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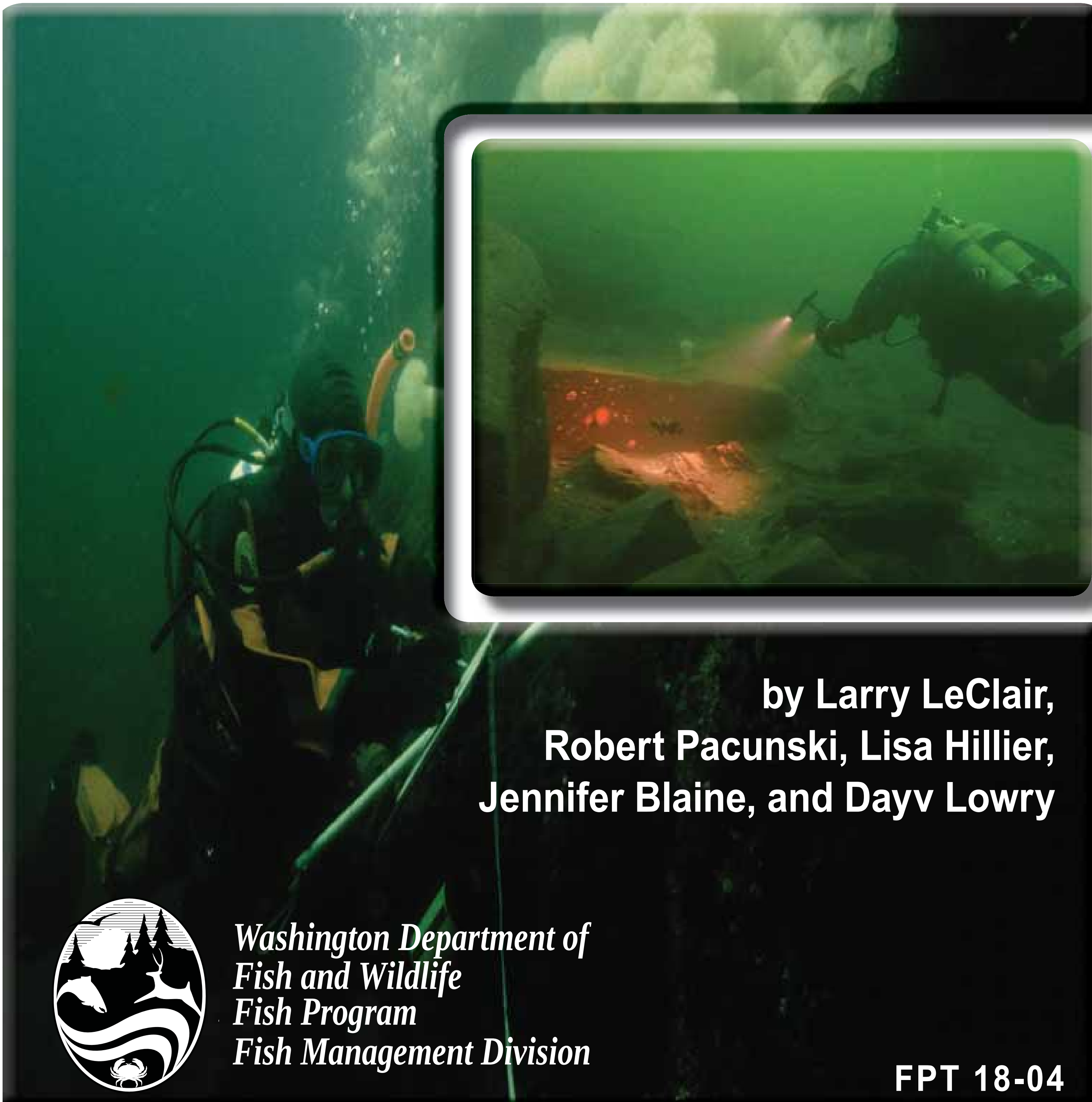
Summary of Findings from Periodic Scuba Surveys of Bottomfish Conducted Over a Sixteen-Year Period at Six Nearshore Sites in Central Puget Sound



