

Effect of the San Juan Islands Marine Preserves on Demographic Patterns of Nearshore
Rocky Reef Fish

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Abstract

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Rocky Reef Fish

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Nearshore rocky reef fish were surveyed via subtidal visual transects in reserve and paired non-reserve sites during 1999 and 2000. The investigation occurred in the northern portion of San Juan Channel, in the inland sea of northwest Washington State. Demographic data are presented as fish per hectare (for population density) and length-frequency distribution (for individuals' lengths) and are comprised of two studies.

The first study is a historical time-series at one site, Point George on Shaw Island. Comparisons are made between four time periods: 1974-76 (Moulton 1977), 1987 (Casselle 1987), 1991-92 (Miller unpublished data) and 1999 (this study). Point George, like all the San Juan Islands Marine Preserves, was declared a restricted fishing zone and closed to non-tribal bottomfishing in 1990.

The second study is spatially replicated comparison of reserve sites to paired non-reserve sites. All data used in the second study were collected in 2000. The 2000 spatial study compares population densities and length-frequency distributions of eight species in three pairs of reserve/non-reserve sites. In addition, 2000 length data are compared to

historical data collected from the San Juan Archipelago (Moulton, 1977). Surveys were designed to target the eight largest, most abundant and conspicuous species of nearshore rocky reef fish, including five rockfish: copper (*Sebastes caurinus*), quillback (*Sebastes maliger*), black (*Sebastes melanops*), yellowtail (*Sebastes flavidus*) and Puget Sound (*Sebastes emphaeus*); as well as lingcod (*Ophiodon elongatus*), kelp greenling (*Hexagrammos decagrammus*) and striped surfperch (*Embiotoca lateralis*).

Reserve effects are species specific. Some species were larger and more abundant in reserves, some showed opposite trends and some showed no difference between reserves and non-reserves. In addition, direct reserve effects appear to cause indirect effects via interactions between species, particularly *O. elongatus* predation of *S. emphaeus*. Year 2000 spatial and temporal patterns of young-of-the-year of the *Sebastes caurinus* / *Sebastes maliger* population density and length frequency distribution are also presented.

In general, reserves have a positive, direct effect on density and length-frequency distribution of populations that have been increasing over time and are fished. These effects appear to intensify with fishing pressure. Reserves have no direct effect on unfished populations. Reserves have no direct effect on decreasing (over time) and fished populations, although these populations may be maintained by reserves with high substrate complexity. Alternative management measures appear necessary to recover these species. Reserves can have a negative, indirect effect on populations increasing over time if reserves increase the size of predators.

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INTRODUCTION

Marine Protected Areas (**MPAs**) have recently been defined as “any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or has regulations to provide lasting protection for part or all of the natural and cultural resources within” (Presidential Executive Order 13158, 2000).

A marine reserve is a particular type of MPA that specifically restricts fishing activity. This thesis studied three areas known as the San Juan Islands Marine Preserves, established by the State of Washington in 1990. These areas function as marine reserves for nearshore rocky reef fish.

Marine reserves have been recommended for protecting habitat and promoting recovery of fish populations (Parker *et al.* 2000), and have been described as a method of increasing fishery yields (Alcala and Russ 1996, Roberts and Bohnsack 2001). In addition, marine reserves have been shown to contain greater reproductive potential of targeted species than non-reserve areas (Palsson 1998).

Marine reserve theory predicts that conservation of broodstock in certain areas increases production of larvae and juveniles that are exported to the surrounding area. This will cause total biomass and landings in exploited fisheries to increase and length frequency distributions to shift upward (Bohnsack 1996; Ballantine 1994). This ‘reserve effect’ should be especially evident for long-lived species, with high site-fidelity and

increasing fecundity with age, such as rockfish (Bloeser 1999). However, this effect has yet to be empirically demonstrated for many species and ecosystems.

Most research on marine reserves to date has taken place in tropical systems. Studies have shown temporal increases in abundance and size of fish in marine reserves on tropical reefs (Alcala and Russ 1990; Roberts and Polunin 1991), and export of adult biomass outside reserves (Russ and Alcala 1996). Yet, while the study of tropical systems is important, study of temperate systems is also crucial. Moreover, given that temperate systems typically differ from tropical ones in terms of lower fish diversity, longer-lived fish species and other factors, results from tropical systems may not generalize to temperate ones. In temperate regions, nearshore rocky reef fish are particularly important because they are often a central part of the nearshore ecosystem and, in the northeast Pacific, a key component of recreational and commercial fisheries (Soh *et al.* 1998; Paddack and Estes 2000).

A handful of studies have tested the influence of marine reserves on nearshore rocky reef fish assemblages in temperate regions (McCormick and Choat 1987; Palsson 1998; Paddack and Estes 2000; Martel *et al.* 2000). An early study by McCormick and Choat (1987) studied one species in two locations in New Zealand. Although the primary purpose of their research was methodological, they found that reserves had greater abundance of this species. A study in Washington State by Palsson (1998) compared five species in two reserve and five non-reserve sites. He found mixed effects for density and size for different species, but with greatest density and size in the oldest marine reserve

area. In a more recent study, Paddack and Estes (2000) studied six rockfish and four other species in three reserve and three non-reserve sites in kelp forests along the central California coast. They found that fish in reserves were larger and that the age of the reserve increased the effect. These studies, together with that by Martell *et al.* (2000) on the movement of lingcod in reserves, suggest that fish density and size increase in reserves and these effects increase with the age of the reserve. However, these temperate studies have had small sample sizes, unexplained mixed results, and relied on comparisons of “fished” and “reserve” sites with either: 1) little or no replication of reserve/non-reserve pairs or 2) across limited time scales.

The purpose of this thesis is to extend the examination of marine reserve effects on nearshore rocky reef fish populations’ density and length-frequency distribution in temperate systems. Specifically, this thesis combines two studies. First, a temporal study of a single site at multiple time periods in order to provide a time-series view of marine reserve effects. Second, a spatial study of three pairs of reserve/non-reserve sites for one time period similar to that by Paddack and Estes (2000). In addition, this thesis uses tightly matched pairs of reserve and non-reserve sites to obtain greater study control, gathers a greater number of observations per site to enhance statistical power, and controls for age of reserve by using reserves that were established concurrently.

The first (temporal) study consists of a single permanent transect at one site, with data collected at four time periods from 1974-76 (Moulton 1977), 1987 (Casselle 1987), 1991-92 (S. Miller, unpublished data), and 1999-00 (this study). The site was a non-reserve during the first two time periods and a reserve during the latter two. The protocols for all dive surveys used in the first study were developed by Moulton (1977). The goal of this study was to control for micro-habitat, and so more effectively to isolate the effects of marine reserve status over time. The second (spatial) study consisted of three matched pairs of reserve and non-reserve sites. All data were collected in 2000. The goals of this study were to provide data from six study sites (and thus increase replication of the reserve/non-reserve treatment), increase the number of transects sampled per dive survey (and thus statistical power of analysis), stratify by depth in an attempt to reduce large variance associated with fish counts and resultant population density estimates, collect habitat data for each transect, and collect total length data for every fish sighted. Combined, the temporal and spatial studies should extend previous studies by giving a richer view of the effects of marine reserves.

The research study area is the San Juan Channel. The specific focus is The San Juan Islands Marine Preserves. They were established in 1990, and restrict all forms of fishing except for salmon, herring and in certain areas, crab (Murray 1998). This study area is particularly attractive for this thesis because the three reserves were established at the same time, are in close proximity to one another, have existed for about a decade, and have comparable habitat located outside the reserves for reference sites. The allowed

fishing activity probably has minimal, if any, impact on rocky reef fish. Anglers targeting the two pelagic species have little interaction with rocky reef fish (with the possible exception of minimal bycatch of *O. elongatus*, *S. melanops* and *S. flavidus*; K. Koski, San Juan County Bottomfish Recovery Program and Soundwatch, personal communication). Crabs are fished with pots and usually in soft-bottom habitats.

In the first study, data were collected from the Point George reserve site from October 14th, 1999 to November 19th, 1999 on fish density and year-round from October 14th, 1999 to October 20th, 2000 on fish lengths. These data are combined with data from previous studies as noted earlier in the longitudinal analysis. In the second study, data were collected from six sites (Point George plus five other sites) from July 27th, 2000 to October 5th, 2000. The three San Juan Islands Marine Preserves (**SJIMPs**) in San Juan Channel that contain nearshore rocky reef habitat were selected as study sites. These areas are known as: Southwest Shaw Island SJIMP, Friday Harbor-to-Point Caution SJIMP, and Yellow and Low Islands SJIMP. Study sites within these areas were selected as reserve study sites. These sites will be referred to as Point George, Shady Cove and Yellow Island, respectively. Non-reserve sites were selected to pair with each reserve site to provide similar bathymetry, substrate complexity, algal communities, and exposure to kilometer-scale tidal current processes within each reserve/non-reserve pair (Figure 1). The non-reserve sites will be referred to as Neck Point, Turn Island and Jones Island (in order of pairing with reserve site above).

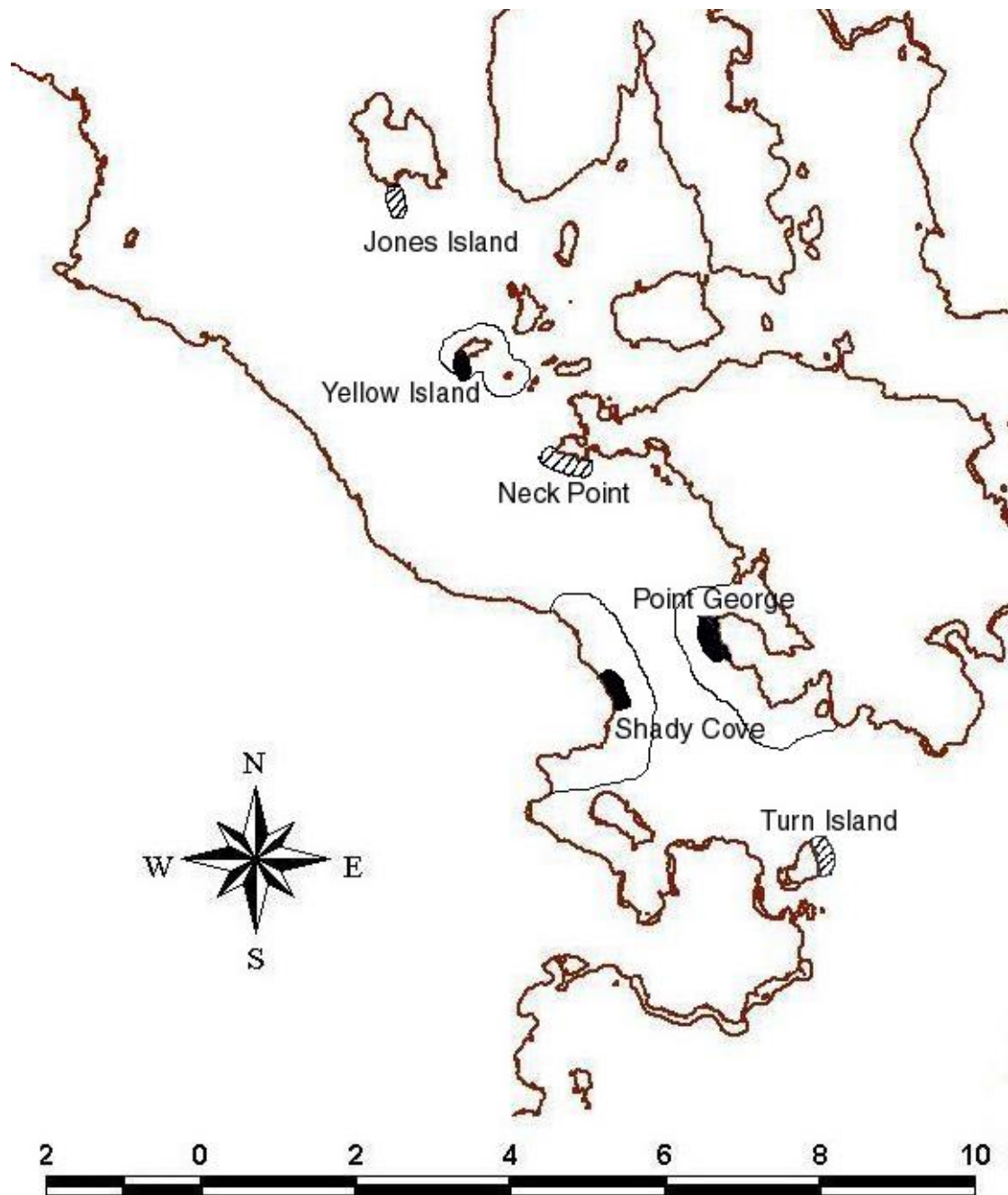


Figure 1. Study sites in San Juan Channel. Dashed lines indicate the boundaries of the San Juan Islands Marine Preserves, established by the State of Washington in 1990, which restrict the removal of anything other than salmon, herring, or crab. Reserve study sites are solid areas. Non-reserve study sites are crosshatched. San Juan Island is on the left, Orcas Island top right, and Shaw Island middle right. Units are in kilometers.

Non-reserve sites were chosen to maximize similarity between pairs to provide accurate replication of the reserve treatment. However, there are some subtle differences amongst pairs. Furthermore, each site more closely resembles its paired site than other pairs. This situation could not be avoided. In brief, the Point George / Neck Point pair has gradually sloping with low relief features, the Shady Cove / Turn Island pair has steep drop-off with high relief, and the Yellow Island / Jones Island pair has classic ridge-like reefs extending away from shore. Shady and Turn had abundant bull kelp (*Nereocystis luetkeana*) while Pt. George had some and the other sites had none. A harbor seal (*Phoca vitulina*) haulout was present in the Yellow Island site, and these animals were seen foraging near the Shady Cove and Turn Island sites. Turn and Jones Islands are State Parks, while the land adjacent to the three reserve sites is restricted (Table 1).

Bottomfish angler trips in North Puget Sound peaked during 1980-83, and by 1994, the annual number of trips was down to early 1970's levels (Figure 2). A ten fish bag limit for rockfish was enacted in 1983, and reduced to 5 fish in 1994. The current daily bag limit for rockfish is one fish. In 1992, the lingcod angler season was reduced from seven months to six weeks and minimum / maximum size limits were introduced. Directed commercial fisheries for rockfish using jig and troll gears were prohibited in the San Jeans in 1984 (Palsson *et al.* 1997). Trawling is allowed (outside reserves), but rarely occurs in San Juan Channel, and has resulted in total annual rockfish catches of less than 100 pounds since 1994. No lingcod have been caught commercially during the

Table 1. Study site profiles.

	Bathymetry	Bull kelp	Marine mammals	Human use
Point George	gradual slope, medium relief substrate	Limited		restricted
Neck Point	gradual slope, medium relief substrate	None		private property
Shady Cove	steep, high relief substrate	Abundant	harbor seals seen foraging nearby	restricted
Turn Island	steep, high relief substrate	Abundant	harbor seals seen foraging nearby	State park
Yellow Island	reef extending perpendicular from shore	None	harbor seal haul out in site	restricted
Jones Island	reef extending perpendicular from shore	None		State park

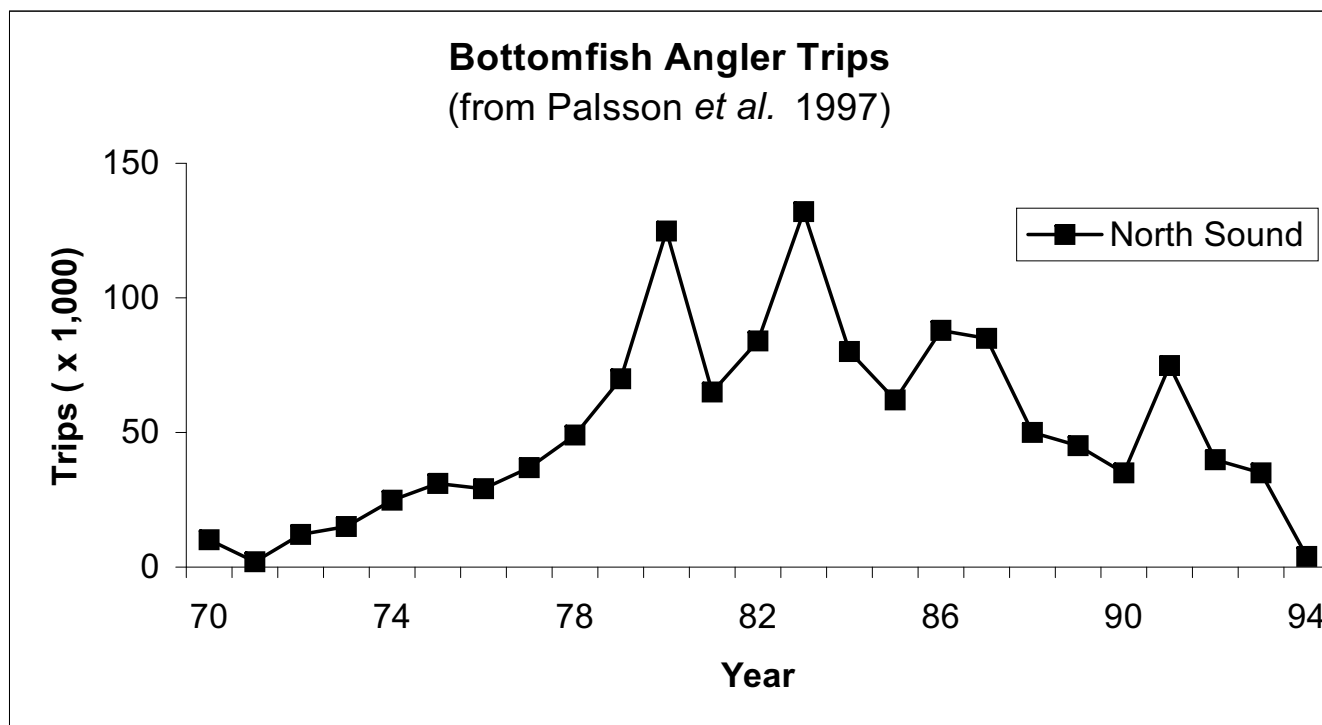


Figure 2. Number of boat-based bottomfish angler trips in North Sound. From Palsson *et al.* (1997). San Juan Channel is part of the North Sound management area.

last few years (W. Palsson, Washington Department of Fish and Wildlife, personal communication).

The eight target species for which data were collected included five rockfish: copper (*Sebastes caurinus*), quillback (*Sebastes maliger*), black (*Sebastes melanops*), yellowtail (*Sebastes flavidus*) and Puget Sound (*Sebastes emphaeus*). The other target species were lingcod (*Ophiodon elongatus*), kelp greenling (*Hexagrammos decagrammus*) and striped surfperch (*Embiotoca lateralis*). These species are distributed over a gradient of susceptibility, a gradient of desirability to local angler effort, and other factors such as size and site-fidelity. For example, lingcod are the most highly prized reef fish and individuals sighted in this study are predominantly males. Although egg nests were seen in the study sites, it appears that females are only present for a short time in which they spawn and leave the nest in the care of the male. Coppers and quillbacks are epi-benthic, demersal species and appear to have high site fidelity and small (~30m²) home ranges. Blacks and yellowtails are meso-pelagic, form aggregations 1-10 meters above the substrate and show substantial movement, often over 100km. Kelp greenling show active movement to underwater observers, but the details and extent of their movement is unknown. Puget Sound rockfish have relatively small maximum size and longevity. They are meso-pelagic forming loose aggregations as well as epi-benthic groups of fewer individuals. Striped surfperch are a schooling species of uneven age structure. Together, these eight species comprise the largest and most conspicuous members of the nearshore rocky reef fish assemblage in San Juan Channel. Therefore, it

should be possible to improve understanding not only effects of marine reserves on the eight species, but also to gain insight into some of the interactions among species. A fortunate byproduct of the second (spatial) study was that sampling occurred during a strong young-of-the-year (YOY) recruitment episode. Data concerning spatial and temporal patterns of YOY fishes of the *S. caurinus* and *S. maliger* complex were collected in 2000 and are presented here.

It should be noted that this study surveyed 0-20m depths. The species studied are also known to inhabit deeper waters. In addition, the San Juan Islands Marine Preserves encompass depths greater than the depth range covered by this study. Therefore, these results should not be extrapolated to all depths.

In general, reserves have a positive, direct effect on density and length-frequency distribution of populations that have been increasing over time and are fished. These effects appear to intensify with fishing pressure. Reserves have no direct effect on unfished populations. Reserves have no direct effect on decreasing (over time) and fished populations, although these populations may be maintained by reserves with high substrate complexity. Alternative management measures appear necessary to recover these species. Reserves can have a negative, indirect effect on populations increasing over time if reserves increase the size and/or density of predators.

METHODS AND MATERIALS

Methods for the first study employed the same permanent leadline transect survey techniques in the same location as used by Moulton (1977). More specifically, visual strip transect surveys were made along 264m of 3/8" leadline. Leadline was attached to the substrate with pitons and tied to pitons around plastic thimbles. Every fish seen was recorded, as well as depth sighted, time sighted, and transect leg (1-4). Width was defined as half the visibility to each side. Visibility was measured by stretching a meter tape between two divers until the point at which a white slate held against black neoprene was just in view. Further details are available in Moulton (1977).

The survey protocol for the second study follows: two observers, utilizing SCUBA, completed visual strip transects in reserve and non-reserve areas of San Juan Channel. The primary diver was equipped with a depth gauge, thermometer, measuring device, and data recording slate with underwater paper and pencil. The measuring device consisted of a meter long section of schedule 40 poly-vinyl chloride marked in 5cm intervals with one end attached to a perpendicularly mounted 30cm acrylic ruler, adapted from Paddock (1996). The secondary diver carried a 25m fiberglass tape, 20ml bottles for water samples, compass, data recording slate, paper and pencil. The start of each transect was randomly chosen from a subset of predetermined GPS coordinates, and bearings to conspicuous shoreline features were noted to provide redundancy if survey locations were to be located in the future. Tide Current Predictor software (Pentcheff 2000) was used to adjust depths for tide height and ensure that depths recorded were consistent with

mean lower low water (**MLLW**). Any human activity in the area, especially fishing type and intensity, was recorded before and after every dive survey.

The two diver-observers entered the water, descended and checked the anchor line, and proceeded via the most direct route 2m off the bottom to a depth of 14m (~46ft). Once there, the primary observer was tethered to the end of the fiberglass tape and the secondary observer took a water sample. Next, while staying 1m above the substrate, the primary observer began moving across the reef slope at the rate of approximately 30 fin strokes per minute. The observers went roughly north or roughly south from the anchor. Which direction was dependent on the flip of a coin, and precise bearings were dependent on bathymetry of the rocky reef. During the transect, the primary observer looked left, right, up, down, and searched boulder piles, crevices and kelp. The secondary observer remained stationary and held onto the tape reel as it unwound. While swimming the transect, the primary observer noted the depth, total length (to nearest cm), and species for all target species encountered within a 2m x 2m x 2m cube centered on the primary observer. Total length was determined by slowly placing the measuring device directly against or beneath the lateral line of the fish in question, or for stationary lingcod by measuring the distance between two points on the substrate denoted by “below the tip of the lower jaw and below the posterior portion of the ventral caudal fin ray” (Martell *et al.* 2000).

Through practice, the primary observer was able to change depth at a constant slope and end the 25m long transect at a predetermined depth. For example, during the first 25m x 2m x 2m transect the primary observer would start at a depth of 14m and end at a depth of 20m by moving approximately parallel to shore and simultaneously increasing depth as a function of linear distance moved. Therefore, surveys followed a 'zig-zag' pattern, starting a transect at one depth and ending it at another depth about 5m different. Transects alternated increasing depth during the transect with decreasing depth during the transect (Figure 3). Potential bias associated with steering toward/away from fish or particular habitats was avoided by focusing only on the immediate 2m x 2m x 2m cube of the transect, and coupling depth gauge readings with sense of body position in the water to maintain a constant rate of depth change. The width of the transect was widened to 4m after September 5th, in an attempt to keep the number of fish sighted per transect constant as densities decreased seasonally.

Depth strata were chosen according to habitat zones. The 0-5m depth range was typically dominated by algal cover including: *Laminaria*, *Ulva*, *Rhodophyta* spp., *Sargassum muticum*, and if present, *Nereocystis luetkeana* and/or *Zoestra marina*. For the 5-9m depth strata, all of the above were present, plus *Agarum*. The 9-14m depth strata did not generally contain the dominant species from the 0-5m depth strata, and *Agarum* was dominant in the 9-14m depth strata. The lower limit of algal dominance was observed around 14m and the 14-20m-depth stratum was dominated by invertebrate cover. In

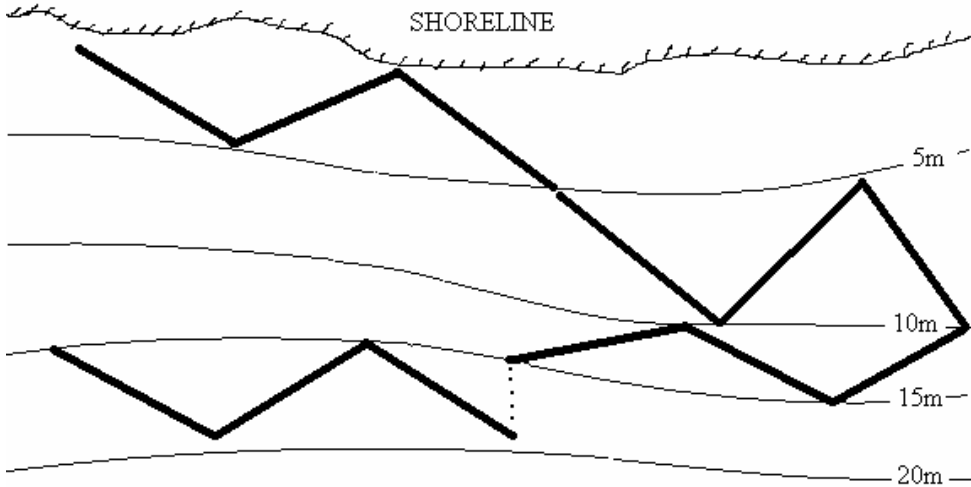


Figure 3. Diagrammatic sketch of 2000 Spatial study SCUBA transect surveys. Figure adapted from Moulton (1977). Depths on right denote bathymetry. Drawing not to scale.

addition, the 14-20m depth strata contained the greatest densities of nearshore rocky reef fish.

The secondary observer informed the primary observer when 25m of tape had been let out with three sharp tugs on the tape. Then, it was the primary observer's turn to remain stationary while the secondary observer reeled up the tape and rejoined the primary observer. As the tape was reeled, the secondary observer passed through the same transect and mentally noted habitat characteristics (to be recorded on a data sheet 1-30 seconds later). The secondary observer surveyed the habitat of precisely the same 25m x 2m x 2m transect that the primary observer had just surveyed. Habitat data included: strike and dip of the reef slope, substrate complexity (0=sediment, 1=flat rock, 2=cobble, 3=boulder<1m, 4=boulder>1m and <3m, 5=boulder>3m), substrate percent cover (sediments, bare rock, encrusting animals, macroalgae by species), and abundance of macroinvertebrates (usually seastars and urchins) by species.

When the secondary observer completed reeling, the observers were rejoined and flashed "OK". Then the secondary observer remained stationary (attached to the tape as it unwound) and recorded the data mentally noted during the previous transect while the primary observer continued on the next transect. In this way, waiting time was minimized for both observers and data collection was maximized.

This cycle was repeated 12 times per dive survey, 3 times in each of four depth strata. Therefore, each dive survey consisted of three 25m x 2m x 2m transects via zigzags between stratum bounds in each of 4 depth strata, totaling 12 transects or 600m² of rocky reef habitat surveyed and encompassing all depths from 20m to the surface. Over the duration of the 2000 spatial study, four surveys were completed at each site, totaling 288 transects and 18,000 m² surveyed. Depth was corrected for tide height such that depths of all transects over all sites and all surveys were uniform with regard to MLLW.

In summary, this data collection protocol sampled four distinct depth/habitat strata of San Juan Channel nearshore rocky reef, including shallow areas typically inhabited by juveniles and YOY of some species as well as deeper habitats (below the lower limit of greater algal abundance) typically dominated by larger, predatory fish. The protocol provides data for analyses of fish density, which control for microhabitat driven variability in fish abundance. Variance of fish densities per transect can be calculated for each depth stratum of each dive survey. This methodology avoids the often time consuming process of installing permanent leadline transects, and yet can still be used to monitor precisely the same (meter scale) locations on a reef year after year. In addition, it provides adequate sample size (n = 48 transects at each spatial study site) to overcome problems with variance typically associated with visual counts of nearshore rocky reef fish.

Dive survey number, study, site, date, start time, water visibility (m), linear distance surveyed (m), area surveyed (hectares), water salinity at depths of 5m (16ft) and 14m (46 ft), water temperature at 14m (deg C), maximum depth of dive (m), duration of dive (min), tidal current (low, moderate, high), global positioning system (**GPS**) coordinates for anchoring location, approximate direction swam from GPS point, and slack tide time and height for dive surveys were recorded for all dives surveys used in the Point George time series study and the 2000 spatial study (Tables 2-3). Any fishing activity observed before and after 2000 spatial study survey dives was recorded (Table 4).

Sampling was completed during days around quarter moons to minimize tidal current in the study sites and thereby allow back-to-back sampling at each reserve/non-reserve pair on the same slack tide. This was done to make all factors other than reserve/non-reserve treatment as equal as possible. Attempts were made to sample three days in a row during each sampling period, thereby sampling each study site once in a 3-day sampling period. Attempts were made to space sampling periods every two weeks. Due to occasional difficulty coordinating volunteer divers, these attempts were not always successful, and in one case, surveys were made on a 4 wk interval (Table 3).

Beginning September 5th, transect width was increased from 2m to 4m in response to declining population densities known to occur seasonally (Moulton 1977). This shift in transect width was done in order to keep the number of individuals of each species sighted on a transect roughly constant for the duration of the study. This methodology

Table 2. Physical data from dives used in the Point George time series (Study 1).

DIVE #	STUDY	SITE	DATE	Start time	VIS (m)	DIST (m)	AREA (ha)	Salinity (5m/14 m)	Temp (°C)	Max depth (m)	Duration (min)	Current (relative)	Start point (N. Lat., deg-min-sec)	Start point (W. Long., deg-min-sec)	Direction swam	Tide	Tide Height (m)
74535	Permanent transect	George-N	8-Oct-74	1235	6.8	250	0.1688		10.8	17	30	Strong	North end of 4 leg zig-zag	NA	HHIGH	0.6	
74538	Permanent transect	George-N	30-Oct-74	943	7	250	0.1750	29.6	10.0	17	40	Slight	North end of 4 leg zig-zag	NA	HLOW	0.4	
74539	Permanent transect	George-N	30-Oct-74	1041	7	250	0.1750		10.0	17	26	Slight	North end of 4 leg zig-zag	NA	flood	0.5	
74542	Permanent transect	George-N	23-Dec-74	1029	6.8	250	0.1688	30.2	8.0	18	31	Slight	North end of 4 leg zig-zag	NA	HHIGH	0.7	
74543	Permanent transect	George-N	23-Dec-74	1145	6.8	250	0.1688		8.0	18	30	Slight	north end of 4 leg zig-zag	NA	HHIGH	0.7	
75518	Permanent transect	George-N	6-Dec-75	1330	5	253	0.1265		8.8	17	50	Slight	north end of 4 leg zig-zag	NA	HLOW	0.5	
91521	Permanent transect	George-N	22-Oct-91	1058	9	250	0.2250	27.0	9.5	15	48	Slight	north end of 4 leg zig-zag	NA	HLOW		
91522	Permanent transect	George-N	23-Oct-91	1140	8	250	0.2000	28.0		15	54	Slight	north end of 4 leg zig-zag	NA	HLOW		
91526	Permanent transect	George-N	5-Nov-91	948	9	250	0.2250	27.0	9.0	15	60	Strong	north end of 4 leg zig-zag	NA	HLOW		
99501	Permanent transect	George-N	14-Oct-99	1547	7.9	264	0.209		9.5	18	45	None	north end of 4 leg zig-zag	NA			
91528	Permanent transect	George-N	8-Nov-91	1219	11	250	0.2750		9.5	15	53	Slight	north end of 4 leg zig-zag	NA	HLOW		
91529	Permanent transect	George-N	9-Dec-91	1425	6.5	250	0.1625	26.0	10.0	15	50	None	north end of 4 leg zig-zag	NA	HLOW		
91531	Permanent transect	George-N	13-Dec-91	1045	7	250	0.1750	26.0	7.4	15	45	Slight	north end of 4 leg zig-zag	NA	HHIGH		
99505	Permanent transect	George-N	7-Nov-99	1448	6.5	264	0.1716		9.0	18	38	Slight	north end of 4 leg zig-zag	NA	HHIGH	0.7	
99502	Permanent transect	George-N	08-Nov-99	1059	7.4	264	0.195		8.8	21	43	None	north end of 4 leg zig-zag	NA			
99506	Permanent transect	George-N	8-Nov-99	1058	7.4	264	0.1954	27.0	9.0	17	42	None	north end of 4 leg zig-zag	NA	HLOW	0.5	
99507	Permanent transect	George-N	10-Nov-99	1235	6.8	264	0.1795	28.0	9.0	17	43	Strong	north end of 4 leg zig-zag	NA	HLOW	0.5	
99503	Permanent transect	George-N	12-Nov-99	1423	6.9	264	0.182		8.7	20	54	None	north end of 4 leg zig-zag	NA			
99508	Permanent transect	George-N	12-Nov-99	1422	6.9	151	0.1042		9.3	17	25	None	north end of 4 leg zig-zag	NA	HLOW	0.6	
99509	Permanent transect	George-N	14-Nov-99	851	6.4	264	0.1690	28.0	9.0	18	34	None	north end of 4 leg zig-zag	NA	HHIGH	0.8	
99504	Permanent transect	George-N	15-Nov-99	923	5.8	264	0.153		8.7	20	49	Slight	north end of 4 leg zig-zag	NA			
99510	Permanent transect	George-N	15-Nov-99	922	5.8	264	0.1531	28.0	8.8	15	46	Strong	north end of 4 leg zig-zag	NA	HHIGH		
99512	Permanent transect	George-N	19-Nov-99	1147	6.5	264	0.1716	29.0	8.8	18	46	Slight	north end of 4 leg zig-zag	NA	HHIGH	0.8	

Table 3. Physical data from dives used in the 2000 spatial study (Study 2).

DIVE #	STUDY	SITE	DATE	Start time	VIS (m)	DIST (m)	AREA (ha)	Salinity (5m/14 m)	Temp (°C)	Max depth (m)	Duration (min)	Current (relative)	Start point (N. Lat., deg-min-sec)	Start point (W. Long., deg-min-sec)	Direction swam	Tide	Tide Height (m)
501	Spatial	Turn	25-Jul-00	1315	8	250	0.05	28/30	10.2	21	56	none	white sign on headland		north	high 1359	1.4
502	Spatial	Shady	25-Jul-00	1515	7	250	0.05	28/30		20	59	slight	mooring		north	high 1359	1.4
503	Spatial	Yellow	26-Jul-00	1430	5	250	0.05	28/28	10.3	21	53	slight	48, 35, 24.7	123, 1, 57.2	south	high 1537	1.7
504	Spatial	Jones	26-Jul-00	1635	6	250	0.05	28/28	10.4	19	61	none	48, 36, 40.0	123, 2, 39.9	south	high 1537	1.7
505	Spatial	George	27-Jul-00	1610	6	250	0.05	29/28	10	20	56	slight	48, 33, 34.5	122, 59, 12.1	south	high 1643	2.0
506	Spatial	Neck	27-Jul-00	1847	5	250	0.05	28/28	10	20	54	slight	48, 34, 50.9	123, 00, 57.1	south	high 1643	2.0
507	Spatial	George	31-Jul-00	1200	5	250	0.05	29/28	9.8	20	59	strong	48, 33, 28.1	122, 59, 07.7	north	low 1130	-0.8
508	Spatial	Neck	02-Aug-00	1315	3	150	0.03		10.8	20	32	strong	48, 34, 46.9	122, 00, 47.9	north	low 1301	-0.4
509	Spatial	Neck	03-Aug-00	1400	3	100	0.02	25/27	12.6	16	24	none	48, 34, 46.10	122, 00, 47.10	north	low 1345	0.0
510	Spatial	Yellow	22-Aug-00	1156	7	250	0.05	--	10.4	20	52	none	48, 35, 24.2	123, 01, 57.7	south	high 1205	1.6
511	Spatial	Jones	22-Aug-00	1334	7	250	0.05	29/28	10.3	20	45	slight	48, 36, 39.3	123, 02, 40.8	south	high 1205	1.6
512	Spatial	Turn	23-Aug-00	1310	8	250	0.05	28/28	10.3	21	53	none	48, 32, 05.1	122, 58, 05.4	north	high 1355	1.7
513	Spatial	Shady	23-Aug-00	1500	7	250	0.05		10.4	20	49	strong	48, 33, 11.6	123, 00, 19.0	south	high 1355	1.7
514	Spatial	Neck	24-Aug-00	1240	7	250	0.05	29/29	10.3	21	54	slight	48, 34, 46.5	123, 00, 46.0	north	high 1520	1.9
515	Spatial	George	24-Aug-00	1410	7	250	0.05	??/29	10.3	21	49	none	48, 33, 35.4	122, 59, 15.0	north	high 1520	1.9
516	Spatial	George	05-Sep-00	1200		250	0.1	29/29	10.5	20	45	slight	48, 33, 28.9	122, 59, 07.8	south	high 1302	1.9
517	Spatial	Neck	05-Sep-00	1350	7	250	0.1	29/29	10.6	19	46	none	48, 34, 47.8	123, 00, 45.6	south	high 1302	1.9
518	Spatial	Turn	06-Sep-00	1350	8	250	0.1	27.5/28	10.5	20	54	none	48, 32, 05.1	122, 58, 05.6	south	high 1429	2.0
519	Spatial	Shady	06-Sep-00	1540	8	250	0.1	29/28.5	10.7	22	50	slight	48, 33, 07.7	123, 00, 15.2	north	high 1429	2.0
520	Spatial	Yellow	08-Sep-00	1355		250	0.1		10.4	21	46	none	48, 35, 24.3	123, 01, 57.1	south	high 1616	2.2
521	Spatial	Jones	08-Sep-00	1515		250	0.1		10.7	20	43	slight	48, 36, 39.2	123, 02, 39.9	south	high 1616	2.2
522	Spatial	Jones	04-Oct-00	1630		250	0.1		10.2	21	51	none	48, 36, 39.5	123, 02, 40.5	south		
523	Spatial	Yellow	04-Oct-00	1750		250	0.1		10.4	22	37	strong	48, 35, 24.4	123, 01, 59.0	south		
524	Spatial	Turn	05-Oct-00	1320		250	0.1		10.2	20	45	slight	white sign on headland		south		
525	Spatial	Shady	05-Oct-00	1500		250	0.1		10.2	22	52	none	mooring		south		

Table 4. Fishing activity observed before and after dives used in the 2000 spatial study (Study 2).

DIVE #	STUDY	SITE	DATE	Start time	Start point (N. Lat., deg-min-sec)	Start point (W. Long., deg-min-sec)	Fishing before dive	Fishing after dive
501	Spatial	Turn	25-Jul-00	1315	white sign on headland		0	2 caurinus speared
502	Spatial	Shady	25-Jul-00	1515	mooring		0	0
503	Spatial	Yellow	26-Jul-00	1430	48, 35, 24.7	123, 1, 57.2	0	0
504	Spatial	Jones	26-Jul-00	1635	48, 36, 40.0	123, 2, 39.9	0	2 lines, salmon troller
505	Spatial	George	27-Jul-00	1610	48, 33, 34.5	122, 59, 12.1	3 lines	0
506	Spatial	Neck	27-Jul-00	1847	48, 34, 50.9	123, 00, 57.1	0	2 caurinus speared 30 cm and 27 cm
507	Spatial	George	31-Jul-00	1200	48, 33, 28.1	122, 59, 07.7	0	0
508	Spatial	Neck	02-Aug-00	1315	48, 34, 46.9	122, 00, 47.9	0	0
509	Spatial	Neck	03-Aug-00	1400	48, 34, 46.10	122, 00, 47.10	0	0
510	Spatial	Yellow	22-Aug-00	1156	48, 35, 24.2	123, 01, 57.7	0	0
511	Spatial	Jones	22-Aug-00	1334	48, 36, 39.3	123, 02, 40.8	0	20' power boat w/ 1 jig heading west
512	Spatial	Turn	23-Aug-00	1310	48, 32, 05.1	122, 58, 05.4	0	0
513	Spatial	Shady	23-Aug-00	1500	48, 33, 11.6	123, 00, 19.0	0	0
514	Spatial	Neck	24-Aug-00	1240	48, 34, 46.5	123, 00, 46.0	0	0
515	Spatial	George	24-Aug-00	1410	48, 33, 35.4	122, 59, 15.0	0	0
516	Spatial	George	05-Sep-00	1200	48, 33, 28.9	122, 59, 07.8	0	0
517	Spatial	Neck	05-Sep-00	1350	48, 34, 47.8	123, 00, 45.6	0	found buzz bomb lure at 56' on leg 3
518	Spatial	Turn	06-Sep-00	1350	48, 32, 05.1	122, 58, 05.6	0	2 small boats/skiffs, 1 fishing on rocks to south
519	Spatial	Shady	06-Sep-00	1540	48, 33, 07.7	123, 00, 15.2	0	0
520	Spatial	Yellow	08-Sep-00	1355	48, 35, 24.3	123, 01, 57.1	0	0
521	Spatial	Jones	08-Sep-00	1515	48, 36, 39.2	123, 02, 39.9	0	0
522	Spatial	Jones	04-Oct-00	1630	48, 36, 39.5	123, 02, 40.5	0	0
523	Spatial	Yellow	04-Oct-00	1750	48, 35, 24.4	123, 01, 59.0	0	0
524	Spatial	Turn	05-Oct-00	1320	white sign on headland		0	0
525	Spatial	Shady	05-Oct-00	1500	mooring		0	0

change was incorporated into population density estimates, i.e. surveys after September 5th had twice the area swept compared to previous surveys.

Transects 7 & 8 were excluded from data analysis due to potential bias from possible double counting. The protocol used in the spatial study called for the observers to double back to the boat beginning with transect 6. Despite the fact that different depth strata were sampled for transects 5 & 6 versus 7 & 8, the corners of these transects surveyed the same locations. 7 & 8 were excluded from analysis because 5 & 6 were always sampled before 7 & 8. However, 7 & 8 were not excluded from YOY *Sebastes caurinus* / *Sebastes maliger* complex data, as it was possible to remove the one instance of double counting for these fish with certainty of no additional error. Aggregations of YOY *Sebastes caurinus* / *Sebastes maliger* complex were observed not to move more than a meter or show immigration or emigration during any dive survey. Double counting between sampling periods was unlikely since different starting locations were used for each dive survey.

