, were replaced by offshore rockfishes, including juveniles of many species that inhabit even deeper waters as adults. Over the middle-shelf, within the 55–150 m depth interval, up to 13 rockfish species were taken in a single tow. About 22% of the hauls made at these depths contained five or more species (Table 2). Species diversity peaked along the outer-shelf, where the centers of abundance for several species overlapped. In waters 151–250 m deep, catches

[3] 1 kg/ha=0.1 t/km².

[4] Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. Virginia Inst. Marine Science, Spec. Sci. Rep. 77, EPA-600/3-77-033, 114 p. Environ. Res. Lab., Off. Res. Dev., U.S. Environ. Protection Agency, Corvallis, OR 97330.

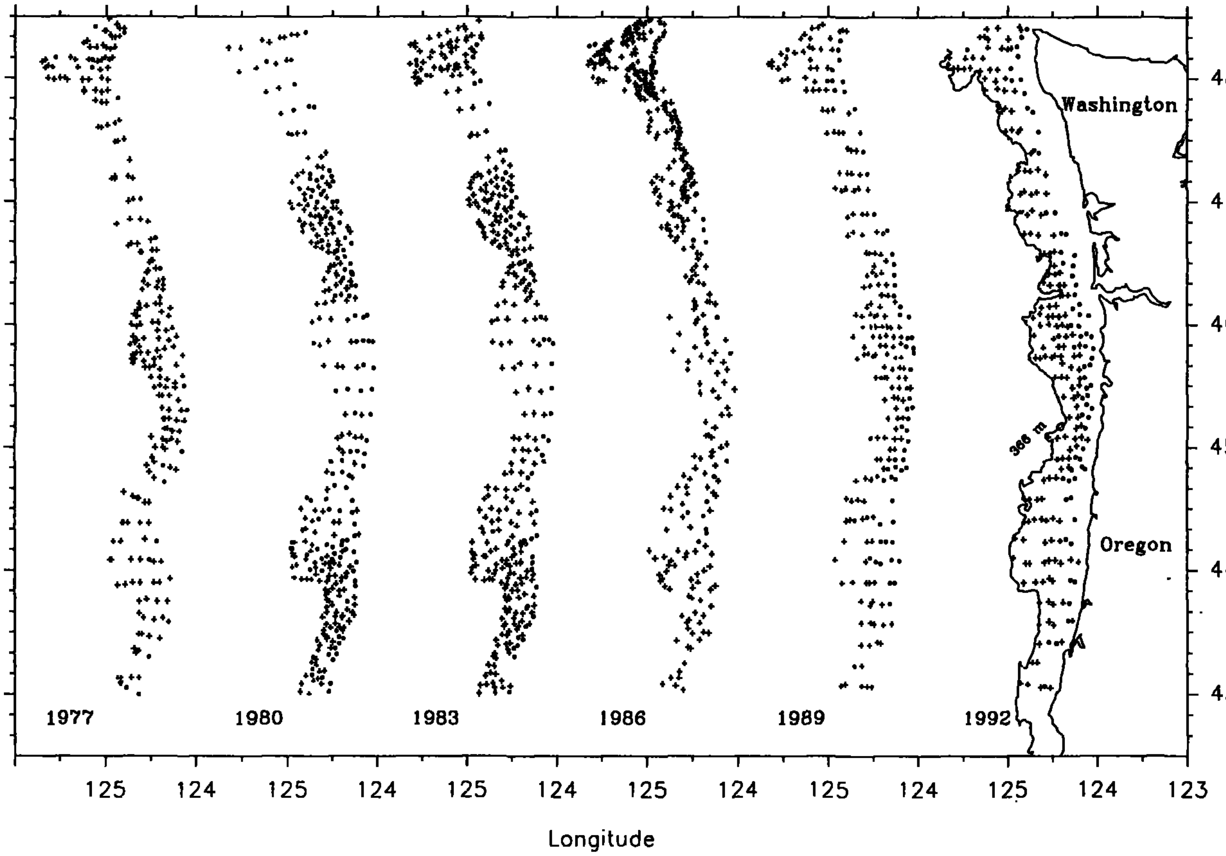

Figure 1

The distribution of hauls from the west coast triennial groundfish surveys showing the presence (+) or absence (o) of rockfish (Scorpaenidae) in the Columbia and U.S.-Vancouver areas.