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Washington Department of Fish and Wildlife
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A SUMMARY OF FINDINGS FROM PERIODIC SCUBA SURVEYS OF BOTTOMFISH CONDUCTED OVER A SIXTEEN-YEAR PERIOD AT SIX NEARSHORE SITES IN CENTRAL PUGET SOUND

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Executive Summary

When only results from short-term monitoring programs are available it can be difficult for resource managers to gauge the effects of regulatory actions aimed at long-term resource conservation. This is particularly true for species that are long-lived, slow-growing, and late to mature. For these species, demographic changes in response to management actions may be slow to manifest and difficult, or impossible, to detect over time spans of fewer than two generations. Data obtained from long-term monitoring is more likely to capture changes over time in fish communities composed of a wide variety of life spans and other life history attributes.

This report summarizes the data from sixteen years of bottomfish surveys via scuba at six central Puget Sound sites. We examined the data for long-term changes or trends in abundance, size, and distribution of several key bottomfish species. Further, we make comparisons among and between those sites surveyed that fall within marine protected areas (MPAs) and those that do not. In order to gain added perspective from our survey data, we compared our data to those acquired from four different scuba-based studies conducted prior to the commencement of our surveys at four of our sites.

At all six sites, species composition was dominated by just three taxonomic groups: rockfishes, surf perches, and greenlings, though the relative proportions of those groups varied among sites. Species richness also varied within and among groups, and within and among sties. Curiously, the greatest number of species observed was at the most heavily fished site, while the fewest number observed was at the most protected MPA. In pairwise comparisons of species composition by season (spring and fall), nearly all were significantly different both within and between sites. Though not confirmed, the data suggest that differences in species composition may occur along a latitudinal gradient. The species that contributed most to the differences between sites were Striped Seaperch, Puget Sound Rockfish, and Brown Rockfish.

At most sites, there was evidence of strong juvenile rockfish recruitment in 2006/07 for one or more of the following species: Black Rockfish, Quillback Rockfish, and Copper Rockfish. This event was made apparent by relatively high density “pulses” in length classes over time, whereby, unusually high numbers of juvenile fish enter a population and, with growth, sequentially moved from smaller to larger length-classes over time (i.e., a detectable “pulse” in length-class frequency was detected over time.)

Some have suggested that Lingcod, a high trophic-level feeder, may exert predatory top-down control over some rockfish species. We examined our data from the site where overall rockfish and lingcod density was greatest, and where the highest density of Puget Sound Rockfish occurred. Puget Sound Rockfish rarely exceed 20 cm in length and bear fewer and less robust spines than many other rockfish species, thus they are more vulnerable to predation than larger rockfishes. We searched for inverse relationships between Lingcod and rockfish density and biomass (e.g., increasing trends in Lingcod density accompanied by decreasing trends in rockfish

density). Such relationships could provide evidence that Lingcod predation is a factor in limiting rockfish population growth. A strong relationship between Lingcod and rockfish density and biomass was not apparent.

The frequencies of occurrence of Lingcod and rockfish in the largest length-classes were greatest at the Bracket's Landing Shoreline Conservation Area, the most longstanding MPA in Puget Sound. However, a substantial downward trend in the density of Copper and Quillback Rockfish in the largest length classes was apparent during the first seven years of the survey period. We considered multiple explanations and reasoned that senescence is the most likely explanation, though poaching may be a contributing factor. Some rockfish populations are known to be dominated by a small number of year classes. Given the age and long-term protection status of fish at Bracket's Landing, we hypothesize that a strong cohort of Copper and Quillback Rockfish reached terminal age and perished over the course of several years. The occasional occurrence of large dead Lingcod and rockfish at Bracket's Landing lends some support to this hypothesis. No dead Lingcod or rockfish were encountered at any of the other surveyed sites.

We compared our findings to studies that were conducted at four of our sites during years prior to our surveys. One of the most striking contrasts was the complete absence of Lingcod noted at Bracket's Landing during surveys conducted in 1975/76. In our surveys, Lingcod frequency of occurrence at Bracket's Landing was 100%. Furthermore, the annual mean lengths for Lingcod were greater at Bracket's Landing than at any other site we surveyed. All four of the comparable studies indicate changes over time in rockfish species composition.