RESULTS

Results are presented in six sections. The first two sections relate to the first study: 1) population densities for the Point George North permanent leadline transect over time (1974-76, 1991, 1999), and 2) length-frequencies from the Point George North permanent leadline transect over time (1974-76, 1987, 1991-92, 2000). The next four sections relate to the second study, the 2000 spatial study. They include: 3) comparison of substrate complexity, rocky reef slope angle and observed fishing activity between spatial study sites, 4) population densities for all six spatial study sites, as well as between grouped reserves and non-reserves by sampling period, depth stratum, and all times and depths grouped, 5) length-frequency distributions comparisons among each spatial study reserve/non-reserve pair, as well as grouped reserve sites versus grouped non-reserve sites, and specimens collected from the region during 1974-76 for food analysis (Moulton 1997, Appendix 1-B), and 6) YOY length-frequencies and population densities for 2000 spatial study sites by sampling date and all sampling dates grouped.

Population densities at the Point George study site over time

In this section, the population density for each species is compared over time. Data from three time periods (1974-76, 1991, and 1999) collected at the Point George North zig-zag transect site were compared using Kruskal-Wallis single factor analysis of variance by ranks. All data were collected during October, November or December. Data from 1987 (Caselle) were not used since they were collected in August and population densities are known to fluctuate seasonally (Moulton, 1977). For each species,

H_0 : population density has remained constant over time, and H_A : population density has changed over time.

Population densities of *S. caurinus*, *H. decagrammus* and *S. emphaeus* have increased overtime ($p < 0.05$, $p = 0.005$ and $p < 0.005$, respectively). Population densities of *S. flavidus*, *S. melanops* and *S. maliger* have decreased overtime ($p < 0.01$, $p < 0.01$ and $p < 0.05$, respectively). In addition, these three species were not sighted at Point George in 1999, and only *S. maliger* were sighted in 1991. Population density of *O. elongatus* changed significantly over time ($p < 0.05$), increased since reserve formation. Data are insufficient for striped surfperch (*E. lateralis*) to compute density (Figure 4).

Length-frequency distributions at the Point George study site over time

In this section, the length-frequency data are compared for four time periods (1974-76, 1987, 1991-92, 1999-2000) at the Point George North leadline transect. Total lengths were collected in 2000, but not in 1999. In 1999, four length classes were used.

Results are grouped by season: January-March, April-June, July-September and October-December. Total length (to nearest cm) data from all time periods were compared using 4x1 ANOVA. For each species, H_0 : total lengths have remained constant over time, and H_A : total lengths have changed over time. Next, all pair wise combinations of time periods were examined. First, by a two sample F-test for variance, H_0 : the

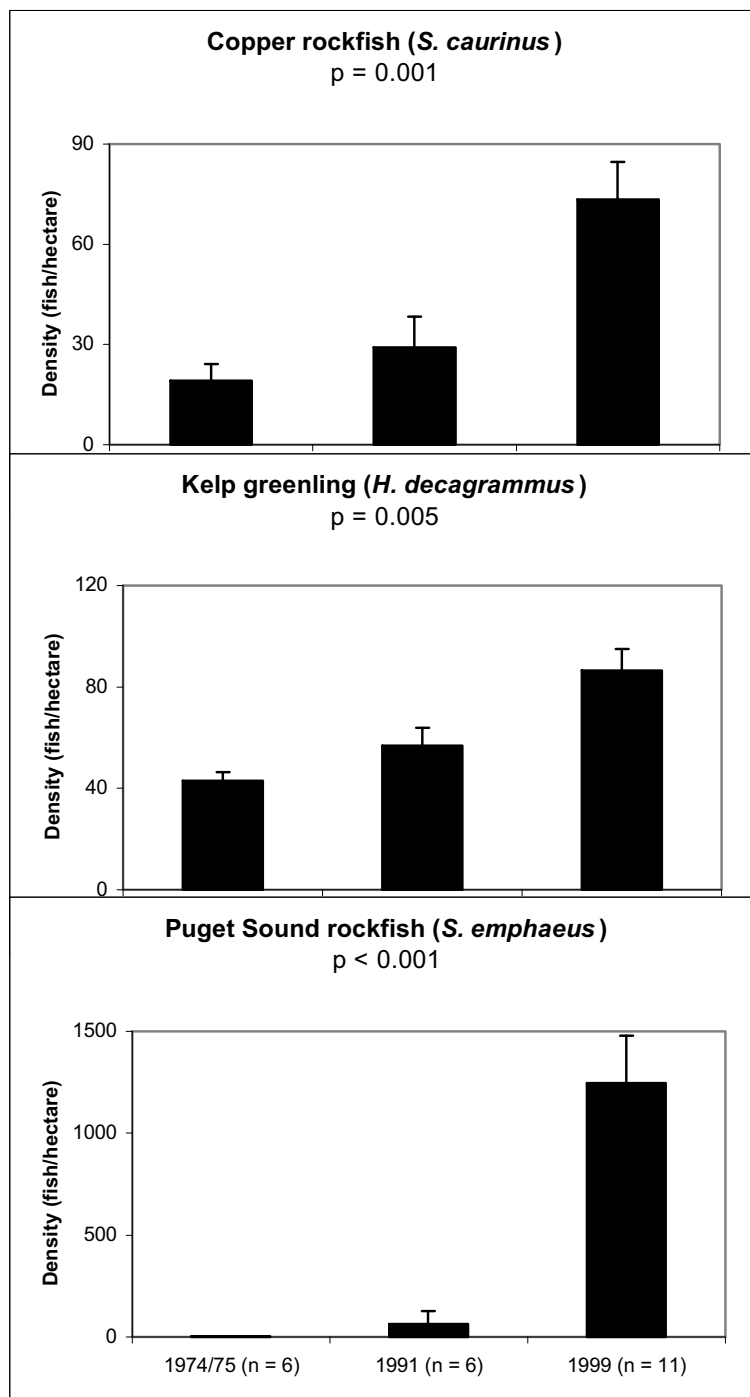


Figure 4. Population densities at Point George overtime. All data collected during the fall (Oct-Dec) for 1974-76, 1991 and 1999. Sample size is the number of transects completed during each time period. Kruskal-Wallis nonparametric statistics were used to compute p-values. Error bars are standard errors.

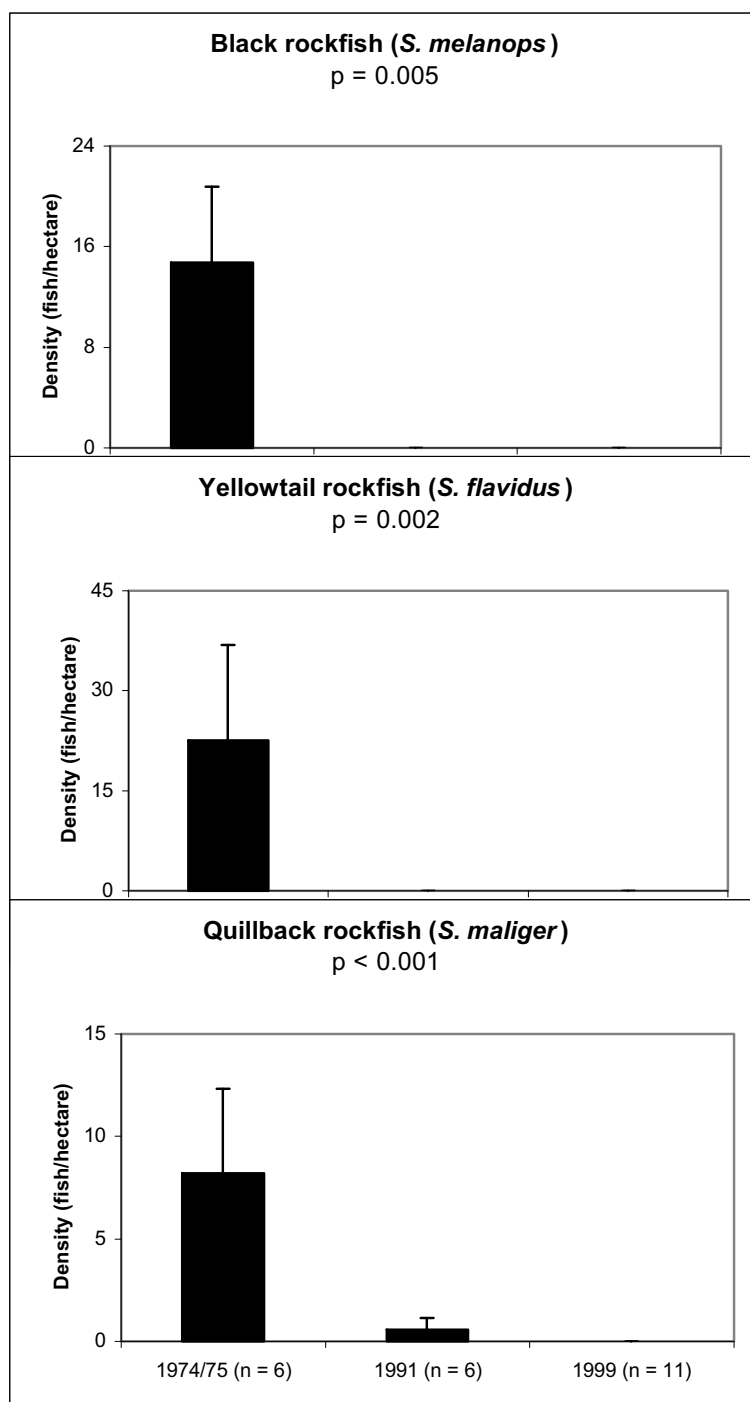


Figure 4 (cont). Population densities at Point George overtime. All data collected during the fall (Oct-Dec) for 1974-76, 1991 and 1999. Sample size is the number of transects completed during each time period. Kruskal-Wallis nonparametric statistics were used to compute p-values. Error bars are standard errors.

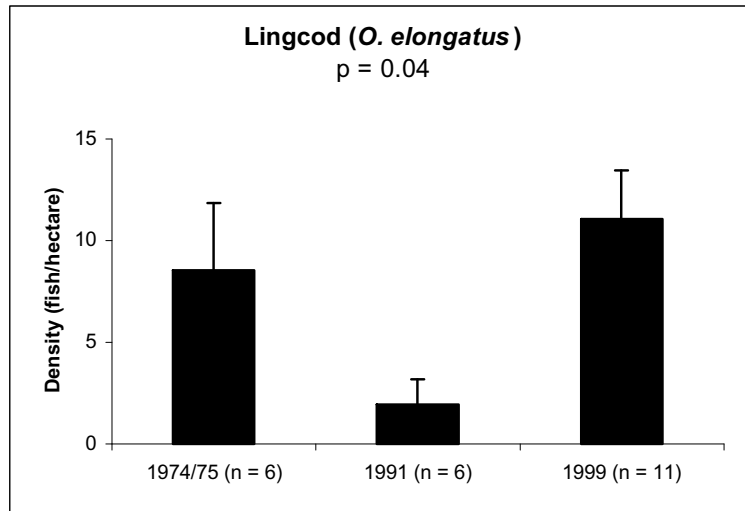


Figure 4 (cont). Population densities at Point George overtime. All data collected during the fall (Oct-Dec) for 1974-76, 1991 and 1999. Sample size is the number of transects completed during each time period. Kruskal-Wallis nonparametric statistics were used to compute p-values. Error bars are standard errors.

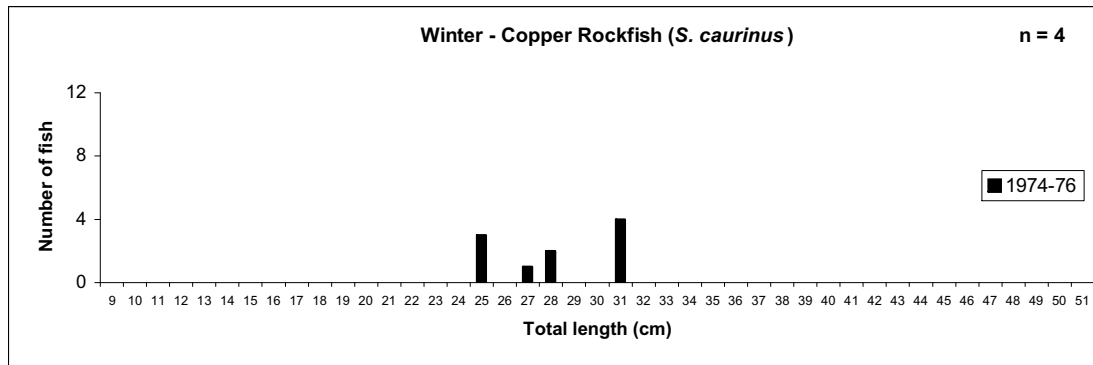
variances of total lengths from the two time periods are equal, and H_A : the variances of total lengths from the two time periods are unequal. This test was followed by the appropriate two sample t-test (i.e. for equal or unequal variance), H_0 : total lengths between two time periods are equal, and H_A : total lengths between two time periods are unequal. Other summary statistics for each time period, season and species were computed, including: number of fish, mean total length, variance, minimum length, maximum length, and percent of individuals larger than length at 50% maturity for males and females.

Results are presented in categories determined by results of the population densities over time. First, the three species with increasing population density over time and an increased rate of increase after reserve implementation, *S. caurinus*, *H. decagrammus* and *S. emphaeus*. Next, the three species which decreased and/or disappeared over time, *S. flavidus*, *S. melanops* and *S. maliger*, followed by the species which recovered over time, *O. elongatus*. For each species, analysis was done for each season. Order of results is winter, spring, summer, and fall.

For *S. caurinus*, total lengths have generally changed significantly over time (ANOVA: $p < 0.001$, $p < 0.01$, $p < 0.05$ and ns for winter, spring, summer and fall, respectively). Specifically, the before-reserve total lengths (1970's-1987 or 1992) generally increased, however results had mixed significance (t-test: $p < 0.001$, ns, $p < 0.001$, ns) and for summer data, the significant change in total length before reserve (1970's-1987) was a decrease (t-test: $p < 0.001$). The since-reserve lengths (1992-2000)

have decreased in all four seasons (t-test: $p = 0.003$, $p = 0.002$, $p = 0.014$, $p = 0.019$) (Figures 5-8, Tables 5-8). Combined with prior analysis, population density of *S. caurinus* was increasing before reserve status and the rate of increase accelerated after reserve status. In contrast, length has showed mixed trends before reserves were implemented and decreased since.

For *H. decagrammus*, overall ANOVAs were significant for summer and fall (ANOVA: $p < 0.0001$, $p < 0.05$) but not for winter or spring. Before reserves were implemented, total length had mixed, mostly non-significant trends. Total length decreased in winter and fall (t-test: ns, ns) and increased in spring and summer (t-test: ns, $p < 0.001$). The since-reserve lengths have increased for winter, spring and fall (t-test: ns, ns, $p < 0.05$) and decreased for summer (t-test: ns) (Figures 9-12, Tables 9-12). Combined with the first analysis, the density of *H. decagrammus* was significantly increasing before reserve status and accelerated after reserve implementation. In contrast, length has generally remained statistically unchanged.



No data available for 1987

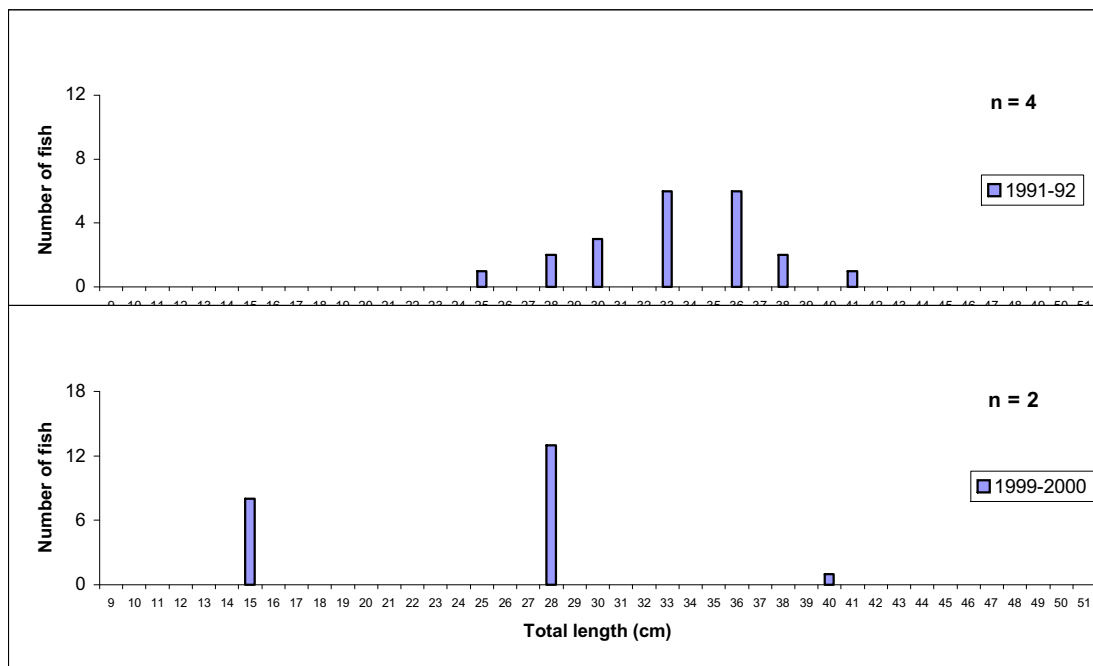


Figure 5. Winter length-frequency distributions of copper rockfish (*S. caurinus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 5. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for copper rockfish (*S. caurinus*) on the Point George permanent leadline transect in winter (January-March).

ANOVA: Single Factor

WINTER *S. caurinus*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	10	279.08	27.908	7.815107	25	31
1991-92	21	702	33.42857	15.25714	25	41
1999-2000	11	255	23.18182	73.36364	15	40

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	788.3624	2	394.1812	13.86066	2.84E-05	3.2381
Within Groups	1109.115	39	28.43885		***	
Total	1897.478	41				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X	0.303	0.002
<i>1991-92</i>		X	0.003
<i>1999-2000</i>	**	**	X

t-Test: Two-Sample

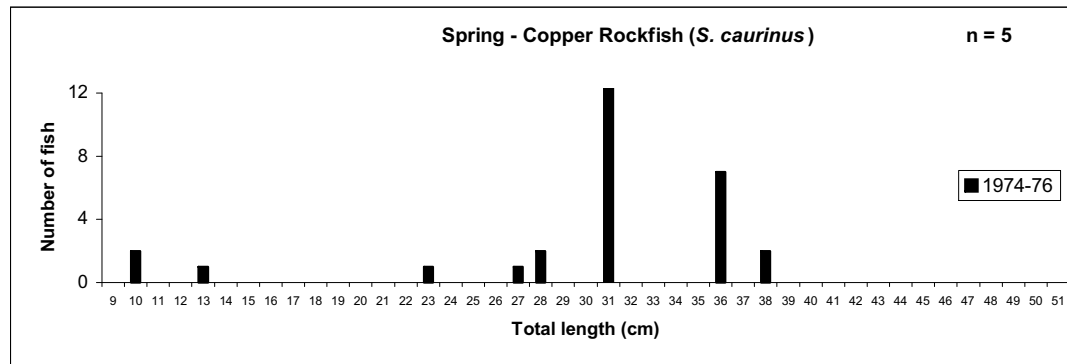
Total length (cm)

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X	0.000	0.108
<i>1991-92</i>	***	X	0.003
<i>1999-2000</i>		**	X

Length (and age) at 50% maturity: Males 25cm (6yr) females 25cm (6yr)
Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
Males	76	100	52
Females	76	100	52



No data available for 1987

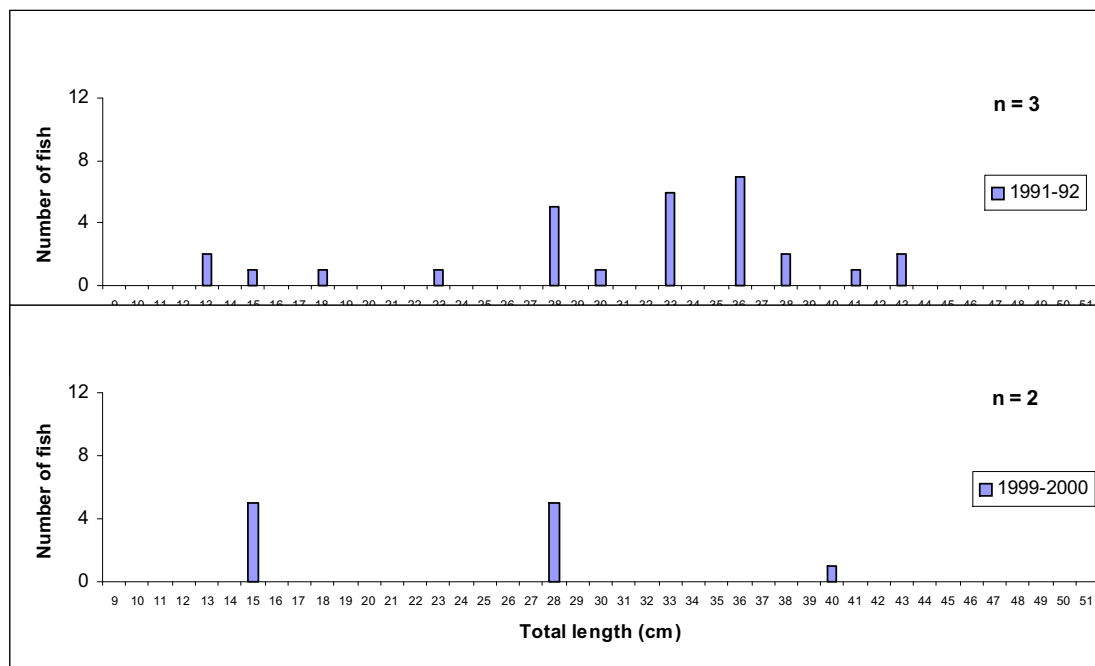


Figure 6. Spring length-frequency distributions of copper rockfish (*S. caurinus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 6. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for copper rockfish (*S. caurinus*) on the Point George permanent leadline transect in spring (April-June).

ANOVA: Single Factor

SPRING *S. caurinus*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	30	891.19	29.70633	51.49653	10	37
1991-92	29	905	31.2069	66.66995	13	43
1999-2000	22	524	23.81818	52.91775	15	40

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	736.6887	2	368.3444	6.425429	0.002611	3.113797
Within Groups	4471.431	78	57.32604		**	
Total	5208.12	80				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X	0.493	0.930
<i>1991-92</i>		X	0.591
<i>1999-2000</i>			X

t-Test: Two-Sample

Total length (cm)

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X	0.456	0.005
<i>1991-92</i>		X	0.002
<i>1999-2000</i>	**	**	X

Length (and age) at 50% maturity: males females
 25cm (6yr) 25cm (6yr)
 Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
Males	88	84	63
Females	88	84	63

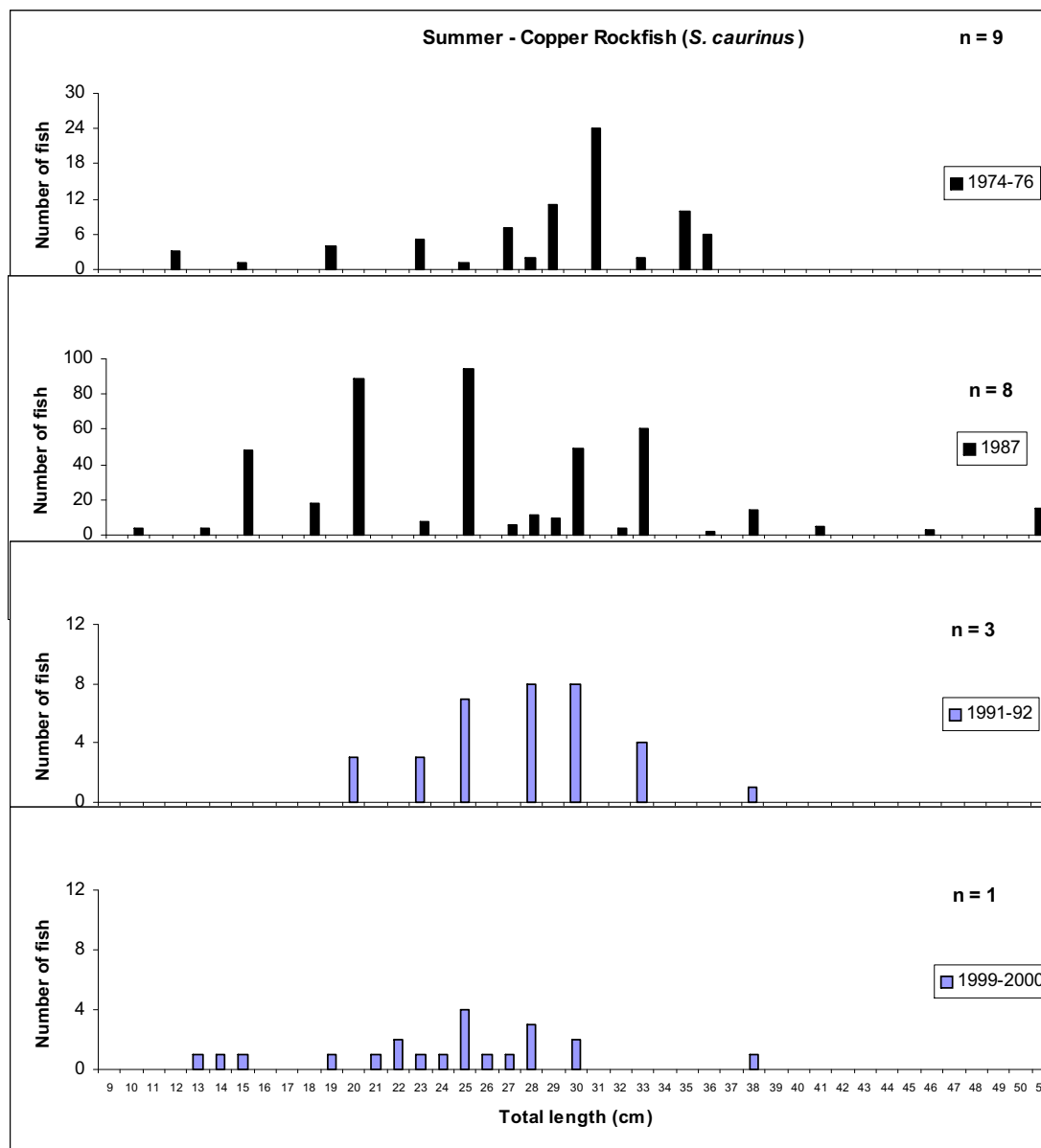


Figure 7. Summer length-frequency distributions of copper rockfish (*S. caurinus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 7. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for copper rockfish (*S. caurinus*) on the Point George permanent leadline transect in summer (July-September).

ANOVA: Single Factor

SUMMER *S. caurinus*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	76	2182.43	28.71618	32.39016	12	35
1987	443	11471	25.89391	67.73759	10	51
1991-92	34	938	27.58824	16.85561	20	38
1999-2000	21	508	24.19048	33.8619	13	38

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	666.5988	3	222.1996	3.769149	0.01066	2.620538
Within Groups	33602.75	570	58.95219		*	
Total	34269.35	573				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. caurinus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
<i>1974-76</i>	X	0.000	0.043	0.829
<i>1987</i>	***	X	0.000	0.065
<i>1991-92</i>	*	***	X	0.074
<i>2000</i>				X

t-Test: Two-

Sample

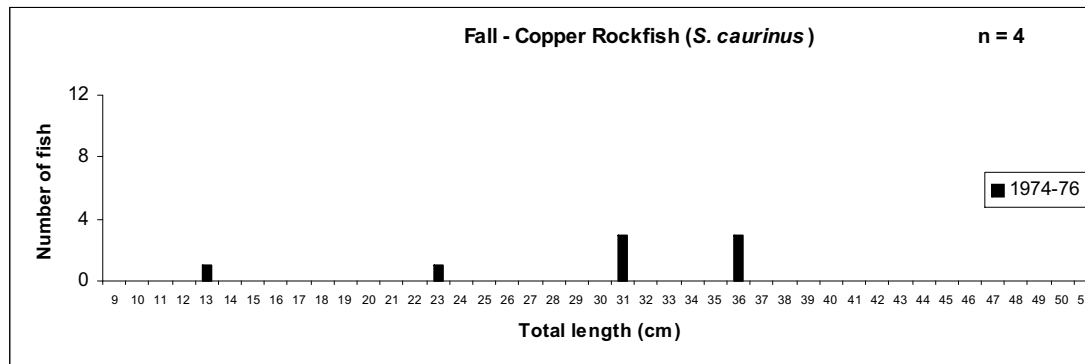
Total length (cm)

<i>S. caurinus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
<i>1974-76</i>	X	0.000	0.215	0.002
<i>1987</i>	***	X	0.041	0.349
<i>1991-92</i>		*	X	0.014
<i>2000</i>	**		*	X

Length (and age) at 50% maturity: males 25cm (6yr) females 25cm (6yr)
Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. caurinus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
Males	83	61	82	55
Females	83	61	82	55



No data available for 1987

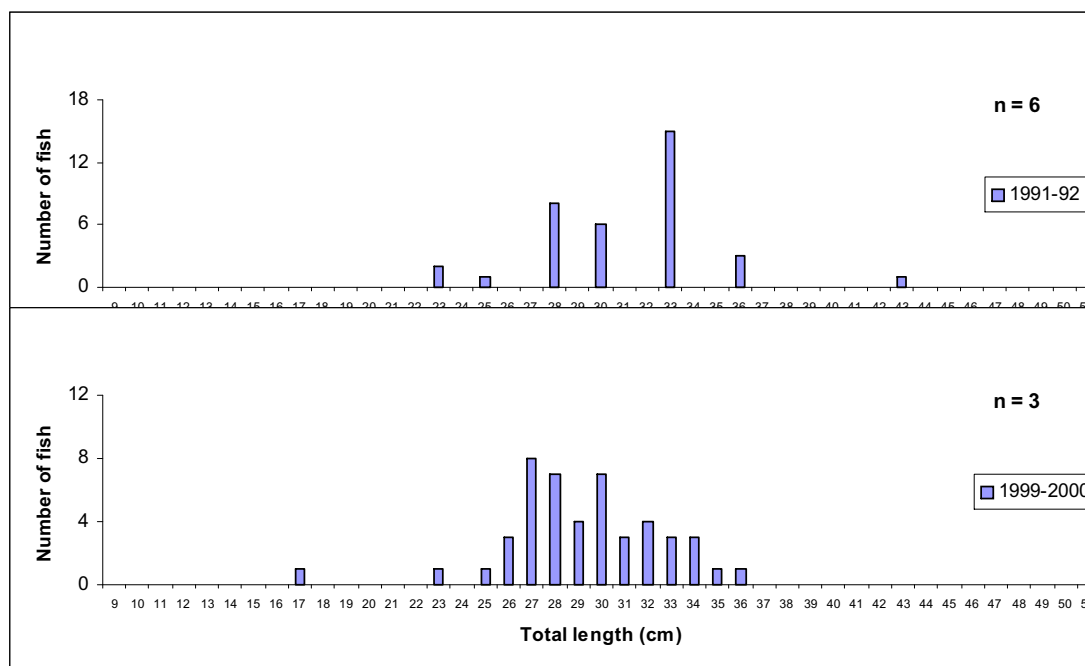


Figure 8. Spring length-frequency distributions of copper rockfish (*S. caurinus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 8. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for copper rockfish (*S. caurinus*) on the Point George permanent leadline transect in fall (October-December).

ANOVA: Single Factor

FALL *S. caurinus*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	8	233.99	29.24875	62.3203	13	35
1991-92	36	1121	31.13889	14.86587	23	43
1999-2000	47	1374	29.23404	11.35708	17	36

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	78.77272	2	39.38636	2.343517	0.101953	3.10007
Within Groups	1478.973	88	16.80651			
Total	1557.746	90				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
1974-76	X	0.004	0.000
1991-92	**	X	0.389
1999-2000	***		X

t-Test: Two-Sample

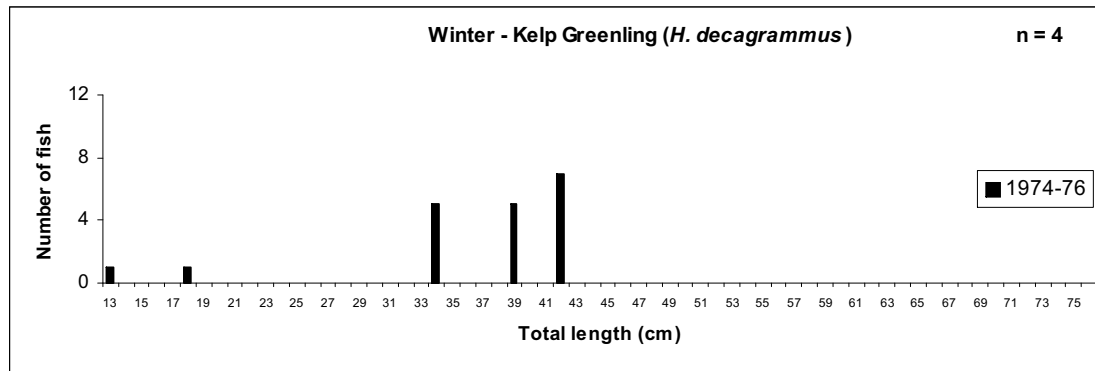
Total length (cm)

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
1974-76	X	0.528	0.996
1991-92		X	0.019
2000		*	X

Length (and age) at 50% maturity: males females
 25cm (6yr) 25cm (6yr)
 Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. caurinus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
Males	82	94	96
Females	82	94	96



No data available for 1987

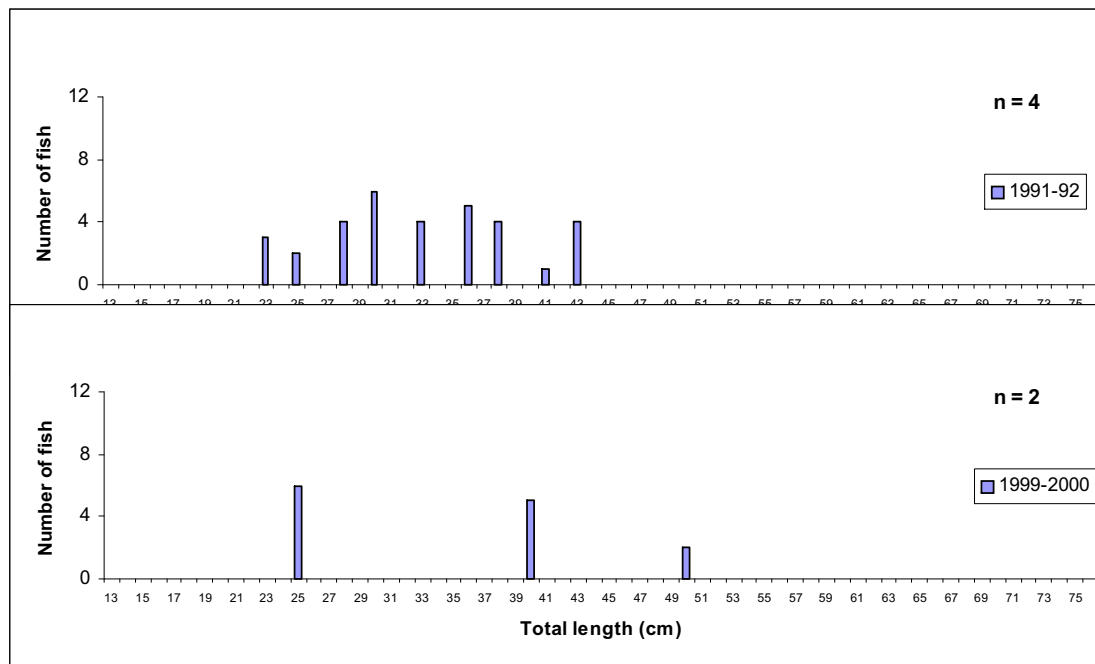


Figure 9. Winter length-frequency distributions of kelp greenling (*H. decagrammus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 9. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for kelp greenling (*H. decagrammus*) on the Point George permanent leadline transect in winter (January-March).

ANOVA: Single Factor
WINTER *H. decagrammus*
 SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	19	685.9592	36.10312	64.1174	13	42
1991-92	33	1088	32.9697	37.2178	23	43
1999-2000	13	450	34.61538	97.75641	25	50

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	120.9945	2	60.49727	1.066134	0.350564	3.14526
Within Groups	3518.16	62	56.74451			
Total	3639.154	64				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. caurinus</i>	1974-76	1991-92	1999-2000
1974-76	X	0.175	0.406
1991-92		X	0.029
1999-2000		*	X

t-Test: Two-Sample

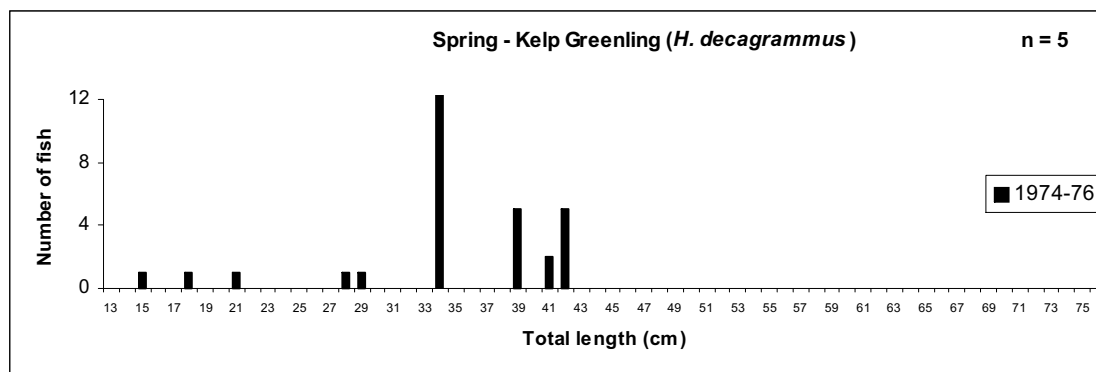
Total length (cm)

<i>S. caurinus</i>	1974-76	1991-92	1999-2000
1974-76	X	0.118	0.642
1991-92		X	0.584
1999-2000			X

Length (and age) at 50% maturity: males females
 29.5cm (3-4yr) 29.5cm (3-4yr)
 Rothrock (1973)

% Mature: Assuming 50:50 sex ratio

<i>S. caurinus</i>	1974-76	1991-92	1999-2000
males	91	73	56
females	91	73	56



No data available for 1987

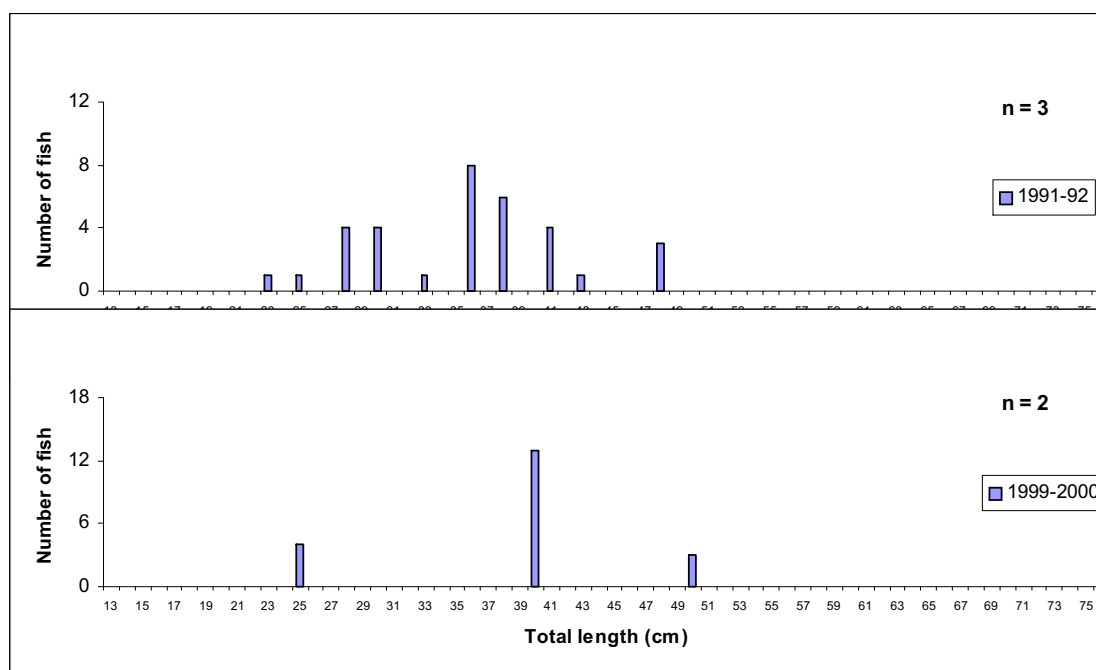


Figure 10. Spring length-frequency distributions of kelp greenling (*H. decagrammus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 10. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for kelp greenling (*H. decagrammus*) on the Point George permanent leadline transect in spring (April-June).

ANOVA: Single Factor
SPRING *H. decagrammus*
 SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	31	1066.576	34.40568	45.54452	15	42
1991-92	33	1180	35.75758	40.68939	23	48
1999-2000	20	770	38.5	60.78947	25	50

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	205.0809	2	102.5405	2.172356	0.120501	3.109307
Within Groups	3823.396	81	47.20242			
Total	4028.477	83				

F-Test Two-Sample for Variance

Total length (cm)

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
1974-76	X	0.753	0.467
1991-92		X	0.308
1999-2000			X

t-Test: Two-Sample

Total length (cm)

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
1974-76	X	0.413	0.052
1991-92		X	0.169
1999-2000			X

Length (and age) at 50% maturity: males females
 29.5cm (3-4yr) 29.5cm (3-4yr)
 Rothrock (1973)

% Mature: Assuming 50:50 sex ratio

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
Males	86	82	83
Females	86	82	83

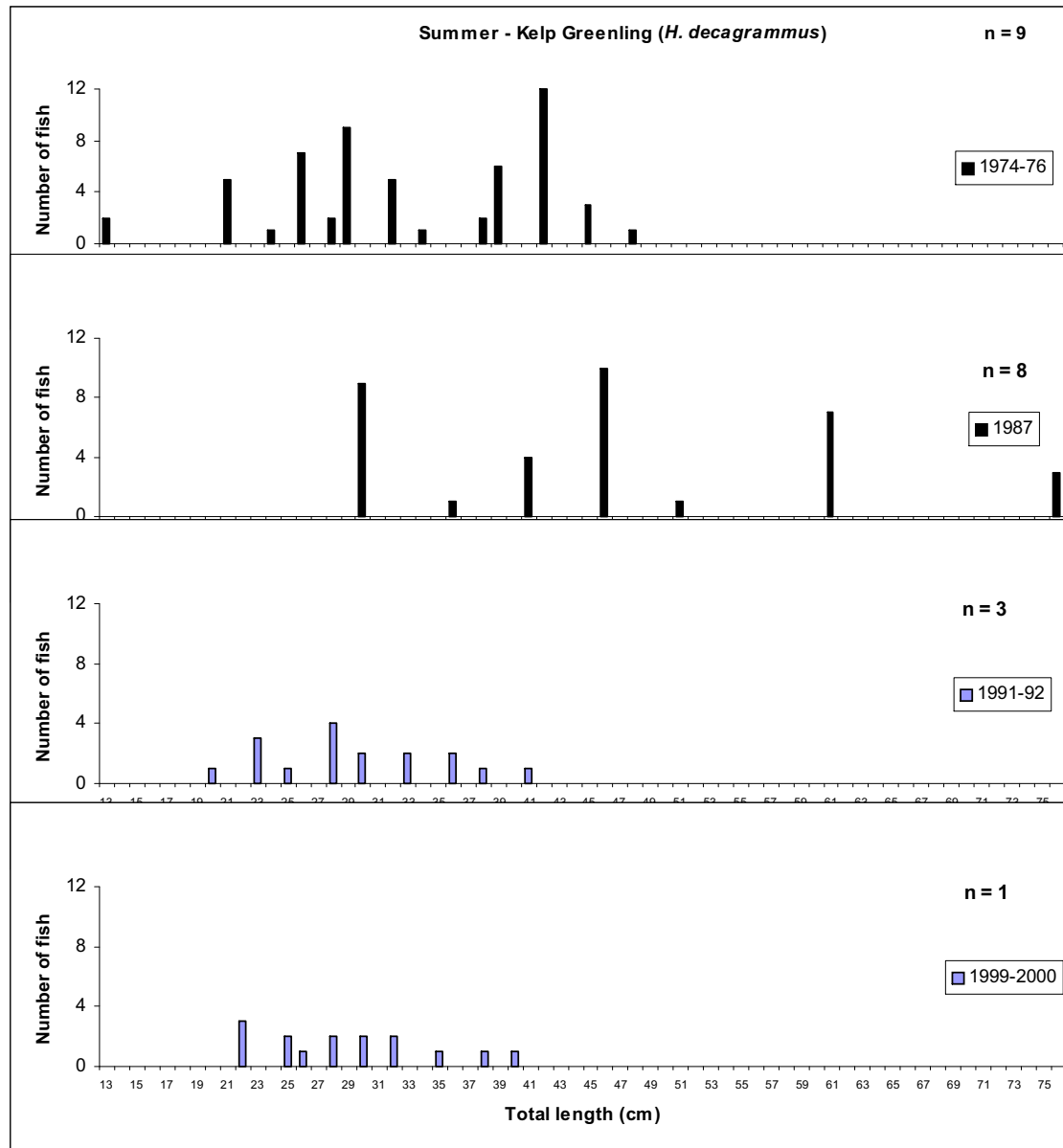


Figure 11. Summer length-frequency distributions of kelp greenling (*H. decagrammus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 11. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for kelp greenling (*H. decagrammus*) on the Point George permanent leadline transect in summer (July-September).

