

San Juan County Bottomfish Recovery Project

2006 Biological Assessment Final Report

November 15th, 2006



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EXECUTIVE SUMMARY

During the 2006 field season the Bottomfish Recovery Project resurveyed three bottomfish recovery zones (**BRZs**) and their respective reference sites. These sites were first surveyed using this protocol in 2001. The three site pairs included: Lime Kiln, Bell Island and Charles Island BRZs and their associated reference sites: Edwards Point, Cliff Island and Long Island. In addition, this report contains analysis of an eight-year period of time-series data from 1998-2001 and 2006 at Lime Kiln and Bell Island BRZs.

Surveys to date reveal scant evidence for successful recovery of bottomfish inside the three BRZs examined in 2006—the only clear result being a decrease in lingcod density. The BRZs appear to benefit copper rockfish and kelp greenling. These findings are supported by acoustic tagging studies of fish movement, which indicate that BRZs contain adequate area for copper rockfish but are too small for lingcod.

Lack of time since reserve implementation is probably no longer a reasonable explanation for the absence of positive reserve effects in the San Juan County voluntary BRZs. Eight year time-series trends for lingcod in Lime Kiln and Bell Island BRZs follow a pattern consistent with non-reserve reference sites associated with a longer time-series from older and larger reserves.

There is need to evaluate bottomfish recovery for the four other BRZs which have only been surveyed in 2002. Surveys of fishing pressure inside BRZs and reference sites during lingcod season also should be updated and expanded in order to better interpret dive survey results. Once these tasks are completed, the project will be at a natural position for a comprehensive data analysis, manuscript write-up for peer-reviewed literature, and final evaluation by the San Juan County Marine Resources Committee.

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INTRODUCTION

In 1997, the recently formed Marine Resources Committee of the San Juan County Board of County Commissioners created eight Bottomfish Recovery Zones (**BRZs**). The BRZs' purpose was to recover populations of bottomfish through voluntary restrictions on bottomfishing (Kaill 1999). In order to measure reserve effects, dive surveys have been undertaken to monitor the bottomfish resource. In 2006, dive surveys of three BRZs and their reference sites (Figure 1) were undertaken. Charles Island BRZ and Edwards Point, Long Island and Cliff Island reference sites were also surveyed in 2001 (Eisenhardt *et al.* 2002). Lime Kiln BRZ and Bell Island BRZ also were surveyed during the same study in 2001 as well as previously from 1998-2000 (Kaill 2001). This report details 2006 findings and summarizes bottomfish trends overtime.

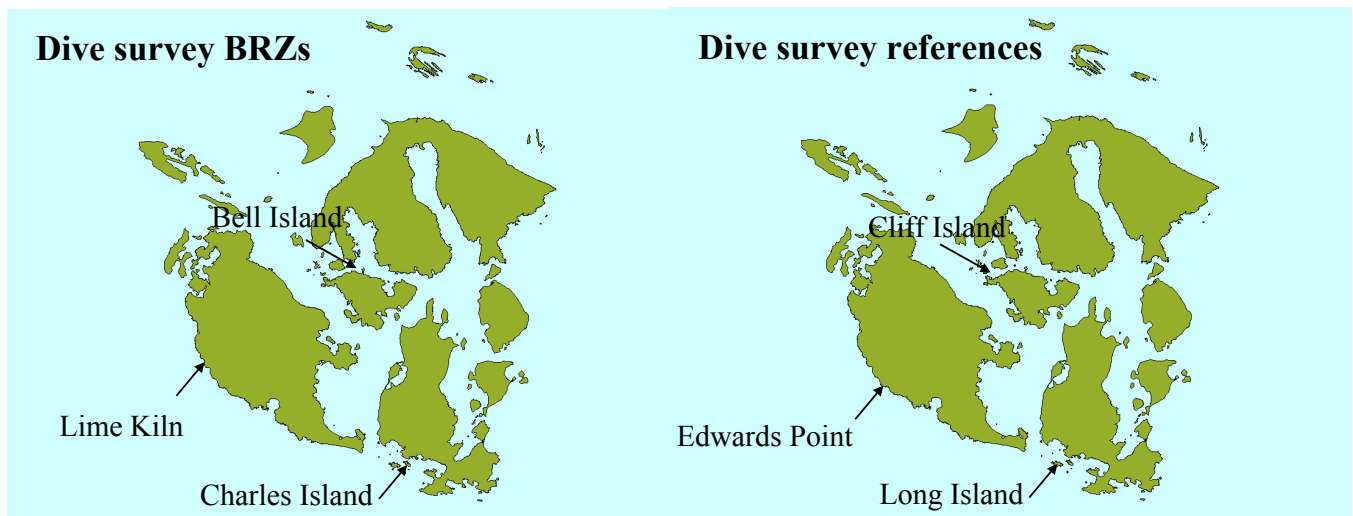


Figure 1. 2006 survey sites. BRZs noted on lefthand map, reference sites noted on righthand map.

METHODS AND MATERIALS

Survey methodology

Four observers, utilizing SCUBA, completed visual band transects. The primary diver was equipped with a depth gauge, fish-length 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 (Paddock 1996). The primary diver was accompanied by a supplemental diver who assisted in spotting fish and took photographs. A second pair of divers carried a 25m fiberglass tape reel, a data recording slate, paper and pencil. All four observers exited the boat at GPS coordinates randomly chosen from a predetermined subset of coordinates. Tide Current Predictor software (Pentcheff 2000) was used to adjust depths for tide height. Any human activity in the area, especially fishing, and its intensity was recorded.

Once observers entered the water, they proceeded via the most direct route 1m off the bottom to a depth of 18.3m (60ft). The primary observer was tethered to the end of the fiberglass tape. Next, while staying 1m above the substrate, the primary observer pair began moving across the reef slope at a rate of approximately 30 fin strokes per minute. The secondary diver pair remained stationary and held onto the tape reel as it unwound. While swimming the transect, the primary observer noted the depth, total length (TL, to nearest cm), and species for every fish encountered within a 2m x 2m x 2m cube centered on the primary observer. A fish that suddenly swam off the transect as the primary observers approached was counted, the assumption being the observers' presence caused the fish to move. Total length was determined by reading off the measuring device as it was slowly placed directly against or beneath the lateral line of the fish in question, or 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). Target species included: 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*).

The primary observer was informed when 25m of tape had been let out with three sharp tugs on the tape. Then, the primary observer remained stationary while the secondary diver pair reeled up the tape and rejoined the primary pair. One secondary diver reeled the tape while the other noted habitat characteristics of the transect. The secondary observers surveyed precisely the same 25m x 2m x 2m transect as the primary observer. 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 & <3m, 5=boulder>3m), substrate percent cover (sediments, bare rock, encrusting animals, macroalgae by species), and abundance of macroinvertebrates by species.

As mentioned above, the first transect of the survey began at 60 ft depth. The first three transects were constant depth, beginning and ending at 60ft. The fourth transect began at 60ft, and ended at 50ft. The fifth began at 50ft (where the fourth ended) and ended at 40ft, and so on up to no more than eight transects per dive. The primary observer was able to change depth along a constant slope and end the 25m long transect at a pre-determined depth. This was accomplished by moving approximately parallel to shore and simultaneously increasing depth at a constant rate with the help of reminders from the supplemental diver. During the transect, the primary observer looked left, right, up, down, and searched boulder piles and crevices. Potential bias associated with steering towards/away from fish or particular habitats was avoided by focusing only on the instantaneous 2m x 2m x 2m cube of the transect and using glances at the depth gauge coupled with sense of body position in the water to maintain a constant rate of both speed and depth change.

In summary, each dive survey consisted of up to eight 25m x 2m x 2m transects. Three transects at constant depth of 60ft were followed by up to five transects (as time, air and current permitted) with the ending depth 10ft shallower than the start. This data collection protocol focused effort on deeper areas (below the lower limit of algal abundance) typically dominated by target bottomfish species. The protocol provides data for analyses of fish density which control for microhabitat driven variability in fish abundance. Minor modifications were made from the “zig-zag” protocol used in 2001 (Eisenhardt 2001) because of diver safety concerns associated with multiple ascent/descent shifts in a dive. These modifications should not effect comparisons between years because the start points were randomized (i.e. not fixed transects) and transects covered the same depth range.

Lime Kiln (BRZ#5) and its reference site, Edwards Point, were surveyed on August 30th and September 1st. Charles Island (BRZ#3) and its reference site Long Island, were surveyed on August 29th and 31st. Bell Island (BRZ#2) and its reference site, Cliff Island, were surveyed on August 28th, 29th, and 30th.

Data analysis

Species and site specific data were analyzed by calculating mean fish density (fish per 100m²) and length-frequency histograms. Primary observer fish counts from each transect were doubled (each transect was 50m², so multiply by 2 to give fish per 100m²) and averaged for each species and site combination. A variance for fish density per transect was calculated for each depth stratum of each dive survey. Values for each BRZ were compared to the corresponding values of its reference site using ANOVA followed by a t-test on significant results. Length-frequency distributions from both the primary and secondary observers were plotted and compared using a t-test.

Time-series data for 1998-2000 (Kaill 2001) and 2001 (Eisenhardt *et al.* 2002) and 2006 (this study) are available for two BRZs: Lime Kiln and Bell Island. Only 2001 and 2006 data are available for

Charles Island BRZ and Edwards Point, Cliff Island and Long Island reference sites. Mean fish density and variance were converted to fish per 100m² units, graphed and compared using 3 x 2 blocked design analysis of variance (ANOVA, SPSS statistical software), $p < 0.05$. In addition, comparisons between fish densities in 2001 and 2006 were made for all sites using a 2 x 6 ANOVA in SPSS statistical software. Comparisons of fish length between 2001 and 2006 were not made since neither verification of 2006 observer accuracy nor measurement of an observer bias conversion factor for 2006 to 2001 were possible due to resource constraints.

RESULTS

Comparisons of fish density between BRZs and associated reference sites showed no statistically significant differences with two exceptions. Copper rockfish (*S. caurinus*) were more abundant at Lime Kiln BRZ compared to the Edwards Point reference site ($p = 0.004$) and both Puget Sound (*S. emphaeus*) and quillback rockfish (*S. maliger*) were less abundant at the Charles Island BRZ as compared to the Long Island reference site ($p = 0.044$ and $p = 0.049$) (Table 1).