Our survey results provide an informative perspective on the recent status of several key bottomfish species at six nearshore sites in central Puget Sound and will serve as an important benchmark for future surveys. However, our ability to identify and interpret trends over time, particularly for rockfishes, was confounded by factors such as high interannual variability in juvenile recruitment, poorly understood post recruitment inter- and intraspecific interactions, and, at some sites, discontinuous sampling and changes in protection statuses. In comparing MPA sites to non-MPA sites, we were not able to discern any trends that could be unequivocally linked to harvest management actions, though at least two observations suggest evidence of a protection response. First, at the Orchard Rocks Conservation Area, subsequent to the year (1998) that it was afforded MPA status, a persistent increase in rockfish density and biomass occurred. And second, the mean length, density, and biomass of Lingcod at the Keystone Conservation Area increased after the year (2002) that it was afforded MPA protection. Unlike rockfishes, which typically grow at substantially slower rates in Puget Sound, Lingcod grow rapidly, particularly during the first several years of their life. The rapid growth, and accompanying rapid increase in fecundity, of Lingcod makes it a potentially valuable first-response species for detecting positive effects of conservation efforts.

We recommend that the surveys be resumed at an interval coinciding approximately with two elapsed generations for key species and, based on our findings here, we conclude with several recommendations for research and management improvements moving forward.

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Introduction

This report summarizes findings from systematic Washington Department of Fish and Wildlife (WDFW) fish surveys conducted by scuba divers over fixed-width strip transects from 1995 through 2010 at six near-shore central Puget Sound sites (Figure 1). Puget Sound is a glacially formed fjord that comprises five hydrographic sub-basins separated by shallow sills. It is connected to the Pacific Ocean via the Strait of Juan de Fuca and the Strait of Georgia. Puget Sound supports a broad diversity of marine life, and its shores are home to most of western Washington's major metropolitan cities. The region has a long history of commercial and recreational bottomfish exploitation, and the WDFW is the primary agency responsible for management of these ecologically and economically important resources.