ANOVA: Single Factor

SUMMER *H. decagrammus*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	56	1822.464	32.54401	77.11773	10	48
1987	35	1636	46.74286	199.5496	30	76
1991-92	17	503	29.58824	35.00735	20	41
1999-2000	15	435	29	32	22	40

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	6133.969	3	2044.656	20.21842	1.17E-10	2.680807
Within Groups	12034.28	119	101.1284		***	
Total	18168.25	122				

F-Test Two-Sample for Variance

Total length (cm)

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
<i>1974-76</i>	X	0.002	0.083	0.073
<i>1987</i>	**	X	0.001	0.001
<i>1991-92</i>		**	X	0.874
<i>2000</i>		**		X

t-Test: Two-Sample

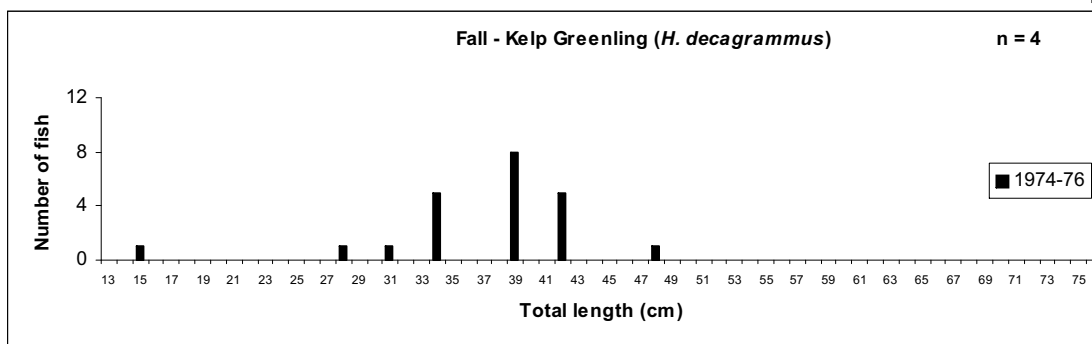
Total length (cm)

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
<i>1974-76</i>	X	0.000	0.198	0.144
<i>1987</i>	***	X	0.000	0.000
<i>1991-92</i>		***	X	0.777
<i>2000</i>		***		X

Length (and age) at 50% maturity: Males Females
 29.5cm (3-4yr) 29.5cm (3-4yr)
 Rothrock (1973)

% Mature: Assuming 50:50 sex ratio

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
Males	54	100	45	45
Females	54	100	45	45



No data available for 1987

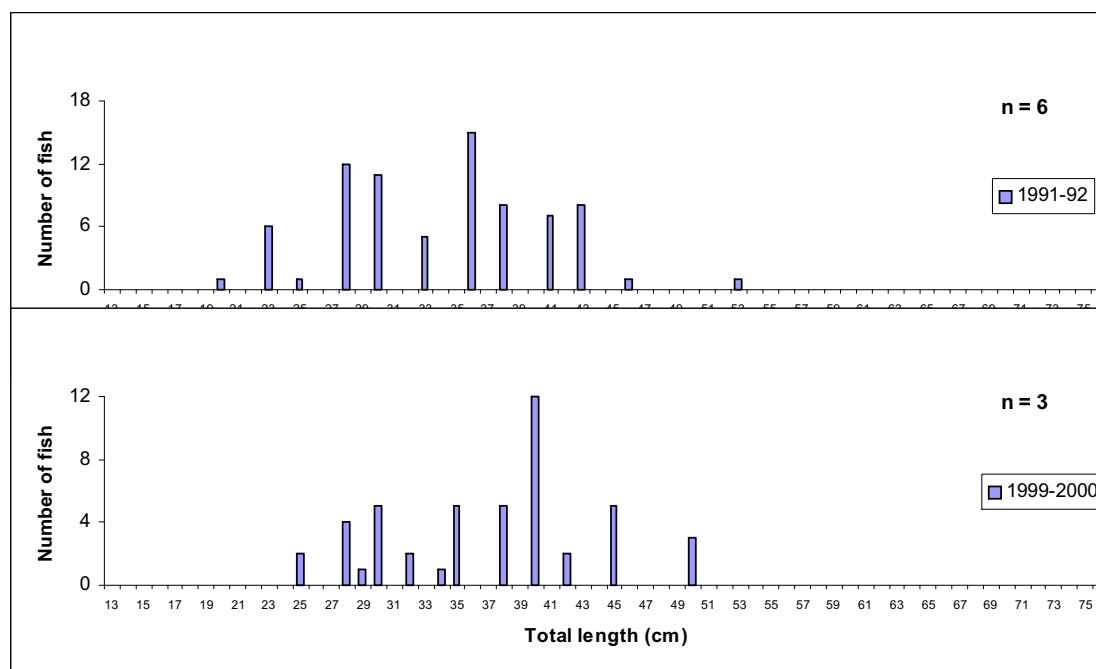


Figure 12. Fall length-frequency distributions of kelp greenling (*H. decagrammus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 12. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for kelp greenling (*H. decagrammus*) on the Point George permanent leadline transect in fall (October-December).

ANOVA: Single Factor

FALL *H. decagrammus*

SUMMARY

Groups	Count	Sum	Average	Variance	Min	Max
1974-76	22	806.365	36.65296	43.88749	15	48
1991-92	76	2587.9	34.05132	44.0268	20	53
1999-2000	47	1743	37.08511	43.25347	25	50

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	306.1129	2	153.0565	3.497979	0.032892	3.059831
Within Groups	6213.307	142	43.75568		*	
Total	6519.42	144				

F-Test Two-Sample for Variance

Total length (cm)

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
1974-76	X	0.781	0.932
1991-92		X	0.809
1999-2000			X

t-Test: Two-Sample

Total length (cm)

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
1974-76	X	0.085	0.800
1991-92		X	0.016
2000		*	X

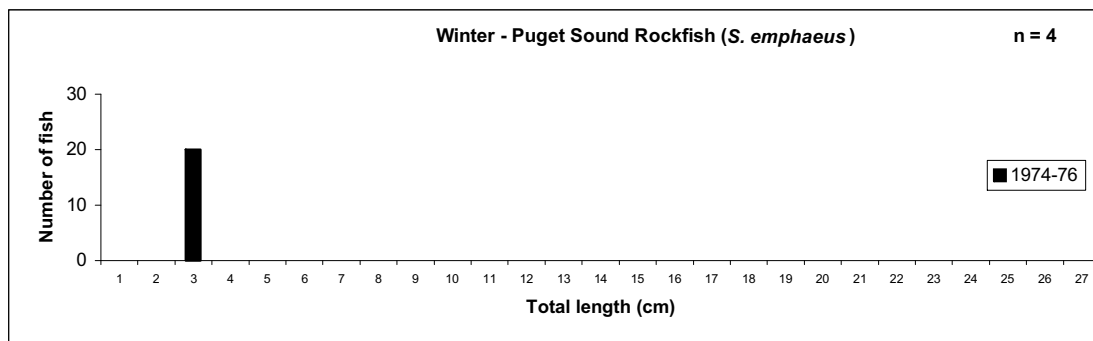
Length (and age) at 50% maturity: males 29.5cm (3-4yr) females 29.5cm (3-4yr)
Rothrock (1973)

% Mature: Assuming 50:50 sex ratio

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
Males	92	74	86
females	92	74	86

The overall ANOVAs for *S. emphaeus* were statistically significant for summer, and fall (ANOVA: $p < 0.0001$, $p < 0.0001$). For winter, data is available only for 1970's and 1999-2000, and these data showed a significant increase in total length over time (t-test: $p < 0.001$). For spring, only 1999-2000 data are available, and therefore no statistics can be calculated. For summer, only data from 1987 and 1999-2000 are available and these data showed a significant decrease (t-test: $p < 0.001$). For fall, only data from 1974-1976 and 1999-2000 are available and these data showed a significant increase (t-test: $p < 0.001$) (Figures 13-16, Tables 13-16). In all cases, data were insufficient to determine trends before or after reserve implementation. Trends could usually be determined from before (1974-1976 or 1987) to after (1999-2000), with mixed results but generally increasing. Combined with the first analysis, the density of *S. emphaeus* was significantly increasing and the increase even accelerated with reserve status, however effects of reserve status on lengths vary.

The second three analyses focus on the three species that were unobserved at the Point George permanent transect in the more recent time periods. *S. melanops* were only sighted during 1974-76 and 1987. In 1987, there was only one sighting. Therefore, a variance could not be computed to determine statistical significance (Figures 17-20, Tables 17-20). There was insufficient data to determine trends in total length of *S. melanops*. Combined with the first analysis, *S. melanops* disappeared over time and therefore effects of reserve status on length cannot be determined.



No data available for 1987

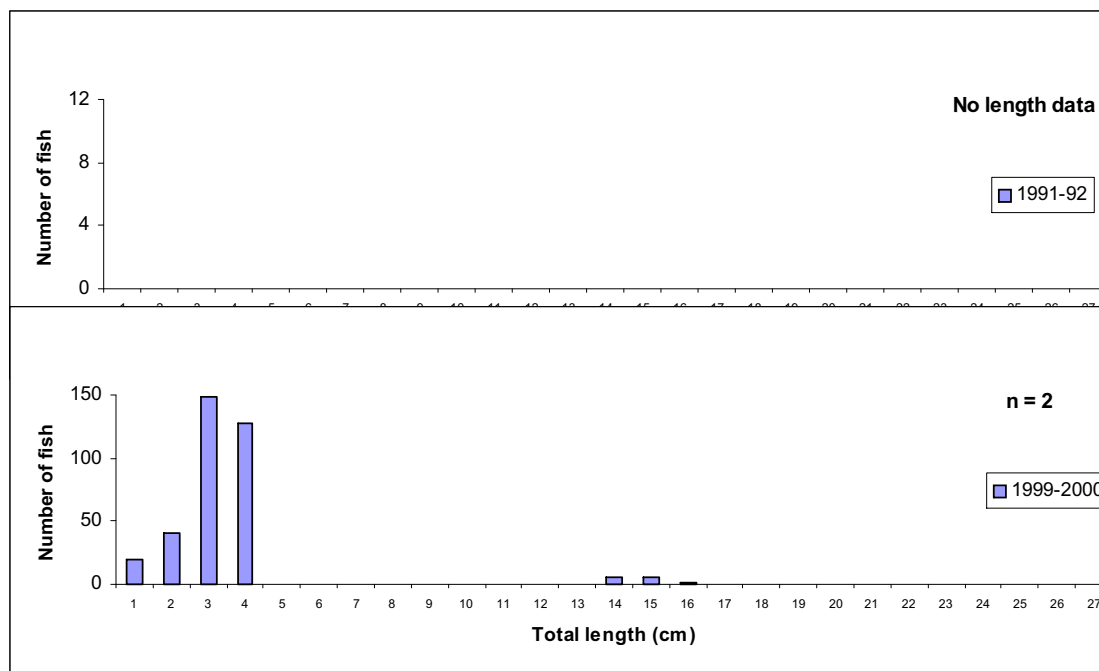


Figure 13. Winter length-frequency distributions of Puget Sound rockfish (*S. emphaeus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 13. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for Puget Sound rockfish (*S. emphaeus*) on the Point George permanent leadline transect in winter (January-March).

ANOVA: Single Factor

WINTER *S. emphaeus*

SUMMARY

Groups	Count	Sum	Average	Variance	Min	Max
1974-76	20	55	2.75	0.06579	3	3
1999-2000	349	1248	3.57593	5.57252	1	16

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12.9038	1	12.9038	2.44046	0.1191	3.86692
Within Groups	1940.49	367	5.28743			
Total	1953.39	368				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. caurinus</i>	1974-76	1991-92	1999-2000
1974-76	X	X	0.000
1991-92	X	X	X
1999-2000	***	X	X

t-Test: Two-Sample

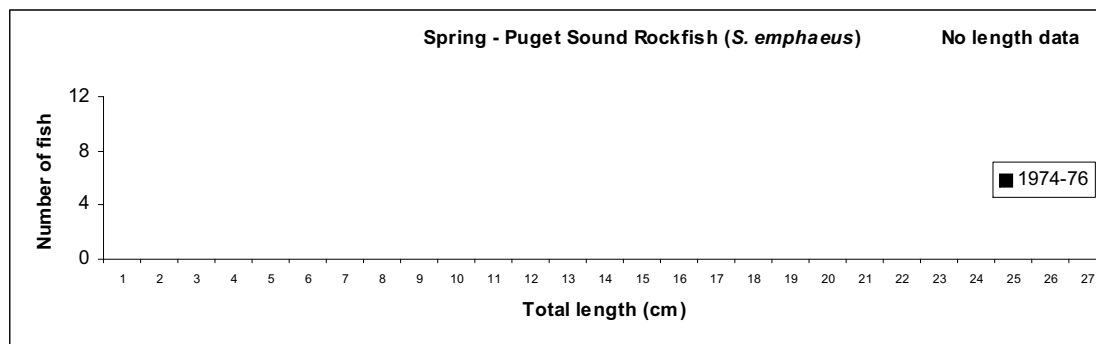
Total length (cm)

<i>S. caurinus</i>	1974-76	1991-92	1999-2000
1974-76	X	X	0.000
1991-92	X	X	X
1999-2000	***	X	X

Length (and age) at 50% maturity: males females
 12.5cm (1.9yr) 12.5cm (1.9yr)
 Beckman (1995)

% Mature: Assuming 50:50 sex ratio

<i>S. caurinus</i>	1974-76	1991-92	1999-2000
Males	0		4
Females	0		4



No data available for 1987

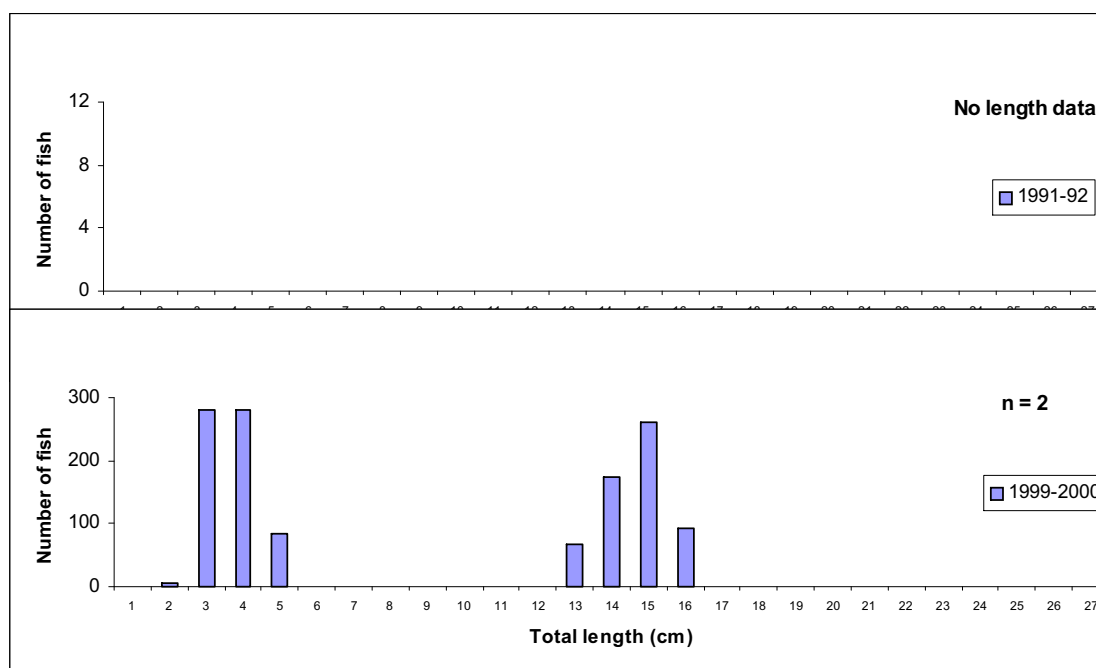


Figure 14. Spring length-frequency distributions of Puget Sound rockfish (*S. emphaeus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 14. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for Puget Sound rockfish (*S. emphaeus*) on the Point George permanent leadline transect in spring (April-June).

ANOVA: Single Factor

SPRING *S. emphaeus*

SUMMARY

<i>Group</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1999-2000	1243	11074	1066.58	30.6206	2	16

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
1974-76	X	X	X
1991-92	X	X	X
1999-2000	X	X	X

t-Test: Two-Sample

Total length (cm)

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
1974-76	X	X	X
1991-92	X	X	X
1999-2000	X	X	X

Length (and age) at 50% maturity: Males females
 12.5cm (1.9yr) 12.5cm (1.9yr)
 Beckman (1995)

% Mature: Assuming 50:50 sex ratio

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
Males			60
Females			60

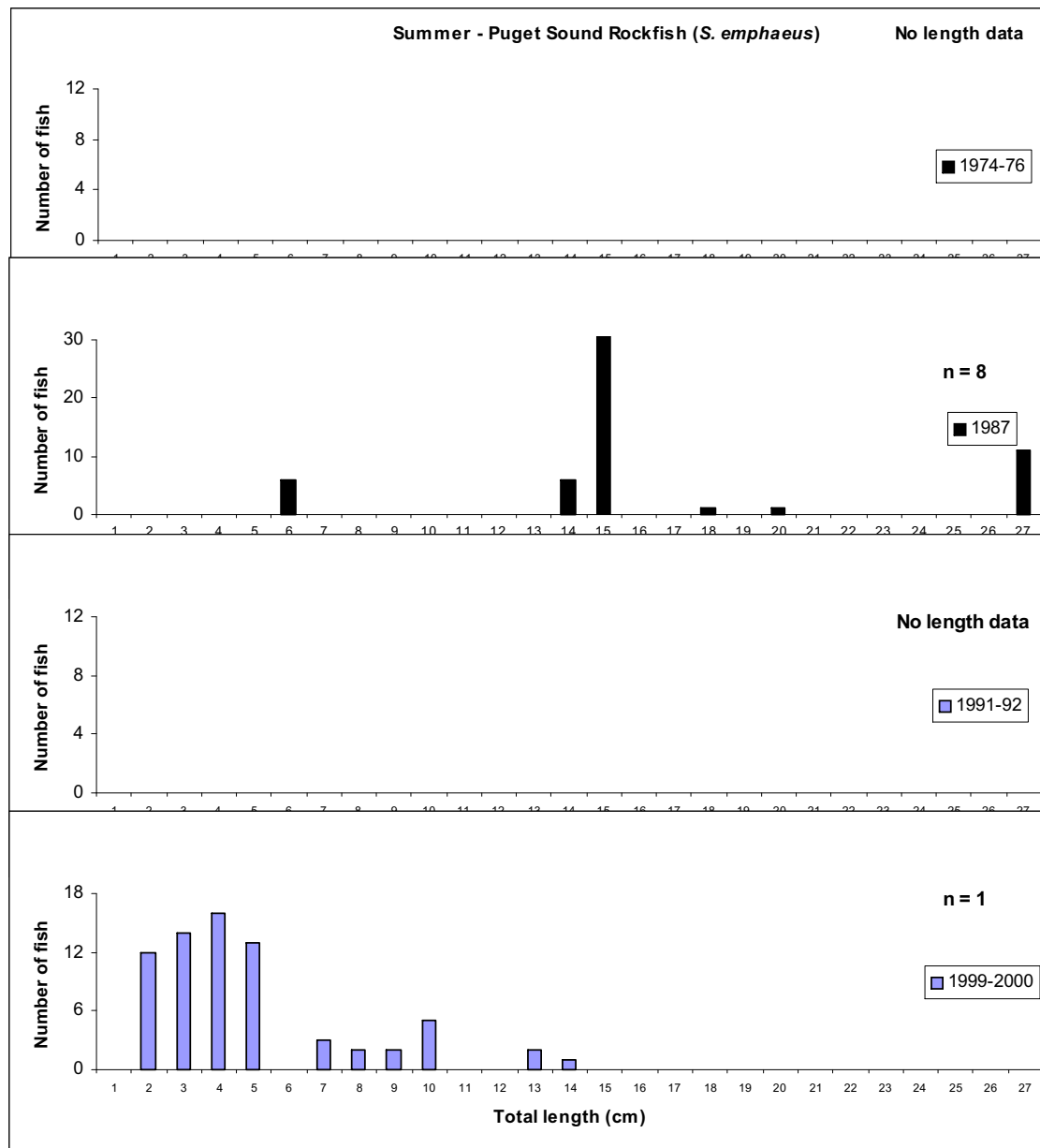


Figure 15. Summer length-frequency distributions of Puget Sound rockfish (*S. emphaeus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 15. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for Puget Sound rockfish (*S. emphaeus*) on the Point George permanent leadline transect in summer (July-September).

ANOVA: Single Factor

SUMMER *S. emphaeus*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1987	56	920	16.4286	36.2857	6	27
1999-2000	70	340	4.85714	8.32712	2	14

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	4165.71	1	4165.71	200.969	1E-27	3.91755
Within Groups	2570.29	124	20.7281		***	
Total	6736	125				

F-Test Two-Sample for Variance

Total length (cm)

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
<i>1974-76</i>	X	X	X	X
<i>1987</i>	X	X	X	0.000
<i>1991-92</i>	X	X	X	X
<i>2000</i>	X	***	X	X

t-Test: Two-Sample

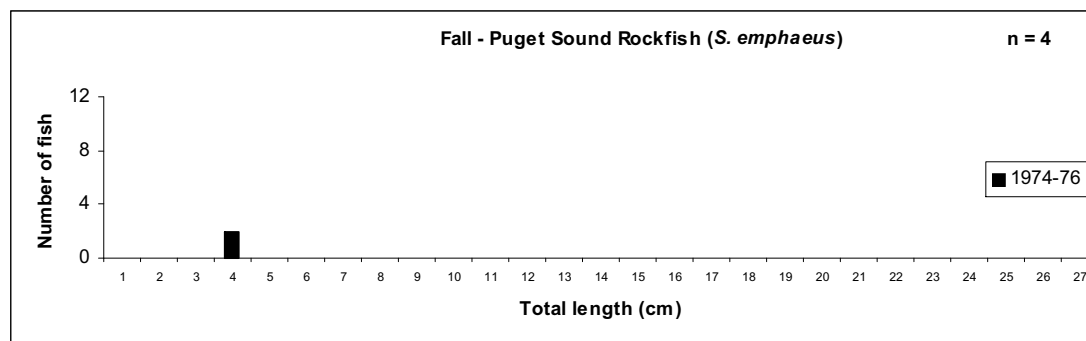
Total length (cm)

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
<i>1974-76</i>	X	X	X	X
<i>1987</i>	X	X	X	0.000
<i>1991-92</i>	X	X	X	X
<i>2000</i>	X	***	X	X

Length (and age) at 50% maturity: Males females
 12.5cm (1.9yr) 12.5cm (1.9yr)
 Beckman (1995)

% Mature: Assuming 50:50 sex ratio

<i>H. decagrammus</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
Males		90		3
Females		90		3



No data available for 1987

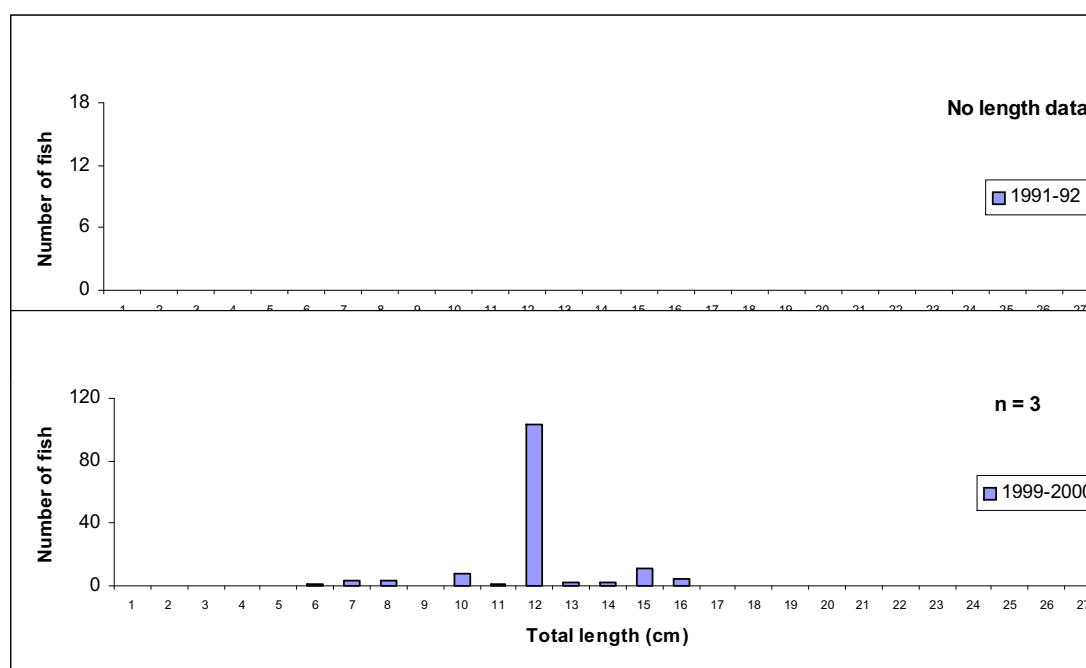


Figure 16. Fall length-frequency distributions of Puget Sound rockfish (*S. emphaeus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 16. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for Puget Sound rockfish (*S. emphaeus*) on the Point George permanent leadline transect in fall (October-December).

ANOVA: Single Factor

FALL *S. emphaeus*

SUMMARY

Groups	Count	Sum	Average	Variance	Min	Max
1974-76	2	8	4	0	4	4
1999-2000	138	1661	12.0362	2.66291	6	16

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	127.317	1	127.317	48.1601	1.4E-10	3.90973
Within Groups	364.819	138	2.64361		***	
Total	492.136	139				

F-Test Two-Sample for Variance

Total length (cm)

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
1974-76	X	X	NA
1991-92	X	X	X
1999-2000		X	X

t-Test: Two-Sample

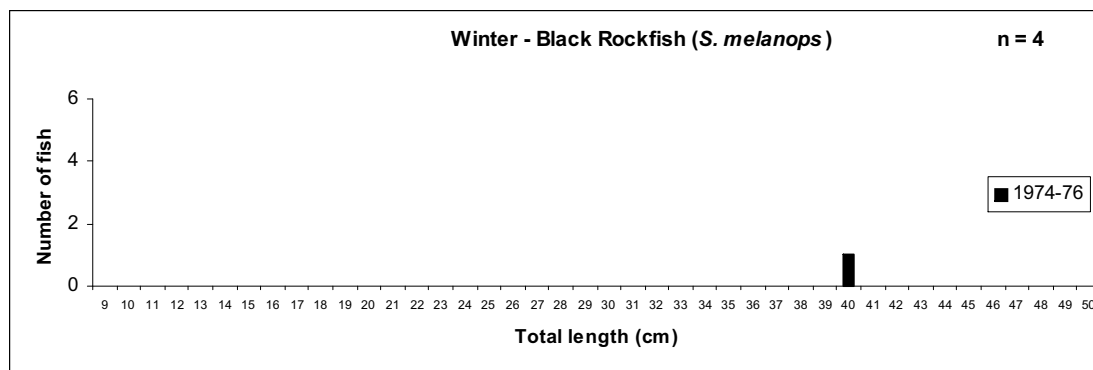
Total length (cm)

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
1974-76	X	X	0.000
1991-92	X	X	X
2000	***	X	X

Length (and age) at 50% maturity: males females
 12.5cm (1.9yr) 12.5cm (1.9yr)
 Beckman (1995)

% Mature: Assuming 50:50 sex ratio

<i>H. decagrammus</i>	1974-76	1991-92	1999-2000
Males	0	#N/A	14
Females	0	#N/A	14



No data available for 1987

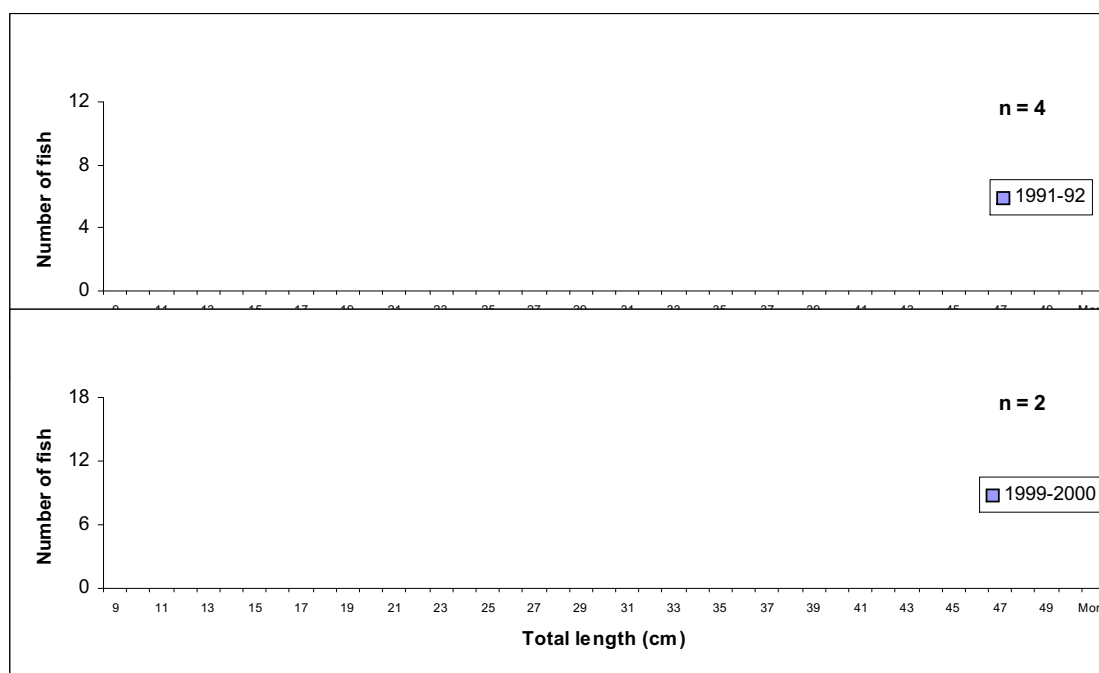


Figure 17. Winter length-frequency distributions of black rockfish (*S. melanops*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 17. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for black rockfish (*S. melanops*) on the Point George permanent leadline transect in winter (January-March).

ANOVA: Single Factor

WINTER *S. melanops*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	1	40	40	NA	40	40
1991-92	0	NA	NA	NA	0	0
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
1974-76	X		
1991-92		X	
1999-2000			X

t-Test: Two-Sample

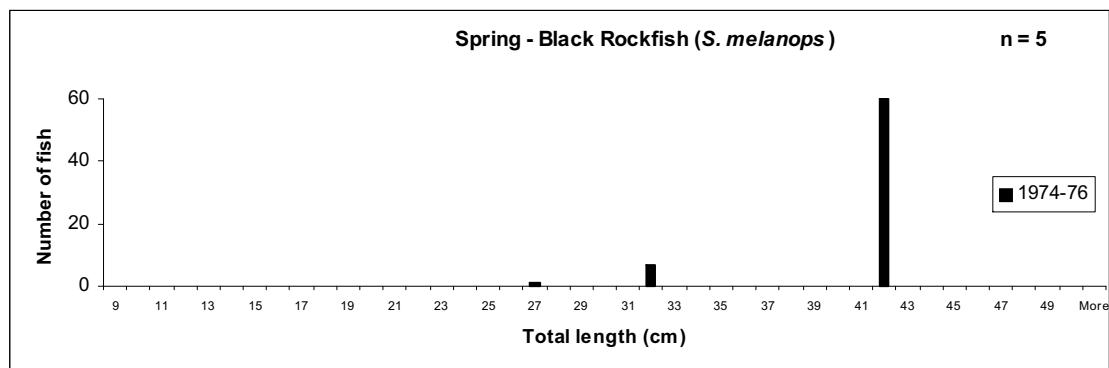
Total length (cm)

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
1974-76	X	#DIV/0!	#DIV/0!
1991-92		X	#DIV/0!
1999-2000			X

Length (and age) at 50% maturity: males females
 38.3cm (6.3yr) 38.3cm (6.3yr)
 Wallace and Taggart (1994)

% Mature: Assuming 50:50 sex ratio

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
Males	100		
Females	100		



No data available for 1987

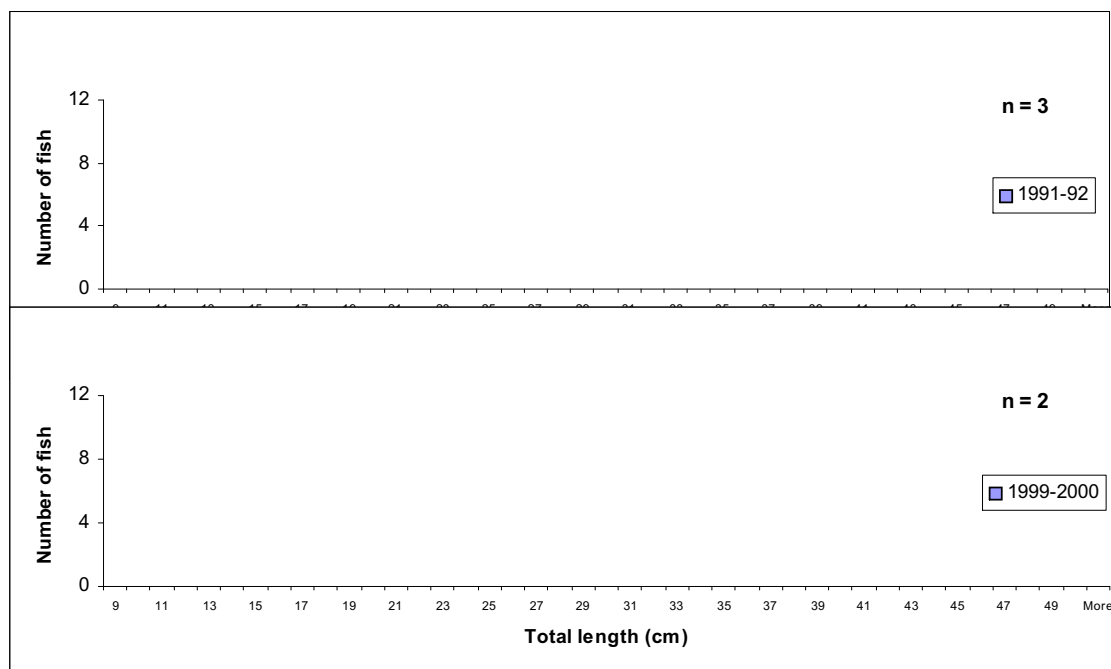


Figure 18. Spring length-frequency distributions of black rockfish (*S. melanops*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 18. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for black rockfish (*S. melanops*) on the Point George permanent leadline transect in spring (April-June).

ANOVA: Single Factor

SPRING *S. melanops*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	68	2747	40	12.03735	27	42
1991-92	0	NA	NA	NA	0	0
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X	NA	NA
<i>1991-92</i>		X	NA
<i>1999-2000</i>			X

t-Test: Two-Sample

Total length (cm)

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X	NA	NA
<i>1991-92</i>		X	NA
<i>1999-2000</i>			X

	males	females
Length (and age) at 50% maturity:	38.3cm	(6.3yr) 38.3cm (6.3yr)

Wallace and Taggart (1994)

% Mature: Assuming 50:50 sex ratio

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
Males	89		
Females	89		

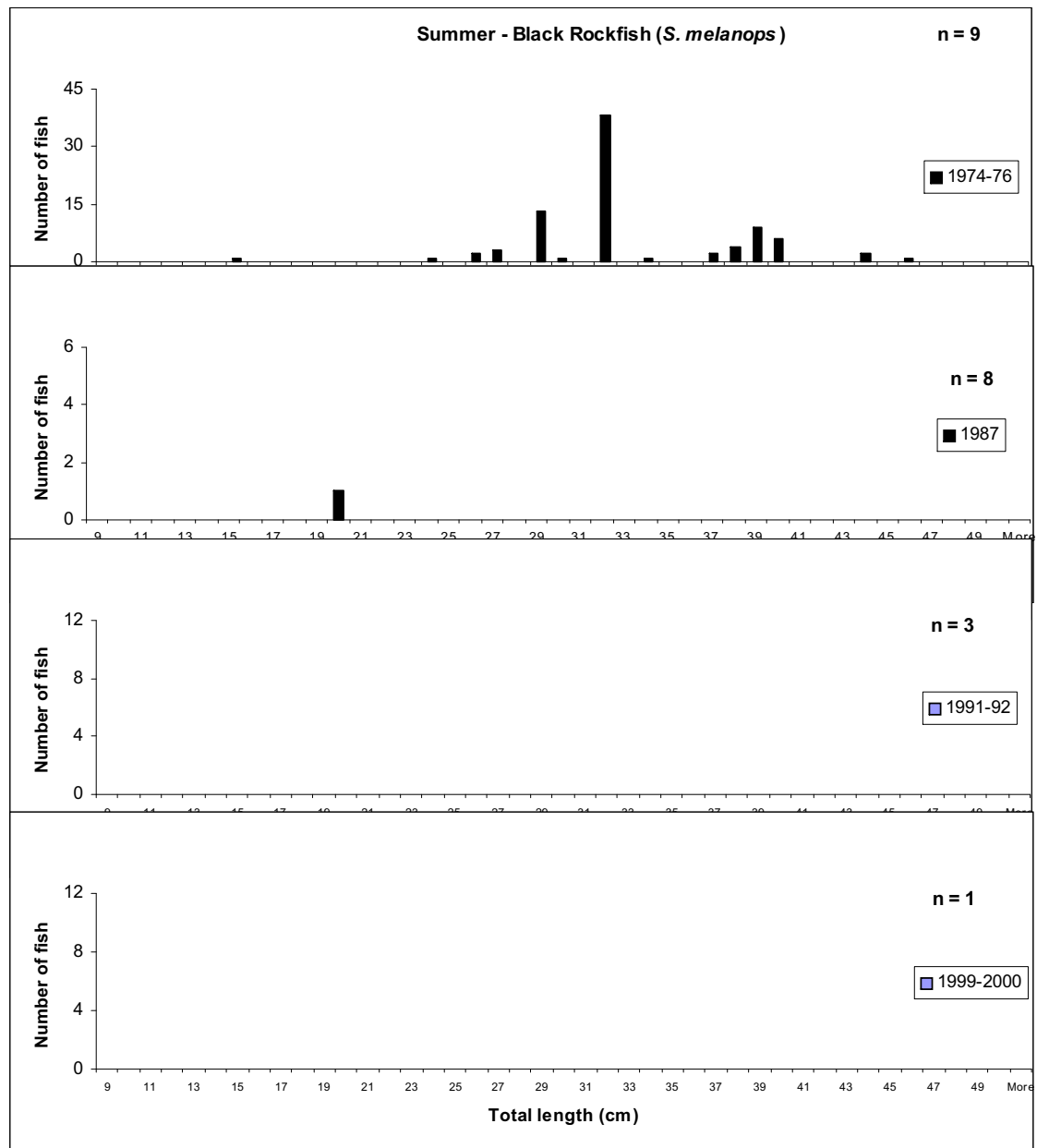


Figure 19. Summer length-frequency distributions of black rockfish (*S. melanops*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 19. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for black rockfish (*S. melanops*) on the Point George permanent leadline transect in summer (July-September).