Lingcod (*O. elongatus*) did not show statistically significant size difference for any of the three reserve/reference pairs (Figure 2, Table 2). Mean length of copper rockfish (*S. caurinus*) was greater in the Bell Island BRZ than the Cliff Island reference site ($p = 0.0013$), while Lime Kiln and Charles Island showed no significant difference compared to their reference sites (Figure 3, Table 3). Black rockfish (*S. melanops*) and yellowtail rockfish (*S. flavidus*) were only sighted in the Lime Kiln BRZ (Figure 4). Mean lengths of kelp greenling (*H. decagrammus*) showed no significant differences between BRZs and associated reference sites (Figure 5, Table 5). Striped surfperch (*E. lateralis*) also showed no significant size differences (Figure 6, Table 6). Mean length of Puget Sound rockfish (*S. emphaeus*) was greater in the Bell Island BRZ compared to the Cliff Island reference site ($p = 0.017$); Charles Island BRZ showed

no significant difference with the Long Island reference; and since no Puget Sound rockfish (*S. *emphaeus**) were sighted at Edwards Point reference a length comparison for the Lime Kiln BRZ could not be made (Figure 7, Table 7). Mean length of quillback rockfish (*S. *maliger**) were not significantly different for all three BRZ / reference comparisons (Figure 8, Table 8).

Habitat characterizations conducted for each BRZ / reference site pair revealed similar findings for substrate percent cover (Figure 9), densities of macroinvertebrates (Figure 10), algal species composition (Figure 11), reef slope (Figure 12), aspect (Figure 13) and substrate complexity (Figure 14). Fishing activity was observed at the Bell Island BRZ on August 28th, and the Long Island reference site on August 31st. Salmon trolling was observed at both Lime Kiln BRZ and Edwards Point reference on August 30th (Table 11).

Time-series data from Lime Kiln BRZ revealed a peak in lingcod density in 2001, a decline in Puget Sound rockfish density from 1999 to 2006, an increase in copper rockfish density from 2000 to 2006, and an increase in kelp greenling density from 1999 to 2000, 2000 to 2001 and 2001 to 2006 (Figure 15). Time-series data from Bell Island BRZ revealed an increase in lingcod density from 2000 to 2001, a decline in Puget Sound rockfish density from 2000 to 2001, a decline in copper rockfish density from 1998 to 1999, and an increase in kelp greenling density from 2000 to 2001 (Figure 15).

ANOVA results show significant models for lingcod, copper rockfish, Puget Sound rockfish, kelp greenling and striped surfperch with a significant year effect for the decrease in lingcod density (Table 12). Associated t-tests reveal increased kelp greenling density at Lime Kiln BRZ from 2001 to 2006, and decreased lingcod and copper rockfish densities at Edwards Point (Lime Kiln's reference) (Table 13). ANOVA including 1998-2000 could not be completed because only averages were available, rather than the necessary transect count data.

DISCUSSION

The 2006 dive survey results show few differences in fish density and mean length between Lime Kiln, Charles Island and Bell Island BRZs and their respective reference sites, Edwards Point, Long Island and Cliff Island. This appears to be a consistent pattern. In 2001, there were also few differences between these sites and their reference sites. The reason for lack of reserve effects could be that there are no differences to detect, or that differences were too small to be detected with the sample size used (i.e. statistical power).

One potential mechanism driving the lack of reserve effects could be a lack of differences in fishing pressure between BRZs and reference sites. Prior studies have shown little or no difference in fishing effort between BRZs and reference sites (Kaill 2001, Koski 2001, Davis 2003). These studies have found limited fishing pressure on bottomfish in San Juan County in general although fishermen disrespecting the voluntary bottomfishing restrictions inside BRZs have been documented. Washington Department of Fish and Wildlife's (**WDFW's**) recent reduction of the legal season for rockfish retention to coincide with lingcod season has probably even further reduced fishing pressure on bottomfish since these studies on fishing pressure were completed. Spatial variation in fishing effort throughout the waters of San Juan County is likely. Bottomfish anglers reported the westside of San Juan Island was a hot-spot for lingcod during anecdotal interviews made over the last few years. Greater intensity of fishing effort could be why comparisons of fish densities from 2001 to 2006 showed most changes at the two sites on the westside, Lime Kiln BRZ and Edwards Point reference.

Limited time since reserve implementation has been previously hypothesized to explain a lack of significant differences between BRZs and reference sites. This is probably no longer a reasonable explanation for lack of reserve effects in the San Juan County voluntary BRZs. Studies of older reserves in the area have shown reserve effects including increased bottomfish densities and/or sizes occurring within a decade (Moulton 1977, Caselle 1987, Miller 1991, Palsson 1998, Eisenhardt 2001). The San

Juan County voluntary BRZs were created almost a decade ago (9 years; 1997) and have yet to show clear and consistent reserve effects.

Marine mammal predation on bottomfish is often mentioned as a potential limit on BRZ effectiveness, however this does not seem likely. A recent study on harbor seal diet in the San Juans (Lance and Jefferies 2006) suggests that they do not typically feed on rockfish and lingcod. Analysis of 506 harbor seal scats collected from 20 locations during spring, summer, fall and winter of 2005 found that the frequency of occurrence for rockfish and *Hexagrammid* (greenling and lingcod) in the scats of harbor seals inhabiting the San Juan Islands was 2.3% and 1.0% of samples collected, respectively. Instead, harbor seals fed mainly on Pacific herring (occurring in 57% of samples), adult salmonids (31%), Gadid species (24%) Pacific sand lance (20%) and Northern anchovy (19%). Another year-round study (Jones 2000) found evidence that rockfish and greenling occurred in 3% and 4% respectively of river otter scat collected from sites around San Juan Island.

The 8-year time-series trends (1998-2006) for Lime Kiln and Bell Island BRZs indicate mixed reserve effects, possibly due to ecological factors. The 2001 peak in lingcod density could have resulted from the regionally strong 1995 year-class of age-0 juvenile recruits (Jagiello and Wallace 2005). Perhaps this strong 1995 year-class preyed upon Puget Sound rockfish, precipitating the downward trend in density for this small rockfish species. Supporting this idea, small *Sebastes* have been observed in 10-30% of lingcod diets examined in a recent, year-round study of lingcod in the San Juans (Beaudreau 2006). Of these *Sebastes*, the only specimens identified to species were Puget Sound rockfish. Increasing densities of kelp greenling and copper rockfish during the same time period, indicate lingcod could selectivity prey upon Puget Sound rockfish before copper rockfish or kelp greenling. Alternately, temporal density trends of Puget Sound rockfish, copper rockfish and kelp greenling could be explained by differences in juvenile recruitment of these prey species. For example, copper rockfish have had relatively strong juvenile recruitment over the past several years (Hayden-Spear 2005). Recruitment

over this time period of Puget Sound rockfish and kelp greenling are unknown, but the hypothesis would follow that Puget Sound rockfish recruitment was down and kelp greenling recruitment was up.

A longer time-series from older and larger reserves with reference sites exists for comparison. This dataset has shown densities of lingcod in the Point Caution reserve, one of the larger San Juan Islands Marine Preserves formed in 1990, increased through the 1990's to a peak around 2002 and then leveled off through 2006 (Palsson 2006). In the same study, lingcod density trends in the non-reserve reference followed the reserve trend through 2002, but then declined back to late 1990's levels by 2006. Lime Kiln and Bell Island BRZs did not follow the reserve trend, but rather mirrored the non-reserve reference trend. In summary, changes in lingcod density overtime at Lime Kiln BRZ follow the pattern described by the non-reserve reference in Palsson's study, supporting a lack of reserve effect for lingcod in the BRZ.

Reserve size is another factor possibly hindering BRZ effectiveness. Other marine reserve studies in the San Juan Islands which have shown reserve effects after a decade (Moulton 1977, Caselle 1987, Miller 1991, Palsson 1998, Eisenhardt 2001) examined larger reserves, suggesting voluntary BRZs could be too small. Copper and quillback rockfish movement has been measured with acoustic tags (Mathews 1990a, Mathews 1990b, Eisenhardt 2003) and shown to be large enough to put some fish outside BRZ-sized areas, especially if fish are tagged near reserve boundaries. Smaller reserves generally have greater perimeter to area ratios and thus increase the likelihood of fish inside the reserve being near a boundary. Sonic tagged lingcod were observed to leave the Lime Kiln BRZ for months at a time and then return (Griffin 2000). Kelp greenling home range are large enough for fish tagged inside a BRZ to move outside the reserve for weeks to months at a time (Perez 2005).

These data do not support that Lime Kiln, Bell Island and Charles Island voluntary BRZs are recovering bottomfish. Potential reasons for this include: limited statistical power to detect change, lack of differences in fishing pressure between BRZs and reference sites, inadequate reserve size, and

ecological factors such as trophic cascade and juvenile recruitment. A local harbor seal population near carrying capacity and time since reserve implementation are unlikely reasons for the lack of a reserve effect.

FUTURE RESEARCH

San Juan County's voluntary BRZs are at a management crossroads. In the case of the Lime Kiln, Bell Island and Charles Island sites, data do not support their success in recovering bottomfish. The other four BRZs (Pile Point, Bare Island, Gull Rock and Kellett Buff) and their reference sites (Eagle Point, Skipjack Island, Flattop Island and Open Bay) have only been surveyed once (in 2002) and should be re-surveyed in 2007. During these surveys, efforts should be made to increase sample sizes and diver consistency.

Surveys of fishing pressure inside BRZs and reference sites during lingcod season also need to be updated and expanded. Aerial surveys would provide coverage of all sites during the same slack tide, when nearly all bottomfishing occurs in San Juan County. Additionally this would decrease bias that could be introduced by boat observer affecting fisherman behavior. Increased knowledge of fishing pressure patterns would be beneficial when interpreting results of future dive survey data.

After completing dive and fishing pressure surveys in 2007, the ten-year project will be at a natural position for a comprehensive data analysis and manuscript write-up for the peer-reviewed literature. At this time, the San Juan County MRC can critically assess the value of voluntary BRZs and the lessons learned can be shared with others through peer-reviewed literature.