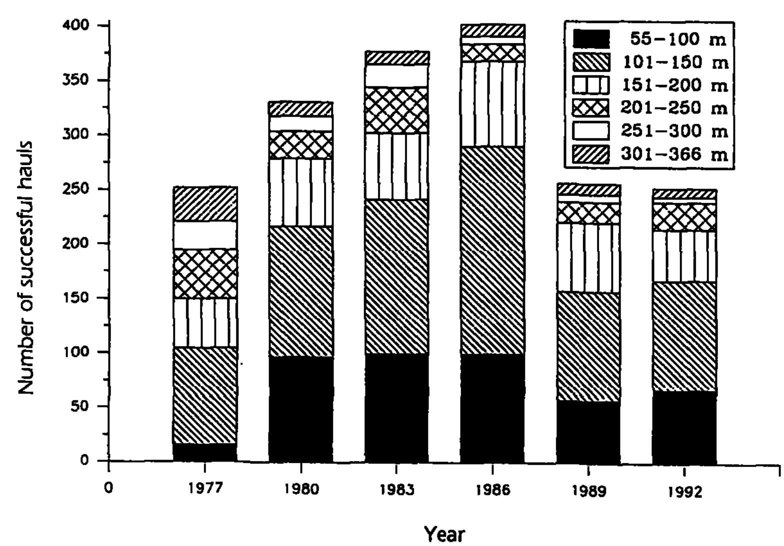

Figure 2

Distribution of successful survey effort by depth interval for the west coast triennial groundfish surveys (1977–92).

Table 1

The frequency of occurrence of rockfishes (Scorpaenidae) in the Columbia and U.S.-Vancouver areas from the west coast triennial groundfish surveys (1977–92).

		Frequency of occurrence						
Scientific name	Common name	1977	1980	1983	1986	1989	1992	Total
Species included in assemblage analyses								
Sebastolobus alascanus	Shortspine thornyhead	140	92	130	113	81	57	613
Sebastes aleutianus	Rougheye rockfish	39	19	36	54	47	46	241
Sebastes alutus	Pacific ocean perch	129	52	92	80	43	54	450
Sebastes babcocki	Redbanded rockfish	72	40	61	40	41	33	287
Sebastes brevispinis	Silvergray rockfish	31	23	54	34	11	8	161
Sebastes crameri	Darkblotched rockfish	129	99	172	163	128	105	796
Sebastes diploproa	Splitnose rockfish	90	38	90	56	50	33	357
Sebastes elongatus	Greenstriped rockfish	98	92	191	185	123	124	813
Sebastes entomelas	Widow rockfish	45	23	45	36	17	24	190
Sebastes flavidus	Yellowtail rockfish	90	83	153	130	44	53	553
Sebastes helvomaculatus	Rosethorn rockfish	42	36	64	59	46	48	295
Sebastes jordani	Shortbelly rockfish	5	46	39	28	11	5	134
Sebastes paucispinis	Bocaccio	45	36	60	34	10	3	188
Sebastes pinniger	Canary rockfish	74	68	143	155	63	50	553
Sebastes proriger	Redstripe rockfish	29	27	47	43	37	28	211
Sebastes reedi	Yellowmouth rockfish	6	4	11	6	4	8	39
Sebastes ruberrimus	Yelloweye rockfish	13	12	23	26	24	19	117
Sebastes saxicola	Stripetail rockfish	35	26	45	27	26	24	183
Sebastes wilsoni	Pygmy rockfish	3	7	21	20	27	13	91
Sebastes zacentrus	Sharpchin rockfish	74	39	82	77	53	48	373
Species excluded from assemblage analyses								
Sebastes aurora	Aurora rockfish	1	—	2	—	—	1	4
Sebastes borealis	Shortraker rockfish	5	1	3	2	—	—	11
Sebastes chlorostictus	Greenspotted rockfish	1	5	1	2	1	3	13
Sebastes eos	Pink rockfish	2	—	—	—	—	—	2
Sebastes goodei	Chilipepper	—	4	4	1	3	1	13
Sebastes levis	Cowcod	—	—	—	—	2	1	3
Sebastes maliger	Quillback rockfish	1	—	1	5	2	3	12
Sebastes melanops	Black rockfish	—	4	7	10	2	—	23
Sebastes melanostomus	Blackgill rockfish	—	4	1	—	—	—	5
Sebastes nigrocinctus	Tiger rockfish	—	—	1	—	—	—	1
Sebastes ovalis	Speckled rockfish	—	—	—	2	—	—	2
Sebastes rufus	Bank rockfish	—	—	1	—	1	1	3
Sebastes semicinctus	Halfbanded rockfish	—	—	—	—	2	—	2

contained up to 16 rockfish species; 73% of the samples contained five or more species. Samples ranging between 251–366 m in depth had up to 13 rockfish species with 52% of the samples having 5 or more species. Rockfish diversity declined at the deepest sites (~366 m).