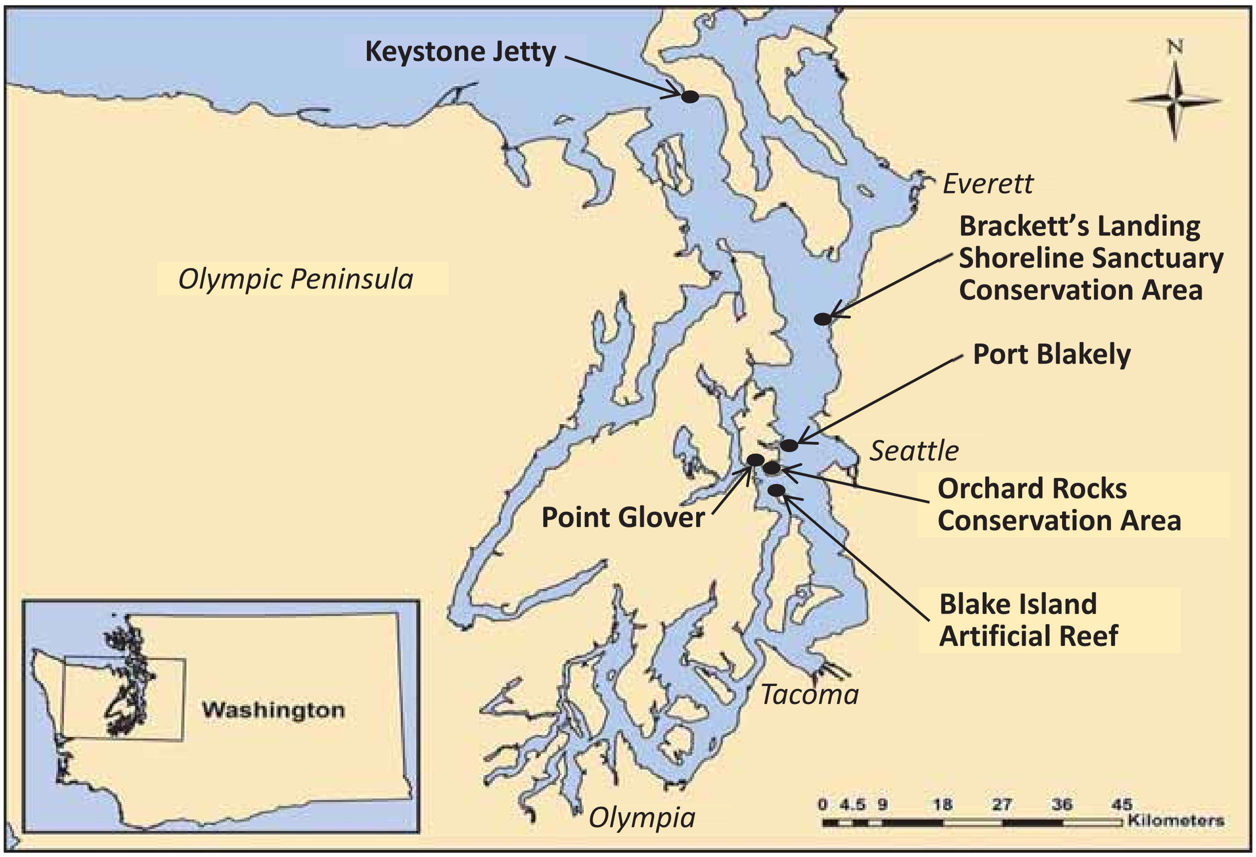

Figure 1. Location of six Puget Sound sites surveyed by scuba for bottomfish from 1995 through 2010.

In order to provide fishery managers with the best available science for informed decision making, the WDFW conducts research and monitoring of bottomfish populations on a range of time scales. Long-term monitoring can provide an indication of the current state of fish biota relative to historical abundance and distribution and can aid in determining whether, or how, our ability to estimate or interpret responses of the biota may be constrained by present monitoring practices. For instance, identifying anthropogenic impacts on fish communities such as those that might occur as a result of harvest regulation, habitat alteration, or pollution, and separating those impacts from "naturally" caused community changes (or changes that are not as clearly linked to human activities) such as natural disasters, phenologic shifts, or bioinvasions, can present challenges to resource scientists and managers who wish to gauge the effects of management actions against desired outcomes. This is particularly true when management objectives include the conservation of long-lived, slow-growing, and late-maturing species for which the success or failure of regulatory interventions cannot be determined over short timespans (*e.g.*, less than two generations). Long-term monitoring can capture changes in fish communities composed of species for which demographic responses to management actions may be slow to manifest, and increase our confidence in assigning detected changes to specific causes.

The objective of the WDFW dive surveys presented in this report was to identify temporal trends in population demographics (*e.g.*, species composition, density, biomass, size) that were discernable using our survey technique. Moreover, if trends were identified, we sought to evaluate whether they were conserved across multiple sites and whether there were detectable changes in fish biota that could be unequivocally linked to serial, or singular, management actions. For example, Puget Sound is occupied by several species of rockfish (genus *Sebastes*), most of which are long-lived, with lifespans in excess of 30 years, and slow-growing relative to other temperate-water reef fish. Most of these species have exhibited declines in local abundance in recent decades due primarily to overharvest by recreational and commercial fishers, prompting implementation of progressively more restrictive harvest regulations over time with the goal of recovering rockfish to historic levels (Table 1).

Table 1. Regulatory history of the recreational rockfish fishery in central Puget Sound (Marine Catch Areas 9 and 10).

Year(s)	Daily limit	Season
1983-1994	5	Year round
1995-1999	3	Year round
2000-2003	1[a]	Year round
2004-2009	1[a]	May 1-30 in CA9, and only during Lingcod and salmon season in CA10. Closed to spearfishing.
2010-Present	0	Closed year round. 120' depth restriction for all bottomfish fishing.