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ACKNOWLEDGEMENTS

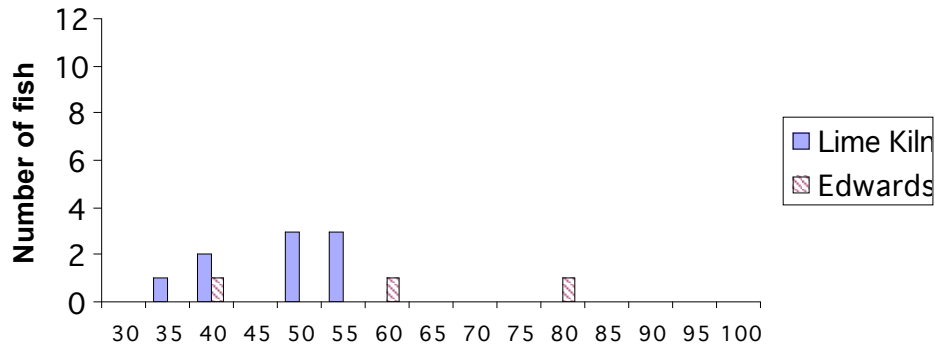
Primary funding for this project was provided by the Northwest Straits Commission through the Marine Resources Committee of the Board of County Commissioners of San Juan County. Volunteer divers J. Gaydos, P. Kitaeff, K. Marrie and J. Nichols assisted with data collection. The author wishes to thank the Friday Harbor Laboratories and Director Ken Sebens for donating dock space, dive lockers and other support. Jody Kennedy kindly opened the Marine Resources Committee office for use as a base of field operations. Finally, a hearty thanks to The SeaDoc Society and especially Joe Gaydos for providing an excellent dive boat, support for volunteer divers, office space and editorial comments during the preparation of this report.

FISH / 100m ²	Lime Kiln (R)	Edwards (NR)	Charles (R)	Long (NR)	Bell (R)	Cliff (NR)
Lingcod						
mean	0.714	0.375	0.375	0.308	0.333	0.286
SD	1.267	0.806	1.088	0.751	0.778	0.726
Two-sample t test,	p = 0.383		p = 0.851		p = 0.873	
Copper Rockfish						
mean	4.000	0.250	1.750	1.231	2.667	2.571
SD	4.707	0.683	1.612	2.088	3.339	3.715
Two-sample t test,	p = 0.004 **		p = 0.456		p = 0.946	
Black Rockfish						
mean	0.286	0.000	0.000	0.000	0.000	0.000
SD	1.069	0.000				
Two-sample t test,	p = 0.293		p = ND		p = ND	
Yellowtail Rockfish						
mean	0.000	0.000	0.000	0.000	0.000	0.000
SD						
Two-sample t test,	p = ND		p = ND		p = ND	
Puget Sound Rockfish						
mean	2.429	0.000	0.375	9.077	4.333	2.000
SD	5.557	0.000	1.500	16.485	5.033	3.419
Two-sample t test,	p = 0.091		p = 0.044 *		p = 0.174	
Kelp Greenling						
mean	3.000	1.875	2.375	2.154	1.500	1.143
SD	2.038	2.247	1.821	2.512	1.931	1.703
Two-sample t test,	p = 0.164		p = 0.786		p = 0.621	
Striped Surfperch						
mean	0.000	0.000	0.125	0.308	0.833	0.286
SD			0.500	1.109	1.337	1.069
Two-sample t test,	p = ND		p = 0.560		p = 0.257	
Quillback Rockfish						
mean	0.429	0.875	0.000	1.077	0.333	0.286
SD	1.158	2.630	0.000	2.100	1.155	0.726
Two-sample t test,	p = 0.562		p = 0.049 *		p = 0.899	

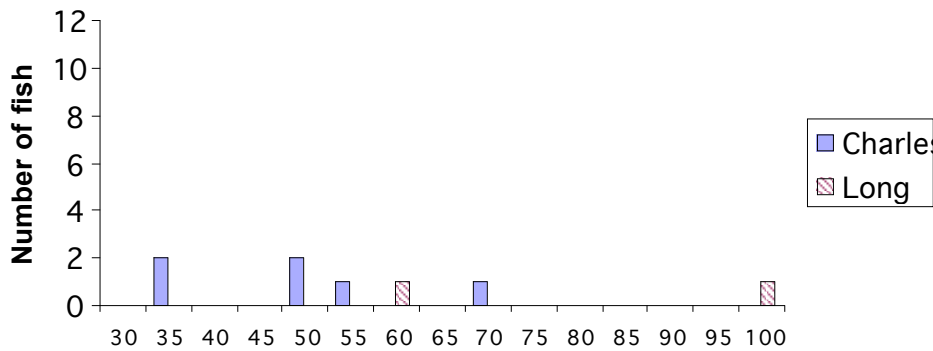
ANOVA (2x3): Reserve, p=.134; Site pair, p=.125; Reserve x Site pair, p=.057

Table 1. Mean fish density and standard deviations for each target species by site. P-values from t-tests, ND = no data since the species was not seen at one or both of the sites. N = 14 transects (2m x 25m) for Lime Kiln and Cliff Island, N = 16 for Edwards Point and Charles Island, N = 12 for Bell Island, and N = 13 for Long Island.

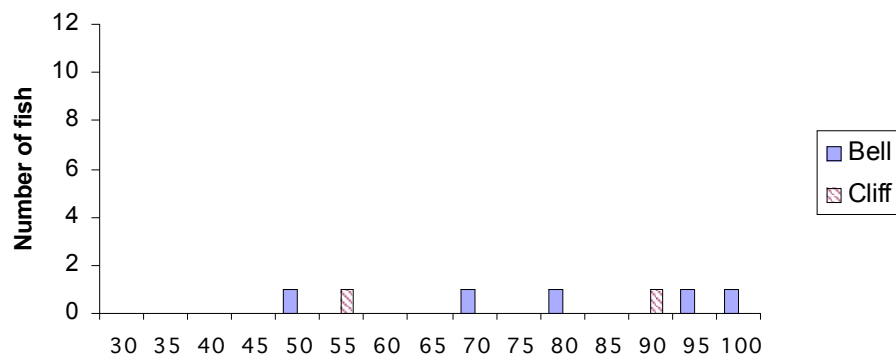
Lingcod (*O. elongatus*)



Lingcod (*O. elongatus*)



Lingcod (*O. elongatus*)



Total length (cm)

Figure 2. Length-frequency distribution of *O. elongatus* by BRZ / reference site pairs.

	<i>Lime Kiln</i>	<i>Edwards</i>	<i>Charles</i>	<i>Long</i>	<i>Bell</i>	<i>Cliff</i>
N	9	3	6	2	5	2
mean	47.33333	60	49.16667	80	79	72.5
SD	7.106335	20	13.19722	28.28427	20.12461	24.74874
t-test p	0.114026		0.064287		0.728172	

Table 2. Sample size, mean length, standard deviation and t-test p-value for *O. elongatus* by site.

Copper Rockfish (*S. caurinus*)

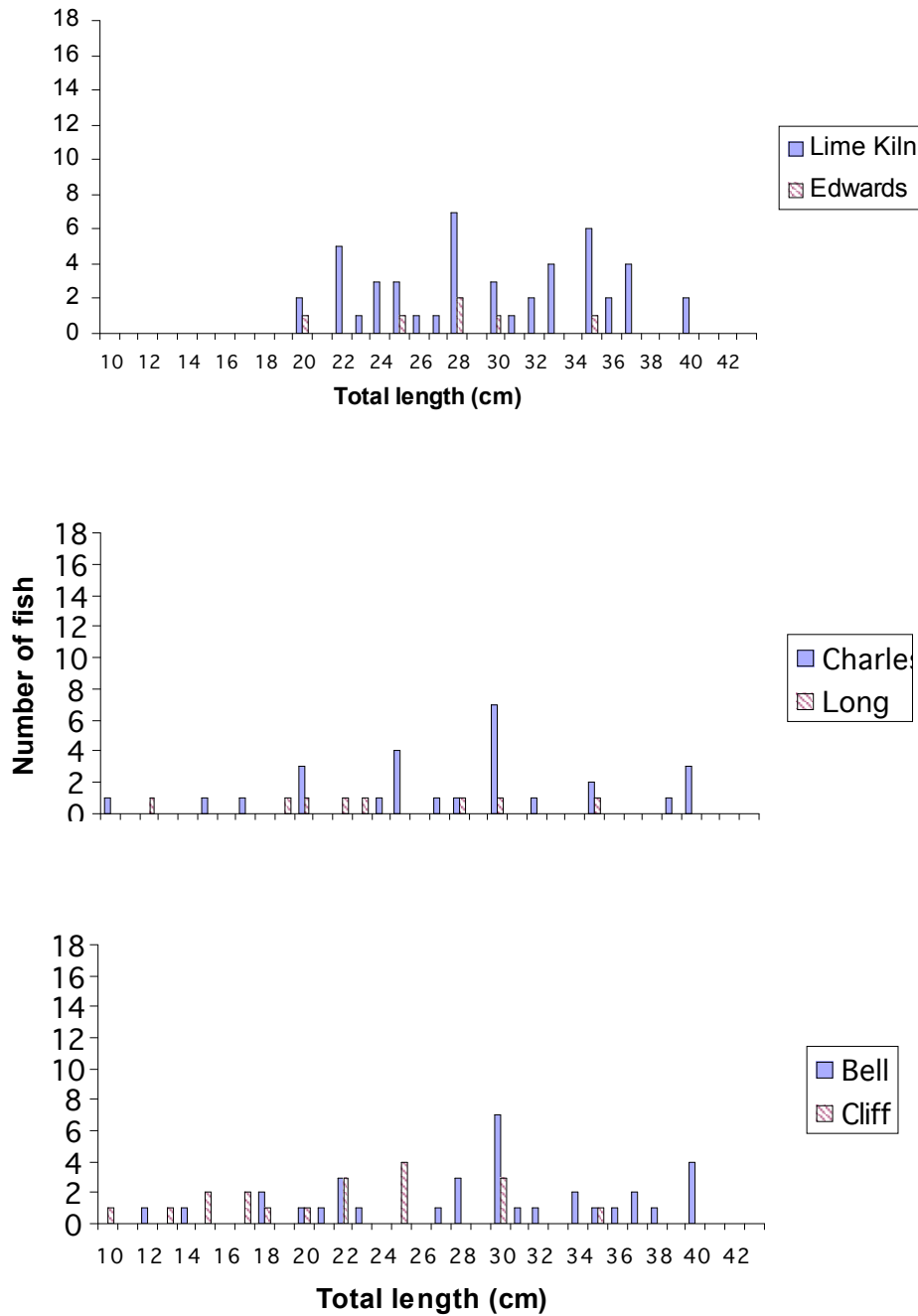
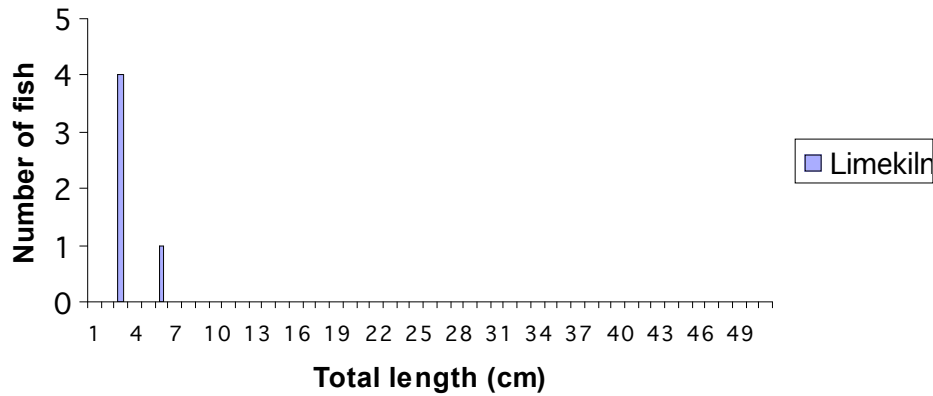