Species assemblages

A total of 1,468 multispecies hauls were pooled together into a multi-survey, "All Years" analysis. Of the 20 rockfish species examined, 10 were identified as belonging to one of three groups or assemblages. Table 3 lists the results of RGA. The results of CA are shown in Figure 5 and summarized in Table 4. Group 1 consisted of shortspine thornyhead, Pacific ocean perch, darkblotched rockfish, and splitnose rockfish, *S. diploproa*. These four species occurred together in 200 samples at an average depth of 247 m (range=141–366 m). The mean rockfish CPUE in these hauls was 45.8 kg/ha of which the assemblage accounted for 82% of the total. Group 2 consisted of canary, yellowtail, and greenstriped rockfish. It also occurred in 200 survey hauls that averaged 150 m in depth (range= 91–291 m). Rockfish catches in hauls containing this assemblage were greater than Group 1, averaging 88.8 kg/ha. Canary, yellowtail, and greenstriped rockfish accounted for about 56% of the total rockfish CPUE at these sites. Group 3 consisted of sharpchin, redstripe, and rosethorn rockfish. This group was present in 99 samples. Its depth range

Table 2

Number of rockfish species (Scorpaenidae) from the west coast triennial groundfish surveys (1977–92) by depth interval in the Columbia and U.S.-Vancouver areas.

	Number of hauls per depth interval (m)						
Number of species	55–100	101–150	151–200	201–250	251–300	301–366	55–366
0	242	124	16	6	5	5	398
1	111	115	12	4	4	4	250
2	33	123	20	3	5	5	189
3	35	123	35	10	3	7	213
4	6	94	42	10	9	8	169
5	5	63	53	14	15	15	165
6	2	44	33	24	14	18	135
7	3	21	32	19	12	12	99
8	0	16	28	25	4	5	78
9	1	12	29	22	3	5	72
10	0	5	19	11	2	1	38
11	0	1	18	13	1	0	33
12	1	0	8	5	1	0	15
13	0	1	8	2	2	0	13
14	0	0	1	1	0	0	2
15	0	0	1	3	0	0	4
16	0	0	1	0	0	0	1
Total	439	742	356	172	80	85	1874

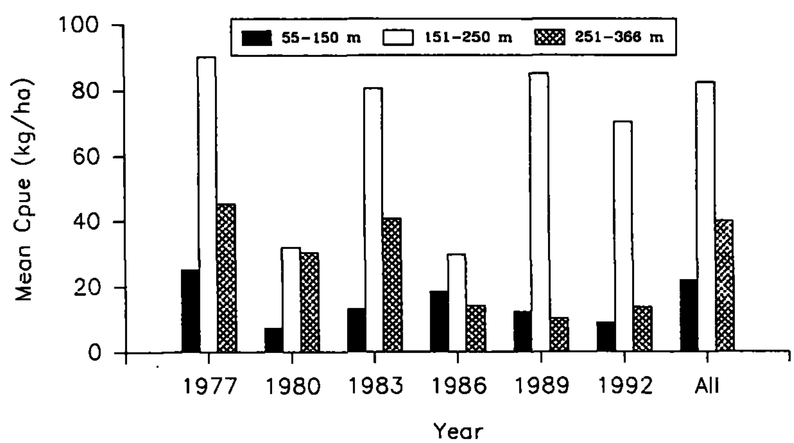

Figure 3

Relative abundance of rockfish (Scorpaenidae) expressed as mean catch per unit of effort (CPUE) for selected depth intervals by survey and for all surveys combined.

overlapped that of Group 2, 99–293 m, but this group was present, on average, in slightly deeper waters, 175 m (Fig. 6). Catches of this assemblage seemed to be more localized than were the others, occurring mainly in areas of highly irregular or hard bottom. Catch rates were highest at sites where this assemblage was present, averaging 159 kg/ha of which these three species accounted for 79% of the total. Shortbelly and pygmy rockfish, *S. wilsoni*, were also grouped together based on very low occurrences, probably an artifact of the grouping process.

The groupings assigned by the RGA and CA techniques were indentical except for two species. These were the assignment of redbanded rockfish to Group 1 by RGA only; and the assignment of greenstriped rockfish to Group 3 by RGA and Group 2 by CA.

