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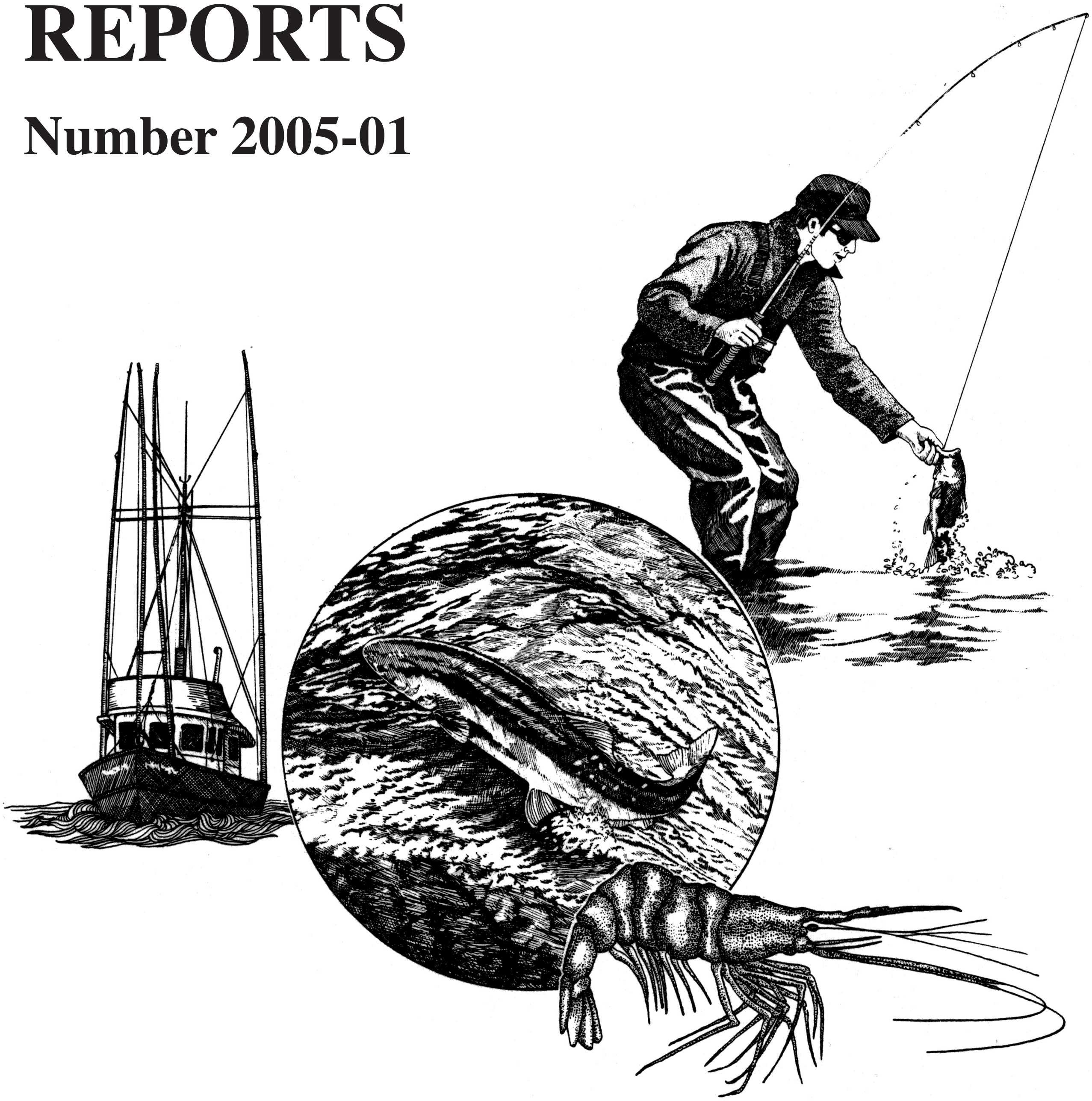

FISH DIVISION

Oregon Department of Fish and Wildlife

A Survey of Shrimp Abundance, Sex Composition, Bycatch and Trawl Gear Perfomance on the Northern Oregon Shrimp Grounds – Fall 2004

A Survey Evaluating Shrimp Abundance, Sex Composition, Bycatch and Trawl Gear Performance on the Northern Oregon Shrimp Grounds – Fall 2004

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Introduction

This reports summarizes the sampling activities and results from a fall 2004 research cruise to investigate selected aspects of the ecology of the ocean shrimp (*Pandalus jordani*) grounds as they relate to the commercial shrimp trawl fishery. The cruise investigated questions related to the fine-scale distribution of shrimp by age, sex and depth as well as the species composition of juvenile rockfish bycatch in the fishery.

The Spatial Structure of Shrimp Abundance

Most of what is known about the distribution and abundance of ocean shrimp off Oregon comes from commercial fishery data, particularly logbook data. Logbook data has been used to demonstrate that the geographic stock area of ocean shrimp expands and contracts roughly proportionally to shrimp recruitment (Hannah 1995). Logbook data, however, provides only a very limited ability to describe the finer scale spatial structure of shrimp abundance on the grounds for several reasons. First, in shrimp logbook data, fishing location is described by the start location for each haul. Since most hauls are two hours long and shrimpers travel at nearly 2 knots, the location of each haul is very approximate. Second, shrimpers record the estimated amount of catch in each haul, but generally record nothing less than about 50 lbs of catch, describing lower catches simply as zeroes. Third, shrimpers spend most of their time fishing in the highest abundance areas and may leave lower abundance areas completely unfished, providing no information on these areas. So, shrimp abundance and distribution derived from logbook data might differ markedly from that obtained from a scientific survey of the shrimp grounds. The primary objective of this research cruise was to conduct a limited survey across the full depth range of the shrimp grounds and compare the spatial structure of shrimp abundance obtained from the survey with results derived from analysis of logbook data.

The Spatial Structure of Shrimp Sex Change

Ocean shrimp are protrandric hermaphrodites; that is they begin life as males and then change into females. They have been shown to alter their age of sex change in response to the demographic environment they are living in (Charnov and Hannah 2002). In general, when older female shrimp are relatively scarce, more age 1 shrimp change into females, also known as "primary females". Conversely, when older female shrimp are relatively more abundant, primary females are not produced and even some age 2 shrimp remain male for an extra season. The mechanism behind this "demographic sex determination" (DSD) is not understood (Charnov and Hannah 2002). The studies that have demonstrated DSD in ocean shrimp have relied on long-term data sets in which data from many years is pooled, providing a wide range in age composition, and in proportion of primary females and age 2 males. The DSD phenomena has not been examined on a single year basis or within a single area. So DSD has never been demonstrated at the spatial or temporal scale at which it is believed to occur. The second objective of this study was to collect shrimp samples across a single shrimp bed over a very short time period, to see if the DSD phenomenon was detectable; to see if variation in age composition on a small spatial scale produces predictable rates of sex change.

Relation of Haul Time To Bottom Time

Data on the density of ocean shrimp on the grounds is calculated from catch per unit of effort (CPUE) of the commercial trawl fishery, obtained from logbooks. Catch by haul is based on estimates by the skipper, corrected using the actual pounds landed at the docks. Fishing effort is based on the estimated time fished, generally calculated by the vessel operator as the time between stopping and restarting the winches at haulback. Studies of survey trawls equipped with bottom contact sensors have shown that the actual time a trawl is "on bottom" is often somewhat longer than the time between stopping and starting the winches, because a trawl takes a few minutes to finish sinking to the bottom and even longer to lift off bottom when haulback begins (King et al. 2004). This extra bottom time can influence the accuracy of CPUE estimates, especially if it varies systematically with depth. Since this survey was designed to cross the full depth range of shrimp grounds, it presented an opportunity to use bottom contact sensors to see how the relationship between haul time and bottom time changed systematically with depth.

Residual Bycatch and Juvenile Rockfish

In April 2003, new regulations were enacted in Oregon and Washington requiring the use of specific types of bycatch reduction devices (BRDs) by all vessels fishing for ocean shrimp at all times. A similar regulation was already in place in California. BRDs greatly reduce finfish bycatch in shrimp trawls but do not completely eliminate it. The residual bycatch is mostly composed of small fish including juvenile hake (*Merluccius productus*), smelt (Osmeridae), slender sole (*Eopseta exilis*), juvenile Dover (*Microstomus pacificus*) and rex (*Errex zachirus*) sole and juvenile rockfish (*Sebastes*). In most prior studies of the residual bycatch (Hannah et al. 1996) the juvenile rockfish component was not described by species, because of the difficulty of accurately identifying very small rockfish in the field. The species composition of the juvenile rockfish catch is important however, because at least one overfished rockfish species, darkblotched rockfish (*Sebastes crameri*), is captured. An additional objective of this study was to collect samples of fish and juvenile rockfish that are currently being caught in the shrimp fishery and conduct laboratory identification of the juvenile rockfish.