Figure 3. Length-frequency distribution of *S. caurinus* by BRZ / reference site pairs.

	<i>Lime Kiln</i>	<i>Edwards</i>	<i>Charles</i>	<i>Long</i>	<i>Bell</i>	<i>Cliff</i>
N	47	6	27	8	34	19
mean	29.70213	27.66667	27.85185	23.625	29.02941	21.84211
SD	5.641133	5.006662	7.729582	7.190023	7.665291	6.726921
t-test p	0.404216		0.177378		0.001259 **	

Table 3. Sample size, mean length, standard deviation and t-test p-value for *S. caurinus* by site.

Yellowtail Rockfish (*S. flavidus*)



Black Rockfish (*S. melanops*)

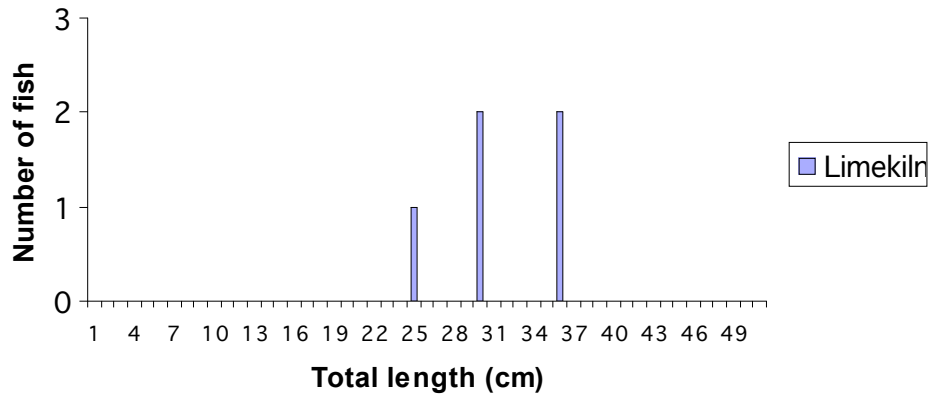


Figure 4. Length-frequency distribution of *S. flavidus* and *S. melanops* at Lime Kiln BRZ, the only site where either species was sighted.

<i>Limekiln</i>	<i>Black</i>	<i>Yellowtail</i>
N	5	45
mean(cm)	31.4	13
SD	4.669047	10.24695

Table 4. Sample size, mean length and standard deviation for *S. flavidus* and *S. melanops* at Lime Kiln BRZ.

Kelp Greenling (*H. decagrammus*)

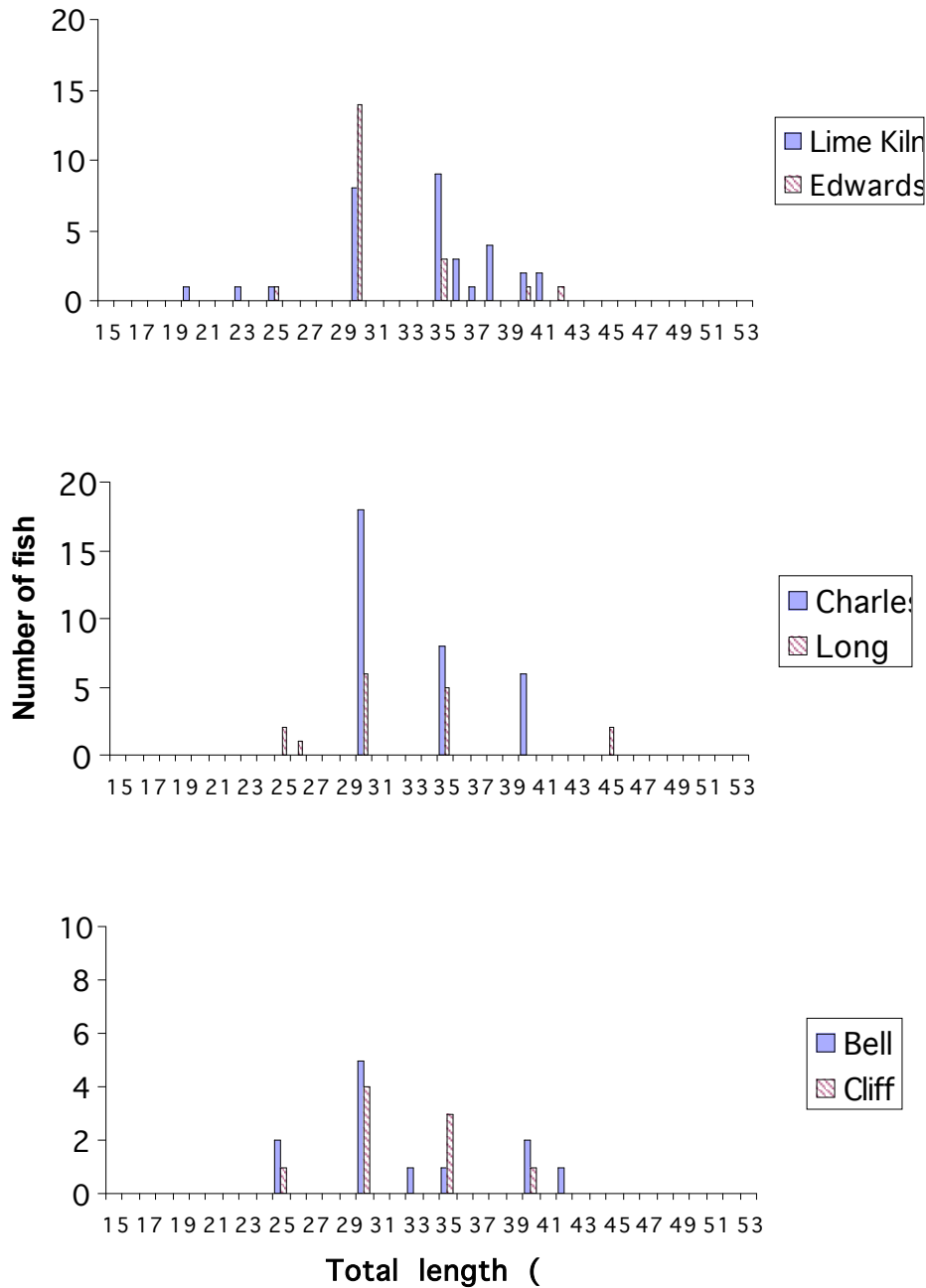


Figure 5. Length-frequency distribution of *H. decagrammus* by BRZ / reference site pairs.

	<i>Lime Kiln</i>	<i>Edwards</i>	<i>Charles</i>	<i>Long</i>	<i>Bell</i>	<i>Cliff</i>
N	32	20	32	17	12	9
mean	33.8125	31.6	33.125	31.23529	32.5	32.22222
SD	5.04456	3.925624	3.965578	7.964997	5.664884	4.409586
t-test p	0.101405		0.271114		0.904367	

Table 5. Sample size, mean length, standard deviation and t-test p-value for *H. decagrammus* by site.

Striped Surfperch (*E. lateralis*)

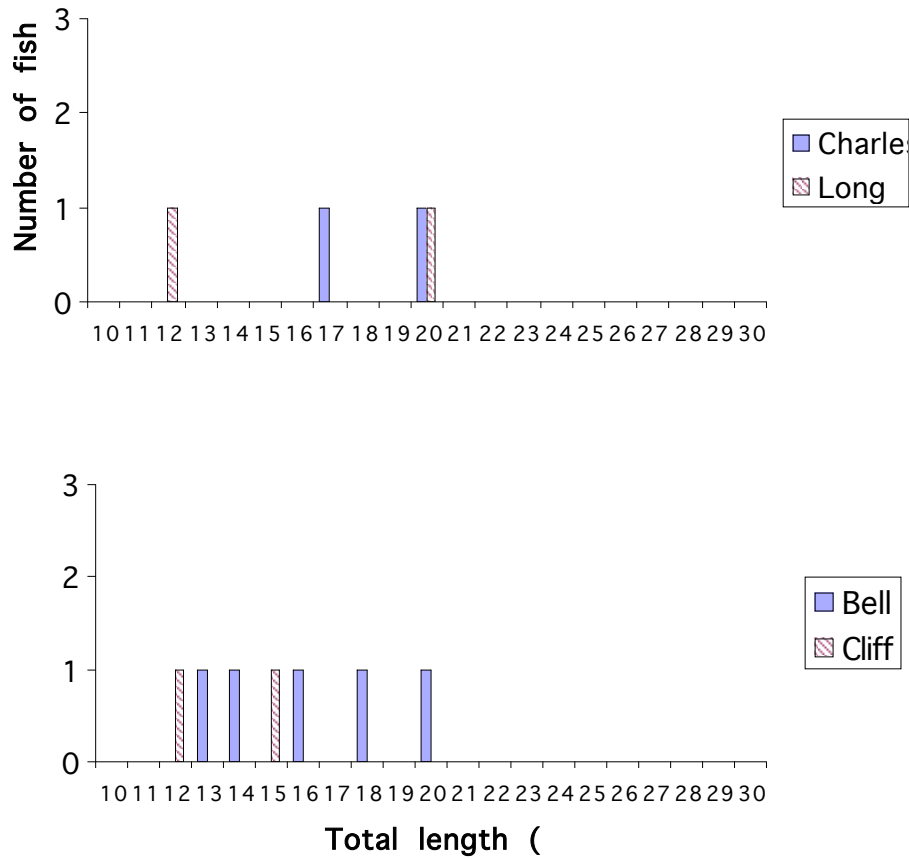


Figure 6. Length-frequency distribution of *E. lateralis* by BRZ / reference site pairs.