[a] No Yelloweye or Canary Rockfish retention permitted as of 2003.

In 1998, the WDFW adopted a policy to use marine protected areas (MPAs) as a working tool to manage and conserve fish and other marine resources (Appendix 1). From the mouth of the Strait of Juan de Fuca to the southernmost extent of Puget Sound there are 108 MPAs managed by a combination of federal, state, and local entities; twenty-two Puget Sound MPAs are managed solely by the WDFW. The protection level afforded varies by site, the most stringent being those that exclude human access or that prohibit the extraction or destruction of natural or cultural resources, whereas less restrictive levels permit limited resource extraction or habitat alterations

(Van Cleve *et al*., 2009). Three of the sites included in our surveys were afforded MPA status either before or shortly after commencement of the surveys. All three sites are no-take zones, whereby all resource extraction or destruction is prohibited.

Scientific experiments aimed at evaluating the impacts of MPAs on fish populations are difficult to design because investigators are often hampered by a lack of suitable control sites, although one of the MPA sites evaluated in this study was paired with a nearby control site on the same type of habitat. By comparing the protected and unprotected sites in this study, we sought to determine if a longitudinal approach, rather than a treatment-control approach, could prove useful for evaluating MPA performance in Puget Sound. Other sites were surveyed either continuously, or intermittently during the course of the surveys reported here; however, data generated from those surveys are neither temporally nor spatially robust enough to detect long-term trends or changes in key population parameters. The WDFW hopes to resume surveys at those sites so that long-term comparisons may be made. Those wishing to access the data from the surveys reported here, or surveys not presented in this report, may contact the WDFW Marine Fish Science Unit.

Site Descriptions

Blake Island Artificial Reef (BIAR)

The Blake Island Artificial Reef (BIAR) was the first of ten artificial reefs constructed by the WDFW[1] to provide accessible, near-urban fishing locations for recreational bottomfish anglers in Puget Sound (Buckley, 1982). In the spring of 1980, approximately 955 metric tons of concrete rubble, varying from cobble-sized chunks to large cylinders and slabs measuring several meters in length and/or width, were placed at the site (Figure 2). In the summer of 1980, approximately 48 auto tire "triad" bundles (described by Walton, 1979) were added on and near the shallower portion of the reef (Laufle, 1982; Laufle and Pauley, 1985). The underlying and surrounding natural substrate consists of mixed sand, gravel, and cobble that slope gradually seaward from the Blake Island shoreline to a maximum depth of about 110 m between Blake Island and the mainland of the Kitsap Peninsula. The total reef area covers approximately 3,000 m^2 (approximately 0.75 acres) and is separated into two distinct patches. The largest and shallowest patch ranges in depth from about 15-20 m (all depths herein are corrected to mean lower low water). A smaller patch (approximately 464 m^2) lies just offshore and ranges from about 25-30 m in depth. Lying between and around these two primary reef patches are isolated pieces of rubble that were either dropped intentionally or displaced during reef construction due to tidal action and/or water friction as they transited the water column from the surface to the seabed. Just offshore of the deepest rubble pile there is an escarpment of consolidated clay and gravel about 1 m in height and about 300 m in length, running from southeast to northwest. Where high concentrations of rubble or tires occur, interstitial and overhead spaces of various sizes are plentiful and provide refuge for many benthic bottomfishes. Some floating kelp (*Nereocystis luetkeana*) occurs inshore and adjacent to the reef. The macroalgae flora on the reef consists primarily of non-floating Laminarials and stalked kelp (*Pterygophora californica*). Due to a near-constant northerly flow of water out of nearby Colvos passage, tidal current over the reef is usually unidirectional during both the flood and ebb tides, running southeast to northwest, and may attain velocities of up to 4 knots. Unlike several other WDFW artificial reefs that have been closed to fishing, BIAR has not been afforded MPA status as of this writing. Despite substantial limitations imposed on the bottomfish fishery within the last decade, BIAR remains popular with hook-and-line anglers and spearfishers, who primarily target Lingcod during the 6-week spring fishery.

[1] At the time of reef construction, the WDFW was the Washington Department of Fisheries.