ANOVA: Single Factor

SUMMER *S. melanops*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	84	2751	33	23.65054	15	45
1987	1	20	20	NA	20	20
1991-92	0	NA	NA	NA	0	0
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. melanops</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
<i>1974-76</i>	X			
<i>1987</i>		X		
<i>1991-92</i>			X	
<i>2000</i>				X

t-Test: Two-Sample

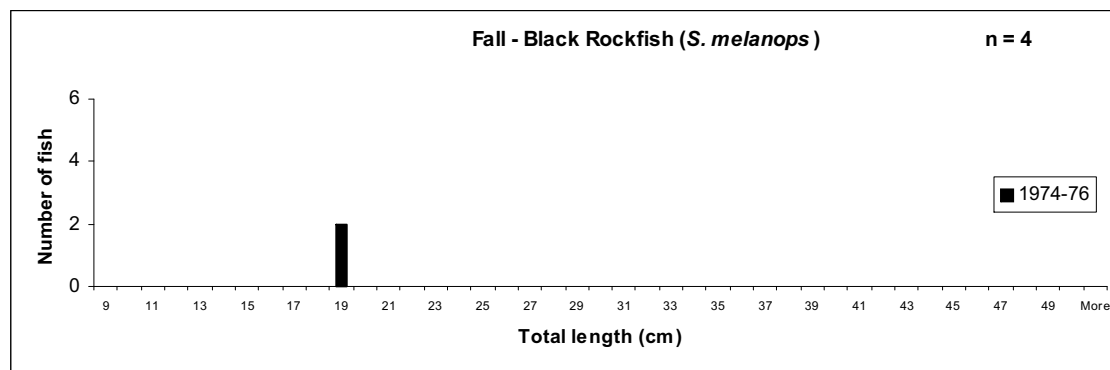
Total length (cm)

<i>S. melanops</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
<i>1974-76</i>	X			
<i>1987</i>		X		
<i>1991-92</i>			X	
<i>2000</i>				X

Length (and age) at 50% maturity: males females
 38.3cm (6.3yr) 38.3cm (6.3yr)
 Wallace and Taggart (1994)

% Mature: Assuming 50:50 sex ratio

<i>S. melanops</i>	<i>1974-76</i>	<i>1987</i>	<i>1991-92</i>	<i>2000</i>
Males	15			
Females	3			



No data available for 1987

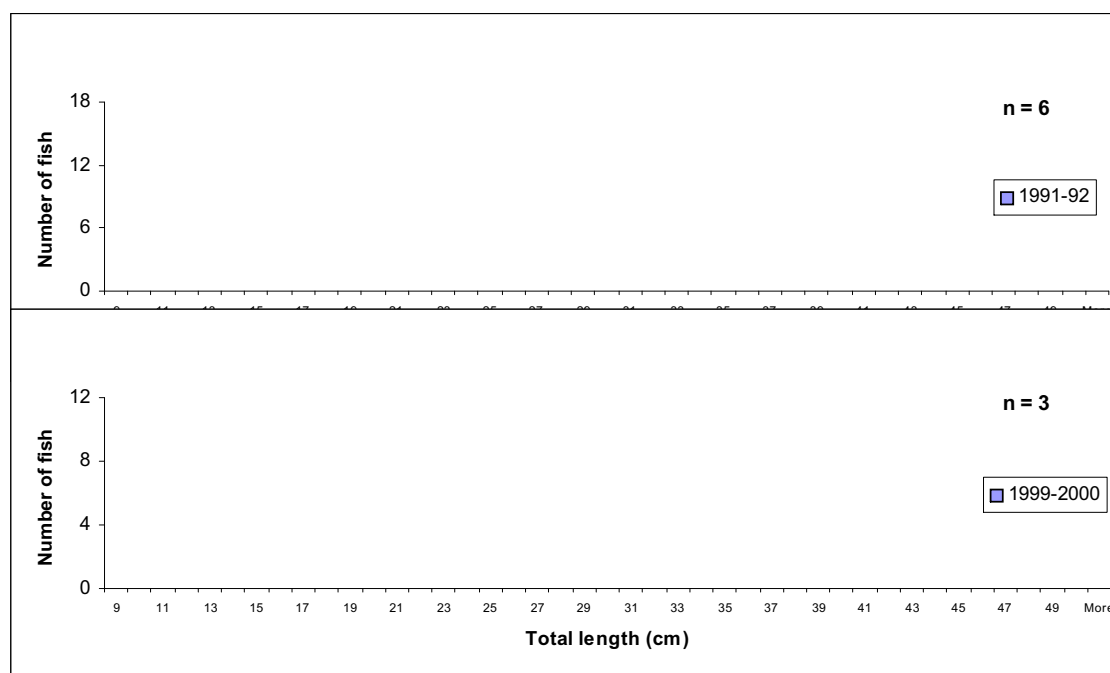


Figure 20. Fall length-frequency distributions of black rockfish (*S. melanops*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 20. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for black rockfish (*S. melanops*) on the Point George permanent leadline transect in fall (October-December).

ANOVA: Single Factor

FALL *S. melanops*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	2	38	19	0	19	19
1991-92	0	NA	NA	NA	0	0
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X		
<i>1991-92</i>		X	
<i>1999-2000</i>			X

t-Test: Two-Sample

Total length (cm)

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X		
<i>1991-92</i>		X	
<i>2000</i>			X

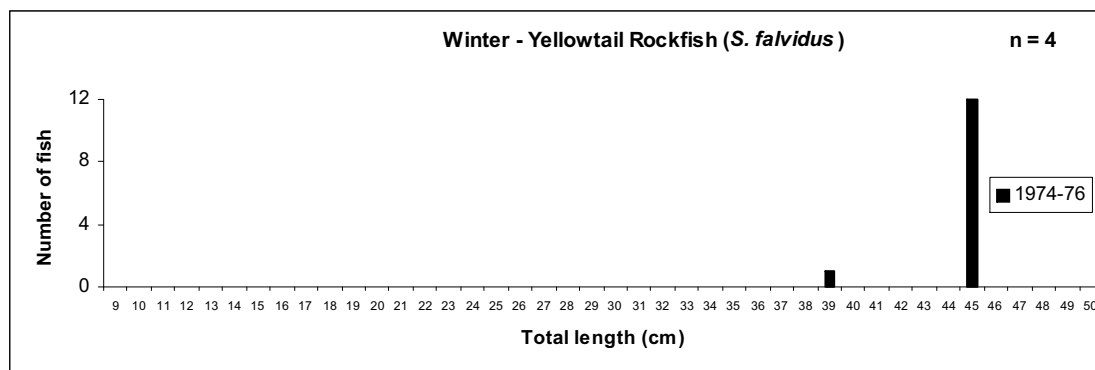
	males		females
Length (and age) at 50% maturity:	38.3cm	(6.3yr)	38.3cm (6.3yr)
			Wallace and Taggart (1994)

% Mature: Assuming 50:50 sex ratio

<i>S. melanops</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
Males	0		
Females	0		

S. flavidus were also only sighted in winter, spring and summer during 1974-76 and summer during 1987. Therefore, statistics can only be calculated for before reserve trends for summer. Total mean lengths between these two summer time periods decreased, but not significantly (t-test: $p = 0.409$) (Figures 21-24, Tables 21-24). There were no sightings in 1991-1992 or 1999-2000. In general, there was insufficient data to determine trends in total length of *S. flavidus*. Combined with the first analysis, *S. flavidus* disappeared over time and therefore effects of reserve status on length cannot be determined.

S. maliger was sighted in 1974-76, 1987, and 1991-1992, but not sighted during 1999-2000. No statistics could be calculated for winter due to insufficient data. For spring, the trend in total length from 1974-1976 to 1991-1992 was a decrease, but not significant (t-test: $p = 0.249$). For summer, total length did not change before reserve implementation, and data from after reserves is insufficient to determine trends. Data from fall are also insufficient (Figures 25-28, Tables 25-28). In general, data were insufficient to determine trends and when there were sufficient data, no significant trend was evident. Given that there were no sightings in 2000, it is not possible to compute the since-reserve effects. Combined with the first analysis, population density of *S. maliger* was decreasing before reserve implementation, and after reserves, *S. maliger* disappeared and no trends in length were evident.



No data available for 1987

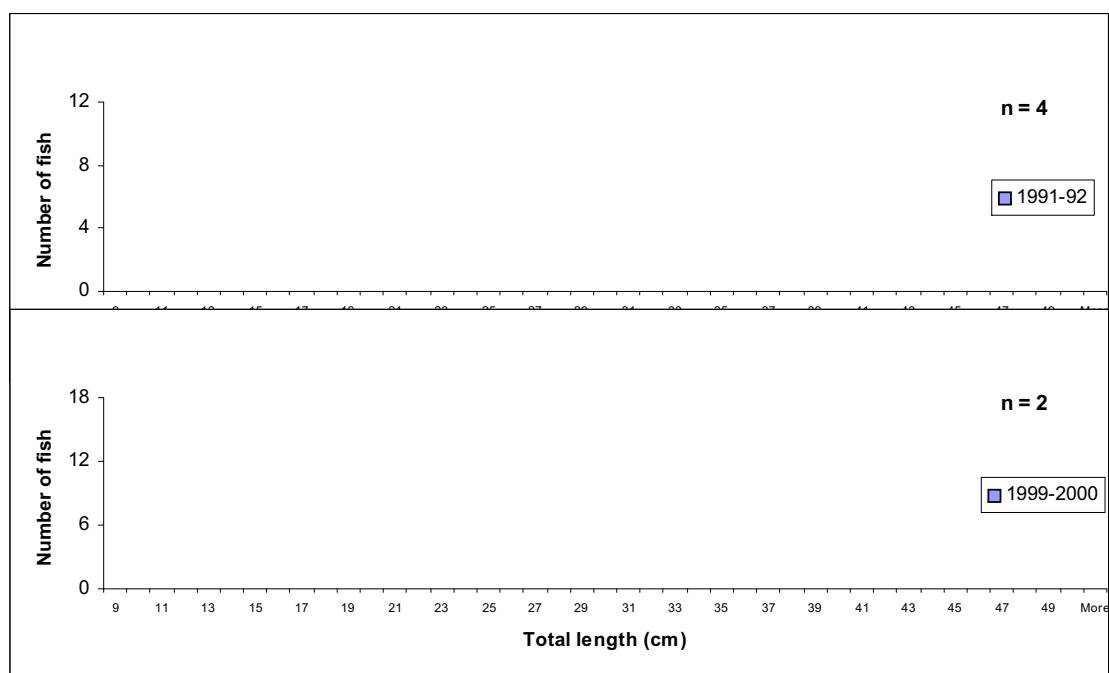


Figure 21. Winter length-frequency distributions of yellowtail rockfish (*S. flavidus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 21. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for yellowtail rockfish (*S. flavidus*) on the Point George permanent leadline transect in winter (January-March).

ANOVA: Single Factor

WINTER *S.*

flavidus

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	13	580	45	2.630164	39	45
1991-92	0	NA	NA	NA	0	0
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. flavidus</i>	1974-76	1991-92	1999-2000
1974-76	X		
1991-92		X	
1999-2000			X

t-Test: Two-Sample

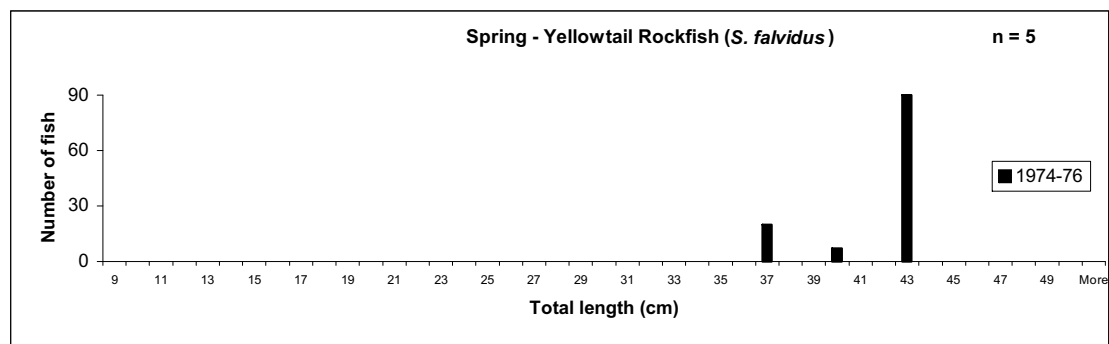
Total length (cm)

<i>S. flavidus</i>	1974-76	1991-92	1999-2000
1974-76	X		
1991-92		X	
1999-2000			X

Length (and age) at 50% maturity: males females
 34-41cm (5-9yr) 34-41cm (5-9yr)
 Taggart *et al.* (2000)

% Mature: Assuming 50:50 sex ratio

<i>S. flavidus</i>	1974-76	1991-92	1999-2000
males	98		
females	92		



No data available for 1987

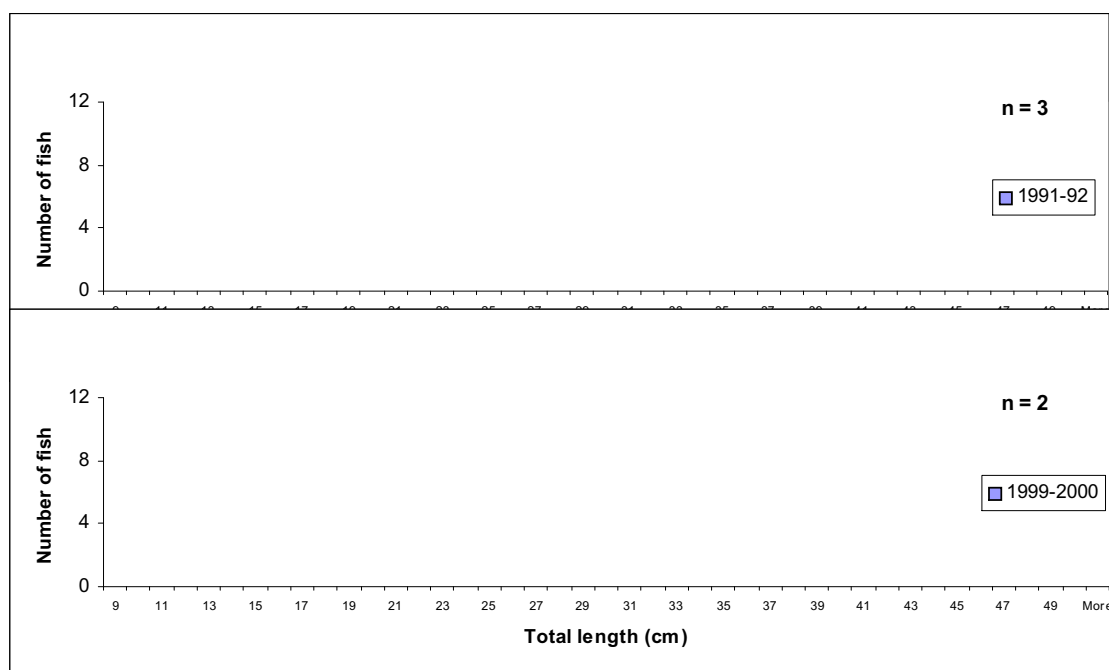


Figure 22. Spring length-frequency distributions of yellowtail rockfish (*S. falvidus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

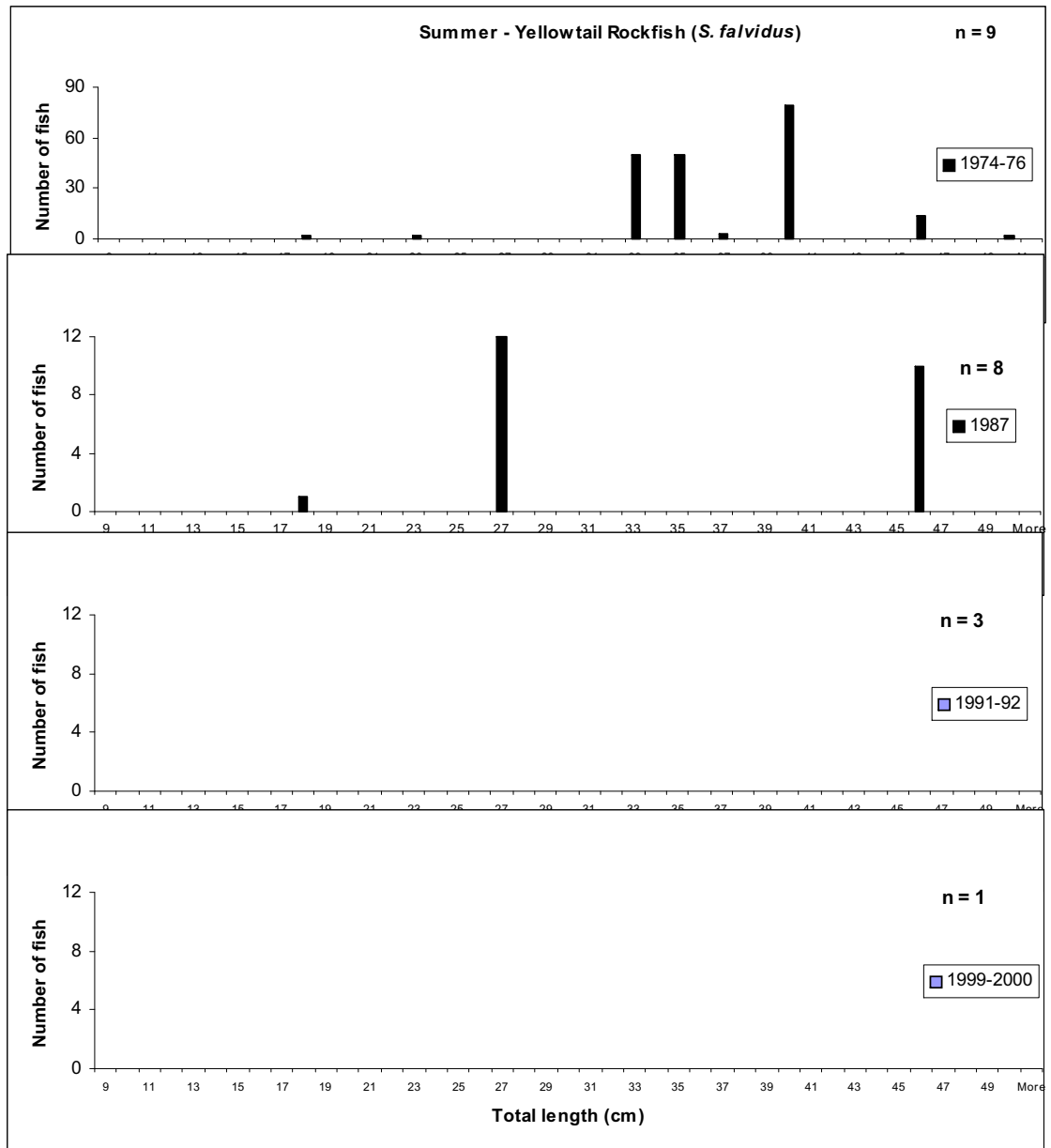


Figure 23. Summer length-frequency distributions of yellowtail rockfish (*S. flavidus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 23. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for yellowtail rockfish (*S. flavidus*) on the Point George permanent leadline transect in summer (July-September).

ANOVA: Single Factor

SUMMER *S. flavidus*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	202	7407	37	19.13823	18	50
1987	23	802	35	103.0277	18	46
1991-92	0	NA	NA	NA	0	0
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. flavidus</i>	1974-76	1987	1991-92	2000
1974-76	X	0.000		
1987		X		
1991-92			X	
2000				X

t-Test: Two-Sample

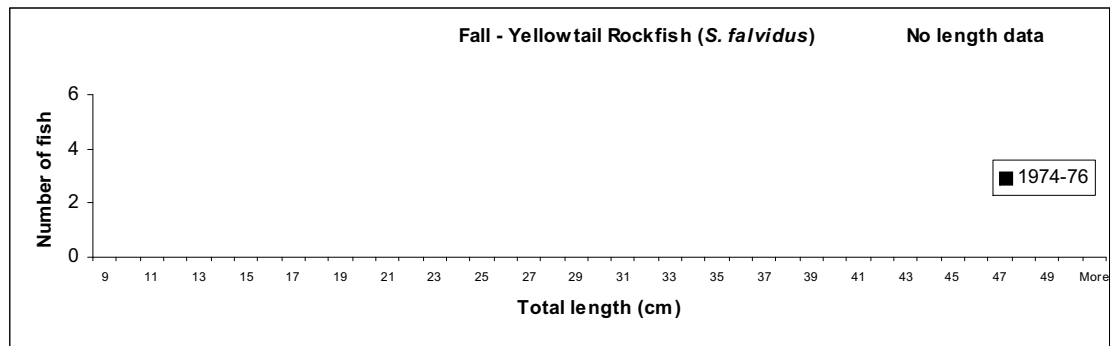
Total length (cm)

<i>S. flavidus</i>	1974-76	1987	1991-92	2000
1974-76	X	0.409		
1987		X		
1991-92			X	
2000				X

Length (and age) at 50% maturity: males 34-41cm (5-9yr) females 34-41cm (5-9yr)
Taggart *et al.* (2000)

% Mature: Assuming 50:50 sex ratio

<i>S. flavidus</i>	1974-76	1987	1991-92	2000
males	8	42		
females	8	41		



No data available for 1987

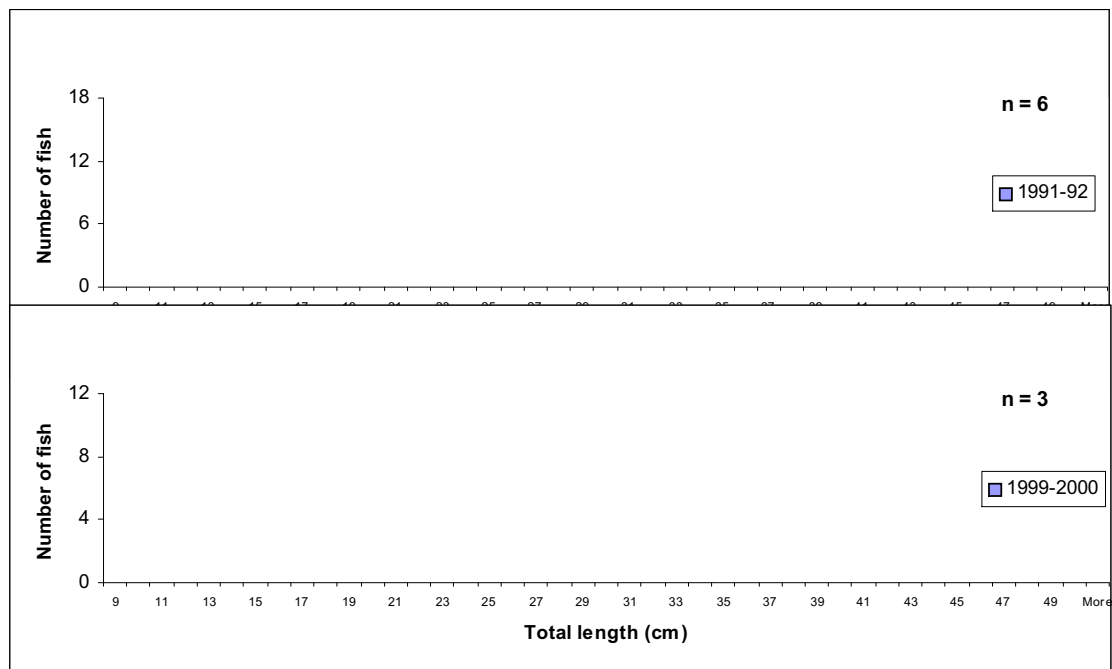


Figure 24. Fall length-frequency distributions of yellowtail rockfish (*S. flavidus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 24. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for yellowtail rockfish (*S. flavidus*) on the Point George permanent leadline transect in fall (October-December).

ANOVA: Single Factor

FALL *S. flavidus*

SUMMARY

Groups	Count	Sum	Average	Variance	Min	Max
1974-76	12	ND	ND	ND	ND	ND
1991-92	0	NA	NA	NA	0	0
1999-2000	0	NA	NA	NA	0	0

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. flavidus</i>	1974-76	1991-92	1999-2000
1974-76	X		
1991-92		X	
1999-2000			X

t-Test: Two-Sample

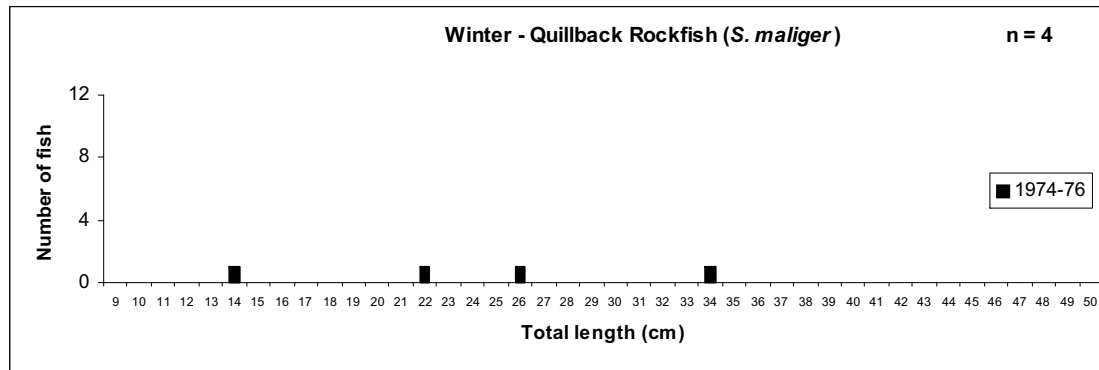
Total length (cm)

<i>S. flavidus</i>	1974-76	1991-92	1999-2000
1974-76	X		
1991-92		X	
2000			X

Length (and age) at 50% maturity: Males females
 34-41cm (5-9yr) 34-41cm (5-9yr)
 Taggart *et al.* (2000)

% Mature: Assuming 50:50 sex ratio

<i>S. flavidus</i>	1974-76	1991-92	1999-2000
males			
females			



No data available for 1987

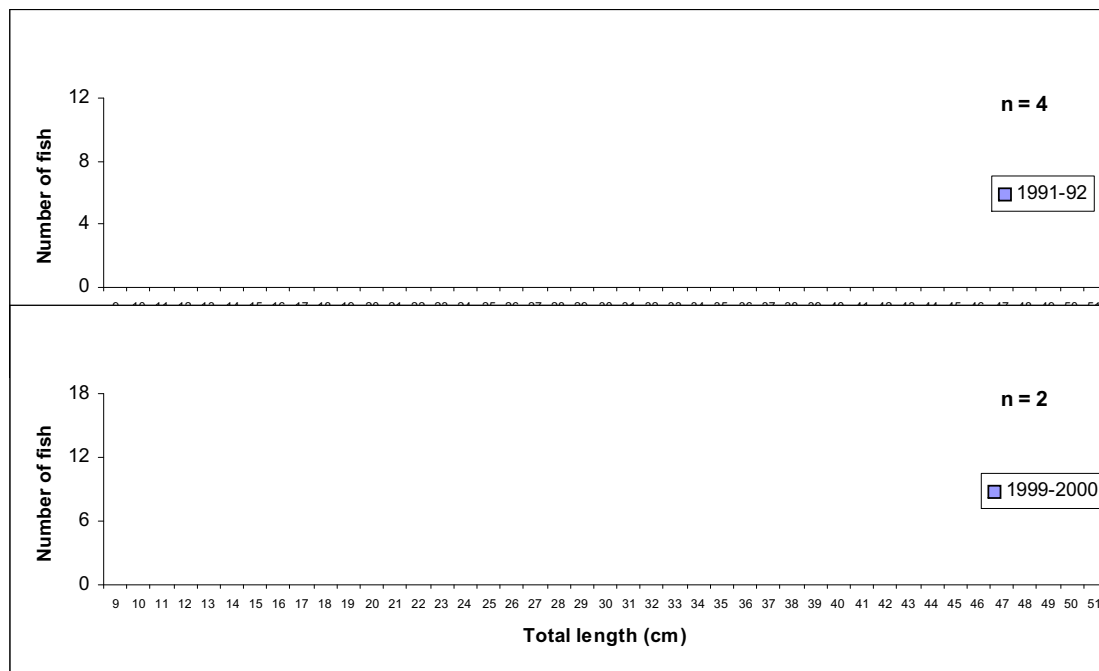


Figure 25. Winter length-frequency distributions of quillback rockfish (*S. maliger*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 25. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for quillback rockfish (*S. maliger*) on the Point George permanent leadline transect in winter (January-March).

ANOVA: Single Factor

WINTER *S. maliger*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	4	97	24	69.90706	14	34
1991-92	0	NA	NA	NA	0	0
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. maliger</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X		
<i>1991-92</i>		X	
<i>1999-2000</i>			X

t-Test: Two-Sample

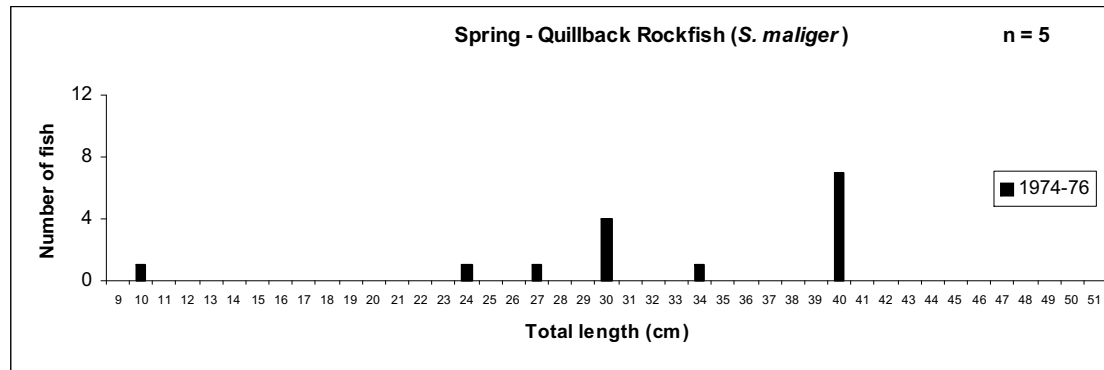
Total length (cm)

<i>S. maliger</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
<i>1974-76</i>	X		
<i>1991-92</i>		X	
<i>1999-2000</i>			X

Length (and age) at 50% maturity: males females
 29.5cm (13yr) 28.1cm (11yr)
 Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. maliger</i>	<i>1974-76</i>	<i>1991-92</i>	<i>1999-2000</i>
males			
females			



No data available for 1987

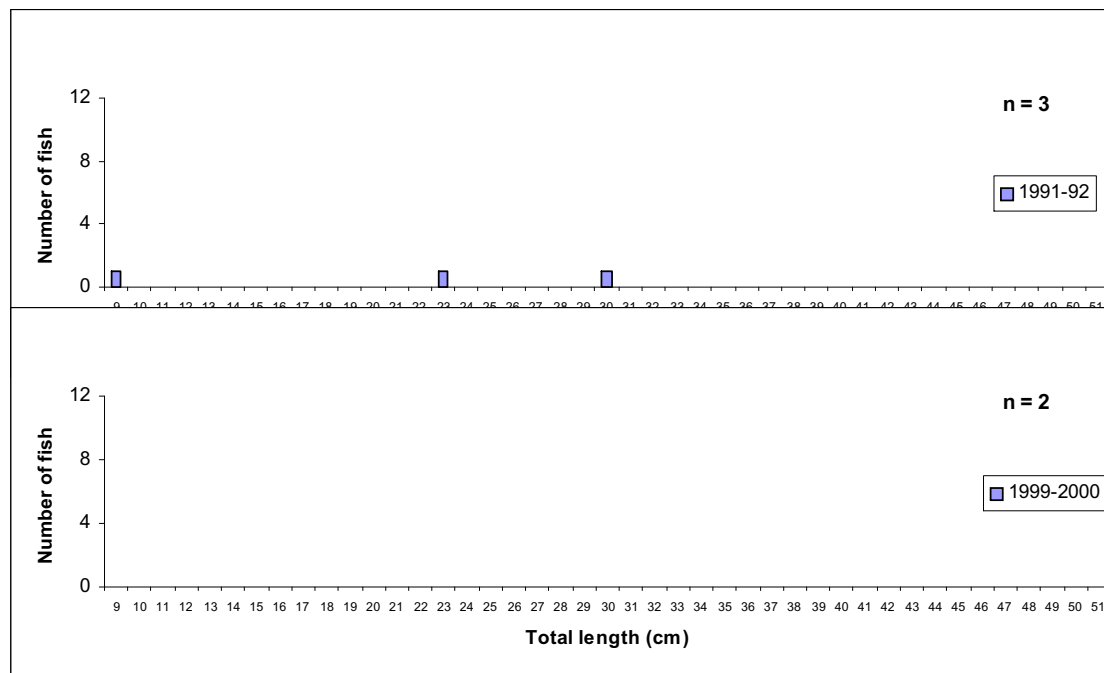


Figure 26. Spring length-frequency distributions of quillback rockfish (*S. maliger*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 26. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for quillback rockfish (*S. maliger*) on the Point George permanent leadline transect in spring (April-June).

ANOVA: Single Factor

SPRING *S. maliger*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	8	216.218	27.02725	56.312	10	34
1991-92	3	59	19.66667	152.3333	6	30
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	118.2071	1	118.2071	1.522304	0.24851	5.11735
Within Groups	698.8507	9	77.65008		9	7
Total	817.0577	10				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. maliger</i>	1974-76	1991-92	1999-2000
1974-76	X	0.270	
1991-92		X	
1999-2000			X

t-Test: Two-Sample

Total length (cm)

<i>S. maliger</i>	1974-76	1991-92	1999-2000
1974-76	X	0.249	
1991-92		X	
1999-2000			X

Length (and age) at 50% maturity: males females
 29.5cm (13yr) 28.1cm (11yr)
 Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. maliger</i>	1974-76	1991-92	1999-2000
males	80	33	
females	80	33	

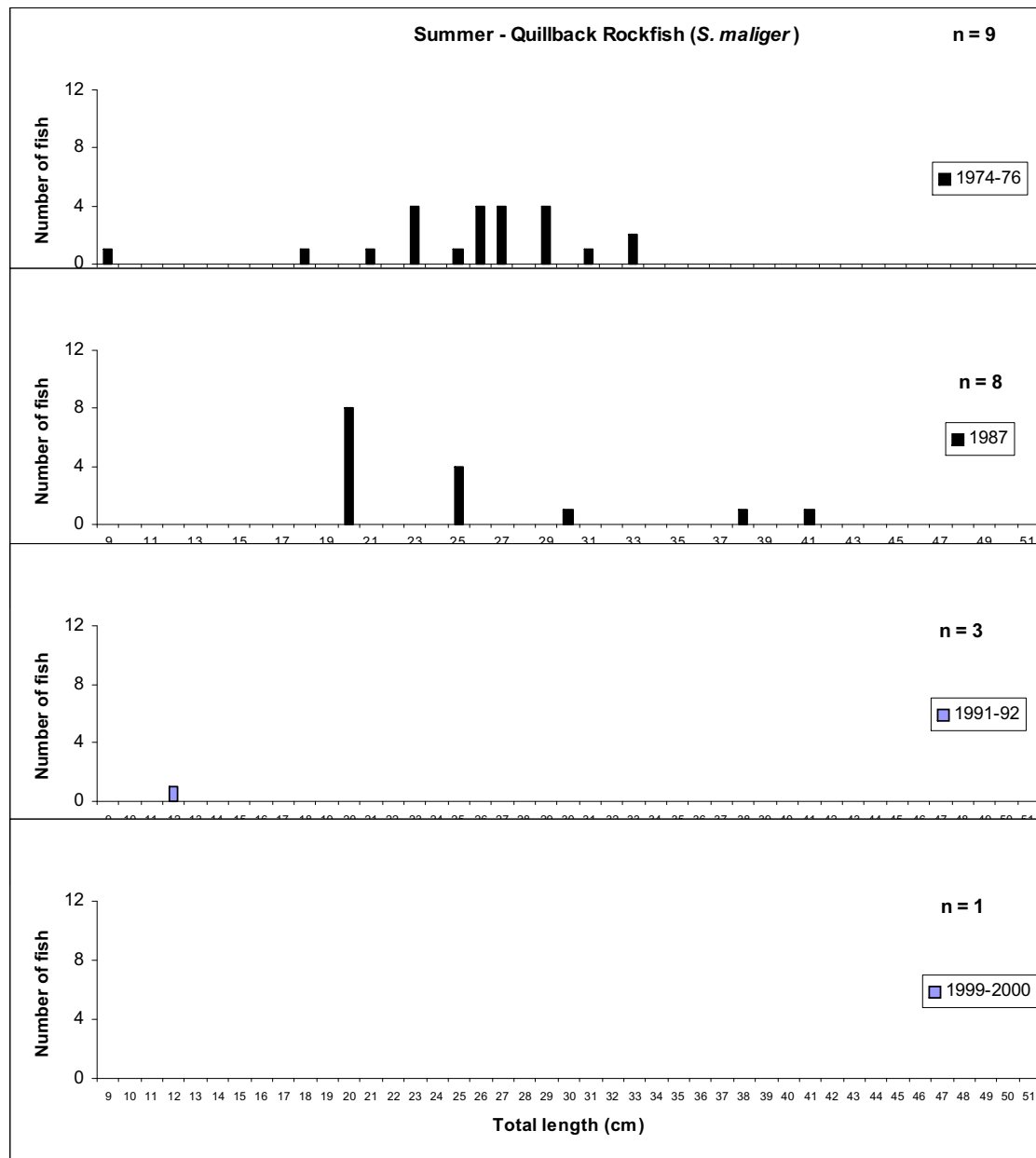


Figure 27. Summer length-frequency distributions of quillback rockfish (*S. maliger*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 27. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for quillback rockfish (*S. maliger*) on the Point George permanent leadline transect in summer (July-September).

ANOVA: Single Factor

SUMMER *S. maliger*

SUMMARY

Groups	Count	Sum	Average	Variance	Min	Max
1974-76	23	575	25	27.45129	7	32
1987	15	369	25	46.25714	20	41
1991-92	1	12	12	NA	12	12
1999-2000	0	NA	NA	NA	0	0

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.529941	1	1.529941	0.044009	0.835021	4.113161
Within Groups	1251.528	36	34.76468			
Total	1253.058	37				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. maliger</i>	1974-76	1987	1991-92	1999-2000
1974-76	X	0.265		
1987		X		
1991-92			X	
2000				X

t-Test: Two-Sample

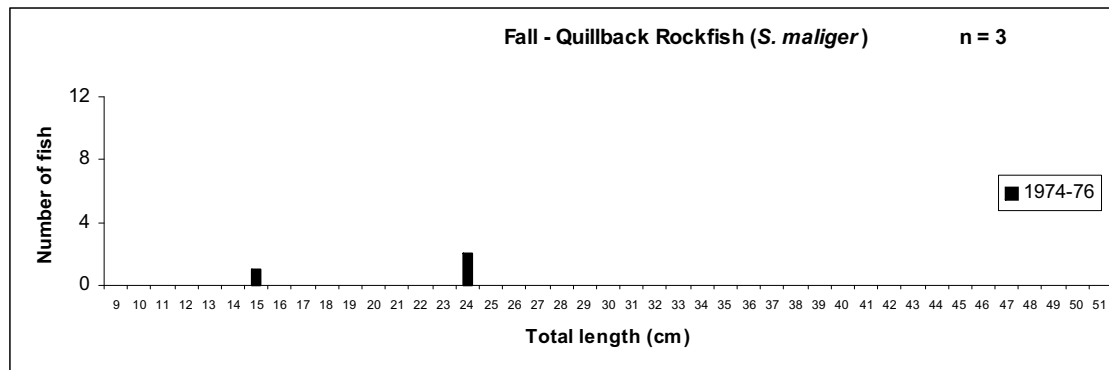
Total length (cm)

<i>S. maliger</i>	1974-76	1987	1991-92	2000
1974-76	X	0.835		
1987		X		
1991-92			X	
2000				X

Length (and age) at 50% maturity: males females
 29.5cm (13yr) 28.1cm (11yr)
 Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. maliger</i>	1974-76	1987	1991-92	2000
males	15	20	0	
females	33	20	0	



No data available for 1987

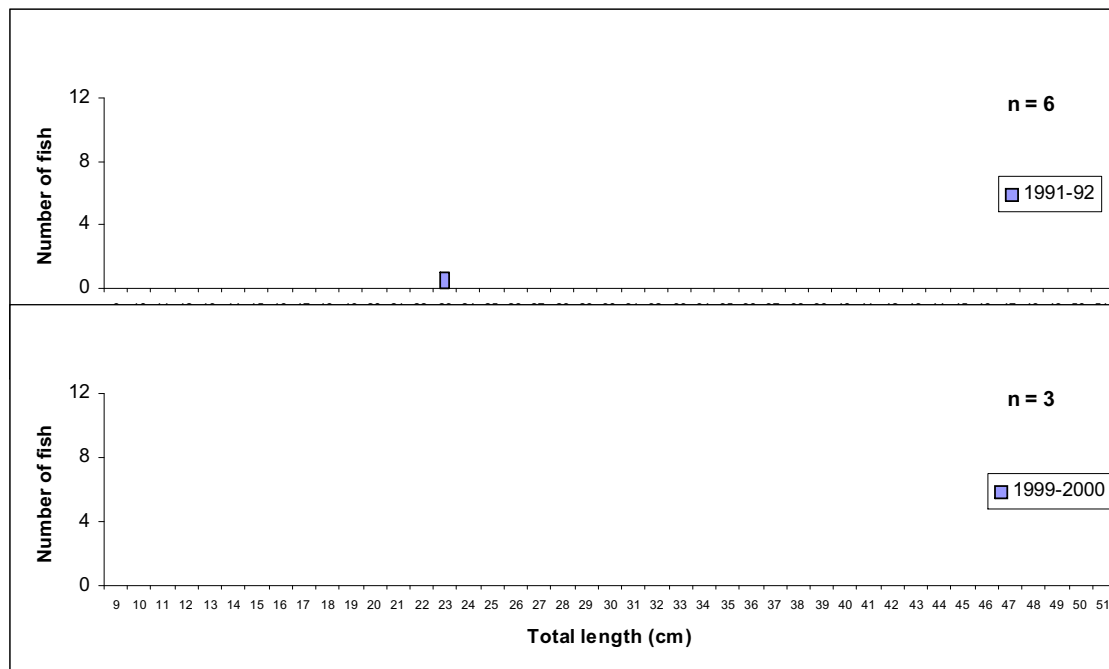


Figure 28. Fall length-frequency distributions of quillback rockfish (*S. maliger*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 28. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for quillback rockfish (*S. maliger*) on the Point George permanent leadline transect in fall (October-December).

ANOVA: Single Factor

FALL *S. maliger*

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>	<i>Min</i>	<i>Max</i>
1974-76	3	63	21	27.5012	15	24
1991-92	1	23	23	NA	23	23
1999-2000	0	NA	NA	NA	0	0

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	NA	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA			
Total	NA	NA				

F-Test Two-Sample for Variance

Total length (cm)

<i>S. maliger</i>	1974-76	1991-92	1999-2000
1974-76	X		
1991-92		X	
1999-2000			X

t-Test: Two-Sample

Total length (cm)

<i>S. maliger</i>	1974-76	1991-92	1999-2000
1974-76	X		
1991-92		X	
2000			X

Length (and age) at 50% maturity: males females
 29.5cm (13yr) 28.1cm (11yr)
 Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

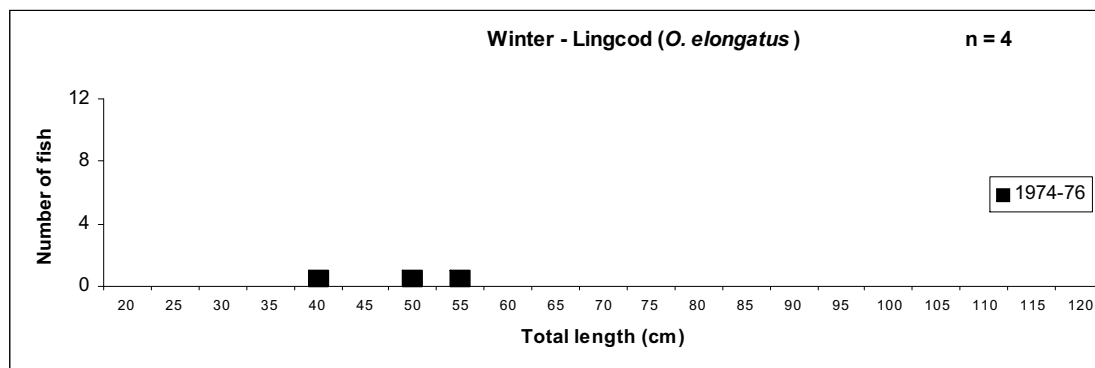
<i>S. maliger</i>	1974-76	1991-92	1999-2000
males	0	0	
females	0	0	

For total length of *O. elongatus*, overall ANOVAs had mixed significance (ANOVA: ns, ns, $p < 0.01$, ns). Before-reserve total length increased for winter and summer (t-test: ns, $p = 0.001$) and decreased for spring and fall (t-test: ns, ns). The since-reserve mean total length has increased for winter and fall (t-test: ns, ns) and decreased for spring (t-test: ns) and summer (insufficient data to calculate statistics). (Figures 29-32, Tables 29-32). In general, *O. elongatus* has shown mixed, mostly non-significant differences before reserves and mixed, non-significant differences after reserve formation. Combined with the first analysis, reserve status reversed the decline in density for this species, in general had no effect on total length over time. Therefore, reserve status appears to have increased density over time, but not affected length over time.