	<i>Lime Kiln</i>	<i>Edwards</i>	<i>Charles</i>	<i>Long</i>	<i>Bell</i>	<i>Cliff</i>
N	0	0	2	2	5	2
mean			18.5	16	16.2	13.5
SD			2.12132	5.656854	2.863564	2.12132
t-test p			0.61764		0.290521	

Table 6. Sample size, mean length, standard deviation and t-test p-value for *E. lateralis* by site.

Puget Sound Rockfish (*S. emphaeus*)

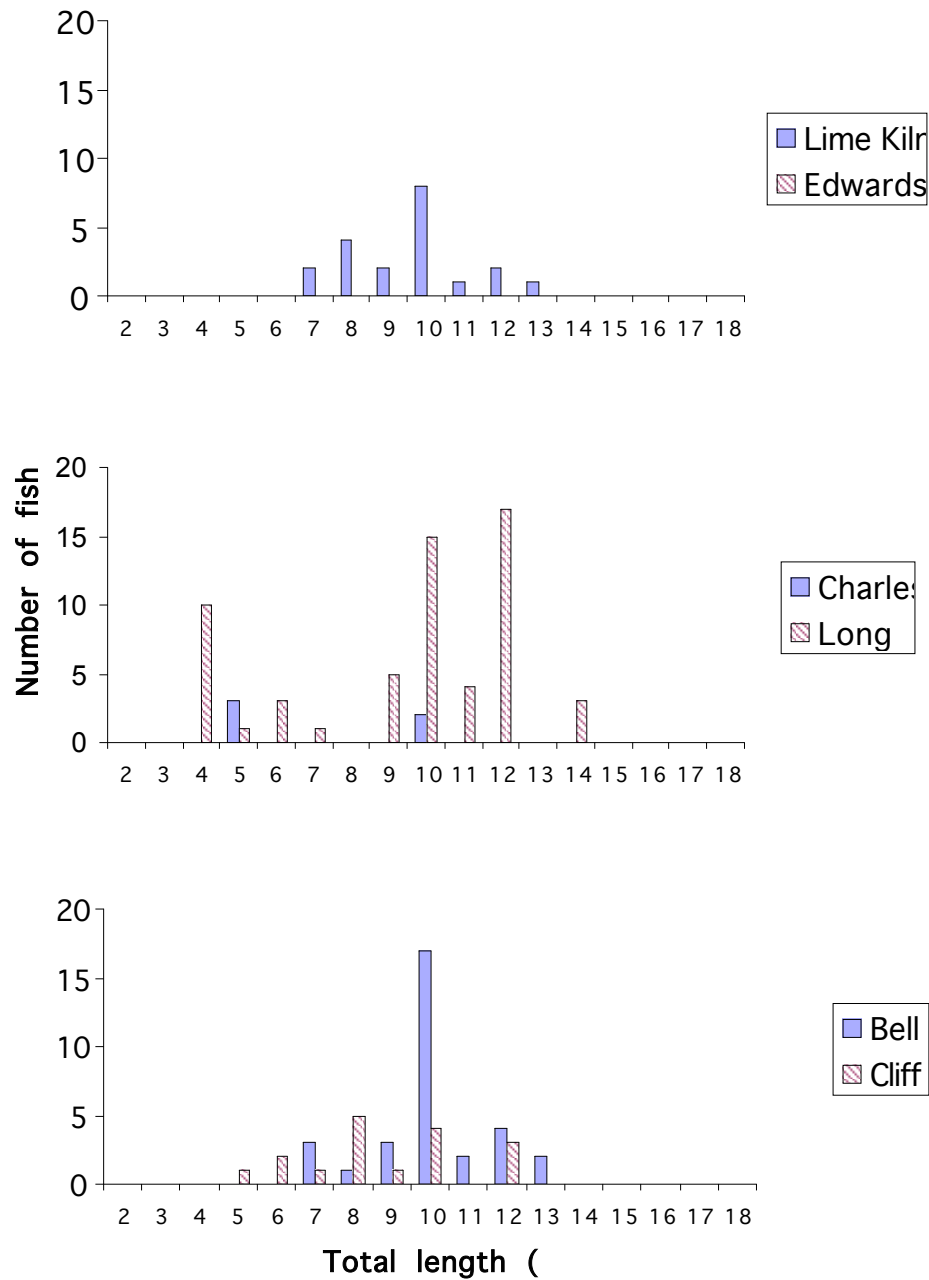


Figure 7. Length-frequency distribution of *S. emphaeus* by BRZ / reference site pairs.

	<i>Lime Kiln</i>	<i>Edwards</i>	<i>Charles</i>	<i>Long</i>	<i>Bell</i>	<i>Cliff</i>
N	20	0	5	59	32	17
mean	9.6		7	9.40678	10.0625	8.764706
SD	1.63514		2.738613	3.068857	1.501343	2.136861
t-test p			0.095106		0.016793 *	

Table 7. Sample size, mean length, standard deviation and t-test p-value for *S. emphaeus* by site.

Quillback Rockfish (*S. maliger*)

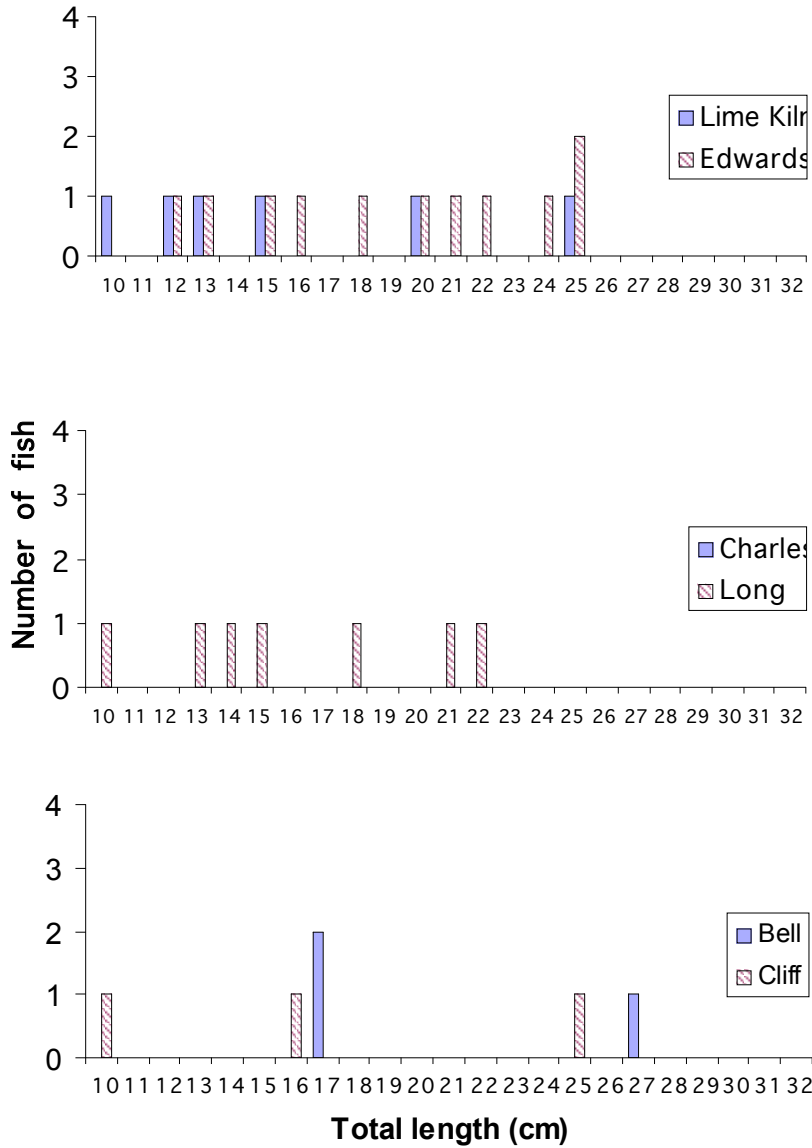


Figure 8. Length-frequency distribution of *S. maliger* by BRZ / reference site pairs.

	<i>Lime Kiln</i>	<i>Edwards</i>	<i>Charles</i>	<i>Long</i>	<i>Bell</i>	<i>Cliff</i>
N	6	11	0	7	6	3
mean	15.83333	19.18182		16.14286	27.5	17
SD	5.636193	4.707827		4.375255	8.712061	7.549834
t-test p	0.209894				0.120296	

Table 8. Sample size, mean length, standard deviation and t-test p-value for *S. maliger* by site.