Methods

Survey Design

Since the primary objective of this study was to evaluate shrimp abundance inside and outside the commercial grounds, transects were established to fully cross the known shrimp grounds, roughly perpendicular to the depth contours in four areas (Figure 1). Stations were established at approximately 10 fathom intervals, however depth intervals were adjusted to make sure that each transect

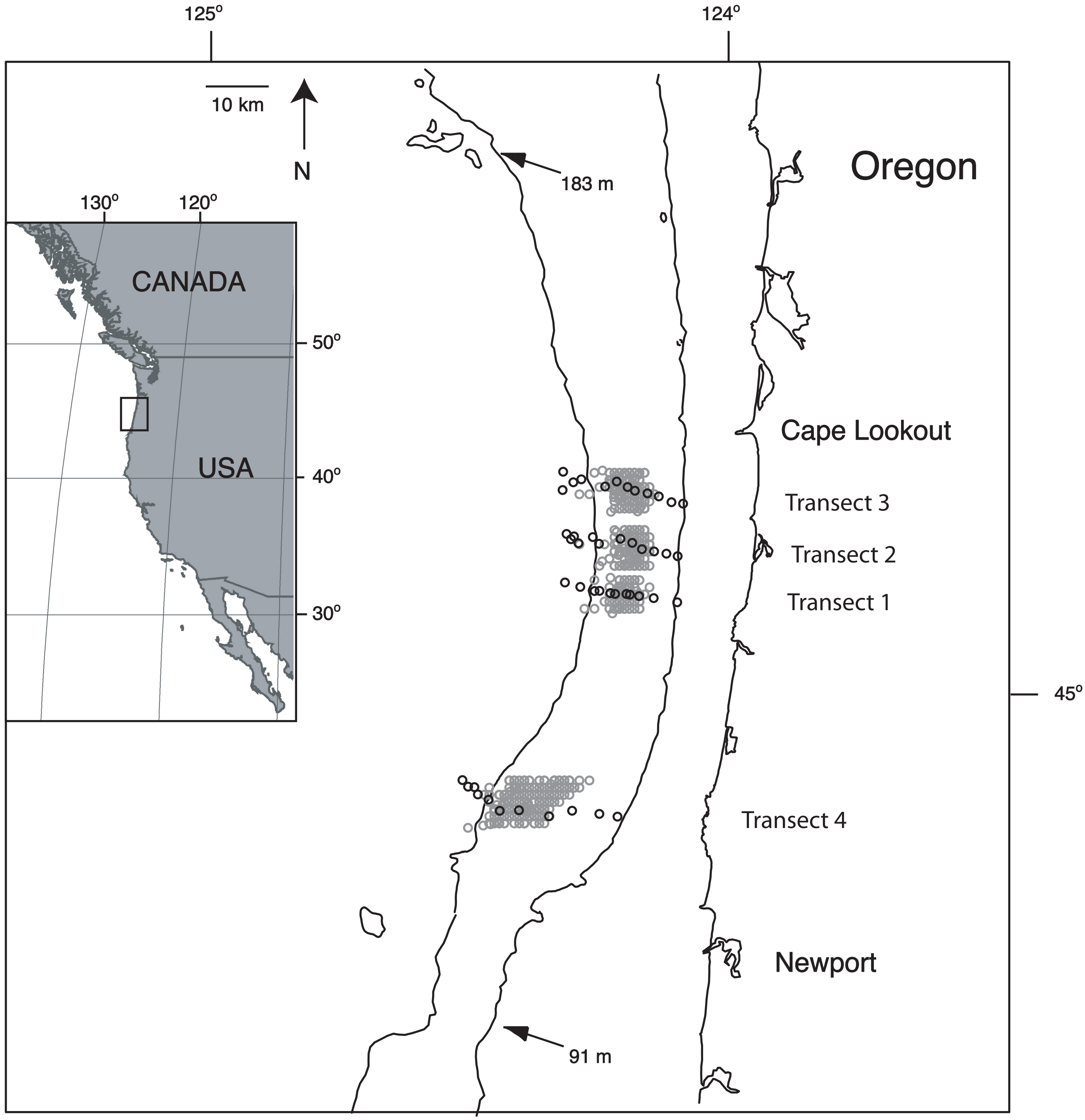

Figure 1. Start locations for trawl stations sampled (black open circles) during F/V *Miss Yvonne* cruise, October, 2004, versus nearby 2004 commercial hauls with non-zero catch per unit effort (grey circles).

could be fully sampled in a single day of fishing. This was done to limit variation in catch rates caused by changes in daily conditions such as weather, sea state and light levels. Shrimp have been shown to lift off the bottom in response to reduced levels of light (Pearcy 1970, Beardsley 1973). At each station, a 15 minute haul was conducted, calculated from the stopping and restarting time of the winches. On the first day of the cruise, hauls were conducted perpendicular to the depth contours. However, on the remaining three days of the cruise, hauls were conducted perpendicular to the depth contours until some sign of shrimp was found, then they were conducted parallel to the contours, progressing in this fashion until shrimp catches declined to low levels. This approach was used to increase chances of finding shrimp in low density areas, while maintaining a precise depth measurement for areas that held quantities of shrimp.

Field Methods

To conduct this study, we chartered the commercial shrimp vessel *Miss Yvonne* and used the vessel's regular shrimp nets for sampling. The *Miss Yvonne* is a 21m double-rigged shrimper, that fishes two four-seam, high-rise box trawls, each with a 22.9m headrope and footrope, coupled to a pair of 1.8m high, rectangular trawl doors. Each net was equipped with a rigid grate BRD (Figure 2) to exclude most large fish. The vertical bar spacing (inside measurement) on the port net BRD averaged 28.5mm, while the spacing on the starboard net averaged 32.5mm. The style of BRD used also incorporates an outer ring (Figure 2) with bar spacing that ranged from 26 to 41mm on the port net and 22 to 55 mm on the starboard net.

To obtain precise estimates of shrimp catch per unit effort (CPUE), bottom contact sensors were used to determine the exact time that the trawl was in contact with the sea floor. After trawl retrieval, the entire contents of each net was sorted and weighed. Samples of shrimp (about 1kg.) were bagged and frozen for later laboratory analysis. All rockfish were also bagged, labeled and frozen for laboratory identification. The vessel operator recorded the depth, latitude and longitude at the setting and retrieval of each haul in a standard logbook.

Lab Methods

From each sample, 200 shrimp were randomly selected and measured (carapace length, mm). Ages were assigned to individual shrimp based on nadirs in the combined length frequency distribution (Figure 1) (Zirges et al. 1981). Shrimp were classified as male, female or transitional based upon close examination of the inner ramus of the first pleopod (Tegelberg and Smith 1957).

Juvenile rockfish were identified to species using characteristics described in Orr et al. (2000) and Matarese et al. (1989). Each fish was measured (mm, fork length), weighed (g) and sexed based on the presence of testes or ovaries. Otoliths were removed from each fish for subsequent age determination. Ages were determined for darkblotched rockfish by staff of the National Marine

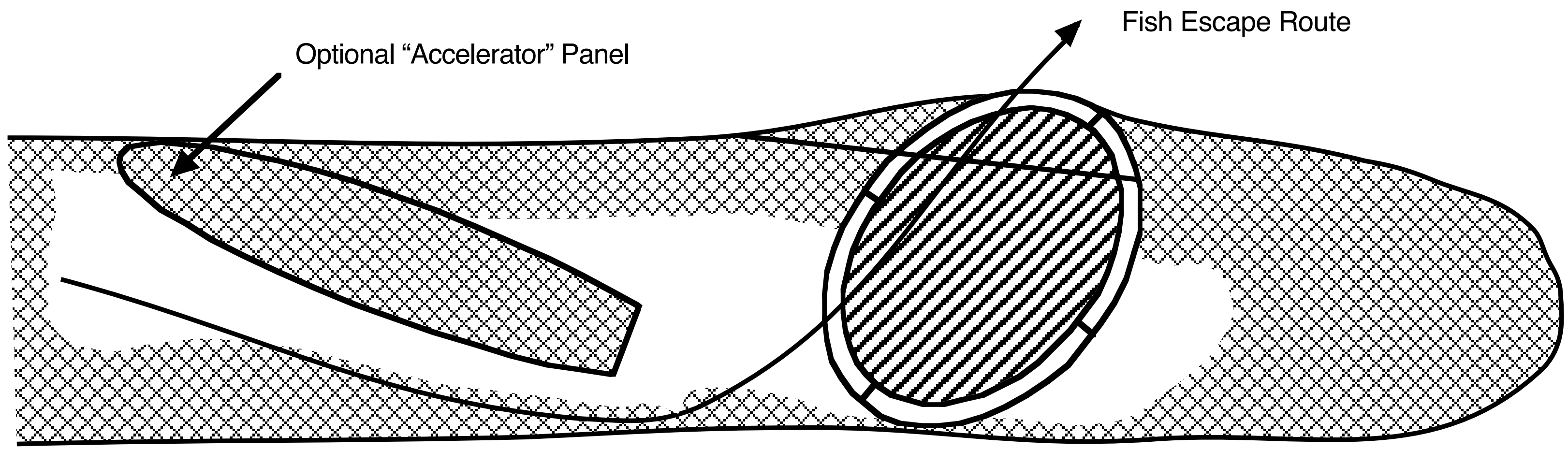

Figure 2. Schematic of the rigid grate bycatch reduction device fished by the F/V Miss Yvonne, October, 2004.