Comparison of habitat and fishing activity between 2000 spatial study sites

Two habitat variables, habitat complexity and reef slope, were compared between each pair of reserve/non-reserve sites. Two sample t-tests were used to compute p-values. H_0 : mean habitat variable at each reserve/non-reserve pair is equal, and H_A : mean habitat variable at each reserve/non-reserve pair is unequal.

Substrate complexity was not significantly different for George/Neck, Shady/Turn or Yellow/Jones (t-test: $p = 0.264$, $p = 0.385$ and $p = 0.915$, respectively) (Figure 33). Reef slope was not significantly different for Shady/Turn and Yellow/Jones (t-test: $p = 0.063$ and $p = 0.786$), but there was a significant difference for reef slope between George and Neck (t-test: $p = 0.002$) (Figure 34).



No data available for 1987

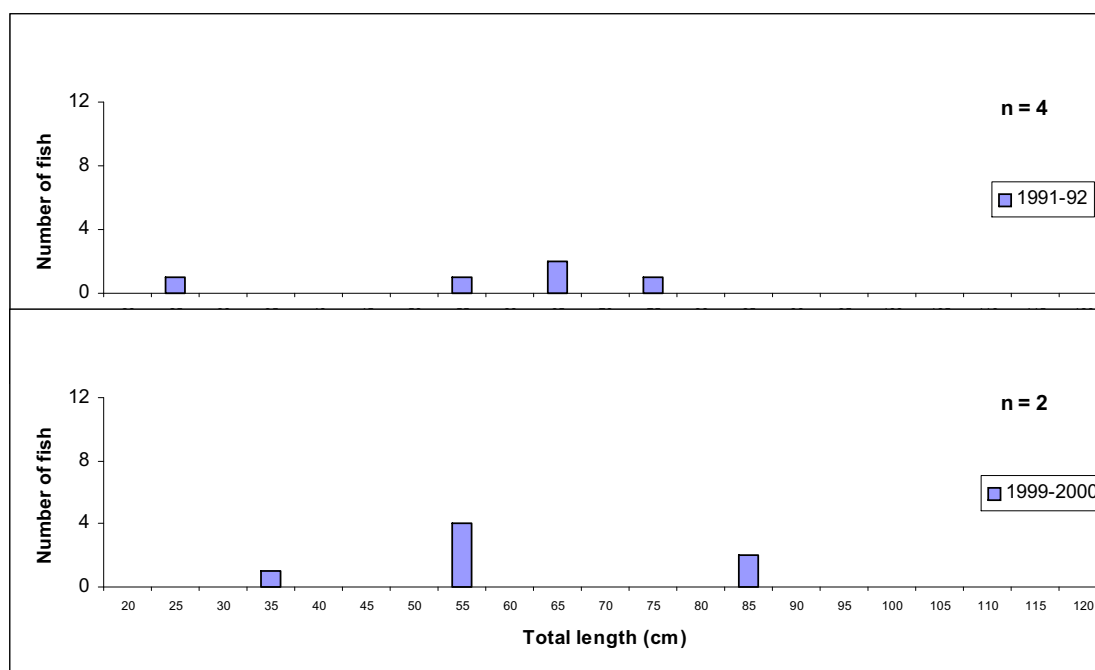
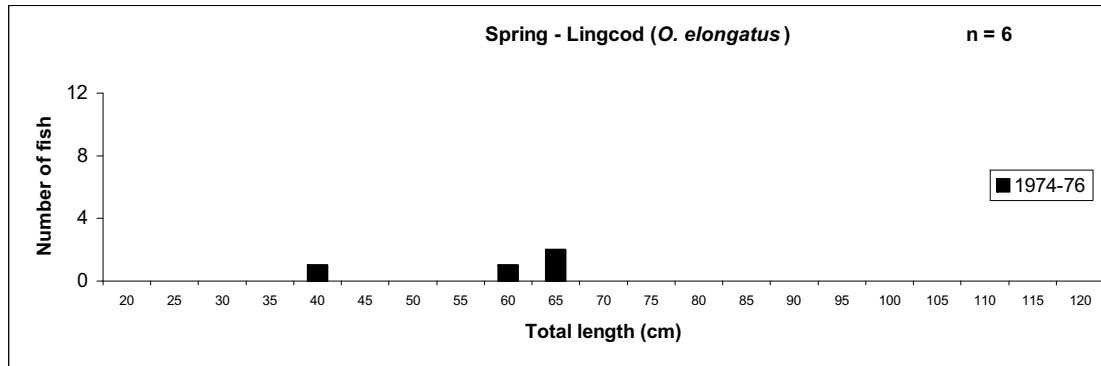


Figure 29. Winter length-frequency distributions of lingcod (*O. elongatus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.



No data available for 1987

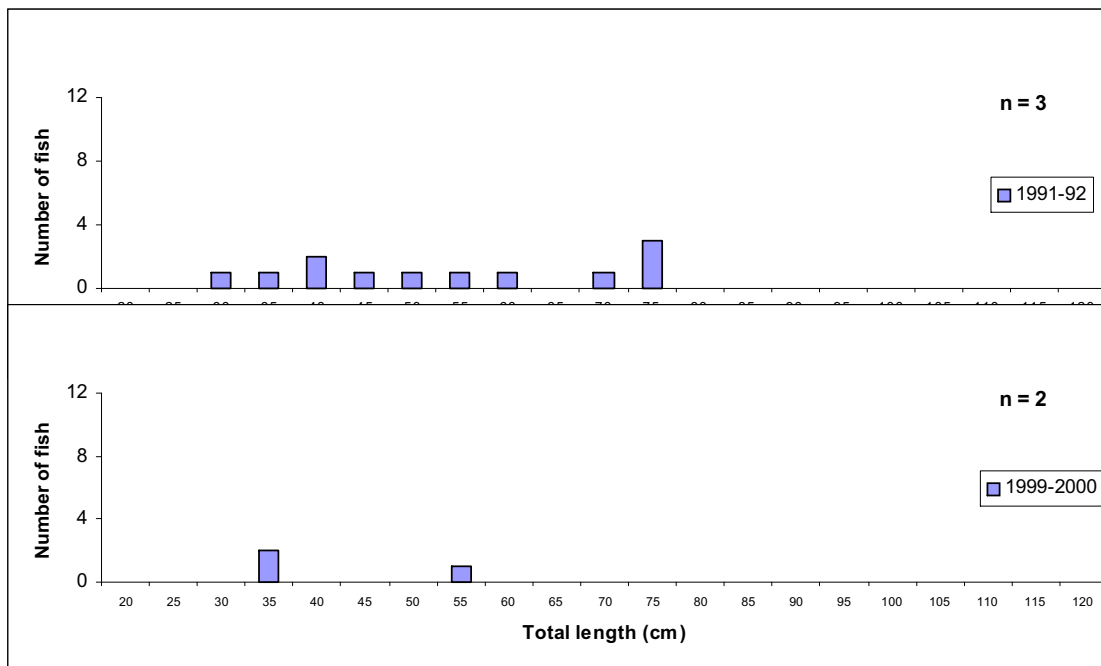


Figure 30. Spring length-frequency distributions of lingcod (*O. elongatus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

Table 30. Summary statistics, ANOVA table, pair wise t-tests and percent mature (if males or females) for lingcod (*O. elongatus*) on the Point George permanent leadline transect in spring (April-June).

ANOVA: Single Factor

SPRING *O. elongatus*

SUMMARY

Groups	Count	Sum	Average	Variance	Min	Max
1974-76	4	223.12	55.78	146.0845	38	64
1991-92	12	632	52.66667	296.0606	30	75
1999-2000	3	125	41.66667	133.3333	35	55

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	379.5521	2	189.7761	0.766465	0.480977	3.633716
Within Groups	3961.587	16	247.5992			
Total	4341.139	18				

F-Test Two-Sample for Variance

Total length (cm)

<i>O. elongatus</i>	1974-76	1991-92	1999-2000
1974-76	X	0.612	0.980
1991-92		X	0.703
1999-2000			X

t-Test: Two-Sample

Total length (cm)

<i>O. elongatus</i>	1974-76	1991-92	1999-2000
1974-76	X	0.745	0.180
1991-92		X	0.319
2000			X

	males		females	
Length (and age) at 50% maturity:	51.3cm	(4.6 yr)	63.4cm	(3.4 yr)
			Jagiello (1994)	

% Mature: Assuming 50:50 sex ratio

<i>O. elongatus</i>	1974-76	1991-92	1999-2000
males	79	45	9
females	9	32	0

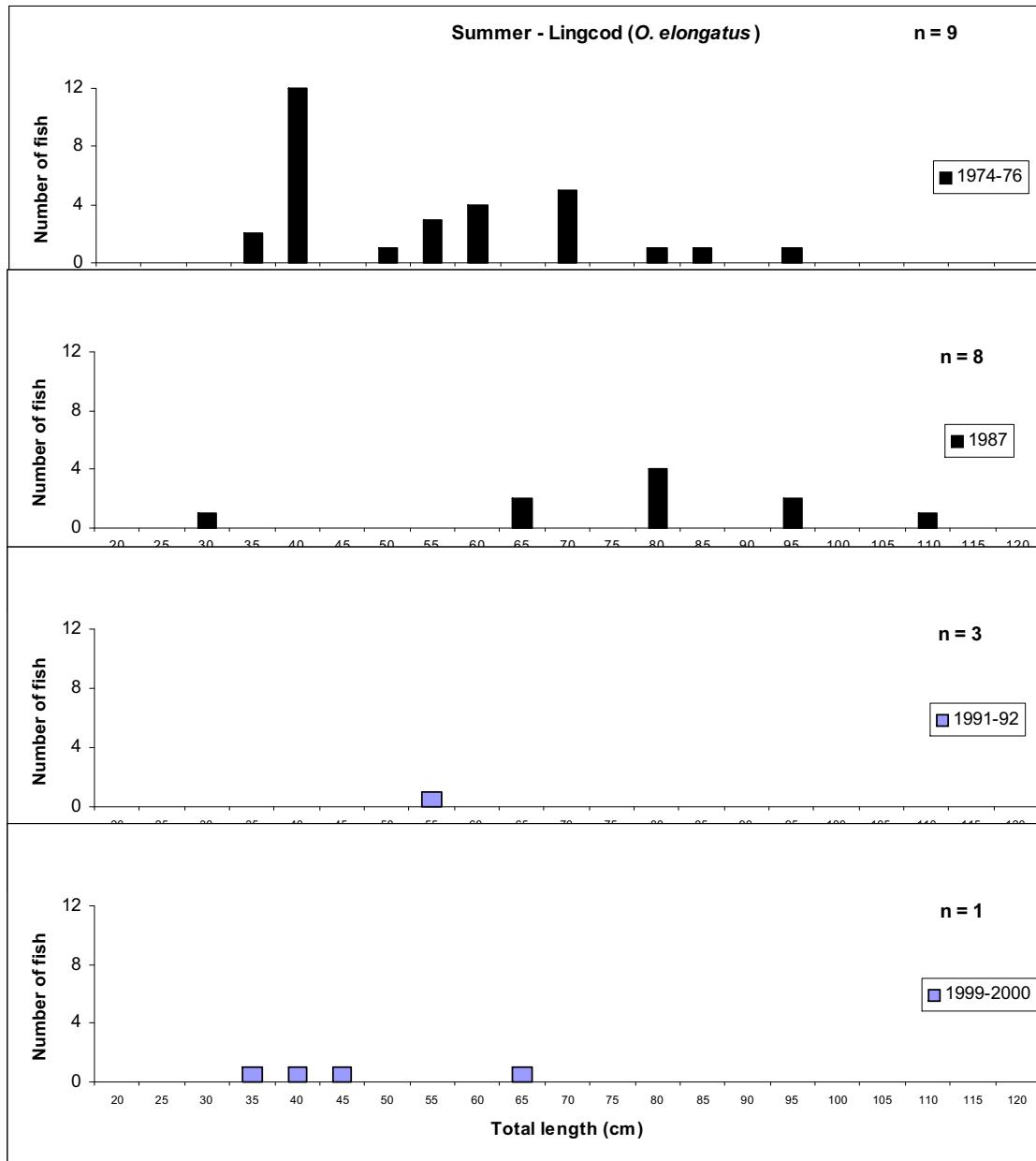
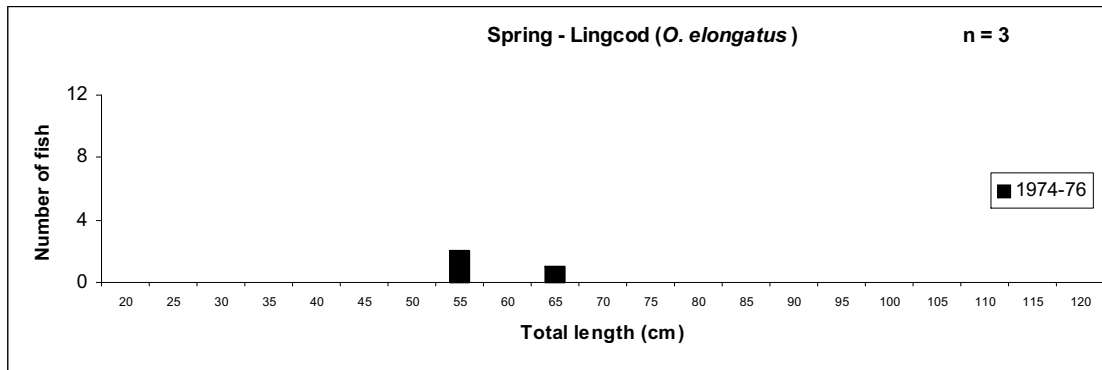


Figure 31. Summer length-frequency distributions of lingcod (*O. elongatus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.



No data available for 1987

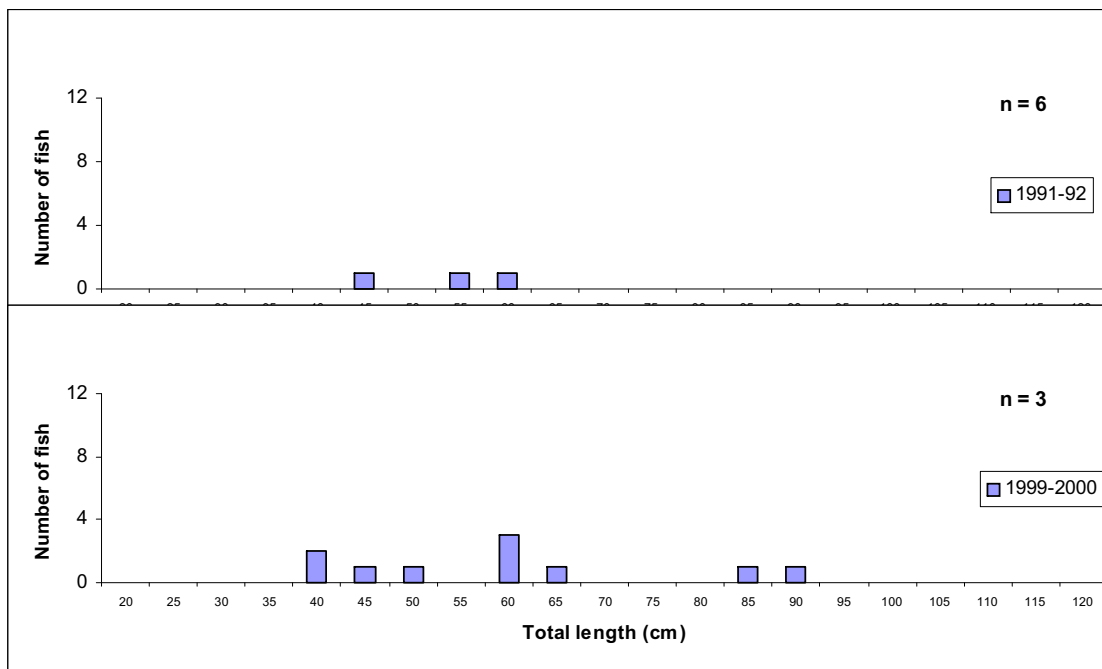


Figure 32. Fall length-frequency distributions of lingcod (*O. elongatus*) populations on Point George North permanent leadline transect. Sample sizes are number dive surveys during each time period.

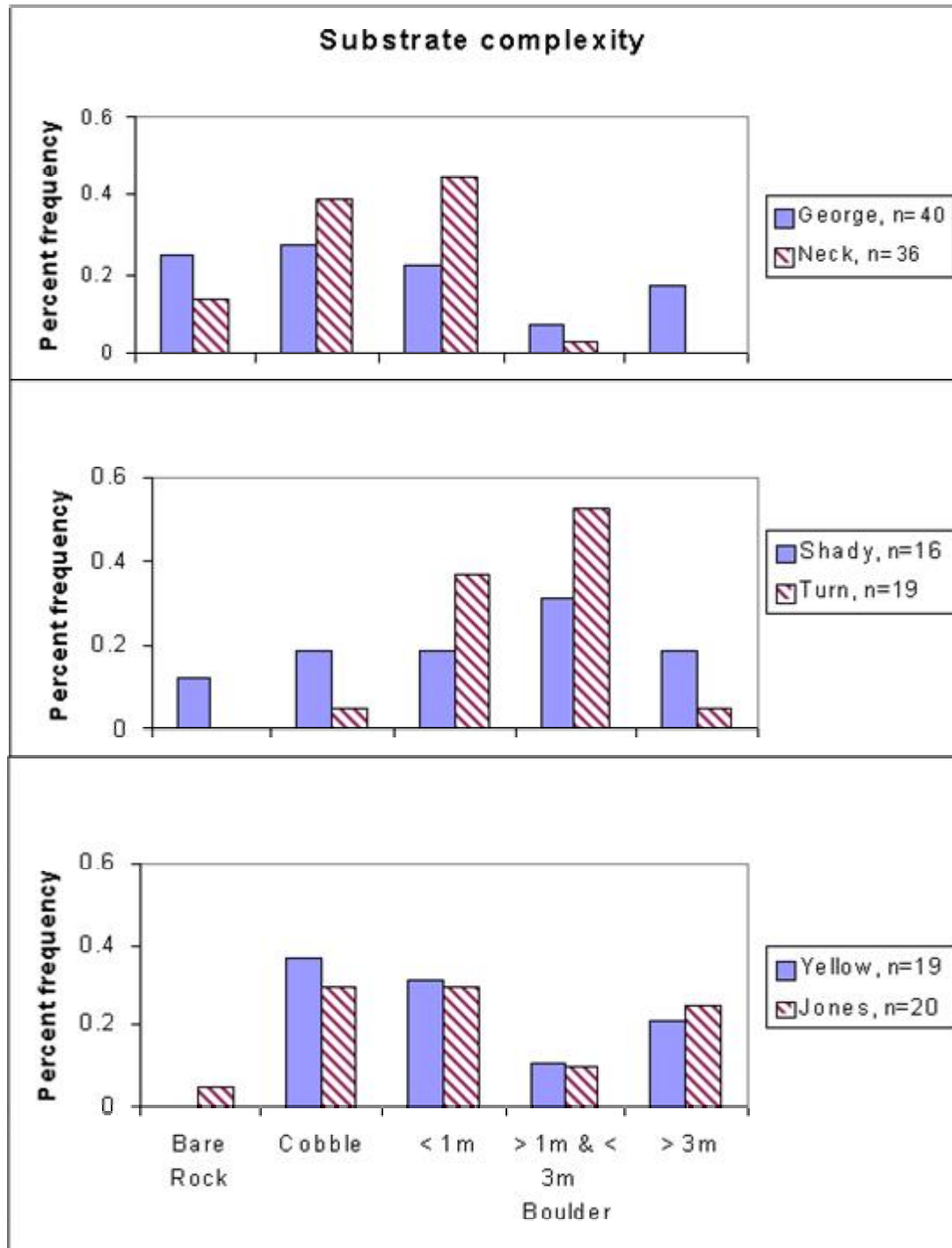


Figure 33. Substrate complexity at the six 2000 spatial study sites. Data are grouped by site pairs. Reserves are solid bars and non-reserves are crosshatched. Sample size is number of transects for which data were collected.

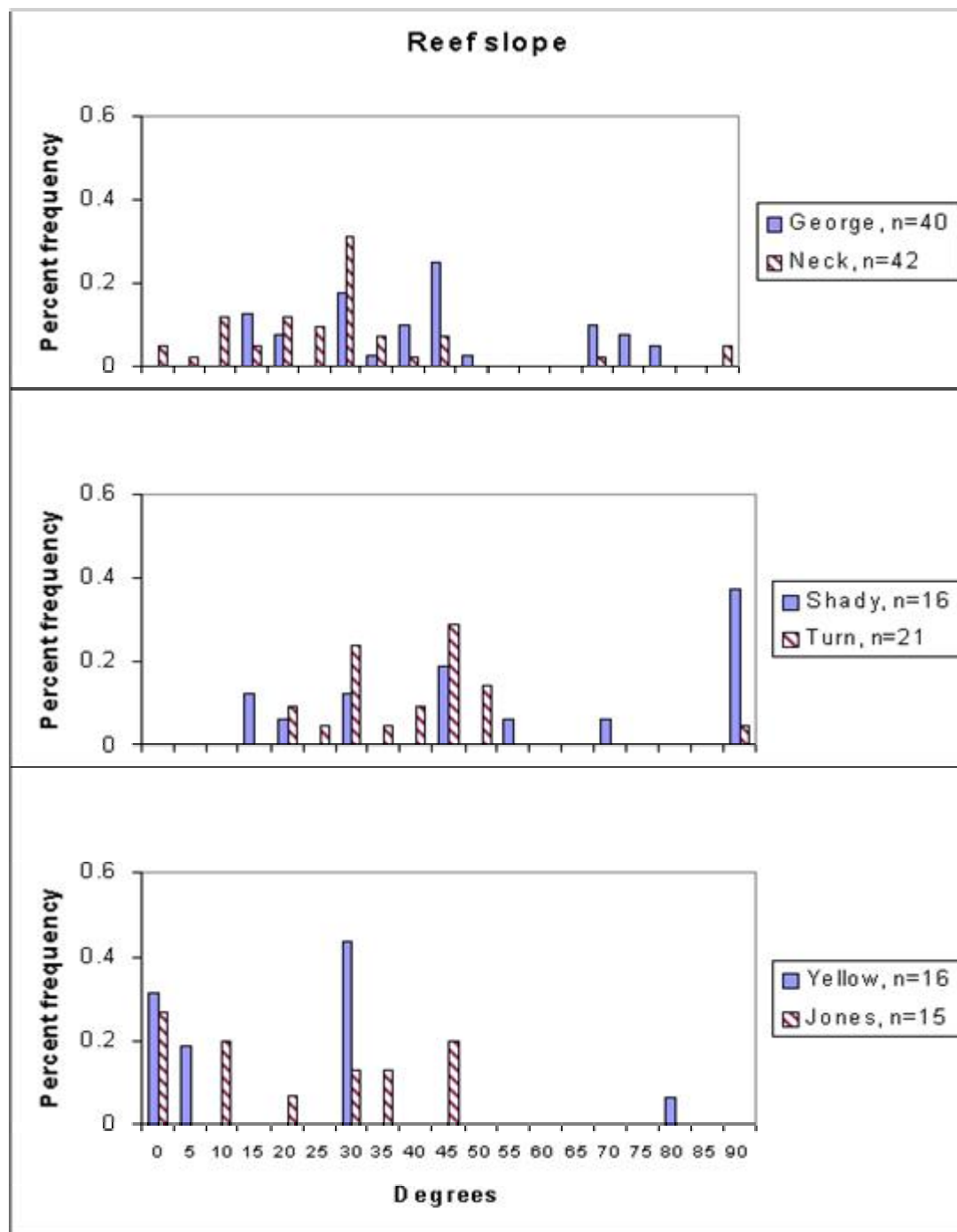


Figure 34. Reef slope at the six 2000 spatial study sites. Data are grouped by site pairs. Reserves are solid bars and non-reserves are crosshatched. Sample size is the number of transects for which data were collected.

Population densities at 2000 spatial study sites

3 x 2 ANOVAs were used to compare population densities at the six sites for each species of interest. H_0 : mean population densities in reserve sites are equal to mean population densities in non-reserve sites, and H_A : mean population densities in reserve sites are different from mean population densities in non-reserve sites. Results are presented in order of categories according to trends from population densities over time at Point George: 1) increasing populations (*S. caurinus*, *H. decagrammus* and *S. emphaeus*) 2) decreasing populations (*S. melanops*, *S. flavidus* and *S. maliger*) 3) recovering populations (*O. elongatus*) and 4) other populations (*E. lateralis* and YOY *S. caurinus* / *S. maliger*).

Significantly greater density (3 x 2 ANOVA: $F = 10.487$, $p = 0.001$) was found for copper rockfish (*S. caurinus*) in reserve sites compared to non-reserve sites. Kelp greenling (*H. decagrammus*) were also significantly more abundant in reserves (3 x 2 ANOVA: $F = 11.656$, $p = 0.001$). Puget Sound rockfish (*S. emphaeus*) showed an opposite trend. *S. emphaeus* had significantly greater density (3 x 2 ANOVA: $F = 10.487$, $p = 0.005$) in the *non-reserve* sites (Figure 35, Table 33).

Black rockfish (*S. melanops*) were significantly more abundant in reserves (3 x 2 ANOVA: $F = 4.728$, $p = 0.031$). Yellowtail rockfish (*S. flavidus*) did not show a significant difference (3 x 2 ANOVA: $F = 1.634$, $p = 0.202$), despite sightings only at the Shady Cove reserve site. Quillback rockfish (*S. maliger*) were more abundant in *non-*

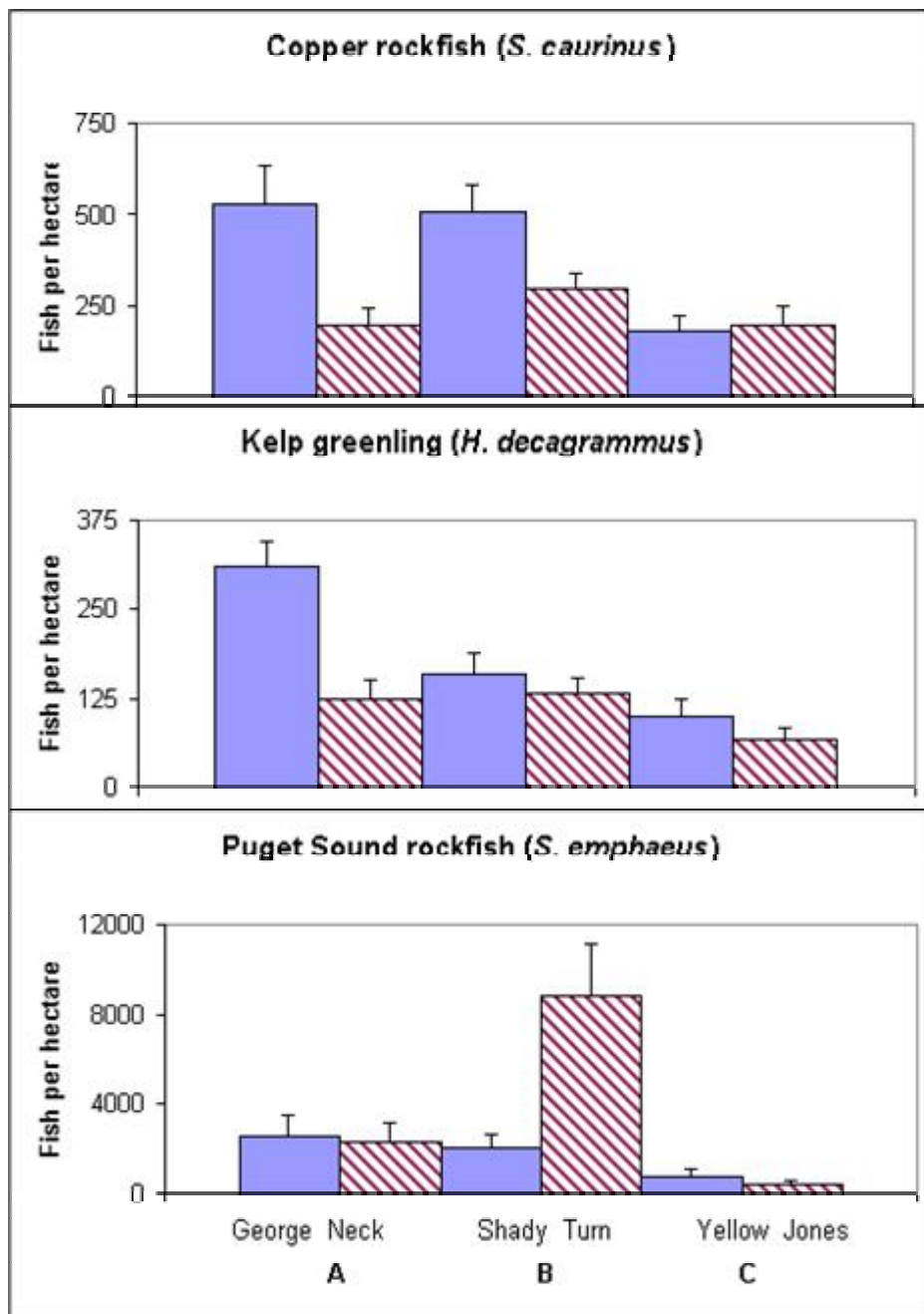


Figure 35. Mean population densities at 2000 spatial study sites for populations increasing over time at Point George. Reserve sites are solid bars. Non-reserve sites are crosshatched. Sample size was forty transects ($n = 40$) for each site.

Table 33. Mean population densities, standard errors and 3 x 2 ANOVA p-values for the six 2000 spatial study sites.

All times & legs SPECIES	George		Neck		Shady		Turn		Yellow		Jones		F-ratio	P
	R	SE	NR	SE	R	SE	NR	SE	R	SE	NR	SE		
<i>O. elongatus</i>	60 ± 14.2		33 ± 11.5		133 ± 31.3		125 ± 25.26		75 ± 22.6		40 ± 11.8		1.509	0.221
<i>S. caurinus</i>	528 ± 103		198 ± 46.6		508 ± 74.7		293 ± 40.34		183 ± 42.2		195 ± 50.9		10.487	0.001 **
<i>S. melanops</i>	0 ± 0		0 ± 0		43 ± 19.2		0 ± 0		0 ± 0		0 ± 0		4.728	0.031 *
<i>S. flavidus</i>	0 ± 0		0 ± 0		28 ± 21.2		0 ± 0		0 ± 0		0 ± 0		1.634	0.202
<i>S. emphaeus</i>	2530 ± 1011		2293 ± 903		2055 ± 569		8833 ± 2311		768 ± 370		440 ± 192		8.041	0.005 **
<i>H. decagrammus</i>	310 ± 36.7		125 ± 27.2		160 ± 29		133 ± 21		100 ± 22.9		68 ± 16.6		11.656	0.001 **
<i>E. lateralis</i>	35 ± 18.8		0 ± 0		25 ± 12.3		3 ± 2.5		8 ± 5.53		28 ± 16.4		2.490	0.116
<i>S. maliger</i>	0 ± 0		38 ± 22.6		18 ± 11.3		0 ± 0		0 ± 0		30 ± 20.9		2.350	0.127
YOY <i>S. caurinus/maliger</i>	10 ± 6.98		328 ± 216		293 ± 199		0 ± 0		0 ± 0		48 ± 40.2		0.222	0.638

F-ratios and P values from 3 x 3 ANOVA (site pair x reserve treatment)

reserves, but this trend was not significant (3 x 2 ANOVA: $F = 2.350$, $p = 0.127$) (Figure 36, Table 33).

Lingcod (*O. elongatus*) had 35% greater mean density in reserves, but this was not a statistically significant difference (3 x 2 ANOVA: $F = 1.509$, $p = 0.221$). Striped surfperch (*E. lateralis*) did not show a consistent trend (3 x 2 ANOVA: $F = 2.490$, $p = 0.116$). YOY copper / quillback rockfish (*S. caurinus* / *S. maliger*) were more abundant in non-reserves, but this trend was not significant (3 x 2 ANOVA: $F = 0.222$, $p = 0.638$) (Figure 37, Table 33). Additional results for 3 x 2 ANOVAs stratified by sampling time and by depth are presented in Appendix A.

Length-frequency distributions at 2000 spatial study sites

Two-sample t-tests were used to compare length-frequency distributions for each pair of sites as well as between grouped reserve sites versus grouped non-reserve sites for each species of interest. H_0 : mean length in reserve sites is equal to mean length in non-reserve sites, and H_A : mean length in reserve sites is different from mean length in non-reserve sites. In addition, length-frequency distributions from 1974-76 were similarly compared to grouped reserve and grouped non-reserve distributions from 2000. The 1970's data resulted from specimens collected for food analysis and are not random samples of the nearshore rocky reef populations (in contrast to the 2000 data). The 1970's food analysis specimens are representative of what bit fish hooks or were in front of

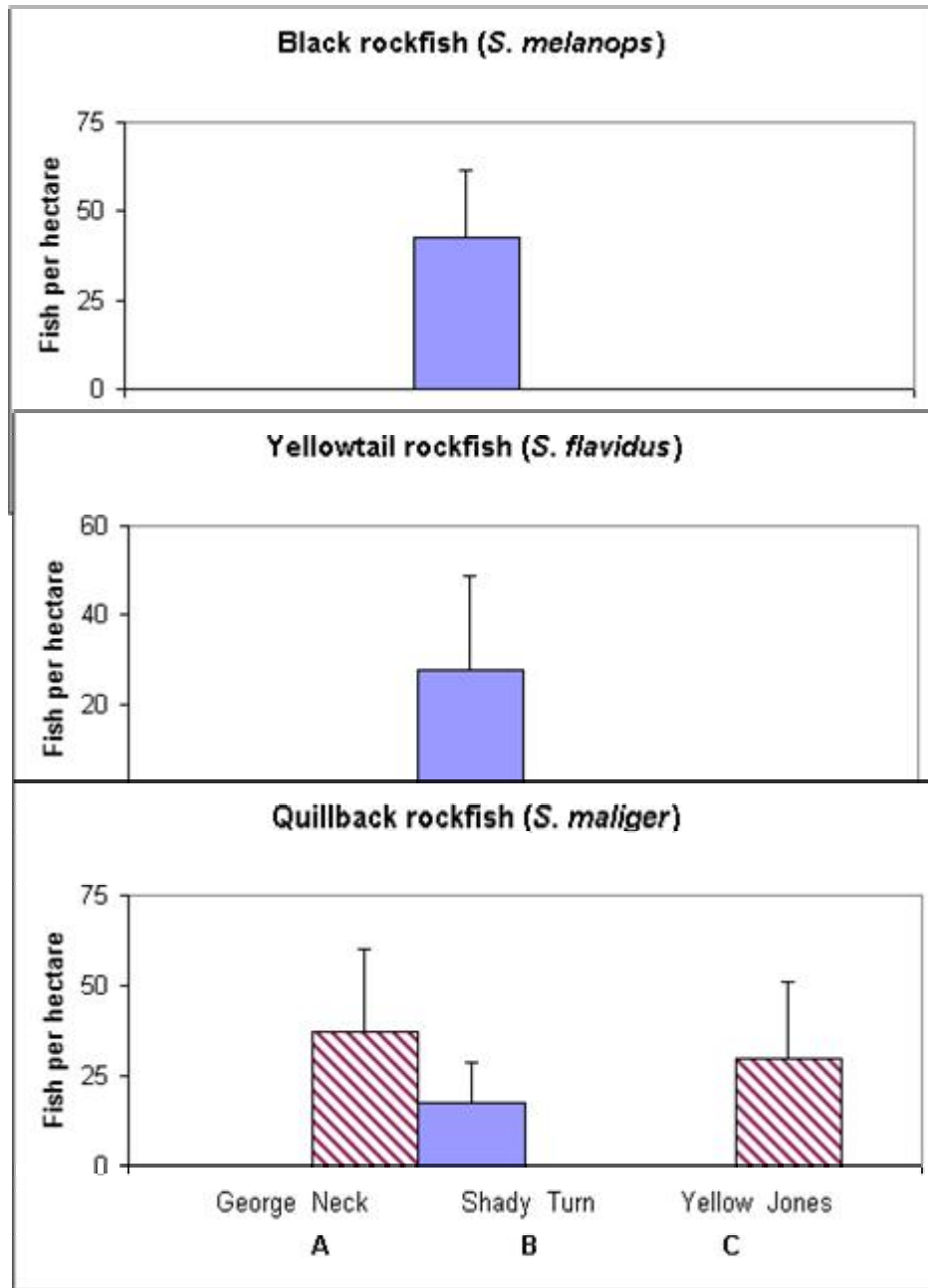


Figure 36. Mean population densities at 2000 spatial study sites for populations decreasing over time at Point George. Reserve sites are solid bars. Non-reserve sites are crosshatched. Sample size was forty transects ($n = 40$) for each site.

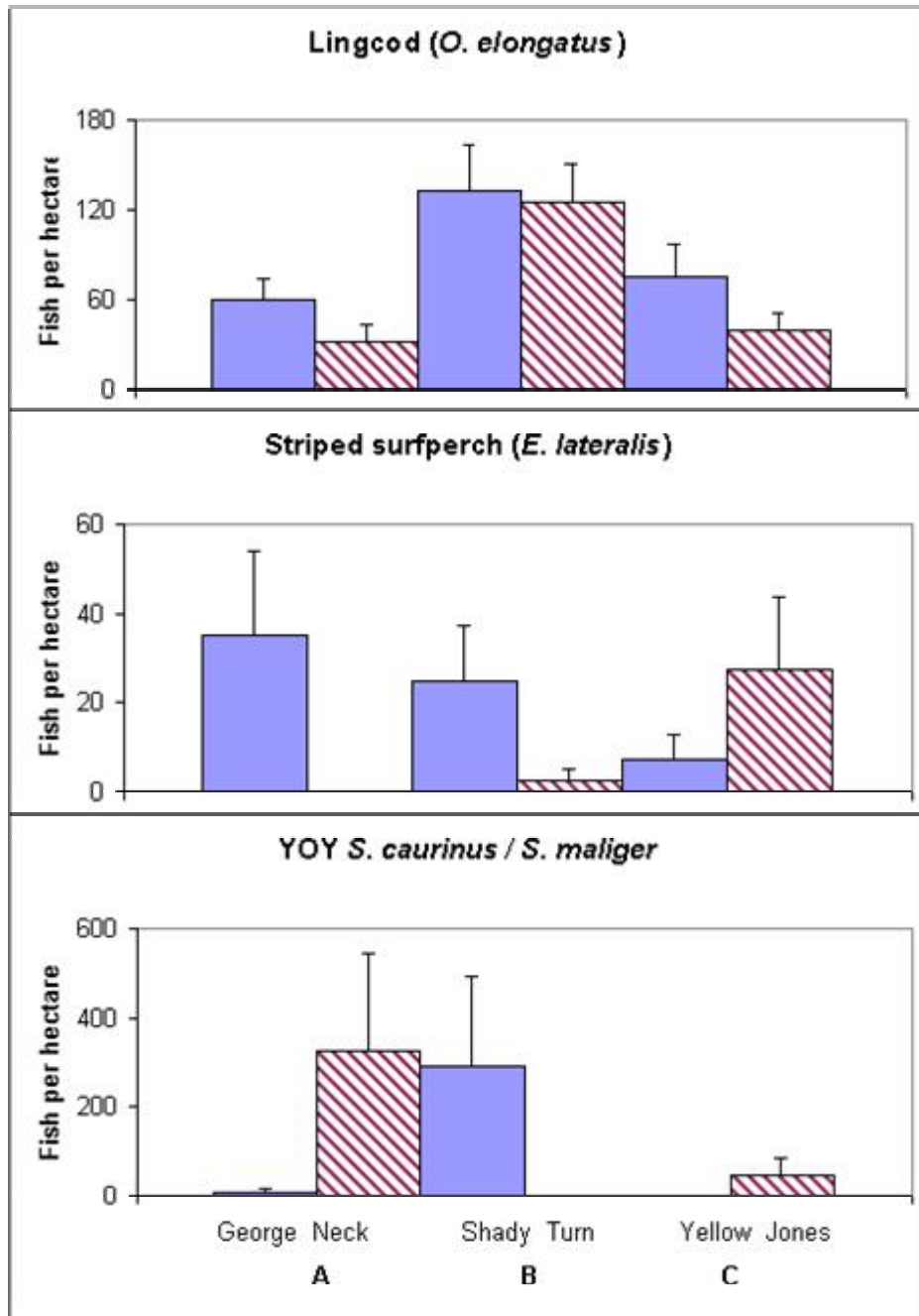


Figure 37. Mean population densities at 2000 spatial study sites for populations recovering over time at Point George and other populations. Reserve sites are solid bars. Non-reserve sites are crosshatched. Sample size was forty transects ($n = 40$) for each site.

spear guns, slurp guns or hand nets. However, effort was made to collect a representative sample of specimens from all life history stages present (L. Moulton, personal communication).

As in previous analyses, results were species specific. Greater mean length (t-test: $p < 0.001$) was found for copper rockfish (*S. caurinus*) in reserve sites compared to non-reserve sites (Figure 38, Tables 34-35). Large *S. caurinus* (>38cm), which have been reported to reach 35 years in age (Richards and Cass, 1986), have virtually disappeared since the 1970's (Figure 38). Kelp greenling (*H. decagrammus*) had no significant difference in mean length between reserves and non-reserves (t-test: $p = 0.480$) (Figure 39, Tables 36-37). Puget Sound rockfish (*S. emphaeus*) had greater mean length (t-test: $p = 0.001$) in reserves (Figure 40, Tables 38-39).

Two sample t-tests of total length for black rockfish (*S. melanops*) and yellowtail rockfish (*S. flavidus*) could not be completed since this species was sighted at only one location, the Shady Cove study site (Figures 41-42, Tables 40-43). Quillback rockfish (*S. maliger*) showed the opposite trend of most other species. *S. maliger* had greater mean length (t-test: $p = 0.013$) in non-reserves (Figure 43, Tables 44-45).