SITE	DATE	VIS (m)	DISTANCE (m)	AREA (ha)	Temp (deg C)	Max depth (ft)	Duration (min)	Current (knots)	Start time
Bell	28-Aug-06	4.0	100	0.02	11.1	66	45	0.2	1000
Cliff	28-Aug-06	4.0	150	0.03	12.2	69	41	0.5	1400
Charles	29-Aug-06	4.0	200	0.04	11.1	65	39	0.5	800
Long	29-Aug-06	4.0	125	0.03	11.1	66	40	1	1027
Bell	29-Aug-06	4.5	200	0.04	12.2	63	41	0.5	1500
Limekiln	30-Aug-06	9.0	200	0.04	10.0	65	36	0.75	1030
Edwards	30-Aug-06	6.1	200	0.04	10.0	63	31	0	1215
Cliff	30-Aug-06	5.5	200	0.04	11.7	63	34	0	1515
Charles	31-Aug-06	6.1	200	0.04	12.2	65	44	0.5	1040
Long	31-Aug-06	7.6	200	0.04	12.2	63	38	no data	1300
Edwards	01-Sep-06	7.6	200	0.04	10.0	63	33	0	1235
Limekiln	01-Sep-06	7.9	150	0.03	10.0	65	34	0->2	1424

Table 9. Physical dive data collected during sampling dives.

SITE	DATE	Start point (N. Lat)	Start point (W. Long)	Direction swam from GPS point
Bell	28-Aug-06	48.35.754	122.58.795	north
Cliff	28-Aug-06	48.35.475	123.00.700	north(1-3) south(4-6)
Charles	29-Aug-06	48.26.527	122.54.759	north
Long	29-Aug-06	48.26.591	122.55.269	south
Bell	29-Aug-06	48.35.822	122.58.841	south(1-3) north(4-7) south(8)
Limekiln	30-Aug-06	48.30.915	123.09.178	north1-3) south(4-8)
Edwards	30-Aug-06	48.29.834	123.08.061	north
Cliff	30-Aug-06	48.35.480	123.00.747	south
Charles	31-Aug-06	48.26.300	122.54.541	north(1-6) surfaced, swam to crack/cove on island for 7&8
Long	31-Aug-06	48.26.200	122.55.641	south
Edwards	01-Sep-06	48.29.985	123.08.165	south
Limekiln	01-Sep-06	48.31.087	123.09.160	south

Table 10. Start points and direction swam for each dive survey.

SITE	DATE	Weather	Fishing before	Fishing after
Bell	28-Aug-06	sun	one boat, 2 rods	0
Cliff	28-Aug-06	sun		0
Charles	29-Aug-06	overcast, W10		0
Long	29-Aug-06	overcast, W15-20		0
Bell	29-Aug-06	sun		0
Limekiln	30-Aug-06	sun		0 1 salmon troll, 2 rods
Edwards	30-Aug-06	sun	1 salmon troll, 2 rods	0
Cliff	30-Aug-06	sun		0
Charles	31-Aug-06	sun		0
Long	31-Aug-06	sun		0 one boat, two rods jigging
Edwards	01-Sep-06	sun, NW10	orcas, 15-20porposing & breaching	0
Limekiln	01-Sep-06	sun		0

Table 11. Weather and fishing activity observed before and after each dive.

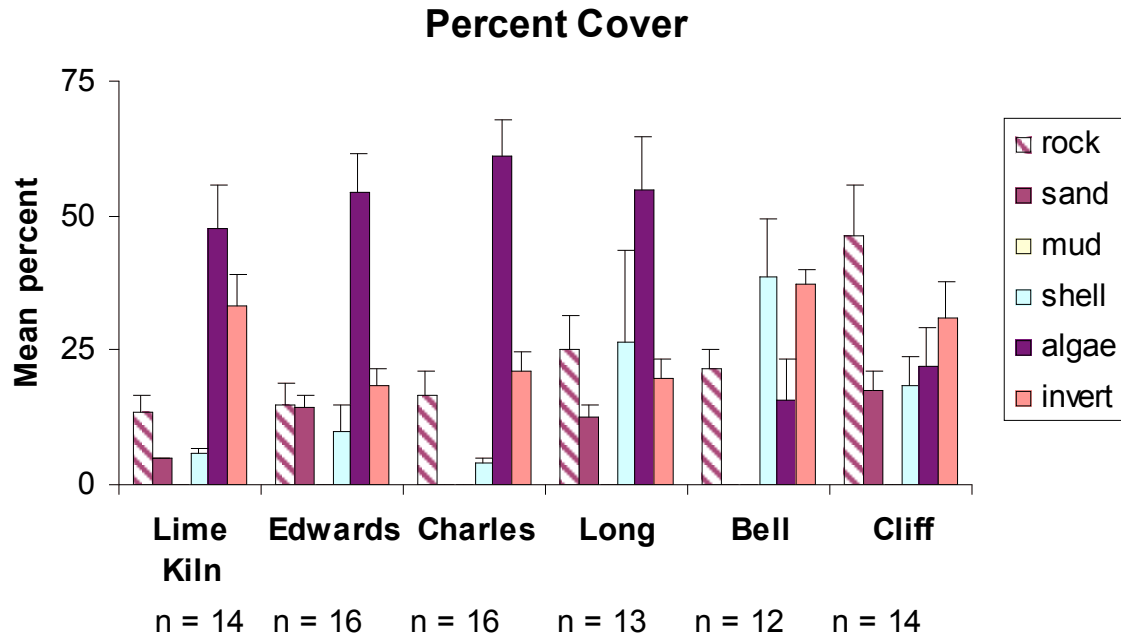


Figure 9. Mean substrate percent covers for each study site. Sample sizes are number of transects for which data were collected. Error bars are standard errors.

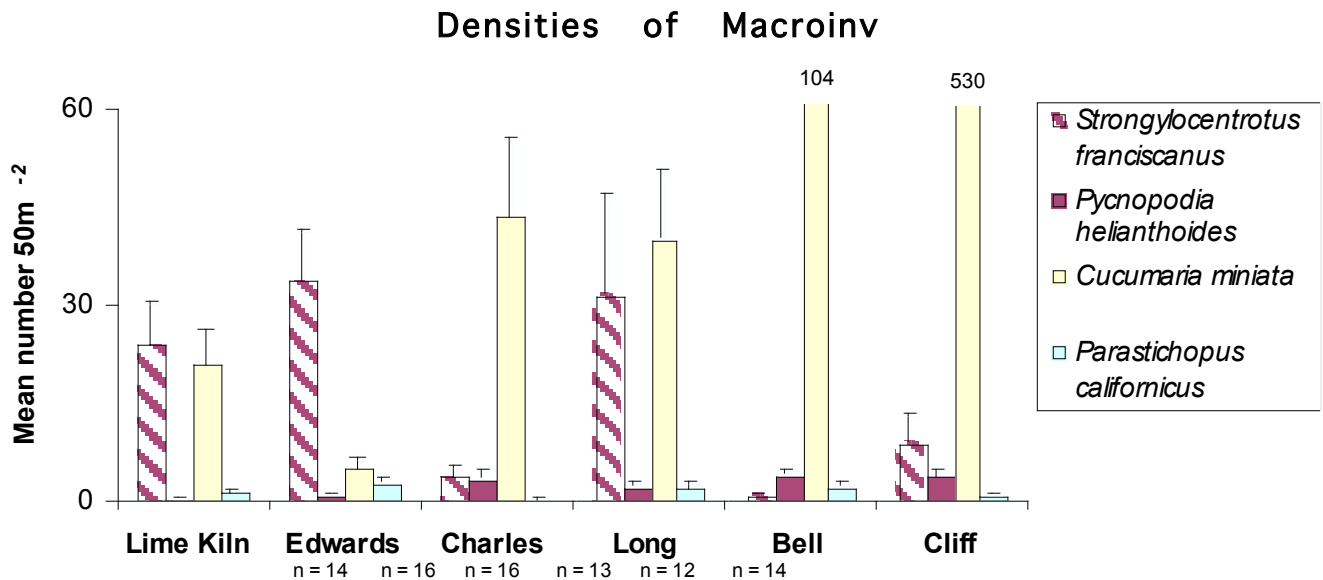


Figure 10. Densities of macroinvertebrates in each study site. Sample sizes are number of transects for which data were collected. Error bars are standard errors.

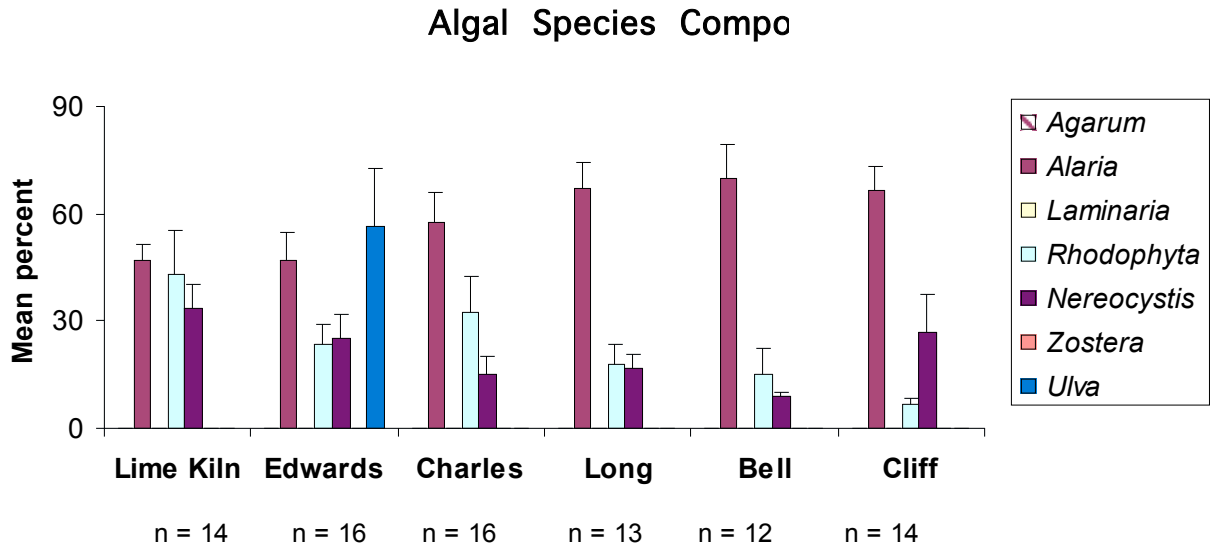


Figure 11. Algal species composition for each study site. Sample sizes are number of transects for which data were collected. Error bars are standard errors.