Fisheries Service cooperative aging unit (Newport, Oregon) using the break-and-burn technique applied to sagittal otoliths (Chilton and Beamish 1982).

Analysis

Data from bottom contact sensors was anlayzed graphically to determine precisely when the survey trawl touched down on the bottom and lifted off during retrieval. Bottom time was calculated from touchdown to liftoff. Touchdown, liftoff and bottom time were compared with nominal start and end times and nominal haul duration, respectively, by depth, using a graphical approach. For the first day of the cruise, the bottom contact sensors were set to sample too frequently and usable bottom contact data was not obtained. Using the hauls with bottom contact sensor data, a multiple regression model was developed to estimate bottom time from nominl haul duration and depth. This model was then used to estimate bottom time from the tows without bottom contact sensor data. Bottom time was used for all subsequent calculations of catch per unit effort (CPUE). All CPUE values were standardized to single-rig equivalent hours (sreh, PFMC 1981).

To evaluate the spatial structure of variation in shrimp abundance, we used a mostly graphical approach. Survey CPUE was graphed versus depth and compared between stations. Survey CPUE was also graphed, by transect and depth, and compared with commercial logbook CPUE from hauls within a band approximately 1.5 nautical miles north or south of each transect.

The spatial structure of shrimp sex change was examined by graphing the percentage of age 1 shrimp that were female to the ratio of older breeders to first breeders, following Charnov and Hannah (2002). Similarly, the percentage of age 2 shrimp that were male was graphed against the ratio of age 1 shrimp to older shrimp.

Data on residual rockfish bycatch was summarized by species and compared with similar unpublished data collected from the shrimp grounds by a graduate student in 1998. Length frequency of rockfish species was graphed. Data on other residual fish bycatch was also summarized by species or species group.

Results and Discussion

Eleven to twelve stations were succesfully sampled on each of four transects (Figure 1, Table 1) spanning a depth range from 51 to 168 fathoms. Bottom contact sensor data showed a statistically significant ($p<0.001$), negative relationship between depth and the time delay between setting and trawl touchdown and between retrieval and liftoff (Figures 3 and 4). In combination, these two effects resulted in a negative linear relationship between depth and the ratio of nominal trawl duration to actual bottom time, resulting in somewhat shorter bottom times at greater depths ($p<0.001$, Figure 5). These relationships result from increased time for the trawl to settle in deeper water and increased time to remove any slack in the winch cables during retrieval in deeper water. Multiple regression analysis of bottom time on nominal trawl duration and

Table 1. Transect and station number, start and end depth, haul start latitude and longitude and shrimp CPUE for trawl stations sampled off northern Oregon, October, 2004 (Figure 1).

Transect	Station	Start Depth (f)	End Depth(f)	Start Latitude	Start Longitude	Shrimp CPUE (lb/h)
1	1	51	54	45.0990	124.1247	0.000
1	2	64	68	45.1049	124.1717	0.000
1	3	74	78	45.1077	124.2008	0.000
1	4	83	86	45.1106	124.2261	311.430
1	5	91	94	45.1119	124.2583	148.881
1	6	99	103	45.1148	124.2898	2.994
1	7	112	122	45.1206	124.3183	4.849
1	8	142	168	45.1267	124.3489	21.221
1	9	97	97	45.1150	124.2799	2.215
1	10	90	87	45.1107	124.2487	491.043
1	11	82	77	45.1097	124.2192	7.075
2	1	51	55	45.1635	124.1239	0.000
2	2	59	64	45.1670	124.1463	0.000
2	3	67	72	45.1701	124.1709	0.000
2	4	75	80	45.1733	124.1951	206.769
2	5	83	84	45.1821	124.2145	613.756
2	6	90	90	45.1877	124.2381	125.793
2	7	99	100	45.1808	124.2809	3.429
2	8	110	112	45.1901	124.2932	4.235
2	9	121	120	45.1815	124.3219	19.81
2	10	133	132	45.1911	124.3308	60.615
2	11	145	145	45.1872	124.3369	22.531
2	12	165	165	45.1946	124.3457	2.667
3	1	51	55	45.2369	124.1130	0.000
3	2	57	62	45.2389	124.1362	0.000
3	3	66	70	45.2470	124.1615	0.000
3	4	73	75	45.2513	124.1841	11.429
3	5	82	86	45.2549	124.2092	367.111
3	6	87	87	45.2601	124.2238	375.385
3	7	92	93	45.2678	124.2455	247.011
3	8	96	97	45.2608	124.2687	2.851
3	9	109	110	45.2709	124.3162	128.129
3	10	120	120	45.2668	124.3322	50.614
3	11	139	139	45.2815	124.3525	0.000
3	12	155	160	45.2559	124.3536	0.000
4	1	154	142	44.8505	124.5536	14.400
4	2	135	134	44.8414	124.5423	132.571
4	3	125	123	44.8407	124.5297	95.392
4	4	113	114	44.8305	124.5228	13.455
4	5	102	101	44.8232	124.5015	1.905
4	6	92	92	44.8076	124.4792	0.000
4	7	83	83	44.8084	124.4407	259.139
4	8	73	73	44.8000	124.3808	0.000
4	9	70	68	44.8077	124.3346	0.000
4	10	63	60	44.8033	124.2802	0.000
4	11	56	53	44.7995	124.2440	0.000

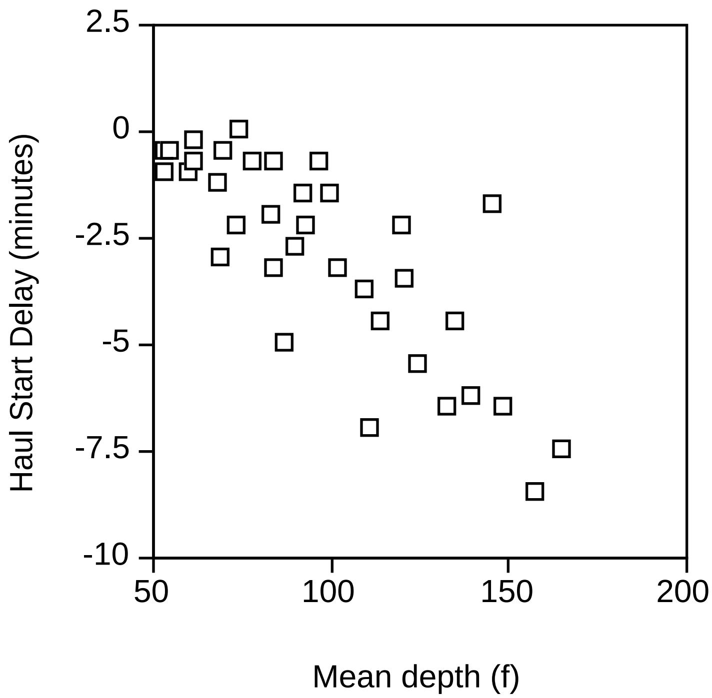

Figure 3. Mean depth (f) versus haul start delay (minutes). Haul start delay was calculated as the elapsed time between the official start of each haul (when the winches are stopped) and the time when the trawl reached the sea bottom (see text).

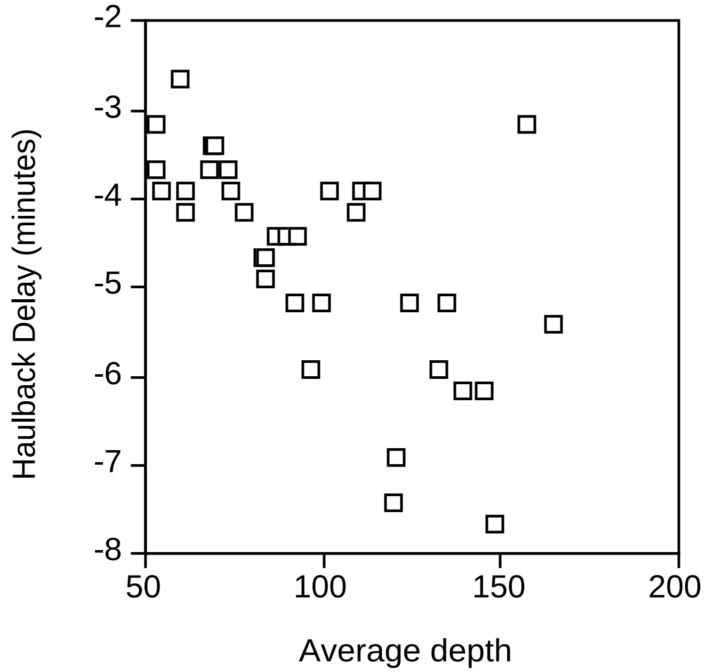

Figure 4. Mean depth (f) versus haulback delay (minutes). Haulback delay was calculated as the elapsed time between the beginning of the retrievel of each haul (when the winches are started) and the time when the trawl lifted off of the sea bottom (see text).