Greater mean length (t-test: $p < 0.001$) was found for lingcod (*O. elongatus*) in reserves compared to non-reserves. In addition, 43% of *O. elongatus* sighted in reserves were greater in length than 50cm, compared to only 17% in non-reserves (Figure 44,

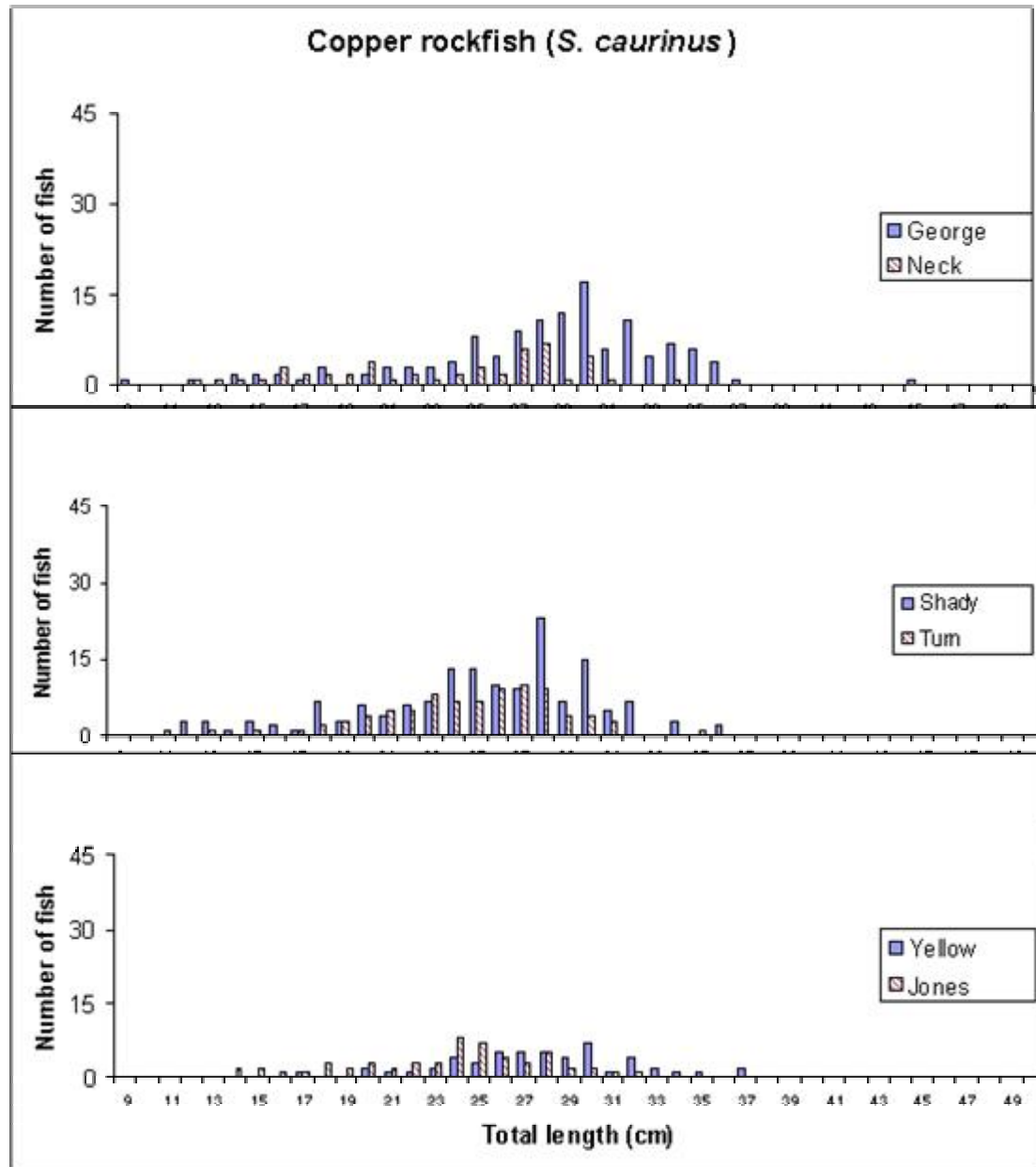


Figure 38. Length-frequency distributions of copper rockfish (*S. caurinus*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

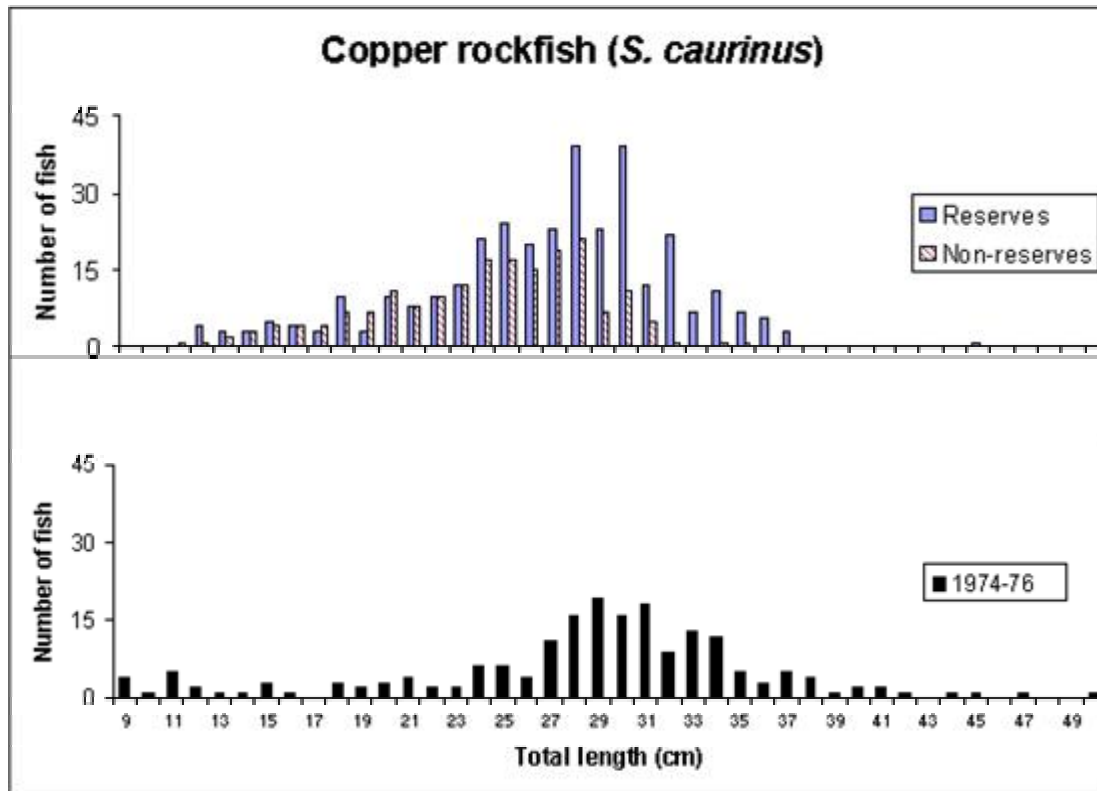


Figure 38 (cont). Upper graph: length-frequency distributions of copper rockfish (*S. caurinus*) for all 2000 spatial study reserve and non-reserve sites. Reserves are solid bars. Non-reserves are crosshatched. Lower graph: length-frequency distributions of copper rockfish (*S. caurinus*) from the same region in the 1970's.

Table 34. Two-sample F-tests for variance of copper rockfish (*S. caurinus*) total lengths.

F-Test Two-Sample for Variance, reserve/non-reserve pairs

Total length (cm)									
<i>S. caurinus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	<i>1974-76</i>
Mean	27.9	23.6	25.2	24.6	27.8	23.5	26.7	24.0	28.5
Variance	33.2	30.5	26.9	17.4	18.0	19.7	28.8	21.5	55.9
Observations	130	49	153	85	51	55	333	189	191
Min	9	12	12	11	17	14	12	11	9
Max	45	34	36	35	37	32	45	35	50
P(F<=f) two-tail	0.747		0.029 *		0.742		0.026 *		see below

F-Test Two-Sample for Variance, 2000 vs. 1974-76

Total length (cm)									
<i>S. caurinus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	
P(F<=f) two-tail	0.002	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	**	*	***	***	***	***	***	***	***

Table 35. Two-sample t-tests of copper rockfish (*S. caurinus*) total lengths, and percentage of populations larger than length at 50% maturity.

t-Test: Two-Sample, reserve/non-reserve pairs

Total length (cm)	Equal Variance	Unequal Var	Equal Variance	Unequal Var
<i>S. caurinus</i>	<i>George</i>	<i>Neck</i>	<i>Shady Turn</i>	<i>Yellow Jones</i>
	<i>Reserves</i>	<i>Non-reserves</i>		
P(T<=t) two-tail	0.000 ***	0.346	0.000 ***	0.000 ***

t-Test: Two-Sample, 2000 vs. 1974-76

Total length (cm)	All Unequal Variance							
<i>S. caurinus</i>	<i>George</i>	<i>Neck</i>	<i>Shady Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	
P(T<=t) two-tail	0.442	0.000 ***	0.000 ***	0.000 ***	0.356	0.000 ***	0.004 ***	0.000 ***

Length (and age) at 50% maturity: males females
 25cm(6yr) 25cm(6yr) Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. caurinus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	<i>1974-76</i>
Males	79	52	61	55	78	45	71	52	79
Females	79	52	61	55	78	45	71	52	79

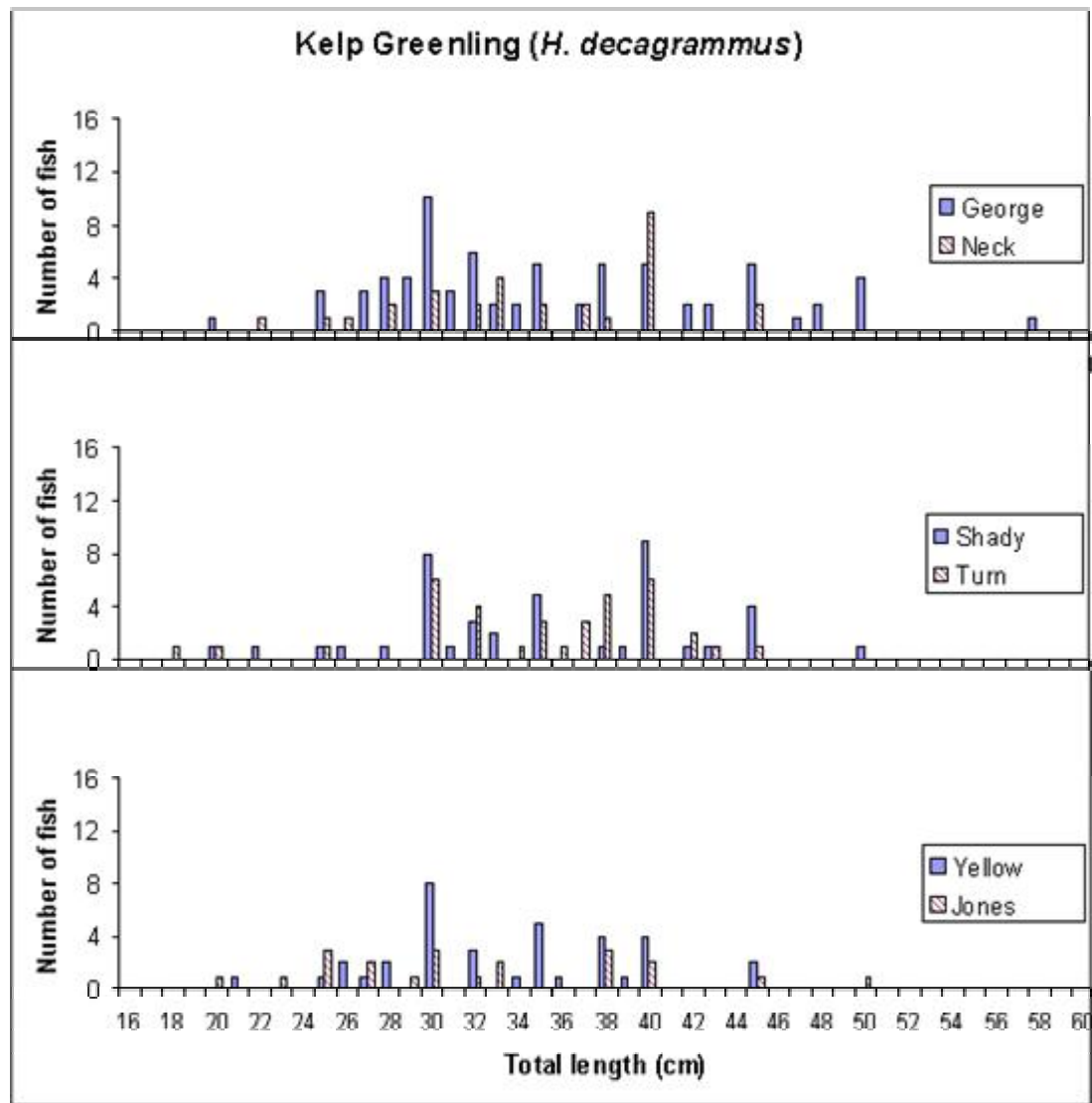


Figure 39. Length-frequency distributions of kelp greenling (*H. decagrammus*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

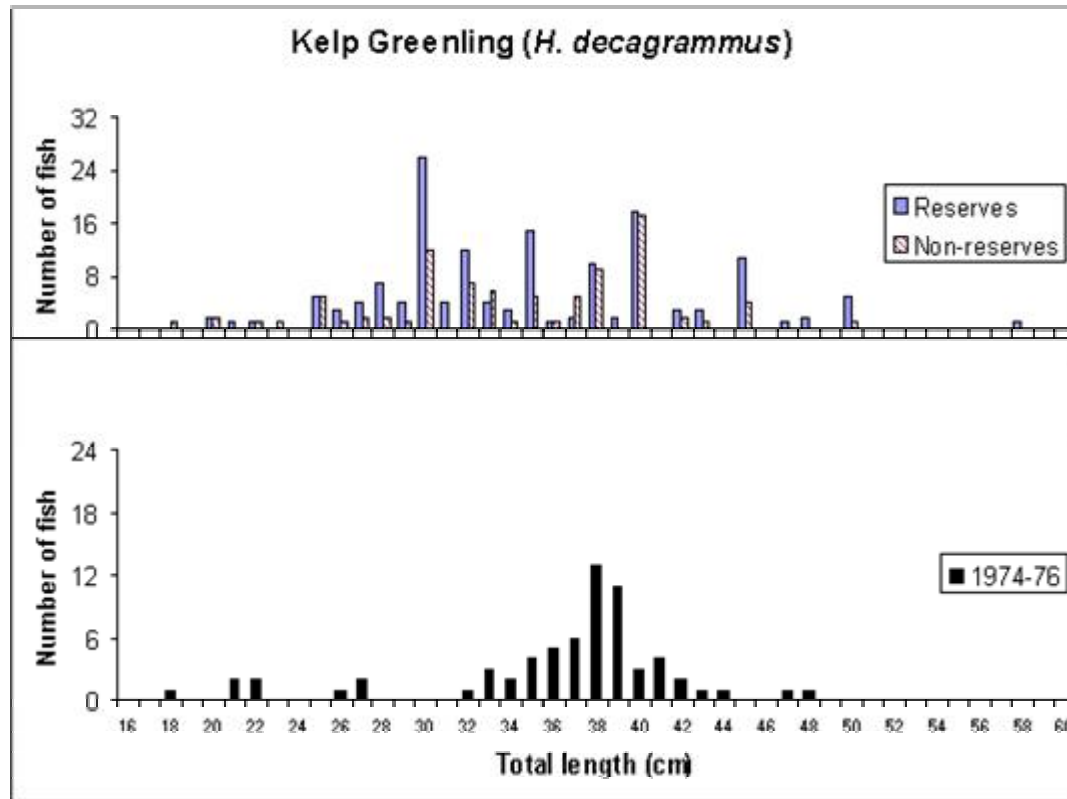


Figure 39 (cont). Upper graph: length-frequency distributions of kelp greenling (*H. decagrammus*) for all 2000 spatial study reserve and non-reserve sites. Reserves are solid bars. Non-reserves are crosshatched. Lower graph: length-frequency distributions of kelp greenling (*H. decagrammus*) from the same region in the 1970's.

Table 36. Two-sample F-tests for variance of kelp greenling (*H. decagrammus*) total lengths.

F-Test Two-Sample for Variance, reserve/non-reserve pairs

Total length (cm)									
<i>H. decagrammus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	<i>1974-76</i>
Mean	35.5	34.9	35.3	35.0	33.4	32.3	34.9	34.3	36.3
Variance	59.4	34.4	45.4	36.3	31.7	58.6	49.0	41.3	34.3
Observations	72	30	42	36	36	21	150	87	66
Min	20	22	20	18	21	20	20	18	18
Max	58	45	50	45	45	50	58	50	48
P(F<=f) two-tail	0.105		0.504		0.109		0.390		see below

F-Test Two-Sample for Variance, 2000 vs. 1974-76

Total length (cm)									
<i>H. decagrammus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	
P(F<=f) two-tail	0.026	0.959	0.310	0.826	0.817	0.110	0.106	0.434	
	*								

Table 37. Two-sample t-tests of kelp greenling (*H. decagrammus*) total lengths, and percentage of populations larger than length at 50% maturity.

t-Test: Two-Sample, reserve/non-reserve pairs

Total length (cm)	Equal Variance	Equal Variance	Equal Variance	Equal Variance
<i>H. decagrammus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>
				<i>Yellow</i>
				<i>Jones</i>
				<i>Reserves</i>
				<i>Non-reserves</i>
P(T<=t) two-tail	0.690	0.843	0.525	0.480

t-Test: Two-Sample, 2000 vs. 1974-76

Total length (cm)	Unequal	Equal	Equal	Equal	Equal	Equal	Equal	Equal	Equal Variance
<i>H. decagrammus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	
P(T<=t) two-tail	0.488	0.270	0.384	0.270	0.017*	0.012*	0.161	0.046*	

Length (and age) at 50% maturity: males females
 29.5cm (3-4yr) 29.5cm (3-4yr) Rothrock (1973)

% Mature: Assuming 50:50 sex ratio

<i>H. decagrammus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	1974-76	
Males	80	84	89	92	81	63	82	82	82	89
Females	80	84	89	92	81	63	82	82	82	89

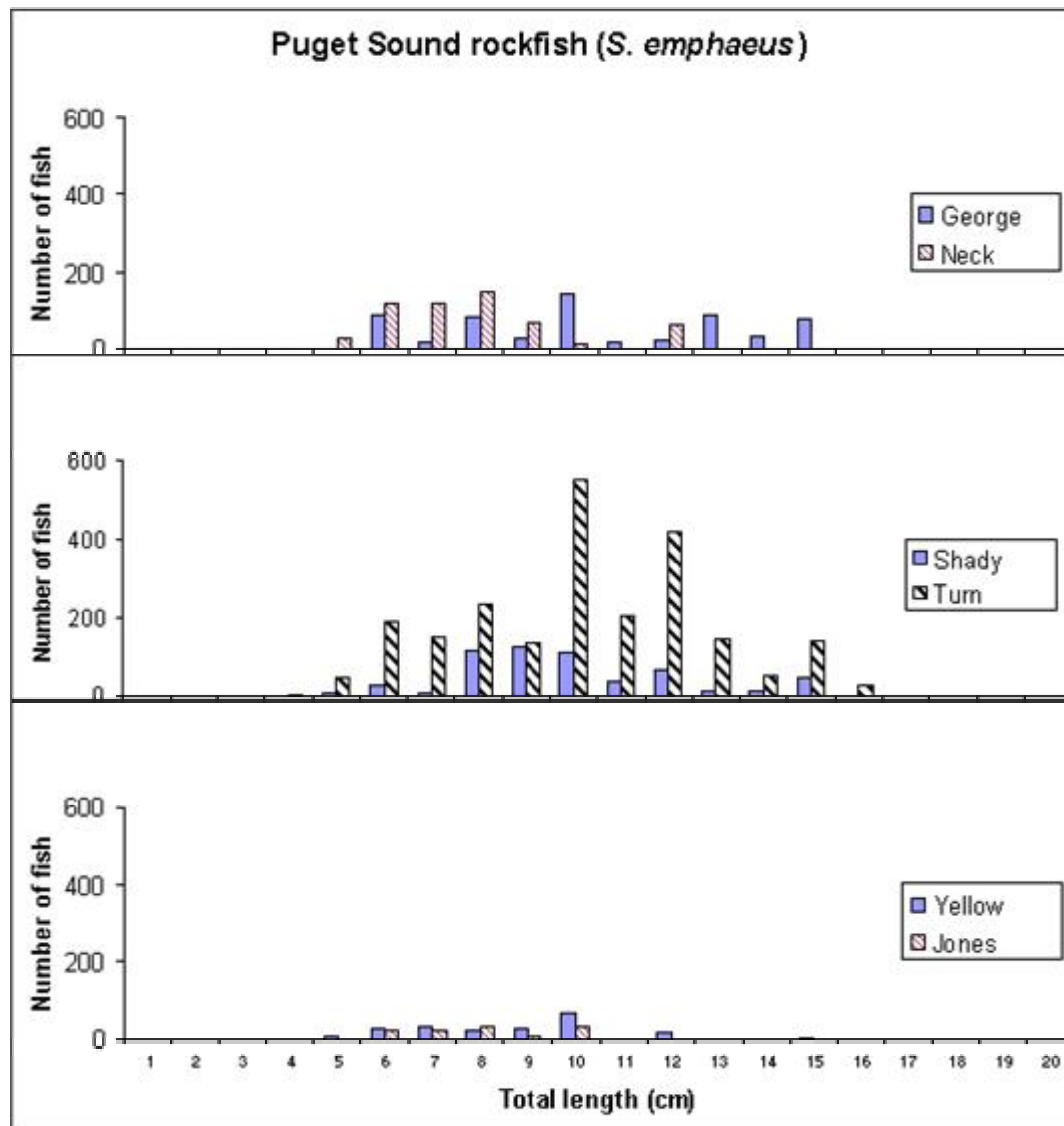


Figure 40. Length-frequency distributions of Puget Sound rockfish (*S. emphaeus*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

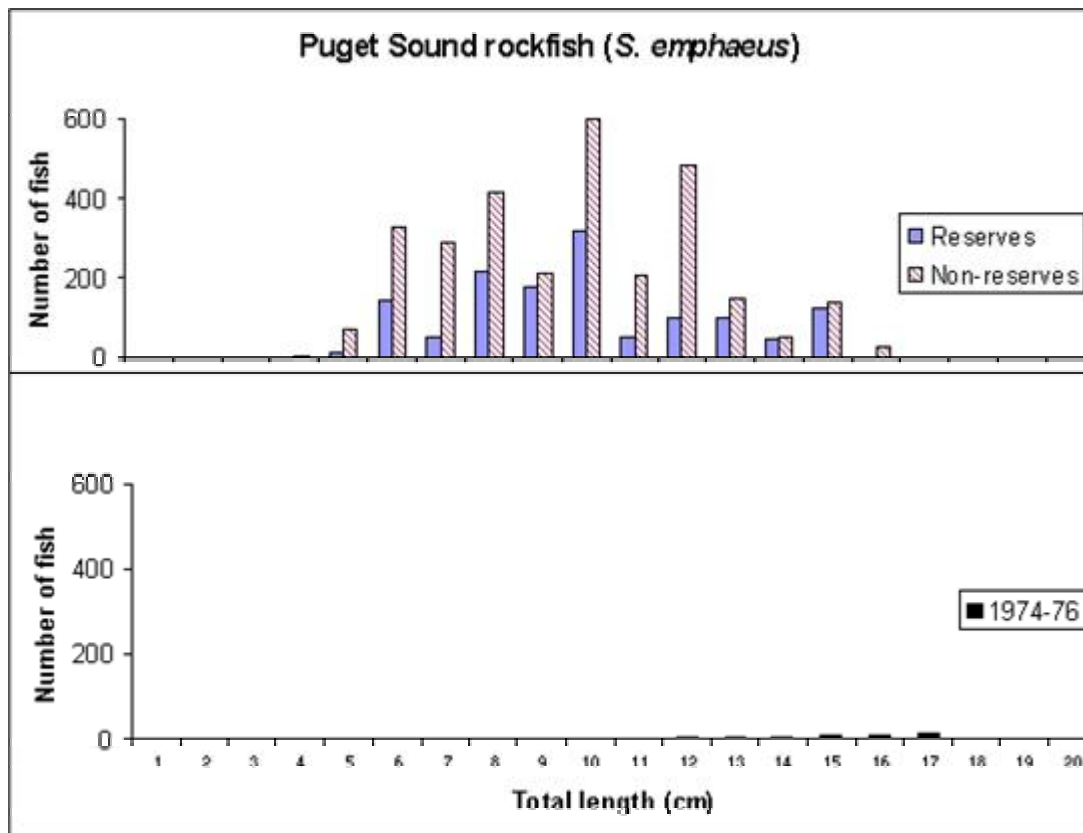


Figure 40 (cont). Upper graph: length-frequency distributions of Puget Sound rockfish (*S. emphaeus*) for all 2000 spatial study reserve and non-reserve sites. Reserves are solid bars. Non-reserves are crosshatched. Lower graph: length-frequency distributions of Puget Sound rockfish (*S. emphaeus*) from the same region in the 1970's.

Table 38. Two-sample F-tests for variance of Puget Sound rockfish (*S. emphaeus*) total lengths.

F-Test Two-Sample for Variance, reserve/non-reserve pairs

Total length (cm)

<i>S. emphaeus</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves	1974-76
Mean	10.4	7.8	9.9	10.2	8.7	8.0	10.0	9.7	14.8
Variance	8.7	3.5	5.5	6.6	4.0	2.1	7.0	6.8	5.8
Observations	585	553	572	2292	200	118	1357	2963	47
Min	6	5	4	4	5	6	4	4	7
Max	15	12	15	16	15	10	15	16	18
P(F<=f) two-tail	0.000 ***		0.008 **		0.000 ***		0.530		see below

F-Test Two-Sample for Variance, 2000 vs. 1974-76

Total length (cm)

<i>S. emphaeus</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves
P(F<=f) two-tail	0.093	0.010 *	0.724	0.633	0.089	0.000 ***	0.457	0.536

Table 39. Two-sample t-tests of Puget Sound rockfish (*S. emphaeus*) total lengths, and percentage of populations larger than length at 50% maturity.

t-Test: Two-Sample, reserve/non-reserve pairs

Total length (cm)	Unequal Var	Unequal Var	Unequal Var	Unequal Var	Equal Variance			
<i>S. emphaeus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>
P(T<=t) two-tail	0.000 ***		0.012 *		0.000 ***		0.001 **	

t-Test: Two-Sample, 2000 vs. 1974-76

Total length (cm)	Equal Var	Unequal Var	Equal Var	Equal Var	Equal Var	Unequal Var	Equal Var	Equal Var
<i>S. emphaeus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>
P(T<=t) two-tail	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***

Total length (and age) at 50% maturity: males females
 12.5cm (1.9yr) 12.5cm (1.9yr) Beckman (1995)

% Mature: Assuming 50:50 sex ratio

<i>S. emphaeus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	1974-76
Males	33	0	13	16	2	0	20	12	86
Females	33	0	13	16	2	0	20	12	86

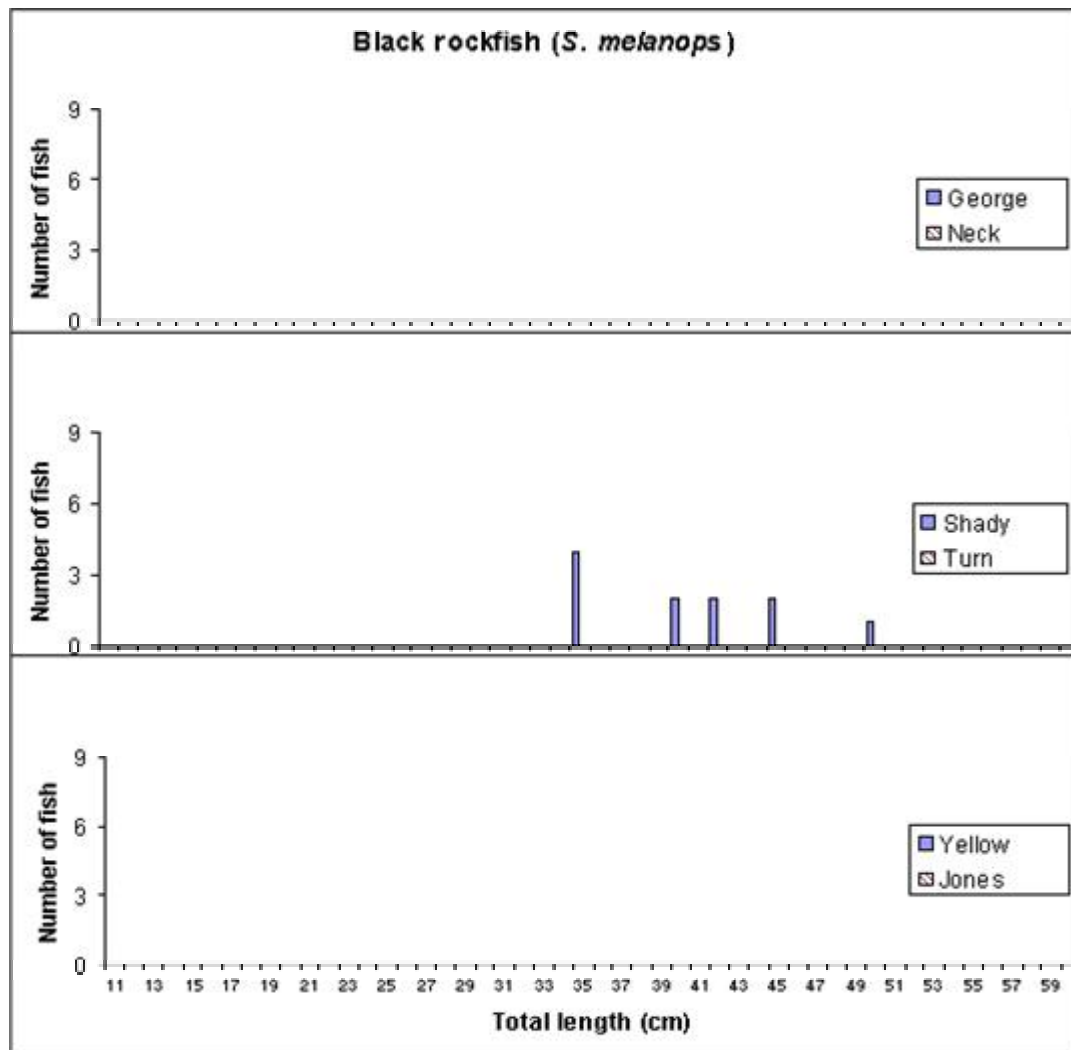


Figure 41. Length-frequency distributions of black rockfish (*S. melanops*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

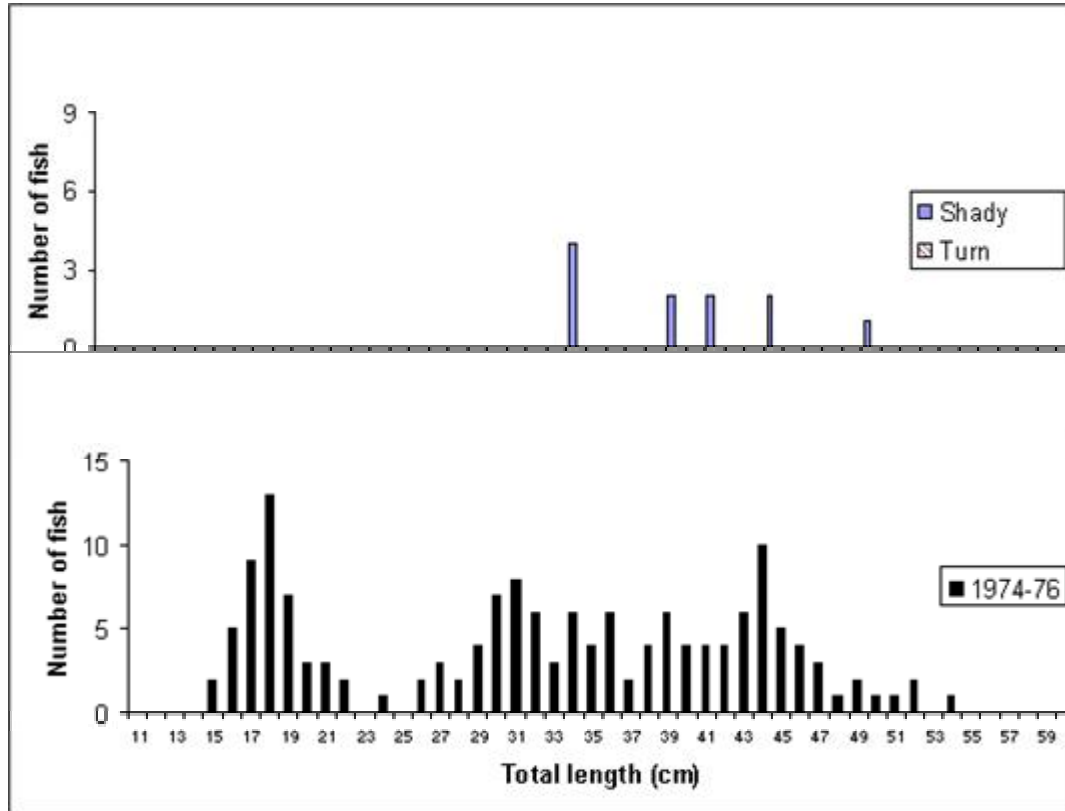


Figure 41 (cont). Upper graph: length-frequency distributions of black rockfish (*S. melanops*) for all 2000 spatial study reserve and non-reserve sites. Reserves are solid bars. Non-reserves are crosshatched. Lower graph: length-frequency distributions of black rockfish (*S. melanops*) from the same region in the 1970's.

Table 40. Two-sample F-tests for variance of black rockfish (*S. melanops*) total lengths.

F-Test Two-Sample for Variance, reserve/non-reserve pairs

Total length (cm)									
<i>S. melanops</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves	1974-76
Mean			40.4				40.4		35.0
Variance			25.7				25.7		221.0
Observations	0	0	11	0	0	0	11	0	51
Min			0				0		10
Max			0				0		60
P(F<=f) two-tail	NA		NA		NA		NA		see below

F-Test Two-Sample for Variance, 2000 vs. 1974-76

Total length (cm)									
<i>S. melanops</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves	
P(F<=f) two-tail	NA	NA	0.001 **	NA	NA	NA	0.001 **	NA	

Table 41. Two-sample t-tests of black rockfish (*S. melanops*) total lengths, and percentage of populations larger than length at 50% maturity.

t-Test: Two-Sample, reserve/non-reserve
pairs

Total length (cm)								
<i>S. melanops</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves
P(T<=t) two-tail	NA		NA		NA		NA	

t-Test: Two-Sample, 2000 vs. 1974-76

Total length (cm)	Unequal var				Unequal var			
<i>S. melanops</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves
P(T<=t) two-tail	NA	NA	0.043*	NA	NA	NA	0.043*	NA

Length (and age) at 50% maturity: males females
 38.3cm (6.3 yr) 42.2cm (7.9 yr) Wallace and Taggart (1994)

% Mature: Assuming 50:50 sex
ratio

<i>S. melanops</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves	1974-76
Males		63					63		70
Females		29					29		70

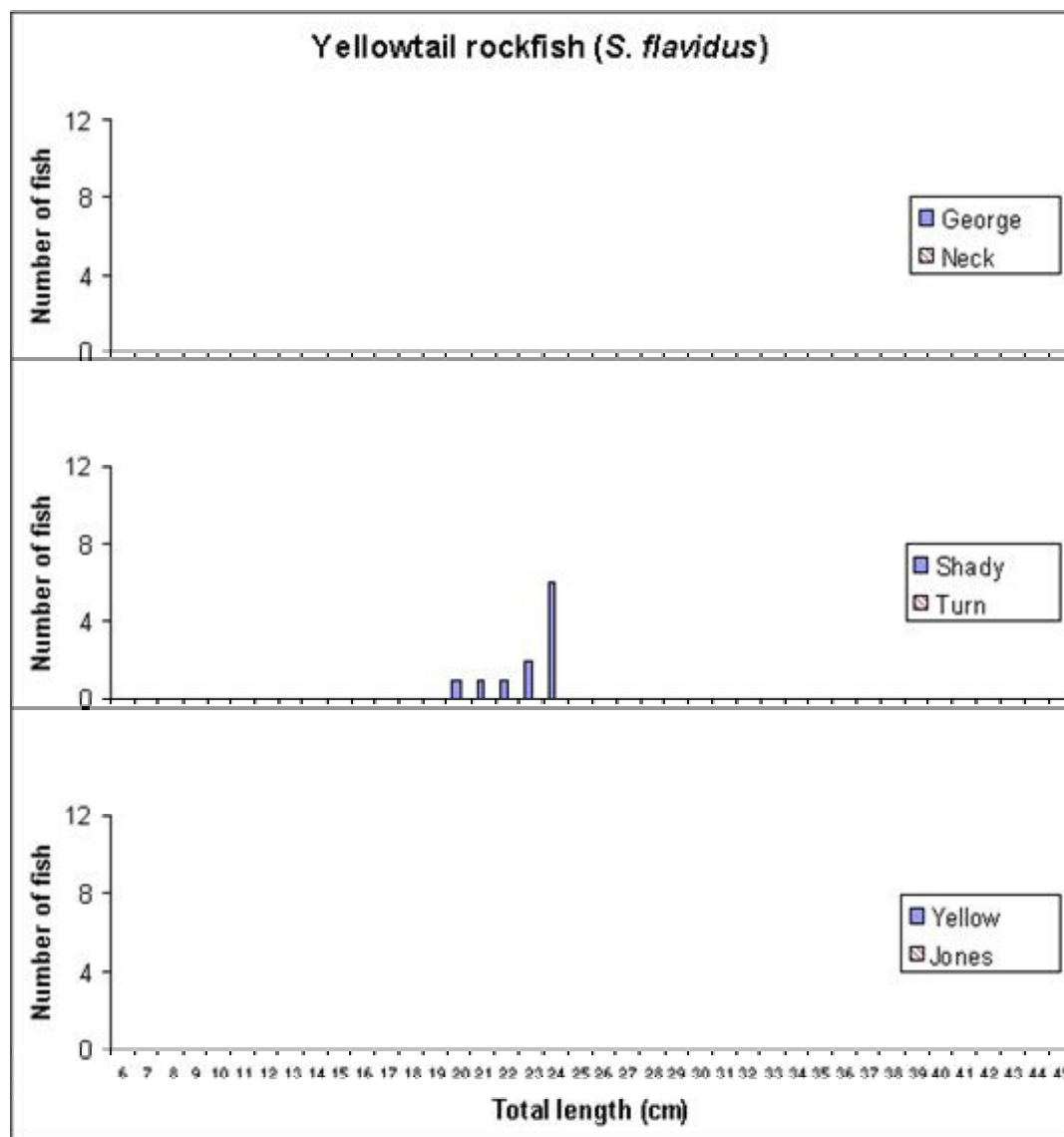


Figure 42. Length-frequency distributions of yellowtail rockfish (*S. flavidus*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

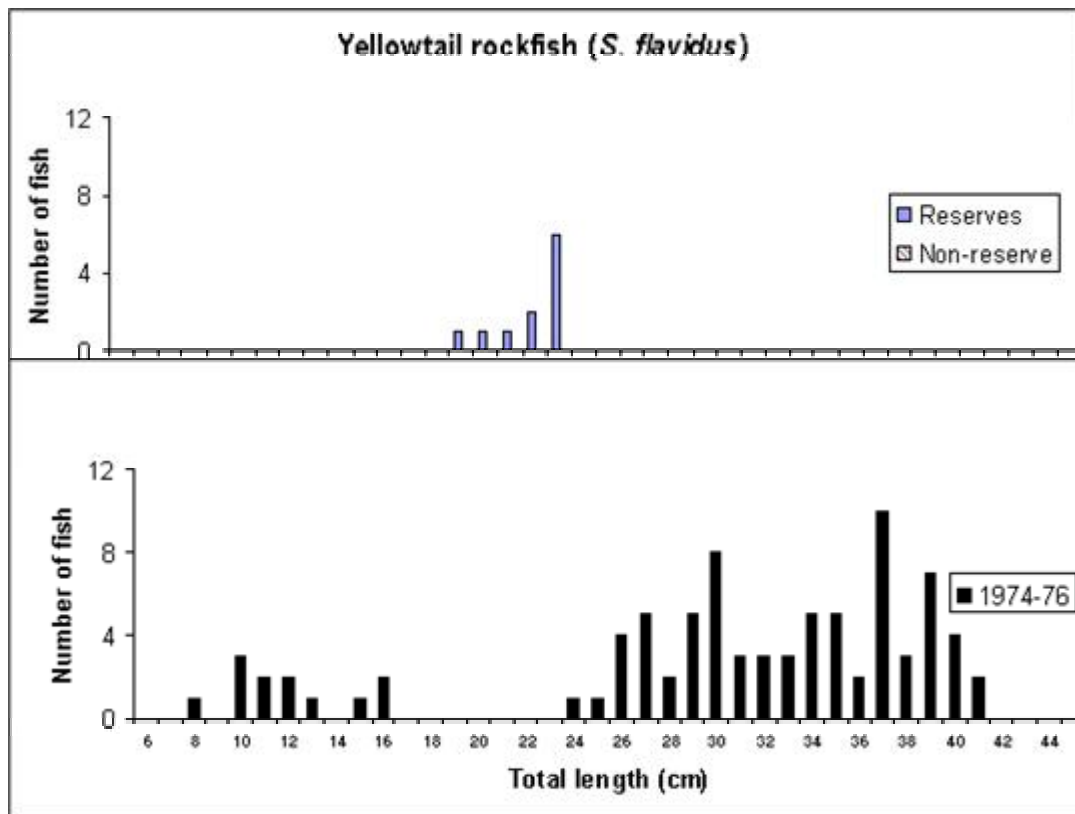


Figure 42 (cont). Upper graph: length-frequency distributions of yellowtail rockfish (*S. flavidus*) for all 2000 spatial study reserve and non-reserve sites. Reserves are solid bars. Non-reserves are crosshatched. Lower graph: length-frequency distributions of yellowtail rockfish (*S. flavidus*) from the same region in the 1970's.

Table 42. Two-sample F-tests for variance of yellowtail rockfish (*S. flavidus*) total lengths.