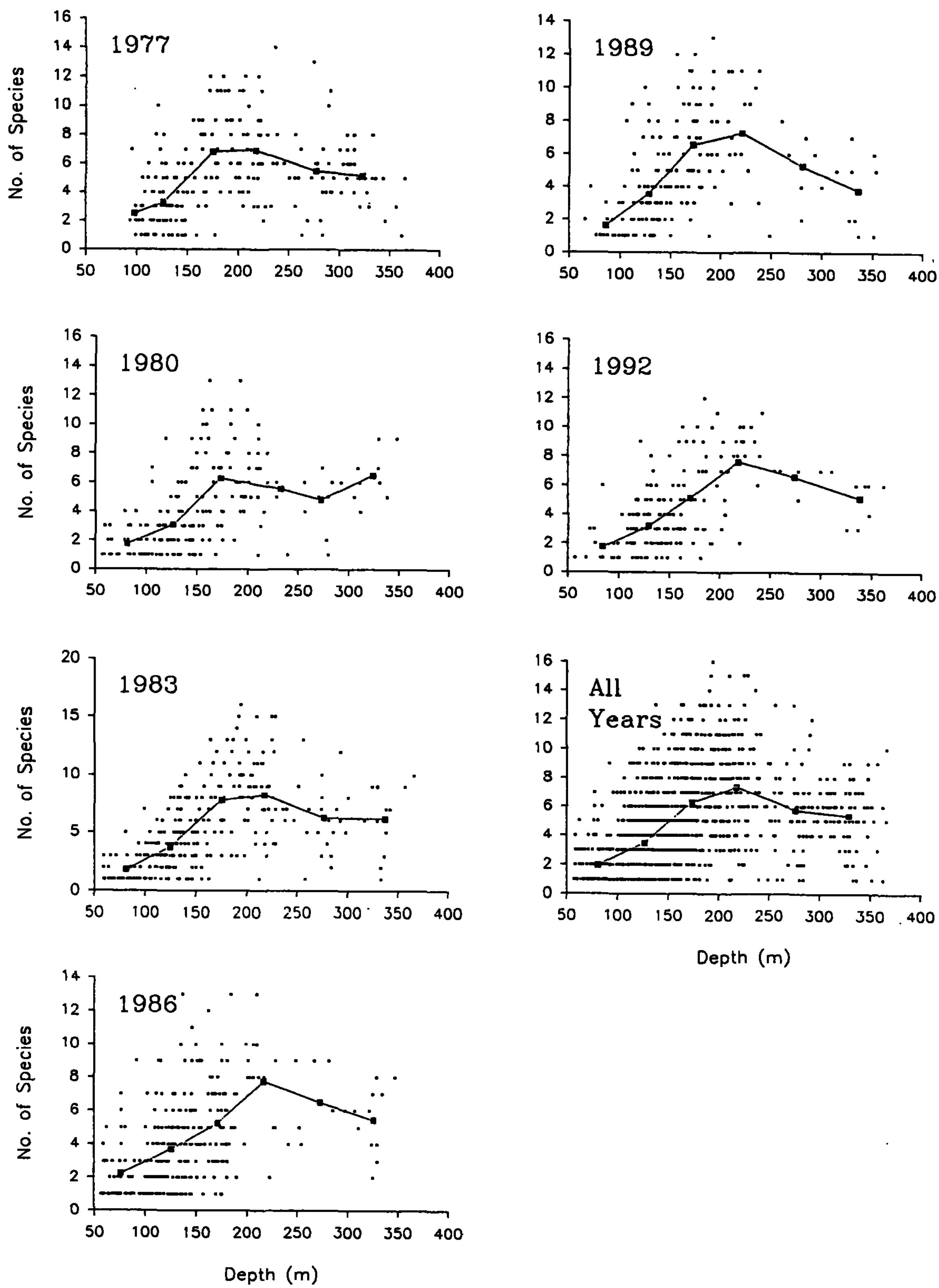

Figure 4

Number of rockfish species (Scorpaenidae) per tow (dots) and averaged over 55–100, 101–150, 151–200, 201–250, 251–300, and 301–366 m depth intervals (squares).

Table 3

Major species groups (1–3) of rockfish (Scorpaenidae) determined by recurrent group analysis by survey and for all surveys combined. Depth (m) and catch per unit of effort (CPUE, kg/ha) statistics refer to samples when all species listed in the group cooccurred. The group mean catch is also presented as the percent of the total average rockfish catch in those hauls. See Table 1 for scientific names.

Species	1977	1980	1983	1986	1989	1992	All years
Shortspine thornyhead	1	1	1	1	1	1	1
Pacific ocean perch	1	1	1	1	—	1	1
Splitnose rockfish	1	1	1	1	1	1	1
Darkblotched rockfish	1	—	1	1	1	2	1
Redbanded rockfish	1	1	—	—	1	1	1
Canary rockfish	2	2	2	2	3	—	2
Yellowtail rockfish	2	—	2	2	—	2	2
Greenstriped rockfish	2	2	1	3	3	2	3
Sharpchin rockfish	3	3	3	3	3	3	3
Rosethorn rockfish	3	3	3	3	3	3	3
Redstripe rockfish	—	—	3	—	—	3	3