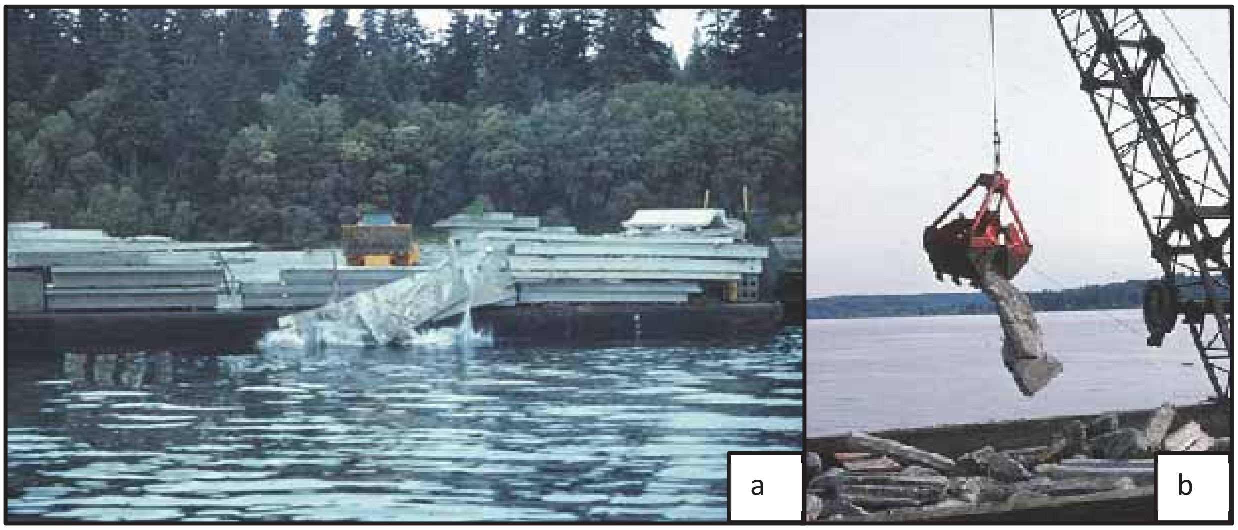

Figure 2. Concrete slabs being pushed by tractor off a barge (a), and concrete rubble being placed by crane (b) during construction of the Blake Island Artificial Reef in 1980.

Orchard Rocks Conservation Area (ORCA)

The Orchard Rocks Conservation Area (ORCA) was established in 1998, three years after the commencement of the surveys, by Washington Administrative Code (WAC) (Appendix 2) as a no-take MPA (resource extraction totally prohibited) and covers an area of approximately 420,000 m^2 (~104 acres). Located within the MPA at the south entrance to Rich Passage, Orchard Rocks is a nearshore, insular rocky reef of about 50,000 m^2 characterized by naturally occurring boulders, bedrock ridges, and escarpments of up to several meters in height, interspersed with areas of unconsolidated sand, cobble, and shell hash. The rocky habitat lies about 600 m from the nearby Bainbridge Island shoreline and is separated from the island by a shallow (less than 13 m in depth), sandy bottom passageway and from the Kitsap Peninsula mainland by depths of up to 30 m. The reef reaches a maximum depth of approximately 27 m near the center of Rich Passage and contains many crevices and undercuts that provide refuge for structure-associated bottomfish. Prior to the no-take prohibition, Orchard Rocks was heavily used by anglers and spearfishers targeting rockfish and Lingcod and remains a popular destination for recreational scuba divers. The shallowest portions of the reef are exposed during low tides and are common haulout sites for Harbor Seals (*Phoca vitulina*), California Sea Lions (*Zalophus californianus*), and Steller Sea Lions (*Eumetopias jubatus*) that frequent the area. Macroalgae flora consists primarily of floating kelp (*N. luetkeana*) and other Laminarials, stalked kelp (*P. californica*), and low-growing red algae. Tidal current strength through Rich Passage is high, attaining velocities of up to nearly five knots, and oscillatory in direction.