F-Test Two-Sample for Variance, reserve/non-reserve pairs

Total length (cm)									
<i>S. flavidus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	<i>1974-76</i>
Mean			23.0				23.0		30.3
Variance			2.0				2.0		75.5
Observations	0	0	11	0	0	0	11	0	85
Min			20				20		8
Max			24				24		41
P(F<=f) two-tail			NA				NA		see below

F-Test Two-Sample for Variance, 2000 vs. 1974-76

Total length (cm)									
<i>S. flavidus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	
P(F<=f) two-tail	NA	NA	0.000 ***	NA	NA	NA	0.000 ***	NA	

Table 43. Two-sample t-tests of yellowtail rockfish (*S. flavidus*) total lengths, and percentage of populations larger than length at 50% maturity.

t-Test: Two-Sample, reserve/non-reserve pairs

Total length (cm)								
<i>S. flavidus</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves
P(T<=t) two-tail	NA		NA		NA		NA	

t-Test: Two-Sample, 2000 vs. 1974-76

Total length (cm)	Unequal var				Unequal var			
<i>S. flavidus</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves
P(T<=t) two-tail	NA	NA	0.000 ***	NA	NA	NA	0.000 ***	NA

Length (and age) at 50% maturity: males females

% Mature: Assuming 50:50 sex ratio

<i>S. flavidus</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves	1974-76
Males			0				0		48
Females			0				0		38

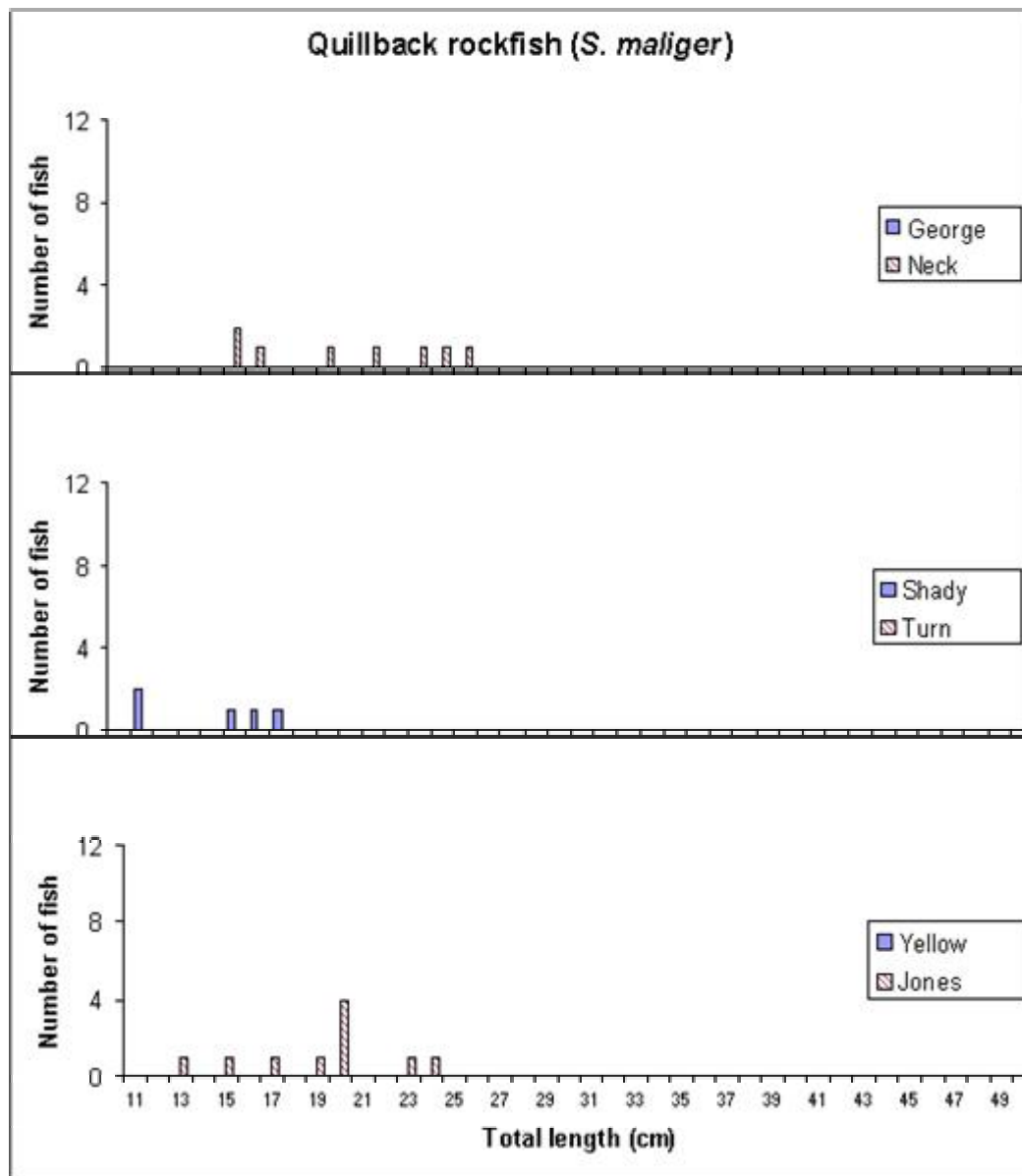


Figure 43. Length-frequency distributions of quillback rockfish (*S. maliger*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

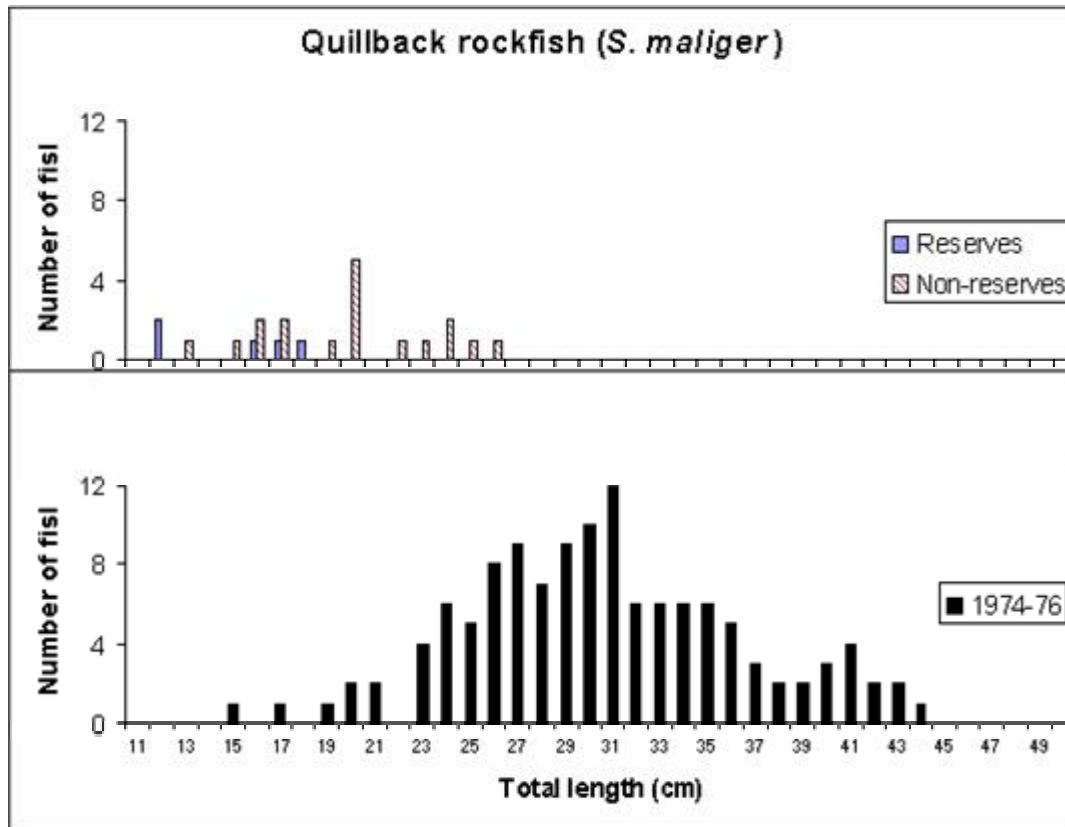


Figure 43 (cont). Upper graph: length-frequency distributions of quillback rockfish (*S. maliger*) for all 2000 spatial study reserve and non-reserve sites. Reserves are solid bars. Non-reserves are crosshatched. Lower graph: length-frequency distributions of quillback rockfish (*S. maliger*) from the same region in the 1970's.

Table 44. Two-sample F-tests for variance of quillback rockfish (*S. maliger*) total lengths.

F-Test Two-Sample for Variance, reserve/non-reserve pairs

Total length (cm)									
<i>S. maliger</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	<i>1974-76</i>
Mean		20.8	15.0			19.1	15.0	19.8	30.6
Variance		16.8	8.0			11.2	8.0	13.6	33.7
Observations	0	8	5	0	0	10	5	18	125
Min		16	12			13	12	13	15
Max		26	18			24	18	26	44
P(F<=f) two-tail	NA		NA		NA		0.651		see below

F-Test Two-Sample for Variance, 2000 vs. 1974-76

Total length (cm)									
<i>S. maliger</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	
P(F<=f) two-tail	NA	0.331	0.166	NA	NA	0.075	0.166	0.034	*

Table 45. Two-sample t-tests of quillback rockfish (*S. maliger*) total lengths, and percentage of populations larger than length at 50% maturity.

t-Test: Two-Sample, reserve/non-reserve pairs

Total length (cm)	Equal Variance							
<i>S. maliger</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>
P(T<=t) two-tail	NA		NA		NA		0.013	*

t-Test: Two-Sample, 2000 vs. 1974-76

Total length (cm)	Equal		Equal		Equal		Unequal Variance	
<i>S. maliger</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>
P(T<=t) two-tail	NA	0.000 ***	0.000 ***	NA	NA	0.000 ***	0.000 ***	0.000 ***

Length (and age) at 50% maturity: males females
 29.5cm(13yr) 28.1cm(11yr) Richards and Cass (1986)

% Mature: Assuming 50:50 sex ratio

<i>S. maliger</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	1974-76
Males		0	0			0	0	0	56
Females		0	0			0	0	0	64

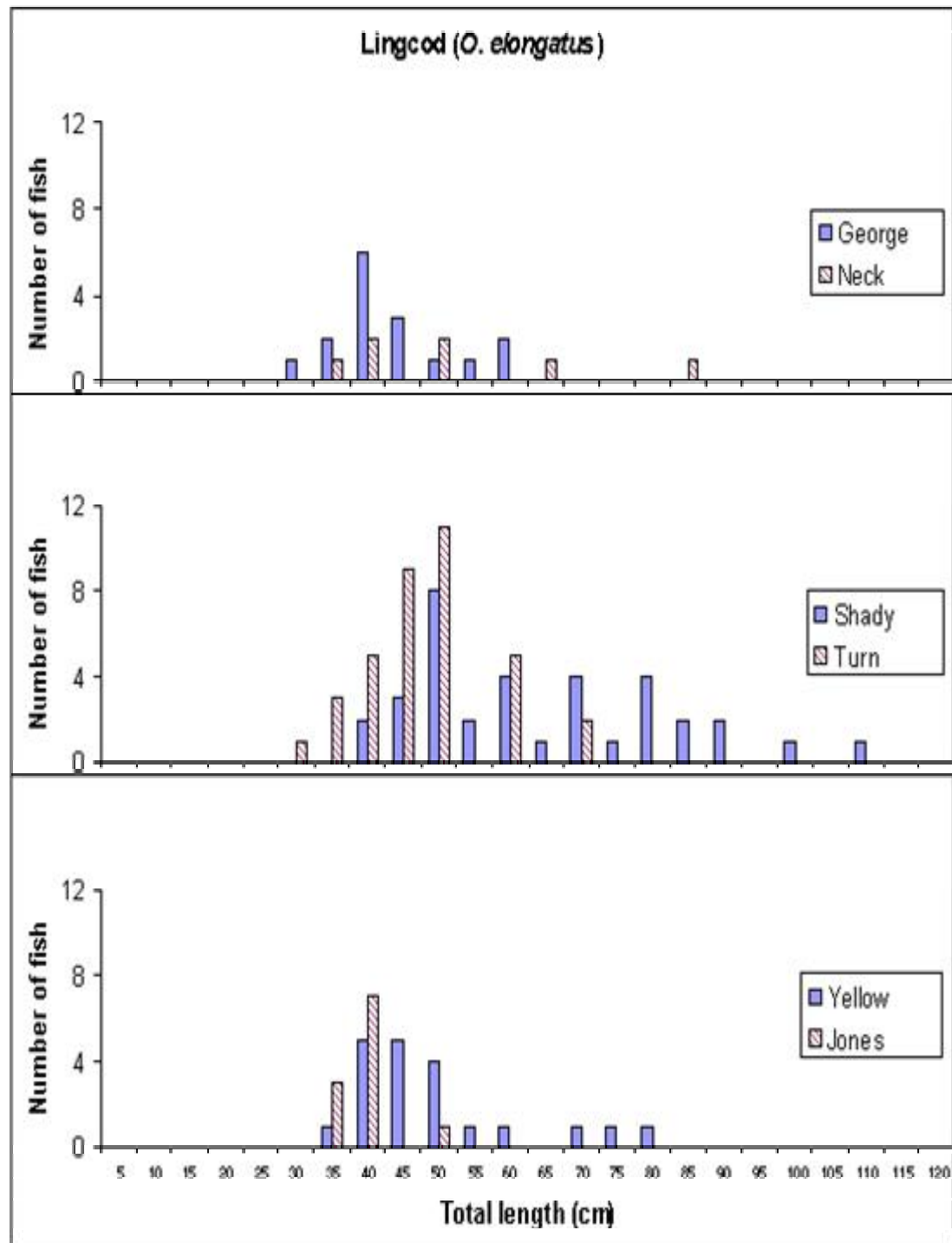


Figure 44. Length-frequency distributions of lingcod (*O. elongatus*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

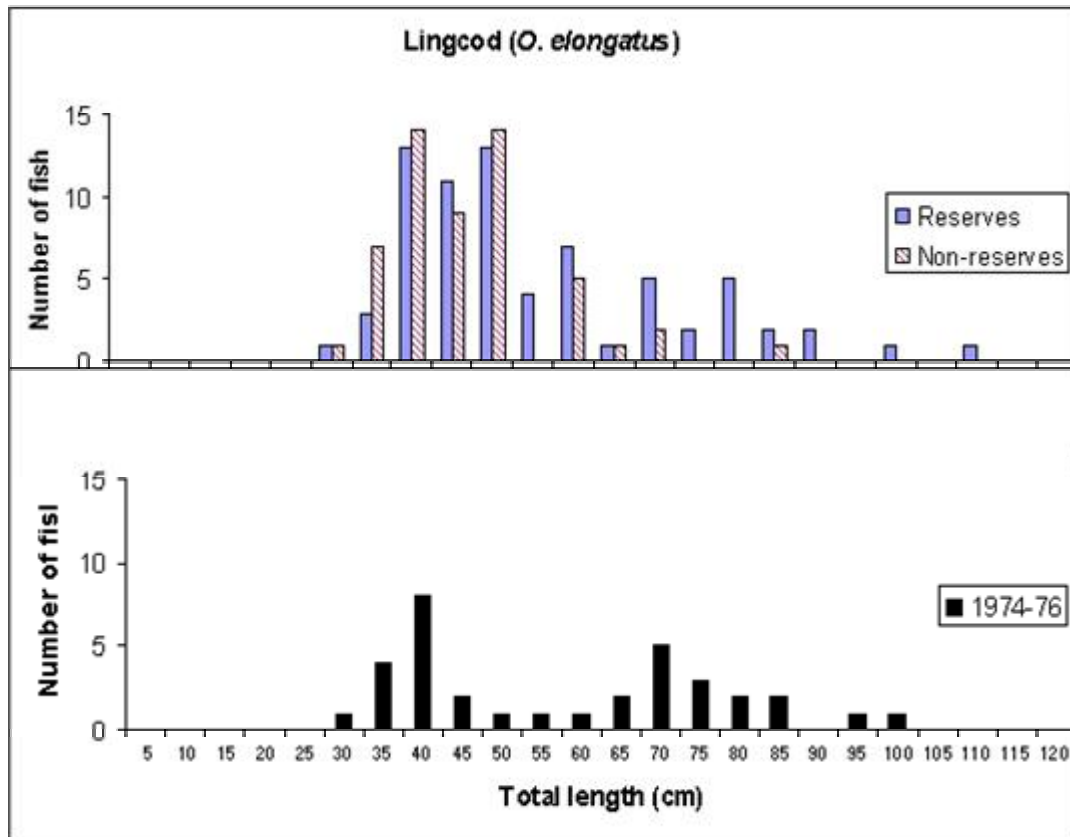


Figure 44 (cont). Upper graph: length-frequency distributions of lingcod (*O. elongatus*) for all 2000 spatial study reserve and non-reserve sites. Reserves are solid bars. Non-reserves are crosshatched. Lower graph: length-frequency distributions of lingcod (*O. elongatus*) from the same region in the 1970's.

Table 46. Two-sample F-tests for variance of lingcod (*O. elongatus*) total lengths.

F-Test Two-Sample for Variance, reserve/non-reserve pairs

Total length (cm)									
<i>O. elongatus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	<i>1974-76</i>
Mean	43.0	52.1	64.7	47.6	49.7	39.2	55.6	46.5	56.3
Variance	82.4	307.1	322.0	89.3	159.2	21.6	305.2	114.0	392.7
Observations	16	7	35	36	20	11	71	54	34
Min	30	35	40	30	35	33	30	30	30
Max	60	85	110	70	80	50	110	85	99
P(F<=f) two-tail	0.036 *		0.000 ***		0.003 **		0.000 ***		see below

F-Test Two-Sample for Variance, 2000 vs. 1974-76

Total length (cm)									
<i>O. elongatus</i>	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	
P(F<=f) two-tail	0.002 **	0.820	0.567	0.000 ***	0.041 *	0.000 ***	0.375	0.000 ***	

Table 47. Two-sample t-tests of lingcod (*O. elongatus*) total lengths, and percentage of populations larger than length at 50% maturity.

t-Test: Two-Sample, reserve/non-reserve pairs

Total length (cm)	Unequal Var	Unequal Var	Unequal Var	Unequal Var	Unequal Var	Unequal Var	Unequal Var	Unequal Var
<i>O. elongatus</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves
P(T<=t) two-tail	0.231		0.000 ***		0.003 **		0.000 ***	

t-Test: Two-Sample, 2000 vs. 1974-76

Total length (cm)	Unequa l Var	Equal	Equal	Unequa l Var	Unequa l Var	Unequa l Var	Equal	Unequal Var
<i>O. elongatus</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves
P(T<=t) two-tail	0.002 **	0.613	0.068	0.025 *	0.140	0.000 ***	0.857	0.011 *

Length (and age) at 50% maturity: males females
 51.3cm (4.6 yr) 63.4cm (3.4 yr) Jagielo (1994)

% larger than length at 50% maturity:

<i>O. elongatus</i>	George	Neck	Shady	Turn	Yellow	Jones	Reserves	Non-reserves	1974-76
Males	18	32	64	20	25	0	43	17	53
Females	0	19	45	5	14	0	26	6	41

Tables 46-47). Striped surfperch (*E. lateralis*) had no significant difference in mean length between reserves and non-reserves (t-test: $p = 0.485$) (Figure 45, Table 48). YOY copper / quillback rockfish (*S. caurinus* / *S. maliger*) had also greater mean length in non-reserves (t-test: $p < 0.001$) (Figure 46, Table 49).

Patterns of YOY *S. caurinus* / *S. maliger* abundance and length-frequency distribution observed in the 2000 spatial study

Of the six spatial study sites surveyed, three had relatively substantial recruitment of YOY *S. caurinus* / *S. maliger* complex fishes. Between 11 and 66 YOY were sighted at these sites during all surveys. The other three sites had one or zero YOY sighted during the 2000 spatial study. The three sites that had substantial recruitment of YOY were Neck Point, Shady Cove and Jones Island. In every case, one site in each reserve/non-reserve pair had relatively substantial YOY recruitment and the other site in the pair had none or extremely little. The sites with recruitment were also split amongst reserves and non-reserves, specifically one reserve and two non-reserves. Length-frequency data for the YOY *S. caurinus* / *S. maliger* complex are presented with all sampling dates grouped (Figure 50) as well as by sampling date to examine changes in abundance and length-frequency distribution over time (Figures 47-49).

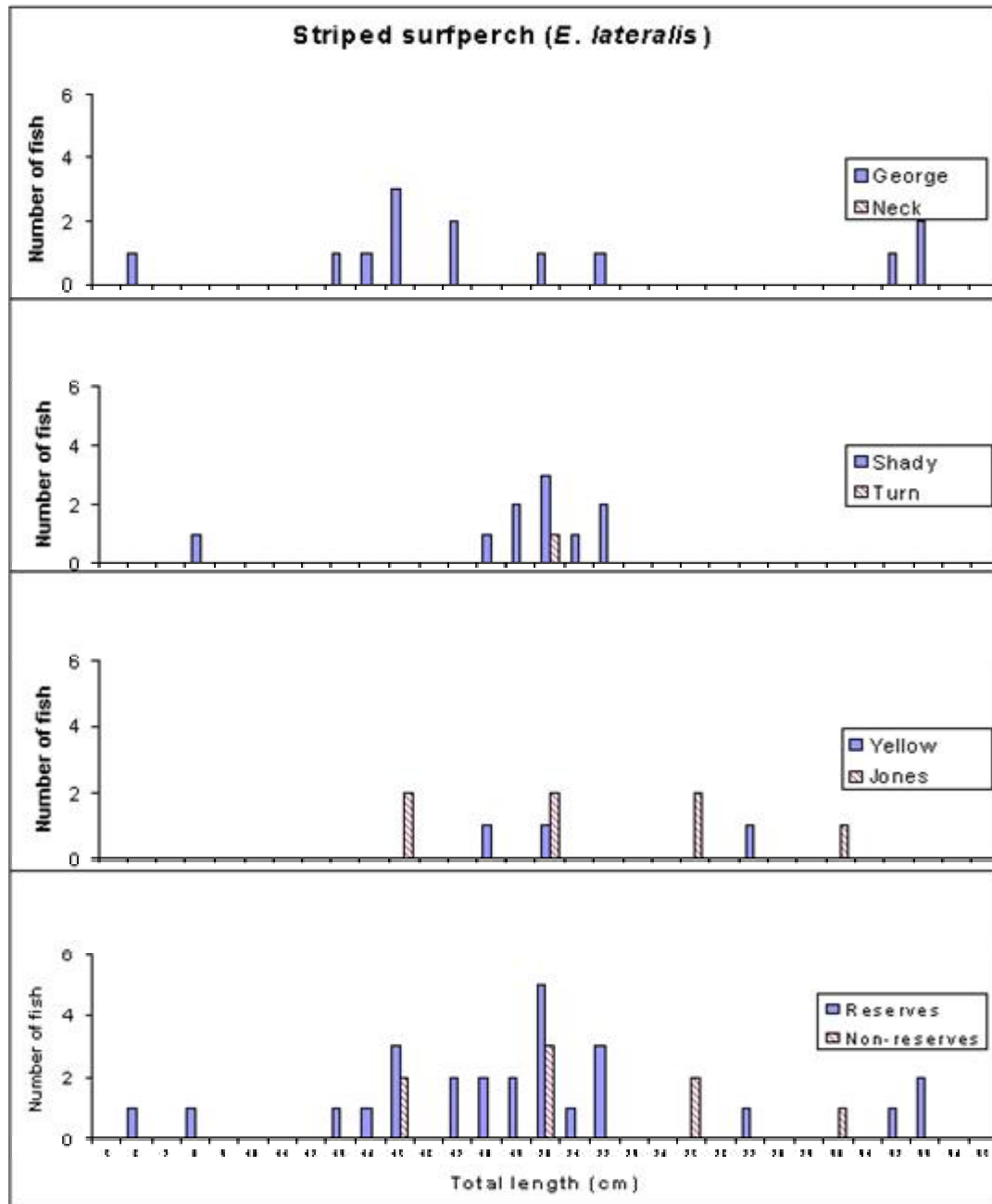


Figure 45. Length-frequency distributions of striped surfperch (*E. lateralis*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

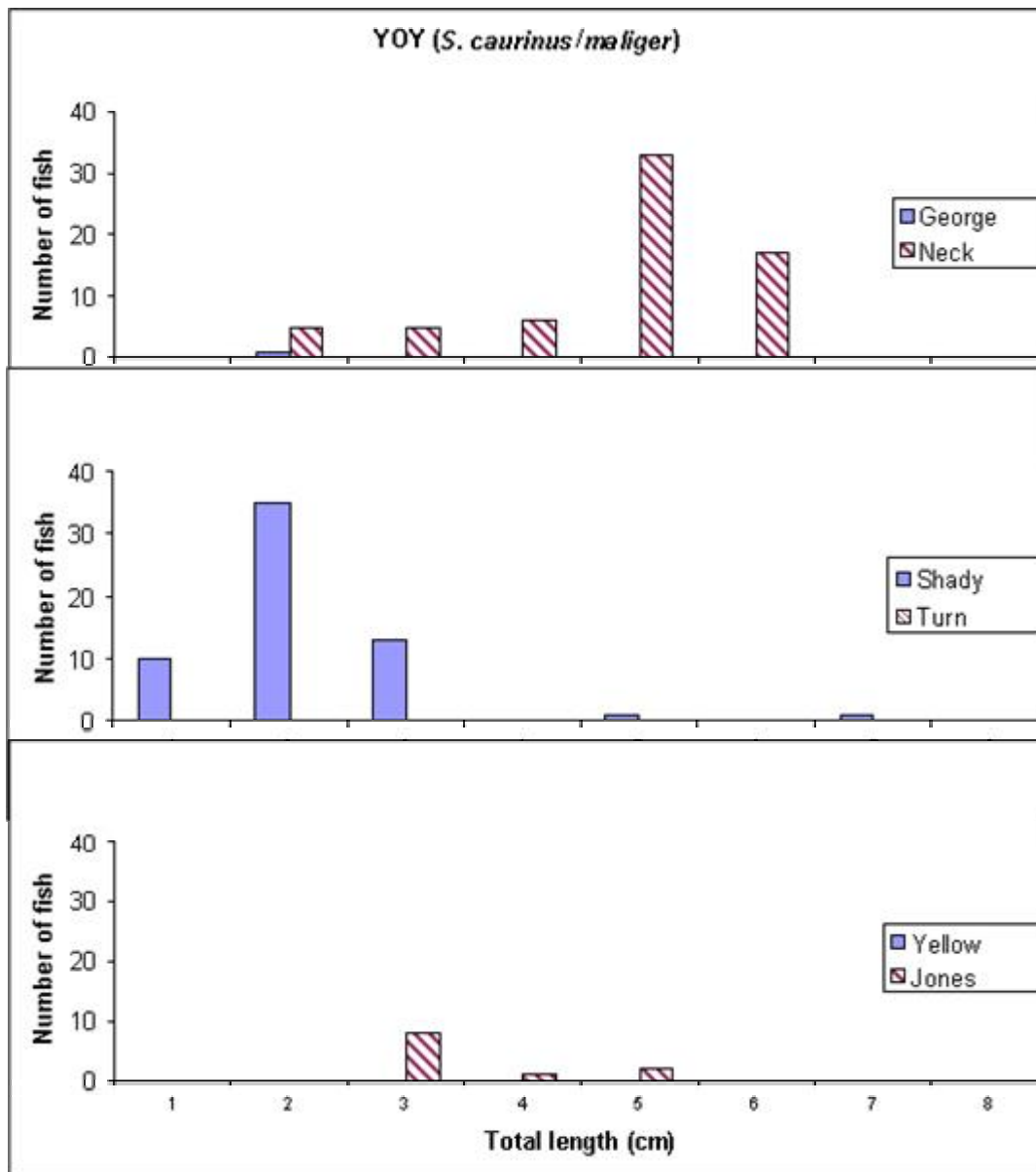


Figure 46. Length-frequency distributions of YOY copper / quillback rockfish (*S. caurinus* / *S. maliger*) at 2000 spatial study sites. Reserves are solid bars. Non-reserves are crosshatched.

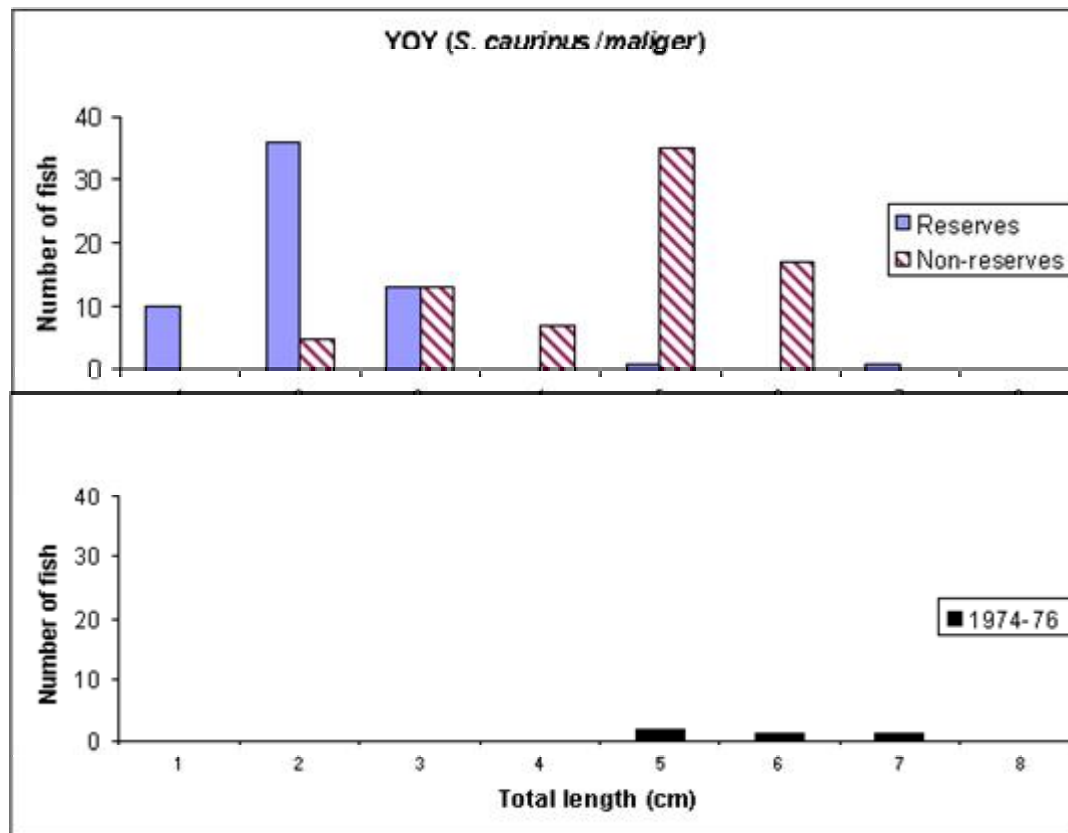


Figure 46 (cont). Upper graph: length-frequency distributions of YOY copper / quillback rockfish (*S. caurinus / S. maliger*) for all 2000 spatial study reserve and non-reserve sites. Reserves are solid bars. Non-reserves are crosshatched. Lower graph: length-frequency distributions of YOY copper / quillback rockfish (*S. caurinus / S. maliger*) from the same region in the 1970's.

Table 49. Two-sample F-test for variance and two-sample t-tests for YOY copper / quillback rockfish (*S. caurinus* / *S. maliger*) total lengths.

F-Test Two-Sample for Variance, reserve/non-reserve pairs

YOY	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>	1974-76
Mean	2.0	4.8	2.2			3.5	2.3	4.6	5.8
Variance		1.3	0.9			0.7	1.4	1.4	0.9
Observations	1	66	60	0	0	11	62	77	4
Min	2	2	1			3	1	2	5
Max	2	6	7			5	8	6	7
P(F<=f) two-tail	NA		NA		NA		0.947		see below

F-Test Two-Sample for Variance, 2000 vs. 1974-76

YOY	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>
P(F<=f) two-tail	NA	0.890	0.813	NA	NA	0.619	0.807	0.819

t-Test: Two-Sample, reserve/non-reserve pairs

Equal Variance

YOY	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>
P(T<=t) two-tail	NA		NA		NA		0.000	***

t-Test: Two-Sample, 2000 vs. 1974-76

Total length (cm) Unequal Equal Equal Equal Equal Equal Equal Equal Variance

YOY	<i>George</i>	<i>Neck</i>	<i>Shady</i>	<i>Turn</i>	<i>Yellow</i>	<i>Jones</i>	<i>Reserves</i>	<i>Non-reserves</i>
P(T<=t) two-tail	NA	0.135	0.004	NA	NA	0.009	0.003	0.091

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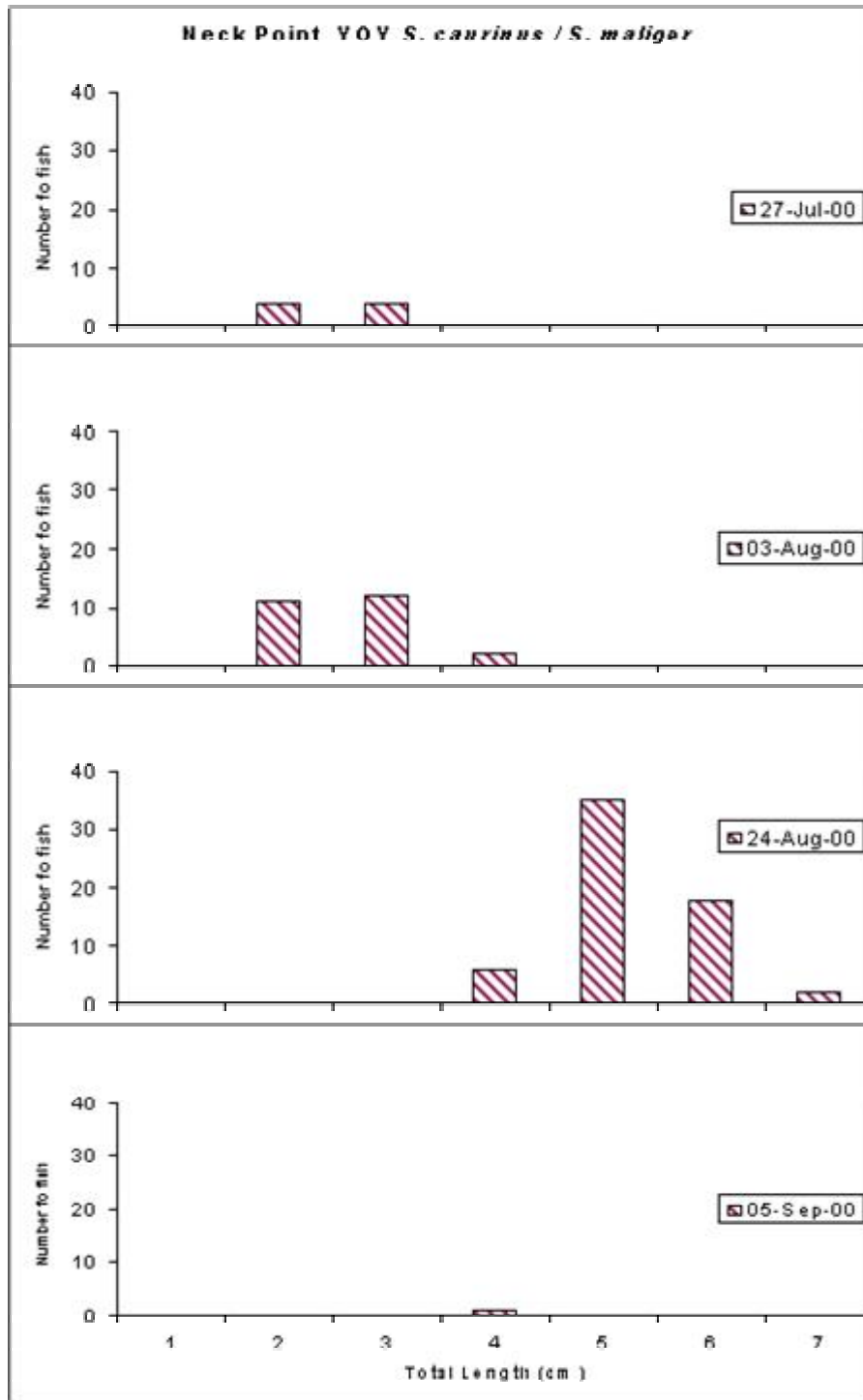
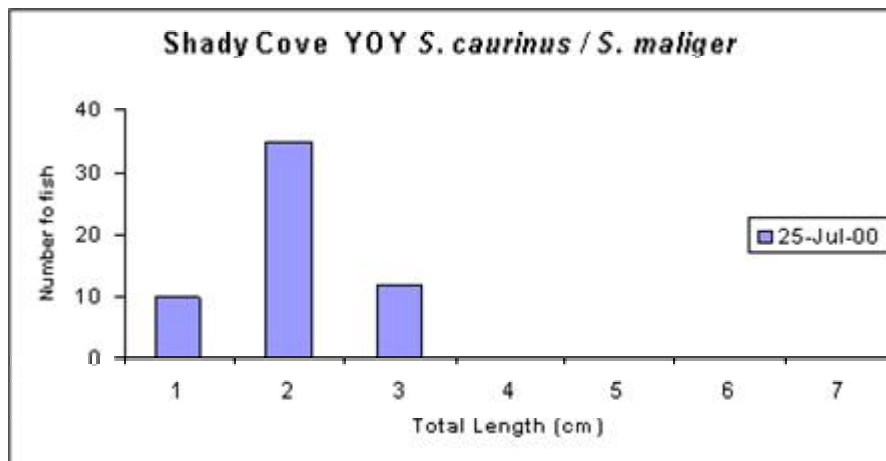


Figure 47. Length-frequency distributions of YOY copper / quillback rockfish (*S. caurinus* / *S. maliger*) by sampling date at the Neck Point spatial study non-reserve site.



None on August survey

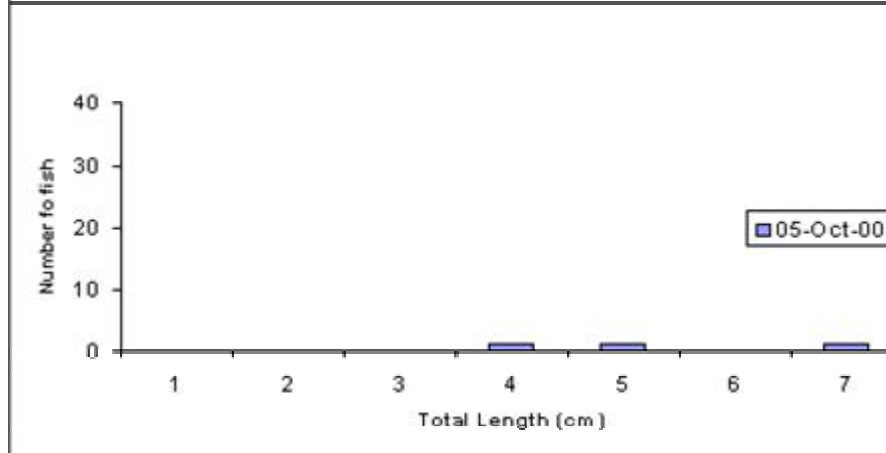
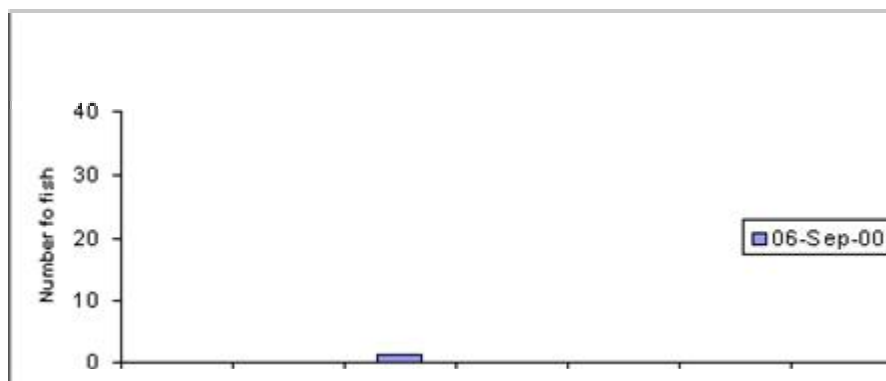
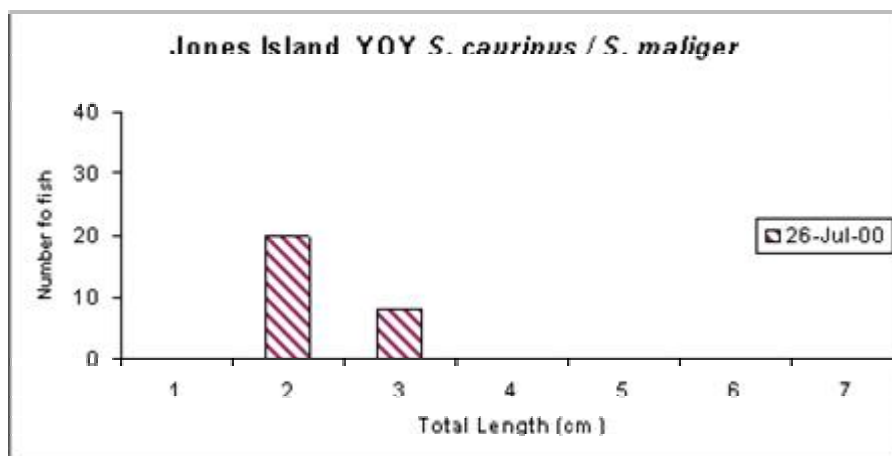


Figure 48. Length-frequency distributions of YOY copper / quillback rockfish (*S. caurinus* / *S. maliger*) by sampling date at the Shady Cove spatial study reserve site.



None on August survey

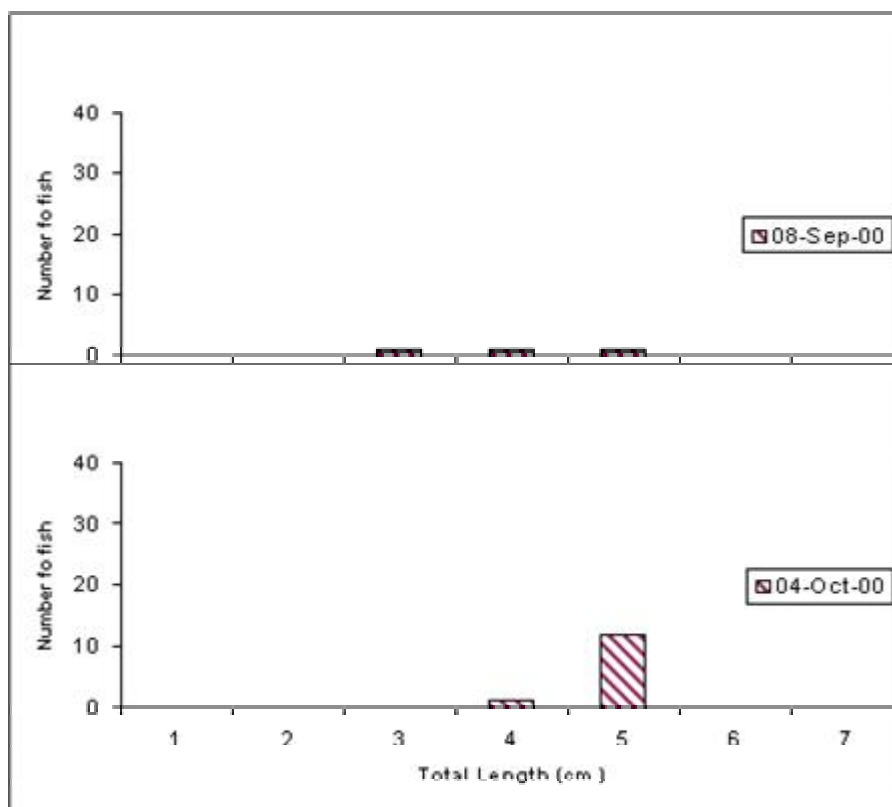


Figure 49. Length-frequency distributions of YOY copper / quillback rockfish (*S. caurinus* / *S. maliger*) by sampling date at the Jones Island spatial study non-reserve site.