Reef Slope

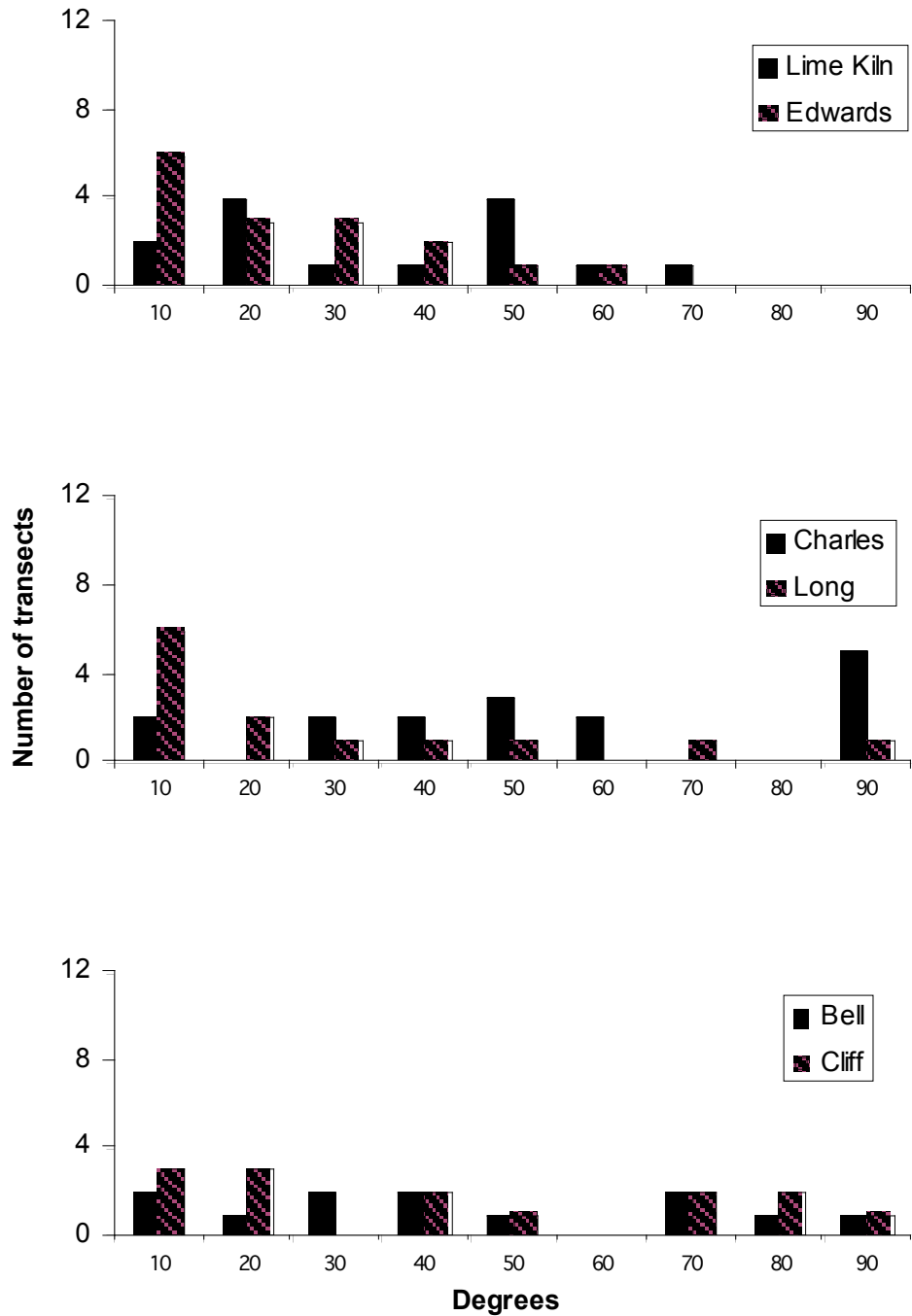


Figure 12. Frequency distribution of reef slope for each BRZ / reference site pair.

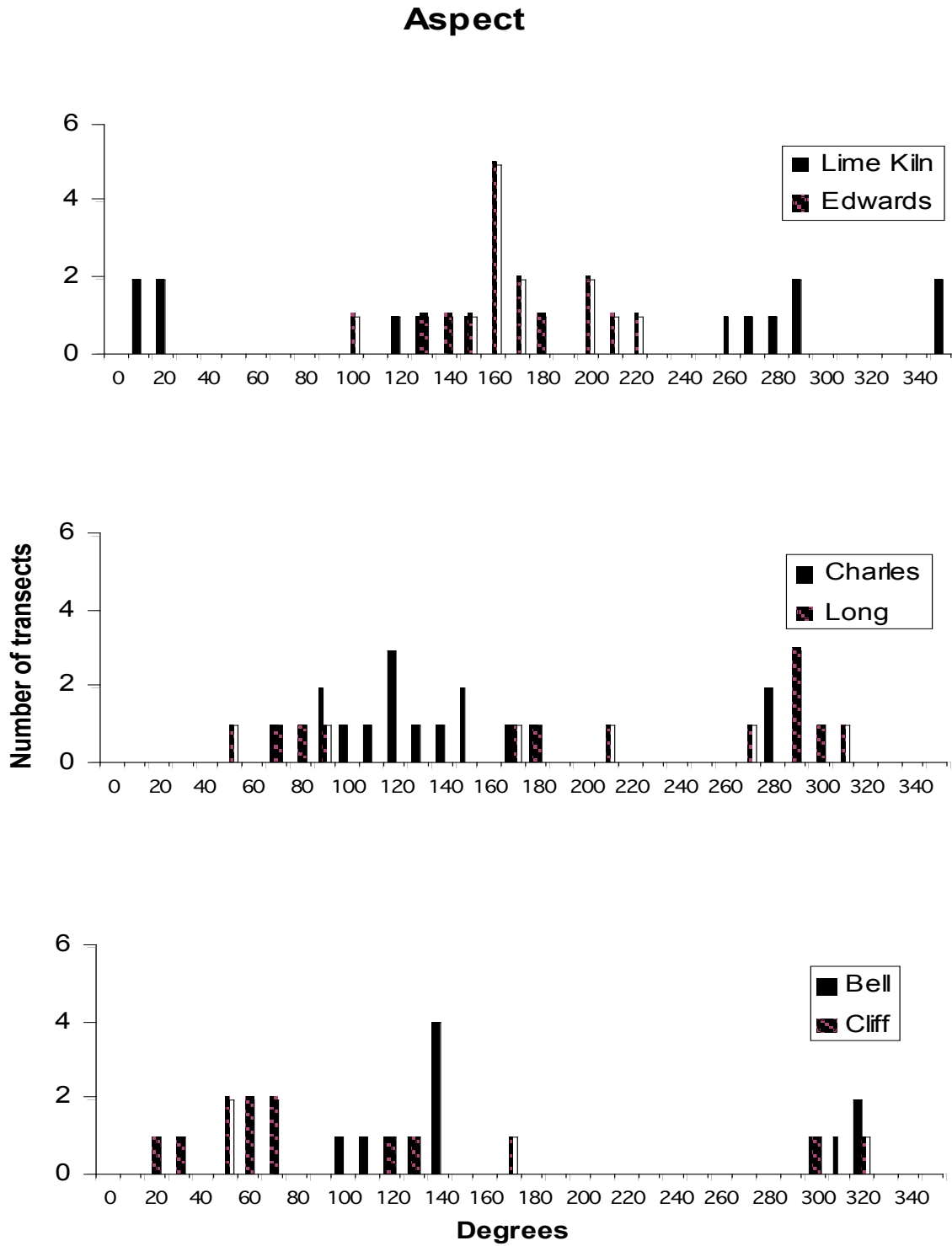


Figure 13. Frequency distribution of aspect for each BRZ / reference site pair.

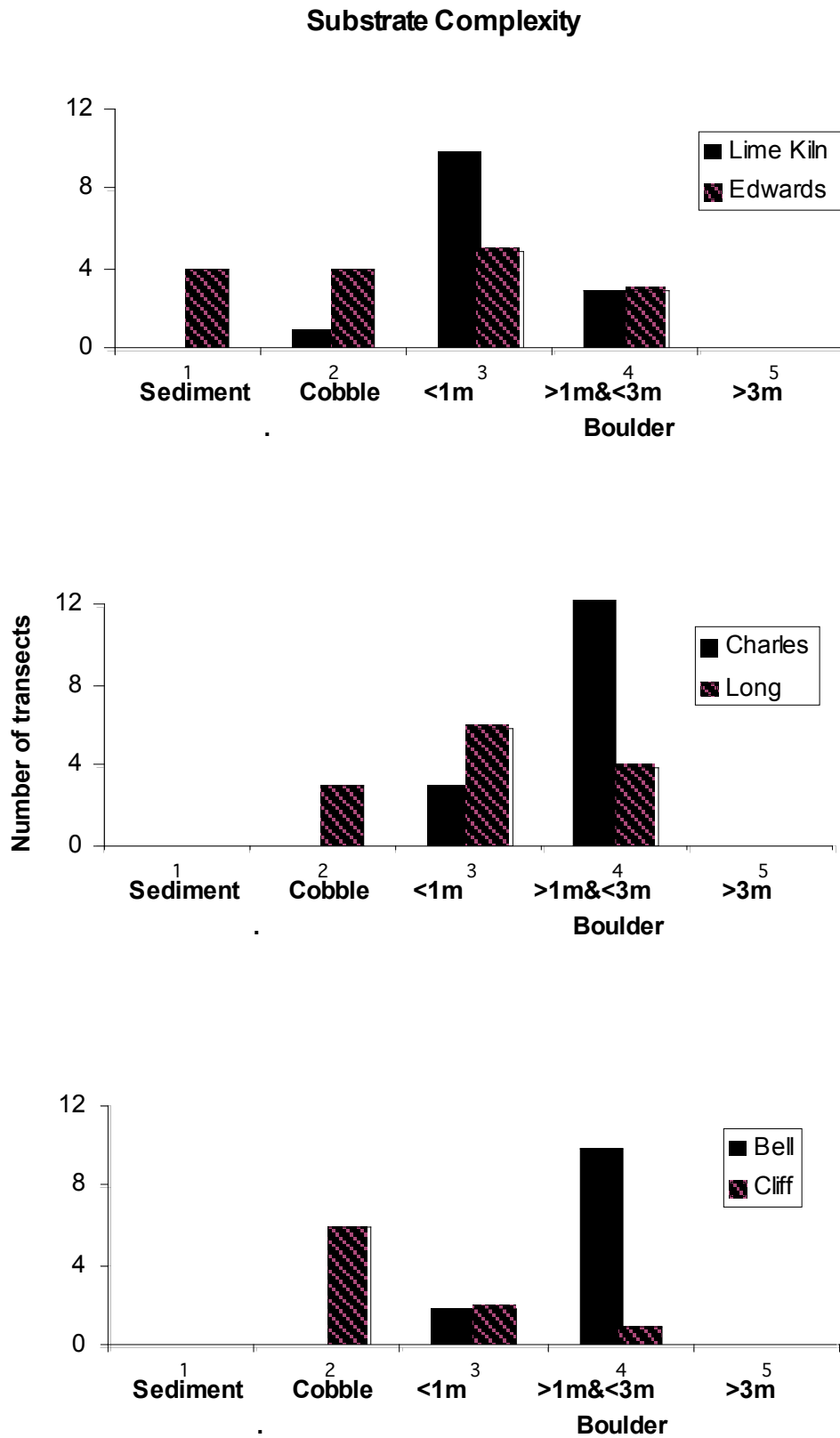


Figure 14. Substrate complexity frequency distributions for each BRZ / reference site pair.