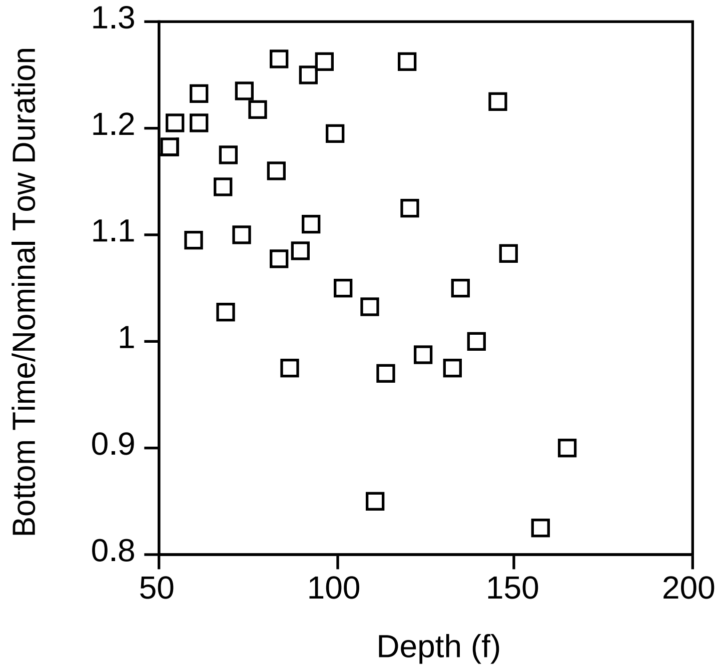

Figure 5. Depth (f) versus the ratio of trawl bottom time (minutes) to nominal tow duration (minutes).

depth showed that bottom time could be approximated for hauls with no bottom contact sensor data ($p<0.001$, Table 2).

Shrimp Abundance

Shrimp CPUE, by depth and transect (Figure 6) shows that ocean shrimp were distributed in distinct depth bands with some degree of correlation by depth between transects. The areas of higher CPUE also had higher levels of age 1 shrimp (Figure 7) however, not all areas with high levels of age 1 shrimp also produced high catch rates. The highest catch rates were found between 77 and 90 fathoms, consistent with the areas commercial fishers were targeting during the survey period. However, a second band of shrimp was also detected somewhat outside of the commercial grounds, between 110 and 135 fathoms, with moderate levels of shrimp density. This second band of shrimp was detected in 3 of the 4 transects (Figures 8-9) and represents a modest portion of the true geographic stock area that was not detected by analysis of commercial logbook data. The commerical fleet simply did not fish in these deeper areas, most likely because catch rates remained high in the shallower portions of the shrimp grounds where setting and haulback take less time and trawl hazards (rocks, wrecks etc.) are better known. This suggests that in years with high CPUE, stock area estimates derived from logbook data may be minimum estimates. Figures 8-9 show clearly the "fishing down" of shrimp density prior to the October survey and also show some evidence that shrimp may have shifted inshore during the April-September period, especially in the vicinity of transects 2 and 4.

Sex and Age Composition

Surprisingly, the data on age and sex composition offer no support for sex change being related to demographics on a small spatial scale (Figures 10-11). Areas with higher levels of age 1 shrimp did not have more primary females and some of the stations with some primary females had comparatively low levels of age 1 shrimp (Figure 10). Similarly, while age 2 males were prevalent, there was no relationship between the absence of age 1 shrimp and the percentage of age 2 shrimp that remained male (Figure 11). This finding is surprising in light of how well the average age and sex composition data from the survey fit with historical data. The mean proportion of age 2 males (0.256, Figure 12) and the mean ratio of age 1 breeders to older breeders (0.897) fit reasonably well with the historical male data for adjacent statistical areas presented by Charnov and Hannah (2002). Likewise, the mean proportion of primary females (0.010) and the mean ratio of older to age 1 breeders (2.218) for the survey fit with the historical data, which predicts essentially zero age 1 females at first/older breeder ratios above about 2.0 (not shown, see Charnov and Hannah 2000).

These findings are difficult to reconcile, as they suggest that individual shrimp do not adjust their age of sex change to the immediate demographic environment, but that the ocean shrimp population as a whole does. It is difficult to imagine how a biological mechanism for demographically driven sex change could evolve without operating in a measurable way at a spatial and temporal

Table 2 . Multiple regression relating trawl time on bottom to nominal tow duration and depth (f). This relationship wa sused to estimate on- bottom time for hauls in transect 1 when bottom contact sensors were not working properly. Model is bottom time = $a + b_1$(nominal tow duration) + b_2 (depth).

Parameter	Coefficient	Partial F-value	R^2 (Adjusted)
a	6.704		
b_1	0.898	55.915	
b_2	-0.031	6.203	
Full Model			0.618

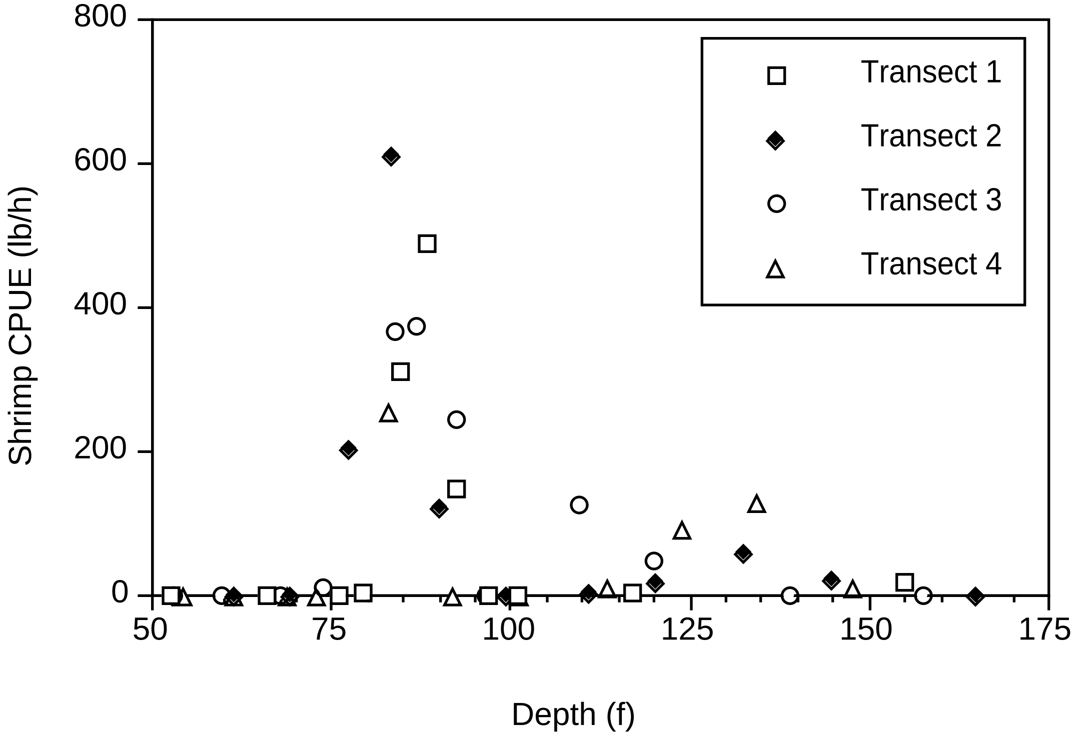

Figure 6. Ocean shrimp catch per unit effort, by depth and transect number (Figure 1), October 2004.

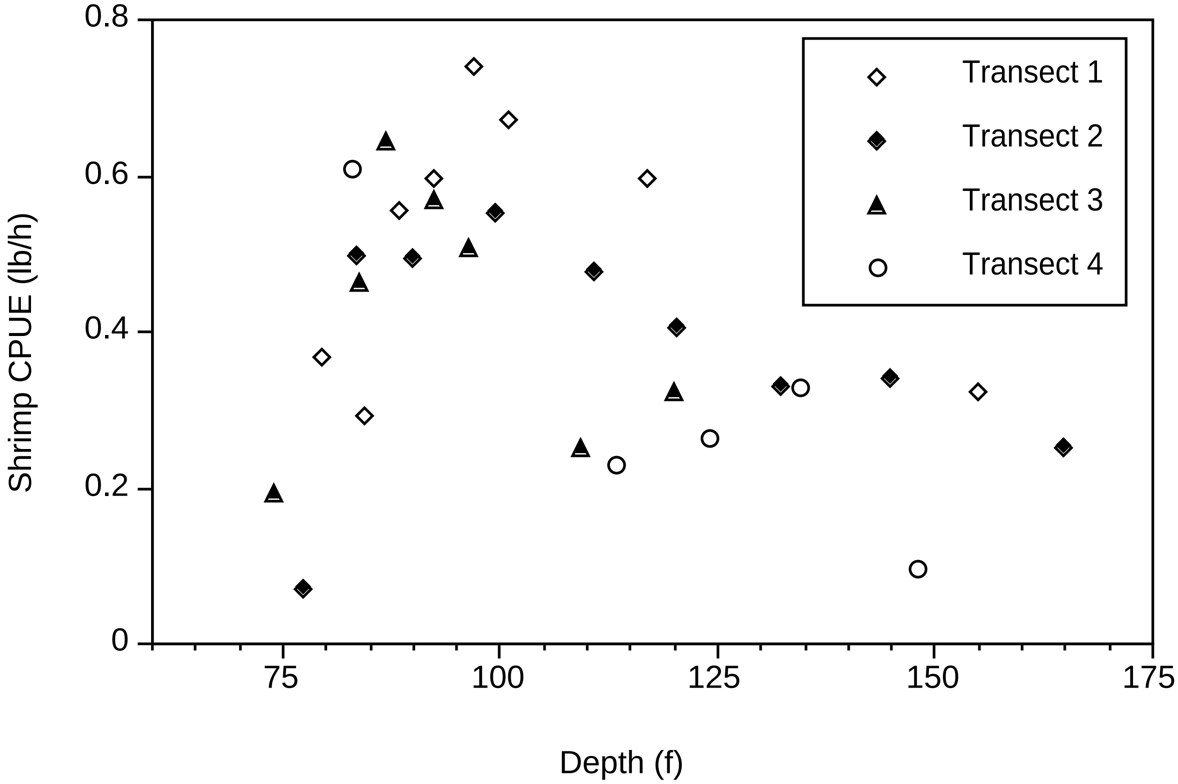

Figure 7. Percentage of age 1 shrimp in the catch, by depth and transect number (Figure 1), October 2004.