Depth and catch statistics	Group 1	Group 2	Group 3
1977			
Occurrences	41	34	31
Mean depth (range)	255 (155–344)	163 (104–291)	217 (108–315)
Mean group CPUE (range)	48.7 (6.2–496.0)	57.6 (1.3–599.4)	11.2 (0.2–72.4)
Proportion of total CPUE (%)	79.8	63.5	9.5
1980			
Occurrences	19	37	24
Mean depth (range)	249 (150–338)	154 (82–274)	195 (144–348)
Mean group CPUE (range)	39.7 (0.9–155.7)	14.0 (0.2–116.7)	11.2 (0.1–94.4)
Proportion of total CPUE (%)	73.6	23.6	13.1
1983			
Occurrences	31	80	26
Mean depth (range)	213 (154–293)	143 (59–251)	196 (124–293)
Mean group CPUE (range)	32.2 (1.7–126.0)	36.1 (0.6–742.5)	71.1 (0.1–681.8)
Proportion of total CPUE (%)	67.9	47.1	34.5
1986			
Occurrences	31	73	34
Mean depth (range)	233 (150–348)	124 (59–185)	165 (97–267)
Mean group CPUE (range)	37.3 (1.5–417.8)	48.0 (0.1–745.3)	9.2 (0.3–87.4)
Proportion of total CPUE (%)	89.2	79.7	15.8
1989			
Occurrences	27	—	22
Mean depth (range)	230 (132–353)	—	174 (112–238)
Mean group CPUE (range)	9.8 (0.3–64.8)	—	22.7 (0.6–92.4)
Proportion of total CPUE (%)	36.3	—	23.3
1992			
Occurrences	9	24	15
Mean depth (range)	230 (214–260)	155 (119–219)	167 (113–223)
Mean group CPUE (range)	31.0 (7.9–98.8)	25.6 (1.3–283.3)	120.8 (0.7–533.4)
Proportion of total CPUE (%)	53.5	76.2	67.3
All years			
Occurrences	135	278	89
Mean depth (range)	259 (155–366)	141 (59–291)	173 (97–293)
Mean group CPUE (range)	45.9 (1.7–496.0)	53.3 (0.1–1205.2)	26.1 (0.3–684.7)
Proportion of total CPUE (%)	80.3	62.8	12.5

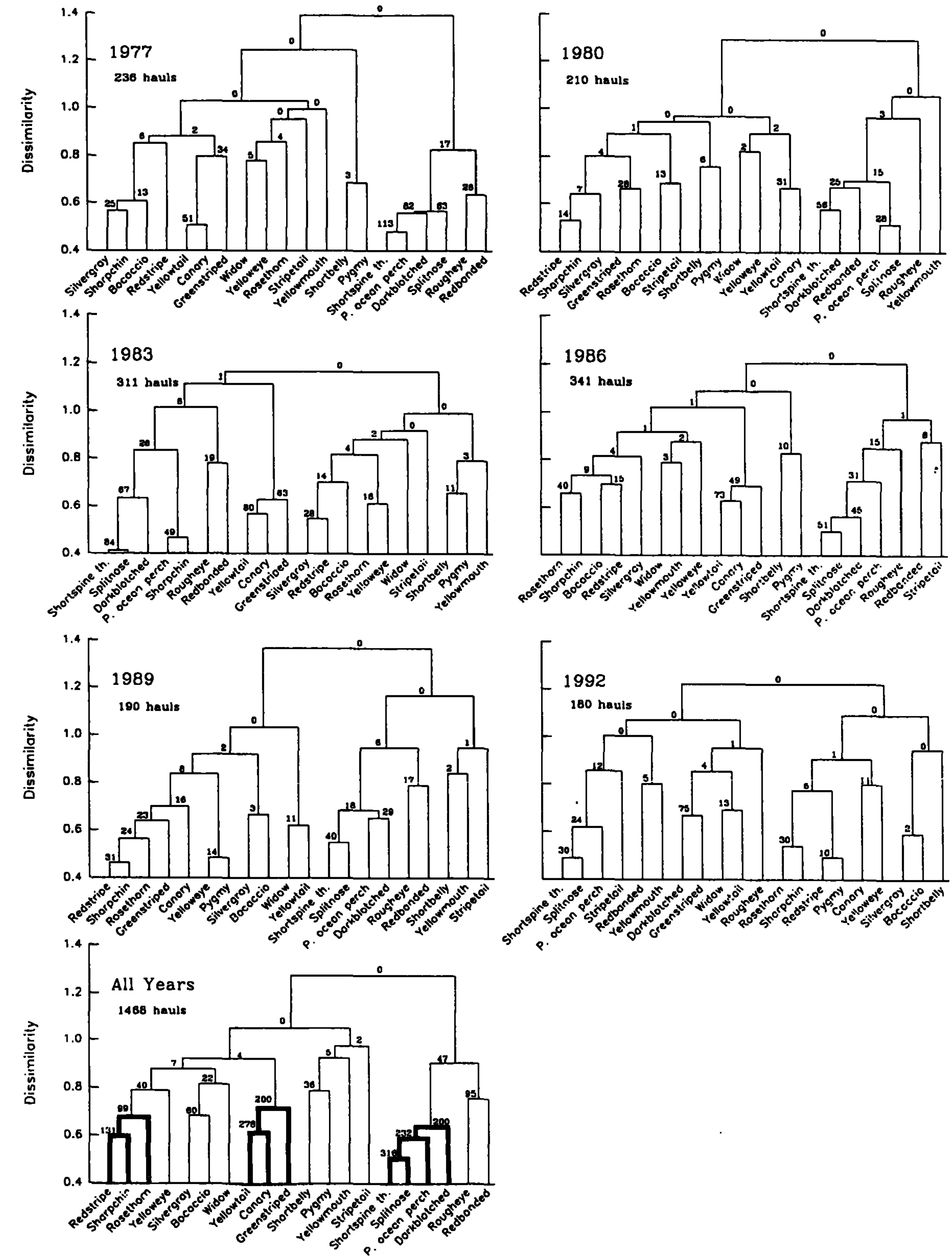

Figure 5

Dendrograms showing the relationships among rockfish (Scorpaenidae) species and assemblages (in bold) in the Columbia and U.S.-Vancouver areas. The values on top of each cluster correspond to its frequency of occurrence with all members present.