Point Glover (PG)

Point Glover (PG), located on the Kitsap Peninsula about 8 watercourse km northeast of Port Orchard, is composed of several near-vertical, uplifted bedrock escarpments adjacent to the Point Glover fault line. There are naturally formed fissures, undercuts, and bedrock surfaces that may attract, and provide refuge for, structure-associated bottomfish. Macroalgae is scarce and is composed primarily of non-floating Laminarials and low-growing red algae. The bedrock surface recedes into a gently sloping sand and gravel bottom at about 25 m depth toward the center of Rich Passage. The study area at PG lies approximately 1.2 km northwest of the ORCA study site and is open to fishing.

Keystone Jetty (KJ)

In 1936, the Keystone Harbor Association was formed for the purpose of constructing a ferry and small vessel harbor that would further link Whidbey Island to other regions in Puget Sound and British Columbia. After at least two failed attempts (1938 and 1940) to convince the then War Department Corps of Engineers to construct the harbor, the association ultimately succeeded, and the harbor was built by the U.S. Army Corps of Engineers in 1947-48. It was formed by dredging a triangular-shaped embayment from an existing barrier beach and a navigable channel of approximately 300 m long by 60 m wide from the head of the bay. To protect the channel and ferry landing from the predominantly southerly winds, a north-south quarry-rock jetty was constructed east of the harbor entrance that disrupted the natural eastward transport of beach material. As a result, continual shoaling occurs at the channel, requiring the harbor entrance to be dredged every four to six years to maintain navigable depths for ferry traffic. Since 1960, over 170,000 m^3 of dredged sediment from the navigation channel has been placed on the beach east of the jetty to mitigate for sediment loss due to erosion resulting from the jetty's construction. In 2002, the area east of the jetty was established by WAC (Appendix 3) as the Keystone Conservation Area (resource extraction totally prohibited). The conservation area's western demarcation line runs due south from the offshore end of the jetty; therefore, the full length of the jetty's eastern half lies within, and the western half outside, the conservation area. The jetty provides the majority of habitat for structure-associated bottomfish, though remnants of an abandoned wharf are present within the MPA near the eastern boundary that are known to provide some habitat for fish, including lingcod and rockfish, in very shallow (< 4 m) water. It should be noted that fish regularly move between the protected and non-protected sides of the jetty during changes in tidal sequences, resulting in transient levels of protection.

Brackett's Landing Shoreline Sanctuary Conservation Area (BLCA)

In 1935, the Black Ball Line, a subsidiary of the Puget Sound Navigation Company, sank the dry dock *DeLeon* near Brackett's Landing at Edmonds. At the time, the dry dock (approximately 100 m long by 25 m wide) formed the only substantial underwater structure on an otherwise gently sloping sandy bottom. Over time, the *DeLeon* attracted large schools of fish and became a popular spearfishing site for skin and scuba divers. In 1970, with the support of local dive enthusiasts concerned about overfishing, the City of Edmonds closed the area to fishing and established the Brackett's Landing Shoreline Sanctuary, thereby creating the first municipal scuba dive park in the country and the oldest marine conservation area in Puget Sound. In 1998, the sanctuary was afforded MPA status by WAC (Appendix 4) as the Brackett's Landing Shoreline Sanctuary Conservation Area (BLCA), wherein all resource extraction was prohibited. The conservation area encompasses approximately 190,202 m^2 (~47 acres) and comprises all of the area known as the Edmonds Underwater Park. A revetment quarry-rock jetty about 75 m in length and lying approximately perpendicular to shore divides the otherwise sand and gravel shoreline within the area into north and south sections. Due to easy beach access, nearshore currents that rarely exceed one knot, and the opportunity to view large fish, the BLCA is one of the most popular scuba diving destinations in Washington. Over the past several decades, a wide variety of scattered anthropogenic structures of various sizes and composition have been placed on the seafloor within the BLCA, providing additional habitat for structure-oriented bottomfishes. In 1972, the 29 m tugboat *M/V Alitak* was sunk at the shallow end of the *DeLeon;*these two structures constituted the primary source of high-relief habitat for structure-associated bottomfish within the conservation area until the placement of the 24 m tugboat *M/V Triumph* in 1999, approximately 200 m north of the offshore end of the *DeLeon*, and the placement of remnants of a floating bridge in 2009. Eelgrass beds (*Zostera spp.)* occur in shallow water within the area, and some floating kelp (*N. luetkeana*) attached to anthropogenic structures occur in deeper water, particularly in the northern portion of the BLCA. More expansive floating kelp beds occur just to the north of the conservation area boundary. The BLCA has been closed to fish harvest longer than any area in Puget Sound and thus provides an important benchmark for comparisons with other index sites, both protected and unprotected.