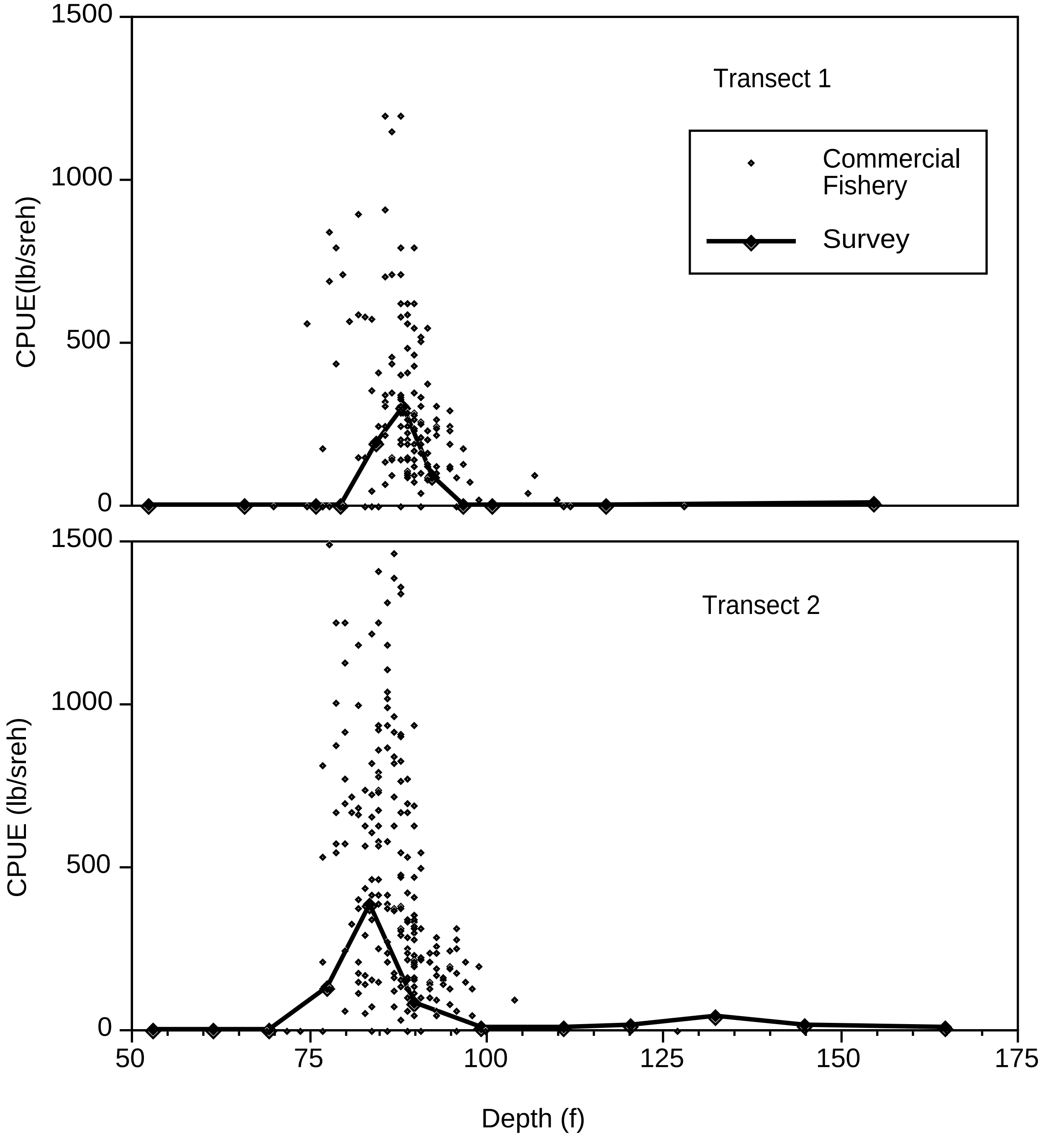

Figure 8. Comparison of commercial CPUE (lb/sreh) from the 2004 shrimp season with research survey CPUE from October cruise on the F/V Miss Yvonne.

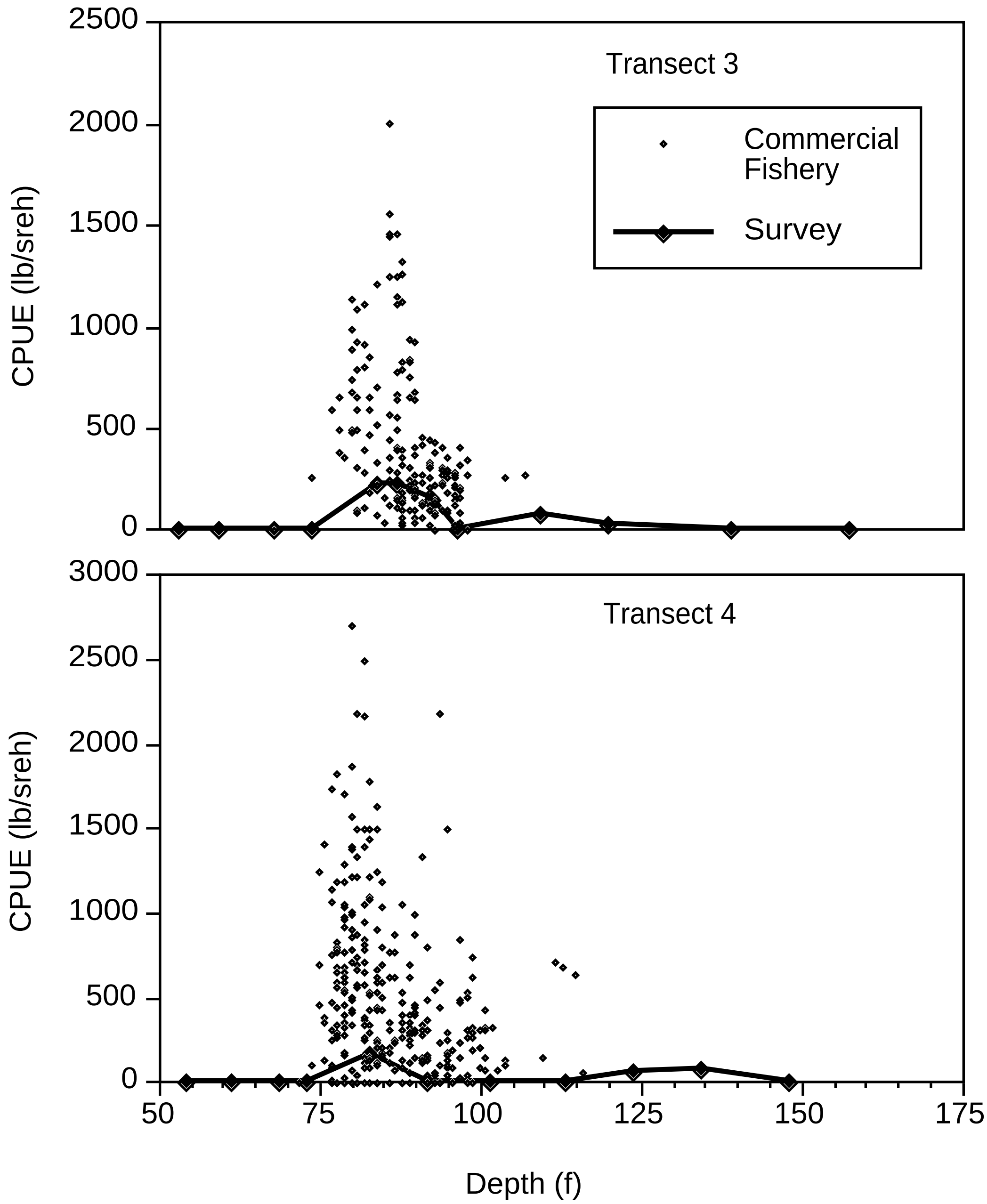

Figure 9. Comparison of commercial CPUE (lb/sreh) from the 2004 shrimp season with research survey CPUE (transects 3 and 4) from the October cruise on the F/V Miss Yvonne.