Table 4

Catch per unit of effort (CPUE) and depth (m) data from the combined 1977–92 west coast triennial groundfish surveys presented for the three rockfish (Scorpaenidae) assemblages identified by cluster analysis. The species catch composition data (listed across) are from hauls containing these assemblages and include mean CPUE (kg/ha) and standard deviation; the percentage of the total rockfish CPUE taken in these hauls, and the percent frequency of occurrence. Values below 0.1 are indicated by the letter *t*. Differences in totals are a result of rounding. See Table 1 for scientific names.

All years (1977–92)	Group 1				Group 2				Group 3			
Total hauls[1]	200				200				99			
Mean depth (range)	247 (141–366)				150 (91–291)				175 (99–293)			
Mean CPUE	45.8				88.8				158.6			
Catch composition	Mean CPUE	SD	% CPUE	% Occur.	Mean CPUE	SD	% CPUE	% Occur.	Mean CPUE	SD	% CPUE	% Occur.
Group 1												
Darkblotched	9.0	2.26	19.7	100.0	1.4	0.27	1.6	52.0	0.5	0.22	0.3	22.2
Pacific ocean perch	17.6	3.06	38.4	100.0	2.9	1.03	3.4	26.0	9.6	3.14	6.1	53.5
Shortspine thornyhead	3.8	0.29	8.4	100.0	0.5	0.13	0.5	37.5	0.7	0.16	0.4	46.4
Splitnose	7.0	1.03	15.4	100.0	0.3	0.10	0.3	21.0	1.1	0.42	0.7	26.3
Total	37.4		81.9		5.2		5.8		12.0		7.5	
Group 2												
Canary	0.4	0.14	0.9	25.5	15.4	4.03	17.3	100.0	16.8	5.59	10.6	66.7
Greenstriped	0.6	*t*	1.3	48.0	2.7	0.33	3.0	100.0	3.9	0.59	2.4	89.9
Yellowtail	0.6	0.19	1.3	19.0	31.2	6.18	35.1	100.0	24.3	7.39	15.3	50.5
Total	1.6		3.5		49.2		55.5		44.9		28.3	
Group 3												
Redstripe	*t*	*t*	0.2	8.0	14.1	4.10	15.9	33.5	46.1	10.28	29.1	100.0
Rosethorn	0.2	*t*	0.4	34.0	0.6	0.14	0.7	40.5	1.9	0.26	1.2	100.0
Sharpchin	3.0	0.78	6.7	43.5	9.8	3.91	11.1	39.5	31.1	8.36	19.6	100.0
Total	3.2		7.3		24.5		27.6		79.1		49.9	
Other rockfish												
Bocaccio	0.3	*t*	0.6	16.5	1.5	0.34	1.7	37.0	2.5	0.68	1.6	42.4
Pygmy	*t*	*t*	*t*	3.0	0.5	0.27	0.6	14.0	3.4	1.52	2.2	31.3
Redbanded	0.8	0.12	1.7	67.5	0.6	0.29	0.7	14.0	0.4	0.16	0.3	28.3
Rougheye	0.5	0.12	1.1	31.5	0.2	*t*	0.2	9.5	*t*	*t*	*t*	7.1
Shortbelly	*t*	*t*	0.2	8.5	0.3	0.14	0.3	18.5	0.7	0.34	0.4	24.2
Silvergray	0.4	0.20	0.9	10.5	1.6	0.38	1.9	25.5	8.8	5.18	5.5	45.4
Stripetail	0.3	*t*	0.7	31.0	0.3	*t*	0.3	17.0	0.5	0.17	0.3	31.3
Widow	0.4	0.19	0.9	23.5	3.4	1.66	3.9	25.5	3.1	1.73	2.0	27.3
Yelloweye	*t*	*t*	0.2	3.0	1.1	0.39	1.2	20.0	1.7	0.69	1.1	40.4
Yellowmouth	*t*	*t*	0.2	3.5	0.1	*t*	0.1	4.0	1.1	0.49	0.7	16.2
Remaining rockfish	0.4		0.5		0.2		0.2		0.3		0.2	
Total	3.4		7.2		9.8		11.1		22.5		14.3	

[1] Includes 18 hauls having both Groups 1 and 2; 11 hauls having both Groups 1 and 3; and 36 hauls having both Groups 2 and 3.