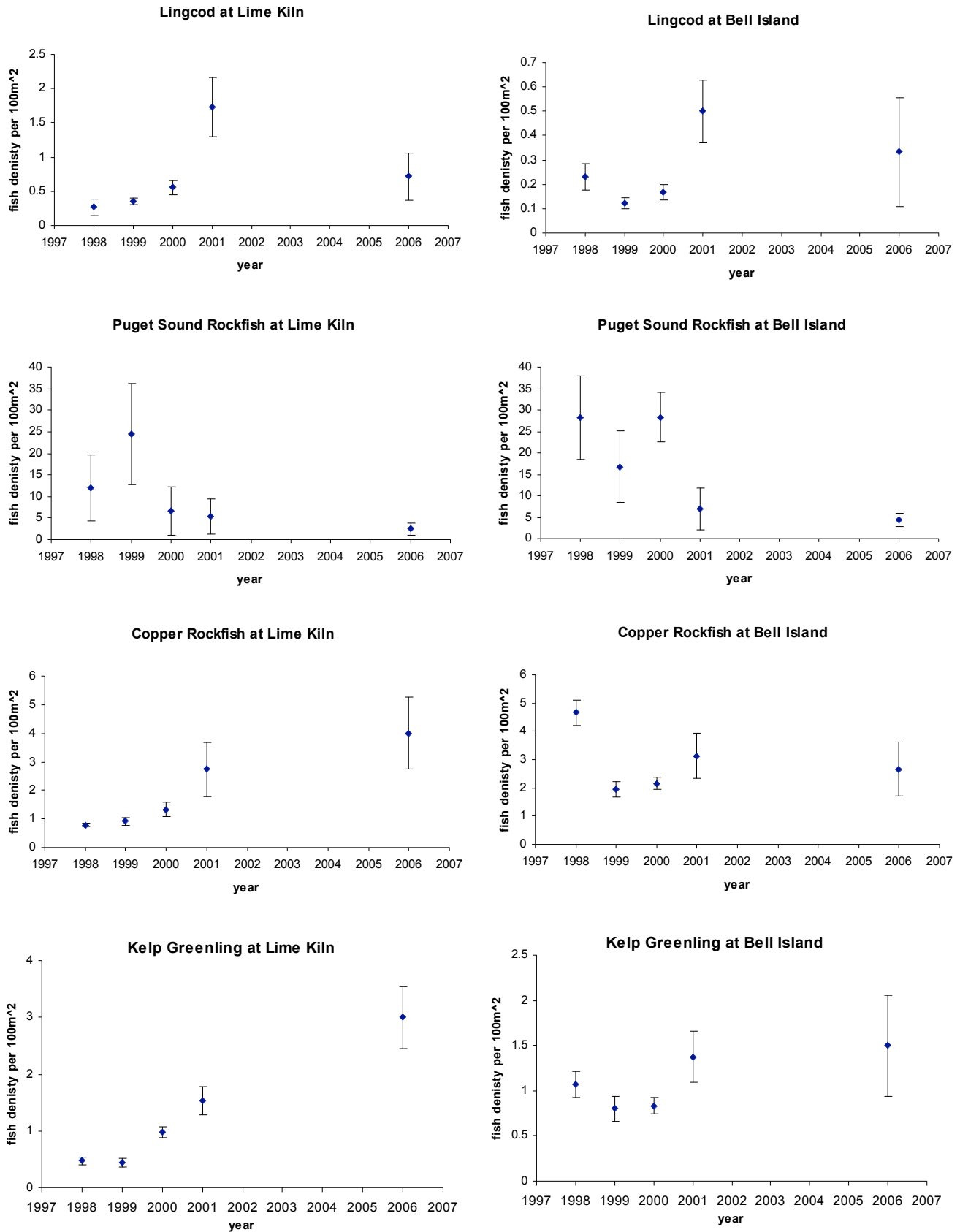


Figure 15. Time-series of fish density for lingcod, Puget Sound rockfish, copper rockfish and kelp greenling at Lime Kiln BRZ and Bell Island BRZ.

Site	Year	Mean	SE	DF	F	Significance
S	2006	a	1	1	8	
	2007	b	1	1	3	
	2008	c	1	1		
	2009	d	1	1		
	2010	e	1	1		
	2011	f	1	7	0	
	2012	g	1	1	6	
I	2006		1	1	8	
	2007		1	1	0	
	2008		1	1		
	2009		1	1		
	2010		1	0	5	
	2011		1	1	6	
	2012		1	1	3	
R	2006		1	1		
	2007		1	1		
	2008		1	1		
	2009	g	1	1	9	
	2010	h	1	1		
	2011		1	1		
	2012		1	0	4	
E	2006	g	5	5		
	2007		5	5		
	2008		5	5	3	
	2009		5	5	5	
	2010	2	5	5	0	
	2011	8	5	0	0	
	2012		5	5	3	
R	2006	2	5	5	8	
	2007	8	5	5	4	
	2008	8	5	5	3	
	2009	8	5	0	5	
	2010	0	5	2	6	
	2011	9	5	9	8	
	2012	8	5	0	2	
E	2006	3	6	5		
	2007	3	6	1		
	2008		6	5		
	2009		6	6		
	2010	0	6	8		
	2011	0	6	3		
	2012	7	6	5		
S	2006	0	9			
	2007		9			
	2008	0	9			
	2009	0	9			
	2010		9			
	2011	0	9			
	2012	30	9			
S	2006	2	3			
	2007		3			
	2008	9	3			
	2009	8	3			
	2010		3			
	2011	0	3			
	2012	2	3			

a
b
c
d
e
f
g

e

Table 12. ANOVA results for fish densities by site and year (continued).

FISH / 100m2	Lime Kiln (R)		Charles (R)		Bell (R)	
	2001	2006	2001	2006	2001	2006
Lingcod						
mean	1.733	0.714	0.625	0.375	0.500	0.333
SD	1.668	1.267	0.885	1.088	0.516	0.778
Two-sample t test,	p =	0.076	p =	0.481	p =	0.502
Copper Rockfish						
mean	2.738	4.000	1.375	1.750	3.125	2.667
SD	3.665	4.707	2.029	1.612	3.222	3.339
Two-sample t test,	p =	0.211	p =	0.567	p =	0.717
Puget Sound Rockfish						
mean	5.333	2.429	0.438	0.375	6.813	4.333
SD	15.500	5.557	1.209	1.500	19.515	5.033
Two-sample t test,	p =	0.514	p =	0.898	p =	0.672
Kelp Greenling						
mean	1.533	3.000	2.250	2.375	1.375	1.500
SD	0.990	2.038	1.000	1.821	1.147	1.931
Two-sample t test,	p =	.019 *	p =	0.811	p =	0.832
Striped Surfperch						
mean	0.067	0.000	0.250	0.125	0.250	0.833
SD	0.258	0.000	0.775	0.500	0.577	1.337
Two-sample t test,	p =	0.343	p =	0.592	p =	0.129
FISH / 100m2	Edwards (NR)		Long (NR)		Cliff (NR)	
	2001	2006	2001	2006	2001	2006
Lingcod						
mean	1.467	0.375	1.000	0.308	0.125	0.286
SD	1.552	0.806	1.265	0.751	0.342	0.726
Two-sample t test,	p =	0.019 *	p =	0.094	p =	0.435
Copper Rockfish						
mean	1.733	0.250	1.438	1.231	2.188	2.571
SD	2.738	0.683	2.159	2.088	2.198	3.715
Two-sample t test,	p =	0.044 *	p =	0.797	p =	0.729
Puget Sound Rockfish						
mean	0.000	0.000	22.688	9.077	3.125	2.000
SD			39.285	16.485	8.732	3.419
Two-sample t test,	p =	ND	p =	0.254	p =	0.655
Kelp Greenling						
mean	1.800	1.875	1.625	2.154	1.000	1.143
SD	0.941	2.247	1.586	2.512	0.730	1.703
Two-sample t test,	p =	0.906	p =	0.495	p =	0.762
Striped Surfperch						
mean	0.067	0.000	0.000	0.308	0.000	0.286
SD	0.258	0.000	0.000	1.109	0.000	1.069
Two-sample t test,	p =	0.310	p =	0.275	p =	0.293

Table 13. Mean fish density and standard deviations for each target species by site and year (2001 and 2006). P-values from t-tests, ND = no data since the species was not seen at one or both of the sites. In 2001, N = 15 transects (4m x 25m) for Lime Kiln and Edwards, and N = 16 for Bell Island, Cliff Island, Charles Island and Long Island. In 2006, N = 14 transects (2m x 25m) for Lime Kiln and Cliff Island, N = 16 for Edwards Point and Charles Island, N = 12 for Bell Island, and N = 13 for Long Island.