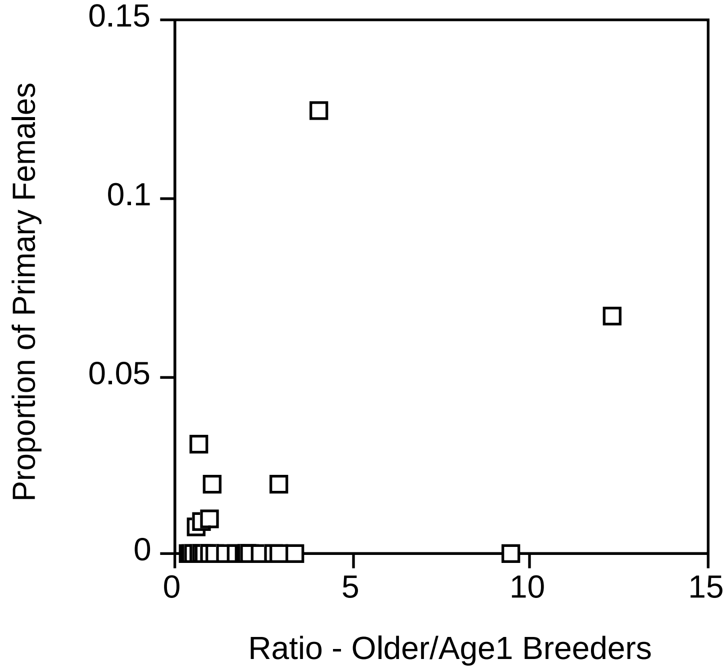

Figure 10. Ratio of older breeders to age 1 breeders versus the proportion of age 1 breeders that are females (primary females) from the Miss Yvonne cruise, October 2004.

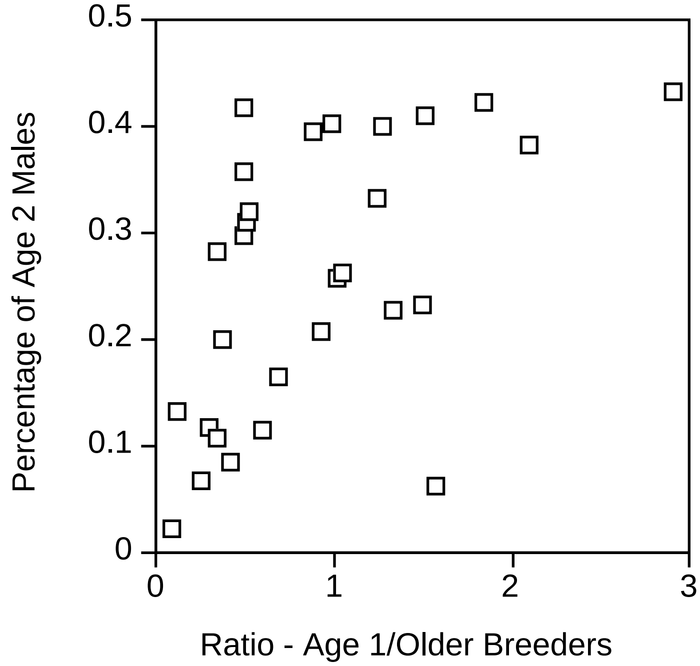

Figure 11. Ratio of age 1 breeders to older breeders versus the proportion of age 2 breeders that are male, from the Miss Yvonne cruise, October 2004.

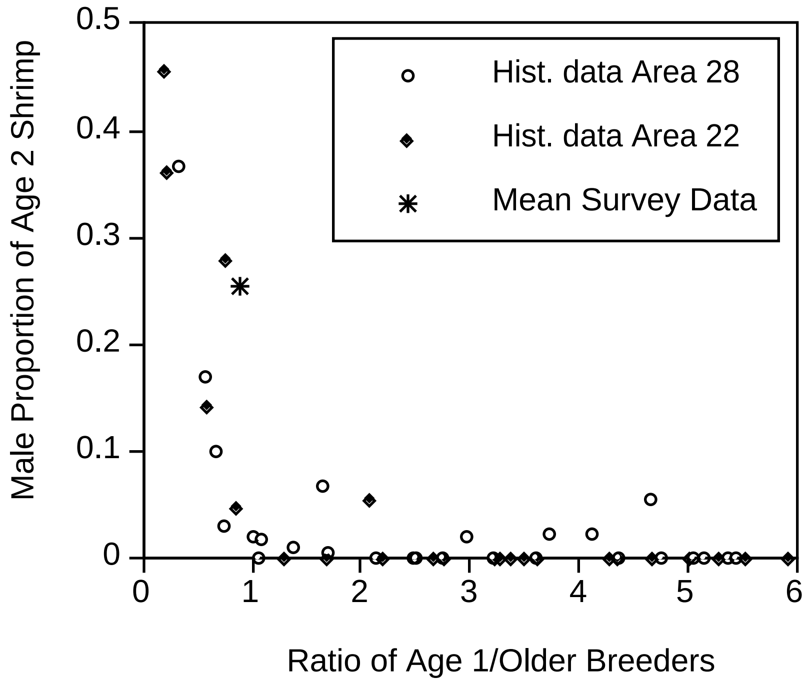

Figure 12. Comparison of historical data on the male proportion of age 2 shrimp versus the ratio of first to older breeders (Charnov and Hannah 2000) with the average of survey data from areas holding commercial quantities of shrimp, October 2004.

Table 3. Residual bycatch (numbers of fish) by depth in survey hauls located on the commercial ocean shrimp grounds (75-90f).

Depth (f)	Juvenile Pacific Hake	Slender Sole	Juvenile Sebastes	Adult Pacific Hake	Rex Sole	Pacific Herring	Smelt spp.	Pacific Sanddab	Arrow-tooth Flounder	Dover Sole	Misc-ellaneous[1]
76.0	286	16	8	0	1	6	20	10	0	0	0
77.5	10	13	3	5	1	22	0	5	0	1	0
79.5	1259	17	3	4	0	0	2	2	0	0	1
83.0	64	28	5	0	1	0	4	0	2	0	0
83.5	456	7	2	2	1	6	0	0	3	1	0
84.0	69	19	15	0	10	13	2	0	3	1	2
84.5	164	11	17	6	3	0	0	0	0	0	0
87.0	1144	12	5	1	13	5	2	0	0	1	2
88.5	50	19	22	5	0	0	0	0	0	0	1
90.0	1494	3	7	0	1	0	0	0	2	0	0

[1]Flathead sole, petrale sole, sturgeon poacher.

scale that would be meaningful to an individual shrimp. One explanation to consider is that the survey sampling may have been inadequate. Sampling can result in an inadequate range to detect a biological phenomenon. However, in this case, survey sampling did produce low ratios of older to first breeders that should have produced more primary females, as well as some higher ratios of first to older breeders, that should have been associated with low levels of age 2 males (Figures 10-11).

There are other potential mechanisms that could modulate sex change in shrimp without individual shrimp adjusting sex change to their immediate demographic environment. One concept that has been proposed is that sex change, by age, could be inherited (Bergström 1997). Increased harvest rates would then favor earlier breeders, leading to higher levels of primary females as a stock is fished down, as has been observed in ocean shrimp (Hannah and Jones 1991). However, sex change data in ocean shrimp do not show a correlation between generations that would support this hypothesis. Another possibility is that sex change and recruitment are linked via a third variable, such as temperature or density. Following this hypothesis, conditions which tend to produce a dominant year class of new recruits would also increase the tendency to change sex early. Conversely, conditions which produce a failed year class would predispose shrimp to an extended male phase. This type of phenomenon, based on density dependent growth, has been proposed as an alternative explanation to environmentally driven sex change in northern shrimp *Pandalus borealis* (Koeller et al. 2000).

Residual Bycatch and Juvenile Rockfish

Fish bycatch during the survey consisted of fish small enough to pass through the rigid grate BRDs fished by the F/V Miss Yvonne. Hauls located on the commercial shrimp grounds (about 75-90f depth) produced bycatch (Table 3) that was dominated by young of the year Pacific hake (*Merluccius productus*), slender sole (*Eopsetta exilis*) and juvenile rockfish (*Sebastes* and *Sebastolobus*). Rex sole (*Errex zachirus*), Dover sole (*Microstomus pacificus*), Pacific herring (*Clupea harengus*) and arrowtooth flounder (*Atherestes stomias*) were also encountered in small numbers. Several species of smelt (Osmeridae spp.) and Pacific sanddab (*Citharichthys sordidus*) were also captured at the shallower stations. Flathead sole (*Hippoglossoides elassodon*), petrale sole (*Eopsetta jordani*) and sturgeon poacher (*Agonus acipenserinus*) were also taken in small numbers.

Shoreward of the commercial fishing grounds, bycatch (Table 4) was reduced and was dominated by smelt, Pacific herring and Pacific sanddab. At deeper depths, young of the year Pacific hake, slender sole and juvenile rockfish were again captured. At the shallower stations, small numbers of market squid (*Loligo opalescens*) and shiner surfperch (*Cymatogaster aggregata*) were captured. English sole (*Pleuronectes vetulus*), northern anchovy (*Engraulis mordax*), sablefish (*Anoplopoma fimbria*), spiny dogfish (*Squalus acanthias*) and eelpouts ((Zoarcidae spp.) were also taken in small numbers.