In addition to the "All Years" analysis, individual surveys were classified, revealing moderate agreement among surveys. Of the two methods, RGA (presence-absence) produced more consistent results across individual surveys. Changes in the structure of the three assemblages in any given year usually involved the addition or omission of one species or the shifting of one of the more ubiquitous species into another group.

On the other hand, assemblage patterns across surveys were less discernible with the biomass-oriented CA because of the high variability in rockfish CPUE's, particularly among shelf species. Usually,

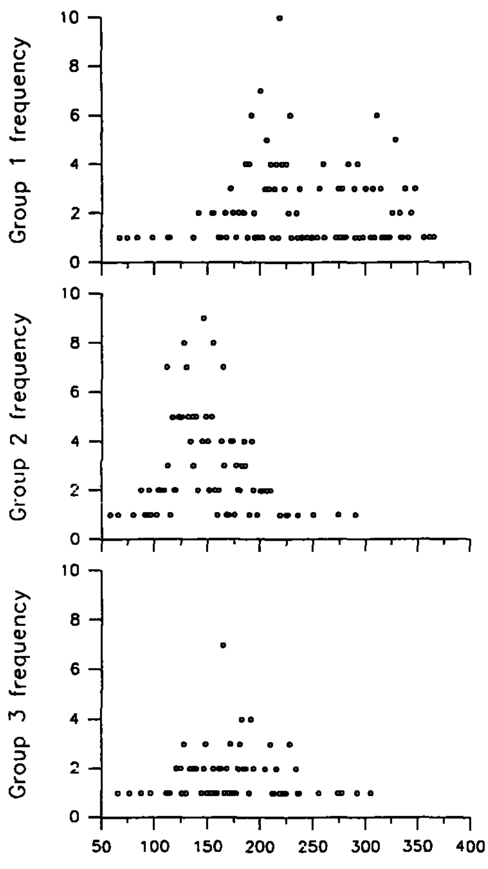

Figure 6

The frequency of occurrence by depth of the three rockfish assemblages determined from cluster analysis. Group 1 consists of shortspine thornyhead, Pacific ocean perch, darkblotched rockfish, and splitnose rockfish. Group 2 consists of yellowtail, canary, and greenstriped rockfish. Group 3 consists of sharpchin, redstripe, and rosethorn rockfish. See Table 1 for scientific names.

at the highest dissimilarity level (Fig. 5), CA partitioned the offshore community into a deep water, upper-slope group and a shallower water, mid-shelf group. The deeper species consisted of shortspine thornyhead, Pacific ocean perch, darkblotched rockfish, and splitnose rockfish. Two additional species, redbanded and rougheye, *S. aleutianus*, rockfish, were often closely associated with this group. In 1983, sharpchin, *S. zacentrus*, rockfish was included. The shallower species comprised two core assemblages (most easily seen in the "All Years" dendrogram). The first of these consisted of canary, yellowtail, and to a lesser extent, greenstriped rockfish. This assemblage was clearly identified from 1977 through 1986. However, in 1989 and 1992, it was not defined, most likely because of the shift in survey design that de-emphasized canary and yellowtail rockfish as target species, thus reducing the sampling effort in areas where they were most likely to have been found together. The other core assemblage among shelf rockfishes consisted of sharpchin, rosethorn, and redstripe rockfish, *S. proriger*. However, since these species were taken along with a variety of other species, such as silvergray rockfish, bocaccio, *S. paucispinis*, yelloweye, *S. ruberrimus*, canary, and yellowtail rockfish, CA dendrograms showed considerable variability between years.

Discussion

Survey data have provided the unique opportunity to study broad-scale community composition of offshore rockfishes, including smaller specimens typically discarded in commercial operations. These data are useful to both ecologists interested in describing the biological associations of our ocean's resources and to resource managers concerned with commercial catch and bycatch issues.

For a variety of reasons however, survey-defined assemblages may differ from assemblages determined through commercial fisheries data. Most of these revolve around the strict adherence to scientific design of most surveys as opposed to industry's opportunistic approach driven by economic needs. For example, the assemblages identified in this study would probably not be detected if sampling were limited to catches made while targeting strong hydroacoustic signals (Richards et al., 1991). Pelagic and semipelagic aggregations, such as widow, shortbelly, and in some cases yellowtail rockfish are under-represented in this study because they were sampled less intensively during the surveys. Differences in catch composition is also gear dependent. Our survey gear and methods of deployment were standardized to facilitate comparisons among surveys. The trawl employed a 89-mm mesh codend with a 32-mm liner, capable of retaining juveniles and smaller-sized species, such as rosethorn and greenstriped rockfish. Smaller species may not be caught in similar proportions in commercial catches.