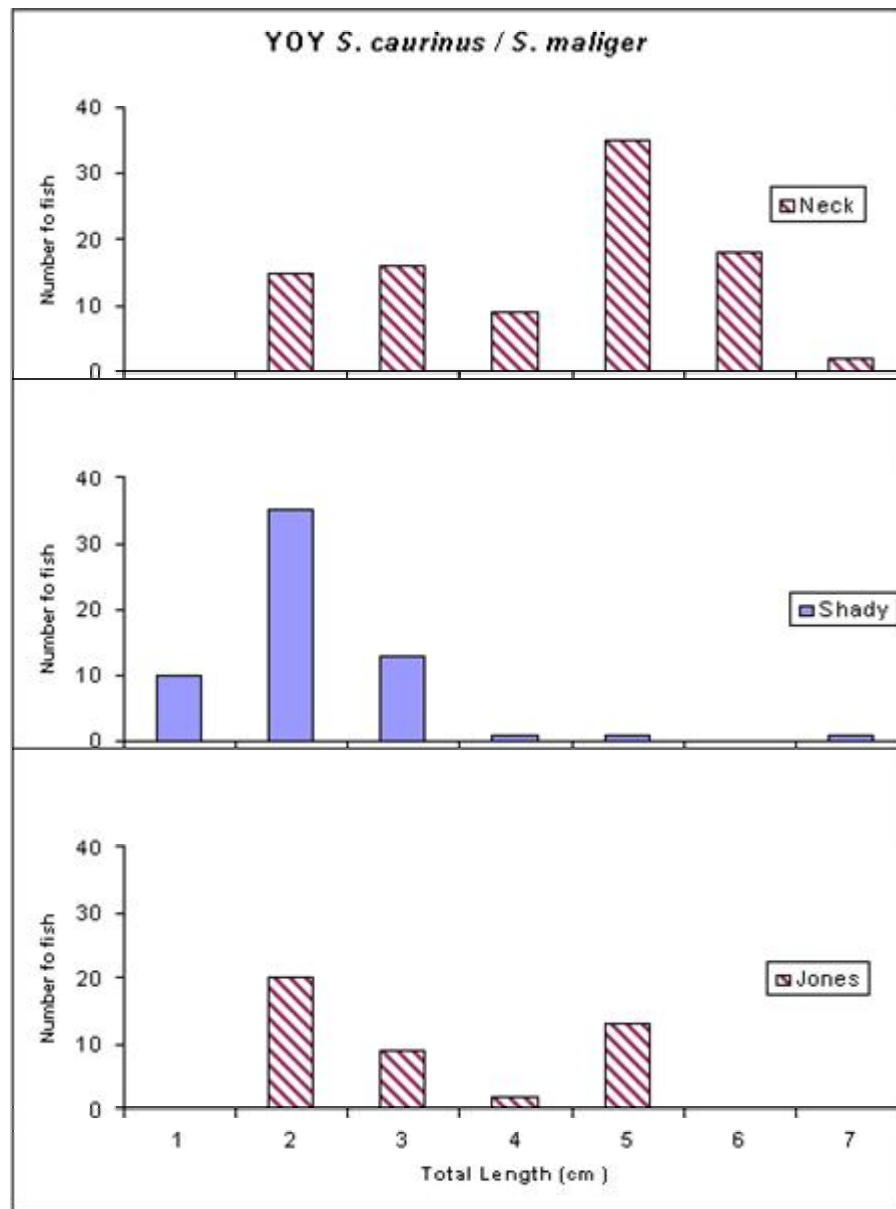


Figure 50. Summary over time of 2000 spatial study length-frequency distributions for YOY copper / quillback rockfish (*S. caurinus* / *S. maliger*) by site.

DISCUSSION

Population densities in the Pt. George study site over time

In summary, populations of *S. caurinus*, *H. decagrammus* and *S. emphaeus* were significantly increasing at the time of reserve implementation and increased at a faster rate after reserve implementation. Populations of *S. flavidus*, *S. melanops* and *S. maliger* had disappeared or were decreasing at reserve implementation and all three had disappeared by 1999. *O. elongatus* were decreasing before reserve implementation and recovered after reserve implementation.

Reduced fishing pressure in reserves appears to be the process driving the trends in *S. caurinus*, *H. decagrammus* and *O. elongatus*. This may be the result of the reserves. However, there is another possibility. Increases in density and length of these species may be the result of reductions in overall bottomfishing effort. Boat based bottomfish angler trips reached a peak in the 1980's. In addition, there appears to be very little current bottomfishing effort. Surveys of the spatial study sites during 2001 from April to October found no fishing effort in reserves and close to none in the non-reserve reference sites. However, the time of year when salmon fishing is not open and angler pressure is most likely to shift to bottomfish was not surveyed (K. Koski, Soundwatch and The Whale Museum, personal communication). Nevertheless, reduction of overall bottomfishing effort does not explain the greater densities and larger sizes seen in reserve sites during the 2000 spatial study.

Fluctuations in population density of *O. elongatus* may have been caused by a strong year class from the early 1990's (L. Britt, University of Washington Graduate Student, personal communication), but this does not explain the greater densities of larger *O. elongatus* in reserves. It appears more likely that this result has been caused by lower mortality in reserves due to restricted fishing since the San Juan Islands Marine Preserves were established in 1990. Furthermore, given that annual bottomfish angler trips reached a peak in the 1980's due to a dwindling salmon resource and greater restrictions on salmon fishing (Palsson *et al.* 1997) *O. elongatus* have been subject to fishing pressure. It appears likely that the reserve status is causing decreased mortality of *O. elongatus* inside reserves, and increasing population density inside reserves over time.

The observed trends have not been reversed after ten years of fishing restriction, except for *O. elongatus*, which indicates that the reserves may be too small, inadequately enforced, or ten years is not enough time for these slow growing and late maturing fish to rebound. In addition, climate regime shifts may drive the observed trends. Shifting climate regimes seems the most likely explanation of trends in the schooling species: *S. melanops*, *S. flavidus* and *S. emphaeus*.

Length-frequency distributions in the Point George study site over time

Trends in length of *S. caurinus* before reserves were mostly increasing, with the exception of summer. Summer was the one season that had 1987 data. It is possible that the apparent increases for other seasons from the 1970's to 1991-92 were the result of

declining bottomfishing effort starting in 1980's. In all seasons after reserves were formed (1991-92 to 1999-2000), lengths of *S. caurinus* at Point George decreased. This atypical decrease in length after reserve formation may be caused by increased recruitment during the 1990's.

Trends in *H. decagrammus* lengths before reserves were mixed, and fluctuated greatly with season. This species generally increased in length after reserves were implemented.

In general, trends in lengths of *S. emphaeus* over time were mixed, and seemed to be dominated by variability in recruitment. When recruitment was greater, mean lengths were smaller and when recruitment was lesser, mean lengths were greater. Historical data concerning lengths of *S. emphaeus* are limited and prevent more detailed analysis of trends in lengths of *S. emphaeus* over time.

Combined with the first analysis, it appears that *S. melanops* may have disappeared from this site before reserve-status, and did not recover with reserve-status. A similar conclusion can be drawn for *S. flavidus*. *S. maliger* exhibits the same pattern although there is evidence of this species at the beginning of the reserve period. Overall, reserve status did not reverse the density decline of these species, although in the case of *S. flavidus* lengths were significantly increasing in the before-reserve period.

O. elongatus had mixed trends before reserves and after reserves lengths generally increased.

The researcher who provided the 1987 data (Caselle 1987) cautioned that the data were collected during an undergraduate's first crack at fish ecology research. Lengths reported seem to be consistently overestimated, especially for *H. decagrammus* and *S. emphaeus*, which show fish larger than maximum reported lengths. These data were included despite these problems because of the rare nature of historical data of this type.

Comparison of habitat and fishing activity between 2000 spatial study sites

Habitat appeared similar between paired sites. These are important results in order to ensure accurate testing of the reserve/non-reserve treatment, and avoid confounding microhabitat effects. Site pairs are comparable in study area size, exposure, bathymetry and substrate complexity. Site pairs had no statistically significant difference on reef slope, except Point George has steeper reef slope than Neck Point. The Shady Cove / Turn Island pair has especially favorable high-relief rocky reef fish habitat (i.e. high substrate complexity). This may explain the persistence of *S. melanops* and *S. flavidus* at this site.

All observed fishing was at non-reserves. Jones Island in particular had fishing more often than the other non-reserve sites. This is probably due to nearly constant recreational use of the area during summer months due to the mooring buoys within

100m of the study site. Pleasure boats up to approximately 40 feet in length were frequently observed on these moorings, and these boaters often launched dinghies to go fishing in the immediate area.

Population densities for 2000 spatial study sites

For populations which increased over time in the Point George time-series study (*S. caurinus*, *H. decagrammus*, and *S. emphaeus*) there were two trends. *S. caurinus* and *H. decagrammus* were more abundant in reserves. Populations of these two species were healthy before reserves and benefited when reserves were implemented. *S. emphaeus* were also more abundant in reserves for two of three site pairs, but overall were more abundant in *non*-reserves because of one site, Turn Island. A possible explanation for this trend is predation of *S. emphaeus* by *O. elongatus*. Stomachs of *O. elongatus* collected in the study area in the last ten years have been found to contain *S. emphaeus* (W. Palsson, Washington Department of Fish and Wildlife, personal communication), and *O. elongatus* were most abundant and largest at Turn's pair, Shady Cove. Perhaps if the densities and sizes of *O. elongatus* were the same between the Shady-Turn pair, the density of *S. emphaeus* would be the same as well.

For populations which decreased over time in the Point George time-series study (*S. melanops*, *S. flavidus* and *S. maliger*) there were two trends. *S. melanops* and *S. flavidus* were more abundant in reserves, but present only at one site, Shady Cove. Possible explanations include: 1) the Shady reserve has particularly good habitat, 2) these

species were too depleted at reserve implementation to recover, 3) these species move outside of reserves and are caught, and 4) the 1970's climate regime shift adversely affected their recruitment. *S. maliger* were more abundant in non-reserves, and they were found only in sites with high YOY recruitment. It appears recruitment dynamics are structuring the patterns of abundance for *S. maliger*, at least within working SCUBA depths.

For the population that recovered in the Point George time-series study, *O. elongatus*, population densities were greater in reserves in all three cases and 35% greater in aggregate, but this difference was not statistically significant.

The two populations with no time-series data, *E. lateralis* and YOY *S. caurinus* / *S. maliger*, had different trends. *E. lateralis* appear unaffected by reserves. This is logical for a species that is not fished for in the study sites and does not appear to interact with other species of interest. YOY *S. caurinus* / *S. maliger* were more abundant in non-reserves. Perhaps this trend is the result of greater predation in reserves. Predators such as large *S. caurinus* and *O. elongatus* were more abundant in reserves.

Length-frequency distributions for spatial study sites in 2000 and 1974-76 from the same region

For populations that increased over time in the Point George time-series study (*S. caurinus*, *H. decagrammus*, and *S. emphaeus*) there were three different trends in 2000

length-frequency distributions. *S. caurinus* were larger in reserves, but only one fish greater than 37cm was sighted in 2000 compared to many in the 1970's. In the future, larger individuals could become more abundant in reserves as *S. caurinus* can live to 35 years (Richards and Cass, 1986). *H. decagrammus* were not different in reserve versus non-reserve or compared to the 1970's. Overall, *S. emphaeus* were larger in reserves, but on a site-by-site basis they were larger where *O. elongatus* were smaller.

Populations that decreased over time in the Point George time-series study (*S. melanops*, *S. flavidus* and *S. maliger*) each had different trends in 2000 length-frequency distribution. First, *S. melanops* and *S. flavidus* were both sighted only in one reserve site, Shady Cove. However, *S. melanops* in 2000 were shifted towards the high end of the length range present in the 1970's, while *S. flavidus* were shifted towards the low end of the length range present in the 1970's. It seems that *S. melanops* in the study area are recruitment limited and the reserve is preserving the presence of a few old individuals. *S. flavidus* appear to have recently begun recruiting after many years of zero recruitment, perhaps in response to the recent climate regime shift. *S. maliger* were larger in non-reserves, and 2000 distributions lacked larger (reproductive) individuals compared to the 1970's distributions.

The population that recovered in the Point George time-series study, *O. elongatus*, was larger in reserves (including 3 times more reproductive sized individuals).

Distributions in reserves were similar to historical distributions while non-reserves lacked larger length-classes present in the other two samples.

The populations that do not have time series data, *E. lateralis* and YOY *S. caurinus* / *S. maliger*, showed two different trends. Length-frequency distributions of *E. lateralis* in reserves compared to non-reserves were not different. YOY *S. caurinus* / *S. maliger* were larger in non-reserves and present in the same locations as age 1+ *S. maliger*, which was probably due to greater predation in reserve sites from larger and more abundant *S. caurinus* and *O. elongatus*.

Patterns of 2000 YOY *S. caurinus* / *S. maliger* abundance and length-frequency distributions by sampling date and site

Substantial numbers YOY *S. caurinus* / *S. maliger* fishes were sighted in three of the six 2000 spatial study sites, Neck Point, Shady Cove and Jones Island. The other three sites had zero or one YOY sighted during the 2000 spatial study. In every case, one site in a pair had high recruitment and the other had little or none at all. Furthermore, recruitment did not appear dependent on reserve or non-reserve status. High recruitment sites were one reserve and two non-reserves.

In both the non-reserve sites with high recruitment, a pattern of accumulation over time was evident. With each subsequent sample date, abundance and length generally increased. In the reserve site with high recruitment, there appeared to be a large initial

pulse of YOY recruits that became less abundant at subsequent sampling dates. It seems that mortality of YOY recruits was greater in the reserve site.

Effect of reserves on demographic patterns of each target species

Copper rockfish (*S. caurinus*) are a commonly targeted bottomfish and are often bycatch of anglers targeting lingcod. The virtual disappearance of *S. caurinus* >38cm (a 45cm individual was sighted during the 2000 survey) is important to note, as fish this size were more common in the 1970's. This trend indicates increased mortality of larger, more fecund individuals since the 1970's, probably due to fishing pressure. This study shows that duration of protection needed to regenerate 1970's levels of abundance of *S. caurinus* individuals >38cm is probably longer than 10 years, which makes sense for a species that can live to be 35 years old (Richards and Cass 1986). Given more time, *S. caurinus* >38cm may become more abundant in reserves.

While there were reproductive adult *S. caurinus* in both reserves and non-reserves, densities were greater in reserves—especially for larger length classes. Given the non-linear increase of *S. caurinus* fecundity as a function of length (DeLacy *et al.* 1964; Washington *et al.* 1978), reserves contain greater reproductive potential than non-reserves. The term “reproductive potential” is used to describe the number of eggs produced per area of habitat by a population (Paddack and Estes 2000). The limitation of using this technique to extrapolate further is that the number of viable larvae produced per area could be different from reproductive potential, especially if fecundity declines at

the upper bounds of size and longevity as has been found for Atka mackerel (*Pleurogrammus monoterygius*) (McDermott 2001). However, the relationship between reproductive potential and number of viable larvae produced per area for species of interest in this study is unknown. For the sake of argument, let us assume that reproductive potential has a linear relationship with the number of viable larvae produced per area.

During the spring of 2000, *Sebastes* larvae identified as *S. caurinus* / *S. maliger* complex were most abundant in the middle of San Juan Channel, and abundance increased with increasing distance from shore (Chasco *et al.* 2000). This trend indicates that planktonic larvae of the *S. caurinus* / *S. maliger* complex in San Juan Channel may be contained in a common larval pool. Therefore, larvae may be dispersing from where they are released to this common pool, and then settling out as juveniles throughout San Juan Channel. If this is correct (and since fish in reserves may contribute a disproportionately greater share of larvae to the common pool than the area of rocky reef habitat encompassed by reserves indicates) reserves may supply a disproportionately larger share of *S. caurinus* larvae to both reserve and non-reserve areas.

Kelp greenling (*H. decagrammus*) appear not to be heavily sought after by anglers. Some locals said they do not consider them good eating and usually throw them back. Survivorship of caught and released individuals should be high. *H. decagrammus*, like all members of the *Hexagrammidae* lack a swim bladder. In addition, *H.*

decagrammus were the most actively moving target species during dive surveys. A combination of these reasons may explain why their distributions are similar in reserves, non-reserves, and historically.

Accurate home range information is unknown for this species, although it is possible that *H. decagrammus* moves more than the size of these reserves (2-3km) and therefore the reserves confer a reduced refuge from fishing pressure. This would also explain the similarity of reserve and non-reserve distributions. However, the similarity of distributions from 2000 and the mid-1970's indicates that the more important process regulating this species' demographics is lack of fishing pressure rather than large home range and/or movement rates. In either case, the network of marine reserves is not playing any direct role in structuring *H. decagrammus* stocks in the area.

Puget Sound rockfish (*S. emphaeus*) are seldom caught by anglers because they feed on plankton and their mouths are too small for a typical bottomfishing hook. They also reproduce at around 2 years of age and reach a maximum size of 18cm (Beckman 1995). In this study, none greater than 16cm TL were sighted. Given the feeding habits of this species and the fishing habits of anglers, fishing is probably not structuring the demographics of this species. The greater abundance of *S. emphaeus* in non-reserves versus reserves is possibly due to increased predation of *S. emphaeus* inside reserves by the more abundant and significantly larger *O. elongatus*. Gut contents of *O. elongatus* collected in the study area revealed presence of *S. emphaeus* (W. Palsson, Washington

Department of Fish and Wildlife, personal communication), and transects with large numbers of *S. emphaeus* often also had *O. elongatus*. It would follow that the greater mean length of *S. emphaeus* inside reserves might be caused by an *O. elongatus* preference for smaller individuals.

The reserve network seems to play an indirect yet major role in regulating the density and mean size of *S. emphaeus* at the various sites, since reserves appear to regulate the demographics of *O. elongatus* at different sites. Human influences appear to be structuring ecosystems directly (in the case of *O. elongatus*) and indirectly (in the case of *S. emphaeus*). There could be other, unknown, indirect impacts on other species, for example killer whales (*Orcinus orca*), harbor seals (*Phoca vitulina*) and river otters (*Lutra canadensis*).

S. emphaeus often behave somewhat similarly to subadult *S. flavidus* and *S. melanops*, schooling above certain features on rocky reefs and swimming into the current looking for prey. They also can behave like the epi-benthic *S. caurinus* and *S. maliger* inhabiting boulder piles, cracks and crevices. Adult *S. emphaeus* are also approximately the same size as subadult *S. flavidus* and *S. melanops*. The large increase in abundance over time of *S. emphaeus* may be facilitated by decreased abundance over time of subadult *S. flavidus* and *S. melanops* and a resultant increase in availability of space and/or prey resources. However, it is impossible to prove this without showing that prey or space is scarce.

Another potential explanation is that food and space are essentially unlimited and the population bottleneck for *S. flavidus* and *S. melanops* is supply of YOY. This appears to be the case for *S. melanops*. The situation for *S. flavidus* is unclear, and neither of these hypotheses explains why *S. emphaeus* has undergone a huge increase in abundance. The network appears to play an indirect role in regulating the density of *S. emphaeus* at the various sites.

Black rockfish (*S. melanops*) are prized by anglers and easily caught by bottomfishers and as bycatch by trollers targeting salmon. The lack of individuals <35cm compared to historical data by Moulton (1977) indicates a recruitment limited population in 2000. In the mid-1970's, *S. melanops* were common at the Turn Island non-reserve site as well as at the Point George reserve site (B. Miller, unpublished data), where they are not currently present. Overfishing (in the San Juan Channel or in outside waters) is likely to be the cause. Climate may be a factor as well, although data that support the claim are very limited. The network of marine reserves seems to be playing a major role in preserving *S. melanops* as a member of the San Juan Channel nearshore rocky reef assemblage, however the continued presence of this species is uncertain.

Yellowtail rockfish (*S. flavidus*) are a commonly taken rockfish. Occurring in schools off the bottom, this meso-pelagic species is characterized by extremely patchy distribution. They are prized by anglers and easily caught by bottomfishers and by trollers

targeting salmon. All eleven *S. flavidus* sighted in 2000 were in reserves. Larvae of *S. flavidus* are thought to drift up the Juan de Fuca Strait and settle in the San Juans. This would explain the presence of subadults without adults. In Puget Sound and the San Juan Islands, no adults have been recorded. Only subadult *S. flavidus* are seen in these inside waters (B. Miller, University of Washington, personal communication).

The lack of larger subadult *S. flavidus* compared to the mid-1970's could be the result of fishing pressure, especially in outside waters where the broodstock for *S. flavidus* in the San Juans is thought to reside (B. Miller, University of Washington, personal communication). However, *S. flavidus* trends in the San Juans could also be related to climate. Much larger reserves, with before and after reserve formation time series data from both inside and out of reserves, are needed to differentiate the relative importance of fishing pressure and climate in regulating temporal fluctuations in abundance (Carr and Reed 1993). The network of marine reserves seems to be playing a role in preserving the *S. flavidus* species as a member of the San Juan Channel assemblage, however the future demographic trend for this species is uncertain.

Quillback rockfish (*S. maliger*) are a commonly targeted bottomfish and are often bycatch of anglers targeting lingcod. *S. maliger* behaves similarly to *S. caurinus*, except that *S. maliger* generally inhabits greater depths. The disappearance of reproductive *S. maliger* from the assemblage since the 1970's is probably due to fishing removals and competition with the steadily increasing population of *S. caurinus* in the

area (Moulton 1977; Caselle 1987; S. Miller, 1991 unpublished data; 1999 this study). Competition with *S. caurinus* could be forcing the lower depth limit of adult *S. maliger* deeper and out of conventional SCUBA working depths. However, lab and field experiments at Friday Harbor Laboratories have not revealed any evidence for competition between *S. caurinus* and *S. maliger*, (B. Miller, University of Washington, personal communication).

Working depth limitations limited the survey protocol to depths less than 20m. Moulton (1977) surveyed the same depth range as this study and half the *S. maliger* he saw were reproductive size. Reconnaissance dives to 30m completed during 2000 found the same abundance (zero) of reproductive *S. maliger* as sighted during all surveys in 2000. Fishing removals could be structuring the demographics of *S. maliger*, and the low fish density relative to the 1970's may be further exacerbated by possible competition with *S. caurinus*. The network of marine reserves is affecting demographics of *S. maliger* indirectly and in adverse ways.

Lingcod (*O. elongatus*) are commonly targeted by anglers and are one the most highly prized and sought after bottomfish in San Juan Channel. The low end of the legal size limit for *O. elongatus* is 26 inches (or 66.04 cm), the same size at which greater fish densities in reserves begin to appear. The distribution of *O. elongatus* in reserves is similar to that found in San Juan Channel during the mid-1970's, while the distribution in non-reserves is lacking larger individuals. This is strong evidence that removals by

anglers fishing in non-reserve areas structure the demographic pattern of *O. elongatus* in San Juan Channel.

O. elongatus inhabiting nearshore rocky reefs seem to be predominantly males, while females reside in deeper water most of the year and enter shallower nearshore waters only briefly to spawn (T. Jagielo, Washington Department of Fish and Wildlife, personal communication). Egg nests have been sighted via SCUBA in the reserves, however most or all of the broodstock may not typically be within working SCUBA depths and are possibly out of the reserve boundaries altogether (except during spawning). Still, assuming larger males guard larger egg masses during the nesting season, larger males should have a disproportionately larger relation (on a per fish basis) with the reproductive potential of the population. In this study, *O. elongatus* were significantly larger in reserves. Therefore, the reserve areas could be contributing disproportionately more to the reproductive potential of the population than the amount of area contained in reserves would indicate.

Despite possible disproportionate contribution to *O. elongatus* reproductive potential from reserves compared to non-reserves, both reserves and non-reserves have similar densities of subadult recruits, i.e. densities of individuals less than 50cm were similar in reserves compared to non-reserves, in fact non-reserves appeared to have slightly more fish this size. YOY *O. elongatus* have been found initially in soft-bottom areas, for example bays and coves, and then disappearing from this habitat and beginning

to appear in nearshore rocky reef habitat sometime before the end of their first year. Due to the rocky nature of the San Juan Channel study area, shallow soft bottom habitat is scarce. Therefore, it is quite likely that *O. elongatus* found on different rocky reefs (including site pairs in this study) initially recruited to the same areas of soft-bottom habitat. If reserves were contributing disproportionately more reproductive potential than a per area basis would indicate and we assume there is not homing in juveniles, it would follow that *O. elongatus* in reserves are augmenting recruitment in non-reserves since densities of subadults are similar in reserves and non-reserves and reserves seem to produce more recruits per area (m²). The network of marine reserves may be augmenting recruitment of subadult *O. elongatus* in the areas outside the reserves.

Striped surfperch (*E. lateralis*) are almost never caught in the San Juan Islands because they are not targeted. A related species, pile perch (*Damalichthys vacca*), inhabits pilings under docks and is commonly caught by anglers, especially youngsters, targeting them. *E. lateralis* does not typically inhabit these piling areas. The lack of fishing pressure for *E. lateralis* explains similar length-frequency distributions in reserves and non-reserves. The network of marine reserves seems to have no direct effect on demographics of *E. lateralis* in the area.

YOY *S. caurinus* / *S. maliger* appear to be affected by factors other than reserve/non-reserve status and differences between site pairs. Possibilities include extreme nearshore (10's of meters-scale and within 10-20m from shore) bathymetry and

resultant physical oceanography. YOY recruit distribution in the field appeared to correlate with tidal current eddies. Retention in tidal current eddies may be the mechanism driving patterns of YOY abundance.

In addition, mortality of YOY appeared higher in reserves, perhaps due to increased predation and/or cannibalism by more abundant and larger fishes, especially *S. caurinus* and *O. elongatus*, in reserve sites. In terms of marine reserve design, this argues for networks of many smaller reserves and avoiding establishment of reserves in zones of high YOY recruitment.

Three species of rockfish were sighted only in the three sites that exhibited large densities of YOY recruits. These three species were *S. maliger* (also note: all 23 *S. maliger* sighted were subadults), *S. flavidus* (also all subadults), and *S. melanops*. These three sites, which had high YOY recruitment and greater *Sebastes* species abundance, were one reserve site and two non-reserves. Recruitment may be structuring species diversity patterns for the *Sebastes* genus in San Juan Channel.

Marine mammal predation inside reserves

One criticism of reserves is the belief some people have that marine mammals will simply consume any increases in fish stocks inside the reserve, effectively canceling out any increases. Marine mammals sighted during two years of 12 months-a-year on the water in San Juan Channel include: numerous harbor seals (*Phoca vitulina*), an

occasional group of river otters (*Lutra canadensis*), one pod of orca whales (*Orcinus orca*), a minke whale (*Balaenoptera acutorostrata*) twice, and a very occasional Dall's porpoise (*Phocoenoides dalli*) and harbor porpoise (*Phocoena phocoena*). Of these, only three seem capable of predation of the target species in this study, namely *P. vitulina*, *L. canadensis* and *O. orca*.

P. vitulina were often seen foraging in waters just offshore from the Shady Cove reserve study site and a haulout exists inside the Yellow Island reserve study site. However, fecal samples (scats) collected in Hood Canal from *P. vitulina* haulouts showed the three most important prey species being Pacific hake (*Merluccius productus*), Pacific herring (*Clupea pallasii*), and salmon (*Salmonidae*); followed by shiner perch (*Cymatogaster aggregata*), market squid (*Loligo opalescens*), Pacific staghorn sculpin (*Leptocottus armatus*), Northern anchovy (*Engraulis mordax*), and plainfin midshipman (*Porichthys notatus*), and not any of the target species in this study (Lance *et al.* 2001). While the San Juan Islands have much more rocky reef habitat than Hood Canal, herring and salmon (2 of the 3 most common prey in the Hood Canal study) are very abundant in the San Juans.

L. canadensis are uncommon, but they have been observed to feed on copper rockfish (*S. caurinus*) (B. Miller, University of Washington, personal communication). This feeding behavior is probably uncommon since *L. canadensis* scat is composed of primarily crab shell.

As for *O. orca*, they are the second most dominant predator in the entire ecosystem, second only to humans (*Homo sapiens*). Rockfish (*Sebastes* spp.) bones have been found in the stomachs of necropsied *O. orca*, however these top predators appear to prefer salmonids (K. Balcomb, Center for Whale Research, personal communication).

SUMMARY

I have divided the eight species of interest in this study into five scenarios based on whether they are increasing or decreasing in density over time, whether they are fished, and whether they are prey.

First, three species are fished and increased in density, *S. caurinus*, *H. decagrammus* and *O. elongatus*. Before reserves, *S. caurinus* and *H. decagrammus* were increasing in abundance and *O. elongatus* were declining. After reserves were implemented, all three increased. These species show direct reserve effects. Species doing well before reserves can do even better after reserves, and reserves can help declining species recover.

Three species are fished and decreased in density, *S. melanops*, *S. flavidus* and *S. maliger*. Before reserves, all three were declining in density. After reserves, *S. melanops* have maintained a presence at the Shady Cove reserve and young *S. flavidus* and *S. maliger* are present. *S. melanops* are not recruiting and *S. flavidus* and *S. maliger* have recently begun recruiting. Why has recruitment of *S. flavidus* and *S. maliger* recurred in the last few years? Perhaps a favorable climate regime improved recruitment. In the future, the combination of increased recruitment and positive reserve effects may help these species recover.

One species was increasing but not fished, *S. emphaeus*. Before reserves, *S. emphaeus* increased. After reserves, continued to increase, but less so where large *O. elongatus* were abundant (this trend was particularly evident at the Shady / Turn pair). Why has the increase been less where large *O. elongatus* are more abundant? The reserve effect is indirect. Reserves appear to increase the densities of predators of small rockfish, in this case *O. elongatus*.

E. lateralis are not fished and not prey. Before reserves, there was insufficient data to determine trends, but after reserves, no difference was evident between reserves and non-reserves. There does not appear to be any reserve effect, direct or indirect, for this species.

YOY *S. caurinus* / *S. maliger* are not fished but are prey. These fishes were larger and more abundant in non-reserves. These fish appear to be affected indirectly by reserves. They are the prey of large *S. caurinus* and *O. elongatus*, which are more abundant and larger in reserves (Table 50).

In conclusion, reserves have a positive, direct effect on increasing, fished populations, such as *S. caurinus*, *H. decagrammus* and *O. elongatus*. These direct effects appear to intensify for species subject to greater fishing pressure. For example, the reserve effect on *O. elongatus* seemed greater than the reserve effect on *S. caurinus*, which was greater than the reserve effect on *H. decagrammus*. Reserves have no direct

Table 50. Factors that may determine the effect of the San Juan Islands Marine Preserves on each species of interest.

Species	Trend over time?	Fished?	Prey?
<i>S. caurinus</i>	Increasing population density	Yes	Perhaps minor
<i>H. decagrammus</i>	Increasing population density	Somewhat	?
<i>S. emphaeus</i>	Increasing population density	Not yet	Yes
<i>S. melanops</i>	Decreasing population density	Yes	?
<i>S. flavidus</i>	Decreasing population density	Yes, and also for probable broodstock in outside waters	?
<i>S. maliger</i>	Decreasing population density	Yes	?
<i>O. elongatus</i>	Recovering population density	Yes	?
<i>E. lateralis</i>	?	Not in study area	?
YOY <i>S. caurinus</i> / <i>S. maliger</i>	?	No	Yes

effect on unfished populations, such as *E. lateralis*. Reserves have no direct effect on decreasing, fished populations such as *S. melanops*, *S. flavidus* and *S. maliger*, although these species may be maintained by reserves with high substrate complexity (e.g. Shady Cove reserve). Alternative management measures appear necessary to recover these species. Reserves can have negative, indirect effects on increasing populations, such as *S. emphaeus*, if reserves increase the density of predators, such as *O. elongatus*. This negative, indirect effect is also apparent for YOY *S. caurinus* / *S. maliger*.

The Point George time-series study allows for examination of trends leading up to reserve implementation, and these results predict which species are most helped by reserves. The 2000 spatial study improves on previous studies with greater statistical power, more species of interest, greater similarity among pairs and uniform age of reserves.

We must be aware of specific local conditions. For example, decreasing species were more successful at the Shady reserve site, perhaps due to favorable habitat. We must also be aware of predator / prey interactions. *S. emphaeus* were very abundant at Turn but not at Shady were large *O. elongatus* were abundant. Also, YOY *S. caurinus* / *S. maliger* and age 1+ *S. maliger* were more abundant and larger in non-reserves.

The results of this work show that marine reserves can be an important fisheries management tool for nearshore rocky reef fish in temperate regions. However, more

traditional fisheries management measures appear to be important components of any viable management scheme. Reserves for temperate nearshore rocky reef should not be expected to show results as quickly as reserves in tropical regions because of the generally slow growing and long lived nature of fish in temperate regions.

FUTURE RESEARCH

Future research needs to address gaps in our knowledge of the life history and ecology of these fish in order to design sound management practices. For example, very little is known about where most rockfish (*Sebastes* species) release their larvae. Some evidence points to migrations away from home sites for parturition. We need to know whether they leave their home site reef. If they do leave their home site reef and go outside reserves, we need to know where they go, at what time of year they go and for how long. Perhaps fishing seasons could be put in place around this activity.

In addition, we need time series data from multiple pairs of reserve and non-reserve sites. We need spatially explicit quantification of fishing effort to better determine fishing mortality. We need to answer the question: “are anglers altering their behavior because of reserves?” perhaps through social science techniques. The effects of climate regimes on each species, especially concerning population growth and recruitment, need to be determined. The food habits of local marine mammals need to be determined. Finally, detailed data on fish movement are needed, including home range sizes of individuals and populations. This information will aid in effective design of marine reserves.

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Appendix A. Population densities for 2000 spatial study sites by species, sampling time and depth strata. Species are the eight species of interest. Sampling time refers to the tidal series during which dive surveys were made. Leg refers to the depth strata of transects (legs 1-3 is 20m-14m, legs 4-6 is 14m-9m, and legs 10-12 is 4m-0m).

Time 1	George R		Neck NR		Shady R		Turn NR		Yellow R		Jones NR		F-ratio P	
SPECIES	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd		
<i>O. elongatus</i>	60 ± 97		80 ± 103		80 ± 140		160 ± 246		80 ± 140		60 ± 97		0.497	0.484
<i>S. caurinus</i>	840 ± 878		220 ± 239		520 ± 424		320 ± 215		220 ± 239		100 ± 141		7.806	0.007 ***
<i>S. melanops</i>	0 ± 0		0 ± 0		100 ± 194		0 ± 0		0 ± 0		0 ± 0		2.647	0.110
<i>S. flavidus</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
<i>S. emphaeus</i>	2180 ± 443		5640 ± 802		1440 ± 2195		5580 ± 8524		720 ± 158		960 ± 2195		3.639	0.062 *
	5		7						9					
<i>H. decagrammus</i>	360 ± 263		80 ± 103		200 ± 211		140 ± 165		60 ± 190		60 ± 135		5.618	0.021 **
<i>E. lateralis</i>	40 ± 126		0 ± 0		0 ± 0		0 ± 0		0 ± 0		60 ± 190		0.077	0.783
<i>S. maliger</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
YOY <i>S. caurinus</i> / <i>maliger</i>	20 ± 63		160 ± 506		1140 ± 2407		0 ± 0		0 ± 0		160 ± 506		1.118	0.295

F-ratios and P values from 3 x 2 ANOVA (site pairs x reserve/non-reserve treatment)

*** P<0.01, ** P<0.05, *

P<0.1

Appendix A (cont). Population densities for 2000 spatial study sites by species, sampling time and depth strata. Species are the eight species of interest. Sampling time refers to the tidal series during which dive surveys were made. Leg is the depth range of the transects (legs 1-3 is 20m-14m, legs 4-6 is 14m-9m, and legs 10-12 is 4m-0m).

Time 3	George R		Neck NR		Shady R		Turn NR		Yellow R		Jones NR		F-ratio P	
SPECIES	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd		
<i>O. elongatus</i>	* 40 ± 84		40 ± 84		280 ± 316		120 ± 169		120 ± 215		40 ± 84		2.945	0.092 *
<i>S. caurinus</i>	500 ± 552		320 ± 444		480 ± 583		340 ± 341		220 ± 382		360 ± 515		0.237	0.629
<i>S. melanops</i>	0 ± 0		0 ± 0		20 ± 63		0 ± 0		0 ± 0		0 ± 0		1.000	0.322
<i>S. flavidus</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
<i>S. emphaeus</i>	4940 ± 9905		1560 ± 4726		3560 ± 5727		19240 ± 20785		1420 ± 4217		200 ± 632		2.034	0.160
<i>H. decagrammus</i>	* 360 ± 207		180 ± 239		240 ± 263		200 ± 163		140 ± 165		60 ± 97		3.872	0.054 *
<i>E. lateralis</i>	40 ± 84		0 ± 0		0 ± 0		0 ± 0		0 ± 0		20 ± 63		0.360	0.551
<i>S. maliger</i>	0 ± 0		140 ± 267		40 ± 126		0 ± 0		0 ± 0		40 ± 84		2.070	0.156
YOY <i>S. caurinus</i> / <i>maliger</i>	0 ± 0		1100 ± 2632		0 ± 0		0 ± 0		0 ± 0		0 ± 0		1.747	0.192

F-ratios and P values from 3 x 2 ANOVA (site pairs x reserve/non-reserve treatment)

*** P<0.01, ** P<0.05, *

P<0.1

Appendix A (cont). Population densities for 2000 spatial study sites by species, sampling time and depth strata. Species are the eight species of interest. Sampling time refers to the tidal series during which dive surveys were made. Leg is the depth range of the transects (legs 1-3 is 20m-14m, legs 4-6 is 14m-9m, and legs 10-12 is 4m-0m).

Time 4	George R		Neck NR		Shady R		Turn NR		Yellow R		Jones NR		F-ratio	P
SPECIES	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd		
<i>O. elongatus</i>	60 ± 84		10 ± 32		110 ± 110		100 ± 82		70 ± 125		20 ± 42		2.751	0.103
<i>S. caurinus</i>	* 450 ± 550		190 ± 273		510 ± 526		310 ± 242		180 ± 244		120 ± 155		3.316	0.074 *
<i>S. melanops</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
<i>S. flavidus</i>	0 ± 0		0 ± 0		30 ± 95		0 ± 0		0 ± 0		0 ± 0		0.636	0.429
<i>S. emphaeus</i>	* 420 ± 702		1890 ± 5977		1840 ± 2258		6150 ± 14221		590 ± 1443		300 ± 675		3.524	0.066 *
<i>H. decagrammus</i>	200 ± 141		100 ± 94		120 ± 92		70 ± 95		120 ± 114		60 ± 70		1.121	0.294
<i>E. lateralis</i>	0 ± 0		0 ± 0		30 ± 95		0 ± 0		10 ± 32		10 ± 32		0.640	0.427
<i>S. maliger</i>	0 ± 0		10 ± 32		20 ± 63		0 ± 0		0 ± 0		0 ± 0		0.192	0.663
YOY <i>S. caurinus</i> / <i>maliger</i>	0 ± 0		10 ± 32		10 ± 32		0 ± 0		0 ± 0		0 ± 0		0.017	0.898

F-ratios and P values from 3 x 2 ANOVA (site pairs x reserve/non-reserve treatment)

*** P<0.01, ** P<0.05, *

P<0.1

Appendix A (cont). Population densities for 2000 spatial study sites by species, sampling time and depth strata. Species are the eight species of interest. Sampling time refers to the tidal series during which dive surveys were made. Leg is the depth range of the transects (legs 1-3 is 20m-14m, legs 4-6 is 14m-9m, and legs 10-12 is 4m-0m).

Legs 1-3	George R		Neck NR		Shady R		Turn NR		Yellow R		Jones NR		F-ratio P	
SPECIES	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd		
<i>O. elongatus</i>	108 ± 100		58 ± 90		217 ± 180		283 ± 185		142 ± 168		58 ± 90		0.118	0.733
<i>S. caurinus</i>	750 ± 616		383 ± 406		850 ± 342		383 ± 244		425 ± 328		258 ± 300		11.982	0.001 ***
<i>S. melanops</i>	0 ± 0		0 ± 0		108 ± 198		0 ± 0		0 ± 0		0 ± 0		3.556	0.064 *
<i>S. flavidus</i>	0 ± 0		0 ± 0		67 ± 231		0 ± 0		0 ± 0		0 ± 0		0.985	0.325
<i>S. emphaeus</i>	8133 ± 9772		7042 ± 8861		4808 ± 4814		21658 ± 19367		2558 ± 3797		750 ± 2050		5.601	0.021 **
<i>H. decagrammus</i>	367 ± 161		258 ± 188		250 ± 265		158 ± 131		183 ± 170		133 ± 130		3.369	0.071 *
<i>E. lateralis</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
<i>S. maliger</i>	0 ± 0		125 ± 245		33 ± 115		0 ± 0		0 ± 0		83 ± 233		2.645	0.109
YOY S.	17 ± 58		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0.985	0.325
<i>caurinus/ maliger</i>														

F-ratios and P values from 3 x 2 ANOVA (site pairs x reserve/non-reserve treatment)

*** P<0.01, ** P<0.05, *

P<0.1

Appendix A (cont). Population densities for 2000 spatial study sites by species, sampling time and depth strata. Species are the eight species of interest. Sampling time refers to the tidal series during which dive surveys were made. Leg is the depth range of the transects (legs 1-3 is 20m-14m, legs 4-6 is 14m-9m, and legs 10-12 is 4m-0m).

Legs 4-6 SPECIES	George R		Neck NR		Shady R		Turn NR		Yellow R		Jones NR		F-ratio P
	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	
<i>O. elongatus</i>	*	75 ± 97	17 ± 58		200 ± 270		100 ± 95		92 ± 178		58 ± 79		3.898 0.053 *
<i>S. caurinus</i>	***	950 ± 735	208 ± 235		733 ± 446		450 ± 235		117 ± 175		367 ± 438		7.524 0.008 ***
<i>S. melanops</i>		0 ± 0	0 ± 0		17 ± 58		0 ± 0		0 ± 0		0 ± 0		0.972 0.328
<i>S. flavidus</i>		0 ± 0	0 ± 0		25 ± 87		0 ± 0		0 ± 0		0 ± 0		0.972 0.328
<i>S. emphaeus</i>	**	300 ± 588	600 ± 1274		2042 ± 2875		7783 ± 9374		0 ± 0		717 ± 754		6.453 0.013 **
<i>H. decagrammus</i>	***	442 ± 223	142 ± 168		175 ± 114		175 ± 142		117 ± 164		67 ± 107		8.254 0.005 ***
<i>E. lateralis</i>		17 ± 58	0 ± 0		0 ± 0		0 ± 0		0 ± 0		8 ± 29		0.302 0.584
<i>S. maliger</i>		0 ± 0	0 ± 0		25 ± 62		0 ± 0		0 ± 0		17 ± 58		0.251 0.618
YOY <i>S. caurinus</i> / <i>maliger</i>		0 ± 0	700 ± 2425		0 ± 0		0 ± 0		0 ± 0		17 ± 58		1.829 0.181

F-ratios and P values from 3 x 2 ANOVA (site pairs x reserve/non-reserve treatment)

*** P<0.01, ** P<0.05, *

P<0.1

Appendix A (cont). Population densities for 2000 spatial study sites by species, sampling time and depth strata. Species are the eight species of interest. Sampling time refers to the tidal series during which dive surveys were made. Leg is the depth range of the transects (legs 1-3 is 20m-14m, legs 4-6 is 14m-9m, and legs 10-12 is 4m-0m).

Legs 10-12 SPECIES	George R		Neck NR		Shady R		Turn NR		Yellow R		Jones NR		F-ratio P	
	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd	fish/ha	sd		
<i>O. elongatus</i>	17 ± 58		33 ± 78		8 ± 29		8 ± 29		0 ± 0		0 ± 0		0.665	0.418
<i>S. caurinus</i>	** 17 ± 58		17 ± 58		25 ± 62		100 ± 128		0 ± 0		0 ± 0		4.383	0.040 **
<i>S. melanops</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
<i>S. flavidus</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
<i>S. emphaeus</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
<i>H. decagrammus</i>	167 ± 235		17 ± 58		83 ± 127		92 ± 131		25 ± 45		8 ± 29		2.447	0.123
<i>E. lateralis</i>	* 100 ± 200		0 ± 0		83 ± 127		8 ± 29		25 ± 62		67 ± 178		3.061	0.085 *
<i>S. maliger</i>	0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0		0 ± 0			
YOY <i>S. caurinus</i> / <i>maliger</i>	17 ± 58		100 ± 249		967 ± 2215		0 ± 0		0 ± 0		133 ± 462		1.270	0.264

F-ratios and P values from 3 x 2 ANOVA (site pairs x reserve/non-reserve treatment)

*** P<0.01, ** P<0.05, *

P<0.1