Table 4. Residual bycatch (numbers of fish) by depth in survey hauls located shoreward of the commercial ocean shrimp grounds (50-74f).

Depth (f)	Pacific Herring	Smelt spp.	Pacific Sanddab	Rex Sole	Arrow-tooth Flounder	Juvenile Sebastes	Juvenile Pacific Hake	Slender Sole	Adult Pacific Hake	Dover Sole	Misc-ellaneous[1]
52.5	4	5	14	0	1	0	0	0	0	1	4
53.0	5	5	4	1	0	0	0	1	0	0	5
53.0	4	8	1	0	0	0	0	1	0	0	3
54.5	48	0	20	2	1	0	0	1	0	0	8
59.5	2	15	8	6	2	0	0	1	0	0	3
61.5	7	99	10	2	0	0	0	1	0	1	2
61.5	16	0	2	1	0	0	0	3	0	0	4
66.0	1	70	0	0	0	0	0	10	0	0	1
68.0	8	27	5	7	2	1	16	4	0	3	3
69.0	3	0	0	1	0	1	1	4	0	0	4
69.5	13	15	12	1	1	5	0	6	1	0	6
73.0	1	0	0	0	1	2	14	15	0	0	7
74.0	8	2	8	6	0	8	286	16	4	6	3

[1]spiny dogfish, surfperch, eelpouts, market squid, flathead sole, sablefish, English sole, northern anchovy.

Table 5. Residual bycatch (numbers of fish) by depth in survey hauls located seaward of the commercial ocean shrimp grounds (92-165f).

Depth (f)	Slender Sole	Juvenile Sebastes	Lantern-fish spp.	Smelt spp.	Rex Sole	Juvenile Pacific Hake	Sturgeon Poacher	Adult Pacific Hake	Arrow-tooth Flounder	Dover Sole	Misc-ellaneous[1]
92.0	2	0	0	1	0	57	1	0	1	0	1
92.5	4	20	0	24	6	47	1	0	0	0	0
92.5	5	2	0	2	1	217	0	4	1	2	1
96.5	52	5	4	3	11	10	1	0	6	0	0
97.0	4	0	0	1	0	24	0	1	0	0	0
99.5	12	1	0	3	1	3	0	0	4	0	1
101.0	4	4	0	1	0	44	1	0	2	1	2
101.5	0	3	0	1	0	15	0	0	4	1	1
109.5	8	58	24	0	4	0	2	0	2	3	0
111.0	6	12	3	0	1	11	0	0	0	1	1
113.5	4	8	0	0	1	5	0	0	1	1	2
117.0	29	7	0	0	0	67	0	1	0	0	0
120.0	3	55	4,617	0	2	0	1	0	5	6	0
120.5	7	38	118	0	0	0	1	0	0	5	1
124.0	10	9	74	0	0	0	1	1	1	1	0
132.5	5	17	3,333	0	1	0	1	0	1	2	1
134.5	13	7	1,682	0	2	0	0	6	2	3	0
139.0	7	37	60	0	5	0	6	1	0	4	1
145.0	8	14	782	0	1	0	0	2	1	4	1
148.0	8	7	28	0	5	0	4	12	0	2	3
155.0	16	23	539	0	0	4	1	4	0	1	0
157.5	89	14	29	0	27	0	4	1	2	10	15
165.0	18	20	3	0	1	0	0	3	0	1	2

[1]Shortspine thornyhead, Pacific herring, sablefish, spiny dogfish, hagfish, flathead sole, Pacific lamprey, ratfish, hatchetfish sp.

At deeper depths, the residual bycatch changed noticeably. Inside about 120 fathoms, young-of-the-year Pacific hake still dominated (Table 5), but outside of this depth, lanternfish (Myctophidae spp.) were most abundant. Juvenile rockfish, rex sole, Dover sole, adult Pacific hake and slender sole also increased in abundance at the deeper stations. On this cruise, some species were only encountered outside the commercial shrimp grounds. These included shortspine thornyhead (*Sebastolobus alascanus*), hagfish (Myxinidae spp.), Pacific lamprey (*Lampetra tridentata*), ratfish (*Hydrolagus colliei)* and silvery hatchetfish (*Argyropelecus sladeni*).

The juvenile rockfish bycatch on the commercial grounds (75-90f,Table 6) was dominated by darkblotched rockfish. At deeper depths, splitnose rockfish (*Sebastes diploproa*), Pacific ocean perch (*Sebasets alutus*) and sharpchin rockfish (*Sebastes zacentrus*) became more prevalent, with splitnose rockfish dominating the juvenile rockfish bycatch by number. A few rougheye rockfish (*Sebastes aleutianus*), greenstriped rockfish (*Sebastes elongatus*), stripetail rockfish (*Sebastes saxicola*) and redbanded rockfish (*Sebastes babcocki*) juveniles were also captured.

The commercial shrimp grounds are clearly a nursery area for darkblotched rockfish. Length frequency of darkblotched rockfish captured (Figure 13) suggests four distinct age classes of juveniles were encountered. Examination of otoliths showed that these four modes of increasing length corresponded to age 0, 1, 2 and 4 fish, respectively. Age 3 darkblotched rockfish were not collected, and may represent a weak year class, at least locally (Figure 14). Ontogenetic migration is also evident from a graph of length versus depth of capture, suggesting the commercial shrimp grounds are important habitat for primarily the first three age classes of post-settlement darkblotched rockfish (Figure 15). Similar graphs for splitnose rockfish did not show distinct size classes (Figure 16) or any evidence of increasing length with depth (not shown). For Pacific ocean perch, a trend towards larger size with increasing depth was found, but total sample size was only 14 fish (not shown).

The species composition of juvenile rockfish bycatch in this survey compared reasonably well with previous data from the commercial shrimp grounds (Table 7). Both studies showed splitnose rockfish numerically dominant, followed by darkblotched rockfish. Both studies produced just a few redbanded rockfish. There were some differences though. In the earlier study, greenstriped rockfish were much more abundant and Pacific ocean perch, rougheye rockfish and sharpchin rockfish were not encountered. The presence of sharpchin rockfish in this survey probably resulted from the survey covering deeper depths than are normally trawled by the commercial fishery.

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Table 6. Number of juvenile rockfish captured (fork length range, mm), by depth, on the F/V *Miss Yvonne* cruise, September, 2004.

Depth Range (f)	Darkblotched Rockfish	Splitnose Rockfish	Greenstriped Rockfish	Pacific Ocean Perch	Sharpchin Rockfish	Rougheye Rockfish	Stripetail Rockfish	Redbanded Rockfish
50-59	0	0	0	0	0	0	0	0
60-69	7 (73-130)	0	0	0	0	0	0	0
70-79	21 (73-141)	0	0	0	0	0	0	0
80-89	64 (72-198)	0	3 (169-184)	1 (68)	0	0	0	0
90-99	22 (70-186)	3 (48-96)	1 (152)	2 (64-131)	0	1 (202)	1 (109)	1 (169)
100-109	5 (75-249)	77 (48-205)	2 (180-272)	10 (64-196)	0	0	0	0
110-119	0	1 (126)	0	0	0	0	0	0
120-129	3 (190-252)	97 (50-209)	1 (267)	0	0	0	1 (192)	0
130-139	1 (250)	55 (142-212)	1 (250)	1 (190)	0	0	0	0
140-149	2 (248-255)	17 (168-233)	0	0	1 (178)	0	0	1 (160)
150-159	0	36 (48-220)	0	0	3 (198-224)	0	0	0
160-169	0	21 (47-207)	0	0	0	0	0	0