On the other hand, fishermen select, modify, and operate their gear based on fishing strategy. These strategies have changed over the years to adapt to reduced allowable harvests and the imposed vessel trip limits. To economize, fishermen target several species over the course of a single trip, using more than one type of gear (Tagart[5]). For example, a vessel may begin using midwater gear directed at catching a limit of widow rockfish, then switch to bottom gear to target on yellowtail rockfish. Once the trip limits for these two species are reached, the captain may opt to fish flatfish or change to a more generalized rockfish strategy keeping larger specimens of darkblotched, silvergray, redstripe, or sharpchin rockfish.

Because survey and fishery tactics differ greatly, I assessed whether the assemblages found to persist in summer surveys based on systematic sampling also occurred in commercial collections characterized by opportunistic sampling, market conditions, and management-imposed restrictions. The literature referred to previously describes various west coast fish assemblages determined from different sampling techniques, classification methods, and data types. Although none of these studies used a time-series of this duration, Rogers and Pikitch (1992) identified two rockfish assemblages using year-round (1985–87), prediscard, commercial trawl data from off the coasts of Oregon and Washington. Briefly, they examined five fishing strategies, one of which targeted demersal rockfishes using bottom trawl gear. Even though the survey depth range was narrower than that of the commercial operations, the results of Rogers and Pikitch (1992) share much in common with the present study. Both studies describe an assemblage of deepwater rockfishes with three species in common: Pacific ocean perch, darkblotched rockfish, and splitnose rockfish. The present study also includes shortspine thornyhead, whereas Roger and Pikitch (1992) include sharpchin and yellowmouth rockfish.[6] Their second rockfish assemblage combined bocaccio, yellowtail, canary, yelloweye, and sharpchin rockfish, species assigned to either one of two separate assemblages or caught too inconsistently to be considered part of any assemblage in the present study.

[5] Tagart, J. Washington Dept. Fish., Olympia, WA 98504-3144. Personal commun., April 1991.

[6] For unknown reasons, fishery data had substantially greater abundance of yellowmouth rockfish than did the survey data.

Rogers and Pikitch (1992) included in their analysis 11 of the 20 scorpaenids that I examined. These were selected based on either an arbitrarily determined weight threshold (1% of the total commercial catch from all five fishing strategies) or if fishermen claimed to target a species (e.g. bocaccio and yelloweye rockfish). Most of those selected represented larger proportions of the commercial catch; however, other rockfishes were continuously affected by trawling. When classifying assembages based on biomass data, one takes the risk of failing to recognize a less abundant member of the community. In the study by Rogers and Pikitch (1992), several minor rockfish species were overshadowed by catches of the area's dominant species. Nearly 60% of the total catch sampled from all fishing strategies combined was nonrockfish. Among the rockfishes, widow rockfish accounted for the highest percentage (15%) of the sample catch, about 75% of which was taken by midwater trawl (Rogers[7]). Assuming that the data from their study is representative of commercial operations, we can infer the impact that trawling has on the overall rockfish community, including the minor species, by examining prediscard catch data from hauls where bottom rockfish were targeted (i.e. bottom rockfish fishing strategy). In these data, nonrockfish composed only 20% of the catch whereas widow rockfish, taken by bottom trawl, still accounted for 15% of the strategy's total. Of the species assemblages identified in the present study, yellowtail, canary, and greenstriped rockfish accounted for 30% of the total; shortspine thornyhead, Pacific ocean perch, darkblotched rockfish, and splitnose rockfish accounted for 13%; and sharpchin, redstripe, and rosethorn rockfish accounted for 10% of the total catch. Large marketable species typically seen in the landings, like bocaccio, silvergray rockfish, and yelloweye rockfish, composed only 4% of the prediscard catch.

Conclusion

The separation of deepwater species from shelf species supports the division of the "*Sebastes* complex" management category into smaller units of greater ecological consequence, as also suggested by Rogers and Pikitch (1992). There is enough variability, however, in the catches of shelf rockfish, as characterized by the relatively high levels of dissimilarity among groupings (Fig. 5), to warrant the use of caution when designating assemblages. While this study recognized two assemblages of shelf species vulner-

[7] Rogers, J. B. Natl. Mar. Fish. Serv., Southwest Fish. Sci. Cent., Tiburon, CA 94920. Personal commun., Nov. 1993.

able to bottom trawling off Oregon and Washington, a resource manager may elect to base management decisions on the union of these two because of the difficulty in monitoring the often discarded sharpchin-redstripe-rosethorn rockfish assemblage. However, in managing the rockfish community as a whole, this assemblage needs to be considered along with other minor species commonly caught in the fishery.

Our understanding of the associations among rockfish has improved greatly. Assemblage studies, combined with studies on life history, distribution, and abundance, continue to assist in refining current resource management policies and may eventually lead to a more multispecies management approach. Such an approach will address the impact on the ecosystem when operations target on a single species, such as yellowtail rockfish, with little regard to the effects on other species, particularly those of lower economic value. Likewise, it will also address the continued removal of a species like yellowtail rockfish due to incidental catch when operations target on another species.

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