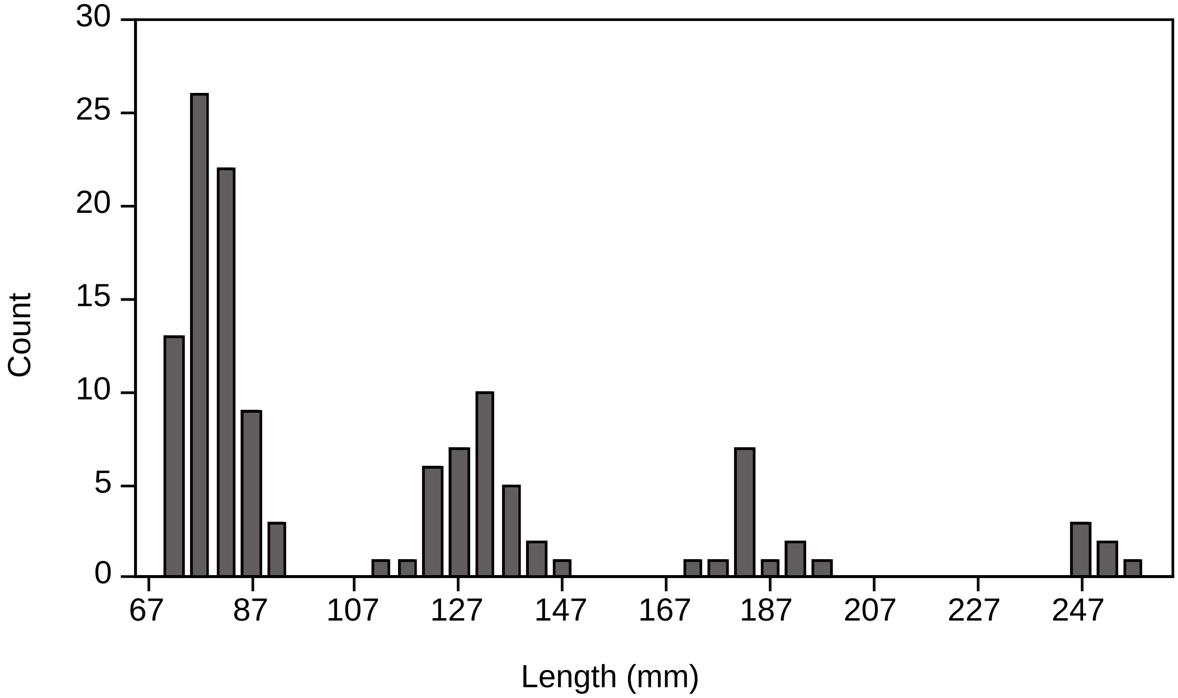

Figure 13. Length frequency (mm, fork length) of darkblotched rockfish captured during the F/V Miss Yvonne shrimp cruise, October, 2004.

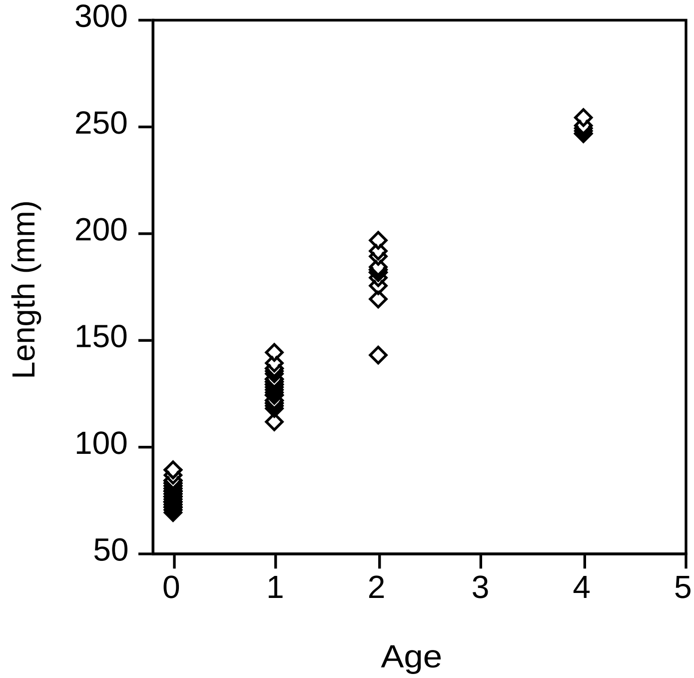

Figure 14. Age versus length for darkblotched rockfish collected during the October Miss Yvonne cruise.

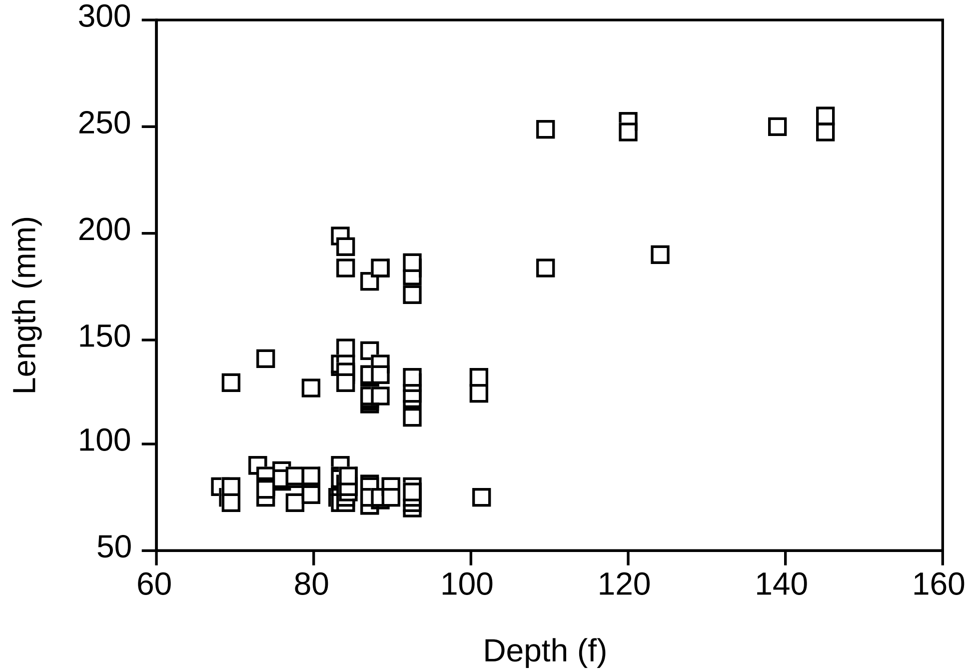

Figure 15. Length (mm) of darkblotched rockfish captured versus depth (f).

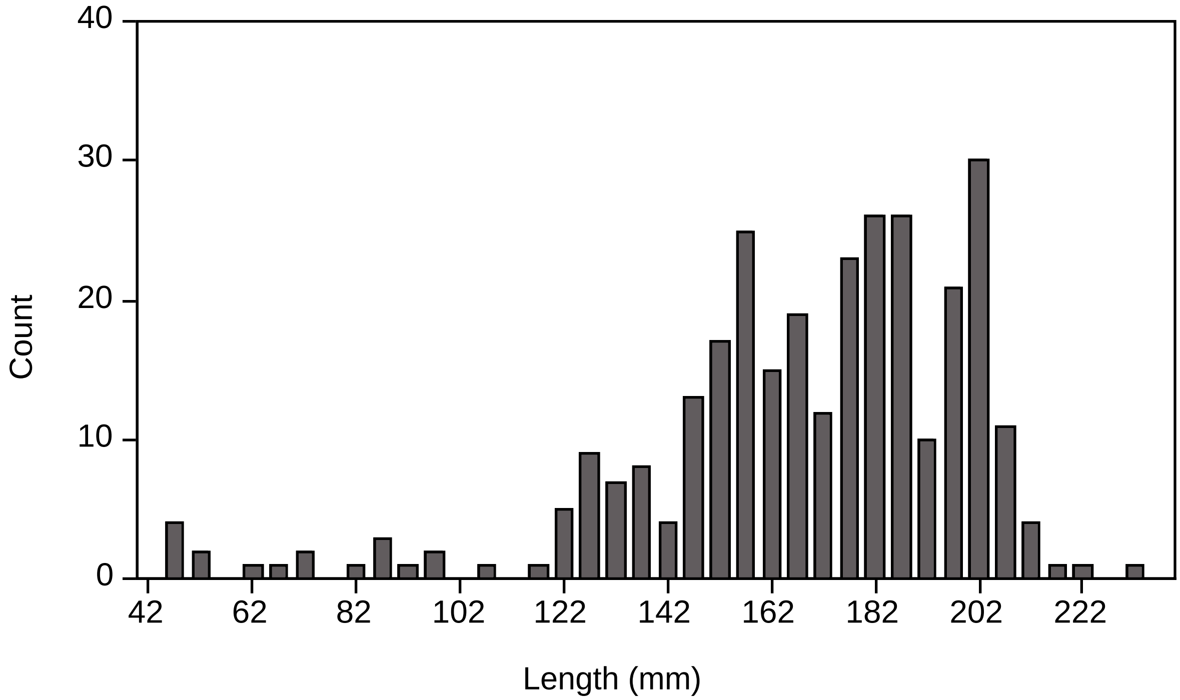

Figure 16. Length frequency (mm, fork length) of splitnose rockfish captured during the F/V Miss Yvonne shrimp cruise, October, 2004.

Table 7. Comparison of juvenile rockfish collected on the F/V Miss Yvonne cruise, September, 2004, with juvenile rockfish collected as shrimp trawl bycatch in 1998.

	October 2004 Samples			1998 Samples		
Species	Number	Percentage	Length Range (mm)	Number	Percentage	Length Range (mm)
Darkblotched Rockfish	125	27.0	70-255	219	28.4	60-280
Splitnose Rockfish	307	66.3	47-233	336	43.5	60-140
Greenstriped Rockfish	8	1.7	152-272	173	22.4	60-270
Pacific Ocean Perch	14	3.0	64-196	0	0.0	
Stripetail Rockfish	2	0.4	109-192	0	0.0	
Redbanded Rockfish	2	0.4	160-169	4	0.5	
Sharpchin Rockfish	4	0.9	178-224	0	0.0	
Rougheye Rockfish	1	0.2	202	0	0.0	
Unidentified Sebastes	0	0.0		40	5.2	60-290
Total	463	99.9		772	100.0	

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