Port Blakely (PB)

The rocky reef near the north entrance to Port Blakely (PB) Harbor on the east side of Bainbridge Island consists of a series of bedrock outcroppings and escarpments, separated by areas of unconsolidated sand, cobble, and shell hash. The bedrock features are oriented perpendicular to the shoreline and form areas of steep vertical relief up to 5 m off the bottom with caves, crevices, and undercut ledges that provide refuge space to structure-oriented bottomfish. The PB reef is among the most heavily fished survey sites in this study; both prior to and throughout the survey period, it was (and remains) popular with spearfishers and hook-and-line anglers targeting bottomfish, and with salmon anglers. Current velocities rarely exceed 1.5 knots.

Methods

Surveys

Three, 30-m long transects were established at each of the six survey sites described above (Figure 3). With the exception of BLCA and KJ, transect lines were permanently installed and anchored with pitons or natural materials to minimize movement during tidal fluxes. The transect locations at BIAR, ORCA, and PB coincided approximately with those used by Matthews (1990a), and in several cases the original transect lines were still in place, which were removed and replaced with new lines. Due to the popularity of the BLCA and KJ with scuba divers, no permanent lines were installed to avoid tampering and/or removal. Instead, divers used construction-grade tape reels to lay out the transect lines prior to each survey using a known starting point and natural landmarks to ensure consistency in placement across surveys. All three transects at BLCA were located over the sunken dry dock *DeLeon*, the only metal structure in this study, although the shallowest transect at BLCA included a small amount of wooden structure due to its origin at the west end of the *M/V Alitak*. The transects at KJ were the only transects laid out end-to-end, originating on the eastern side of the jetty (within the MPA) and ending on the west side of the jetty (non-protected area). At the remaining sites, the majority of each transect line was positioned over hard substrate of medium to high relief (>3 m), and transect depths across all sites ranged from about 5-20 m (MLLW). With the exception of PG, the scuba surveys commenced in 1995. Transect lines were established at PG in 1999 to serve as a paired control site for ORCA, which was designated as an MPA in 1998. To expand the comparability of these two sites, a fourth transect was added at ORCA on 28 April 1999 and to PG on 21 June 1999.

Each transect was surveyed by divers equipped with conventional scuba to a distance of 1.5 m on either side of the transect centerline (total area per transect = 90 m^2) and as high into the water column as permitted by prevailing visibility. Hand-held lights were used to search beneath overhangs and in crevices and other poorly lit areas. Each diver used a hand-held graduated staff to aid in estimating fish lengths and survey lane width. Careful written and hand-signal communication between divers reduced the risk of double counting fish that were swimming across-transect from one survey lane to the other. Most of the surveys were conducted during slack tide; otherwise, no attempt was made to synchronize the surveys to oceanographic or atmospheric conditions (*e.g.*, time of day, sea state, air or water temperatures). All bottomfish, as defined by WAC (Appendix 5), were targeted in the search effort. Individual fish were recorded to the lowest discernable taxonomic level and their length (all fish lengths herein are reported as total length in centimeters) estimated into one of 14 length-classes as follows: < 15; 15 < 25; 25 < 35; 35 < 45; 45 < 55; 55 < 65; 65 < 75; 75 < 85; 85 < 95; 95 < 105; 105 < 115; 115 < 125; 125 < 135; and 135 < 145. Other species, though occasionally noted, were neither targeted nor considered in the analyses. All data were error checked against the field forms prior to analyses.

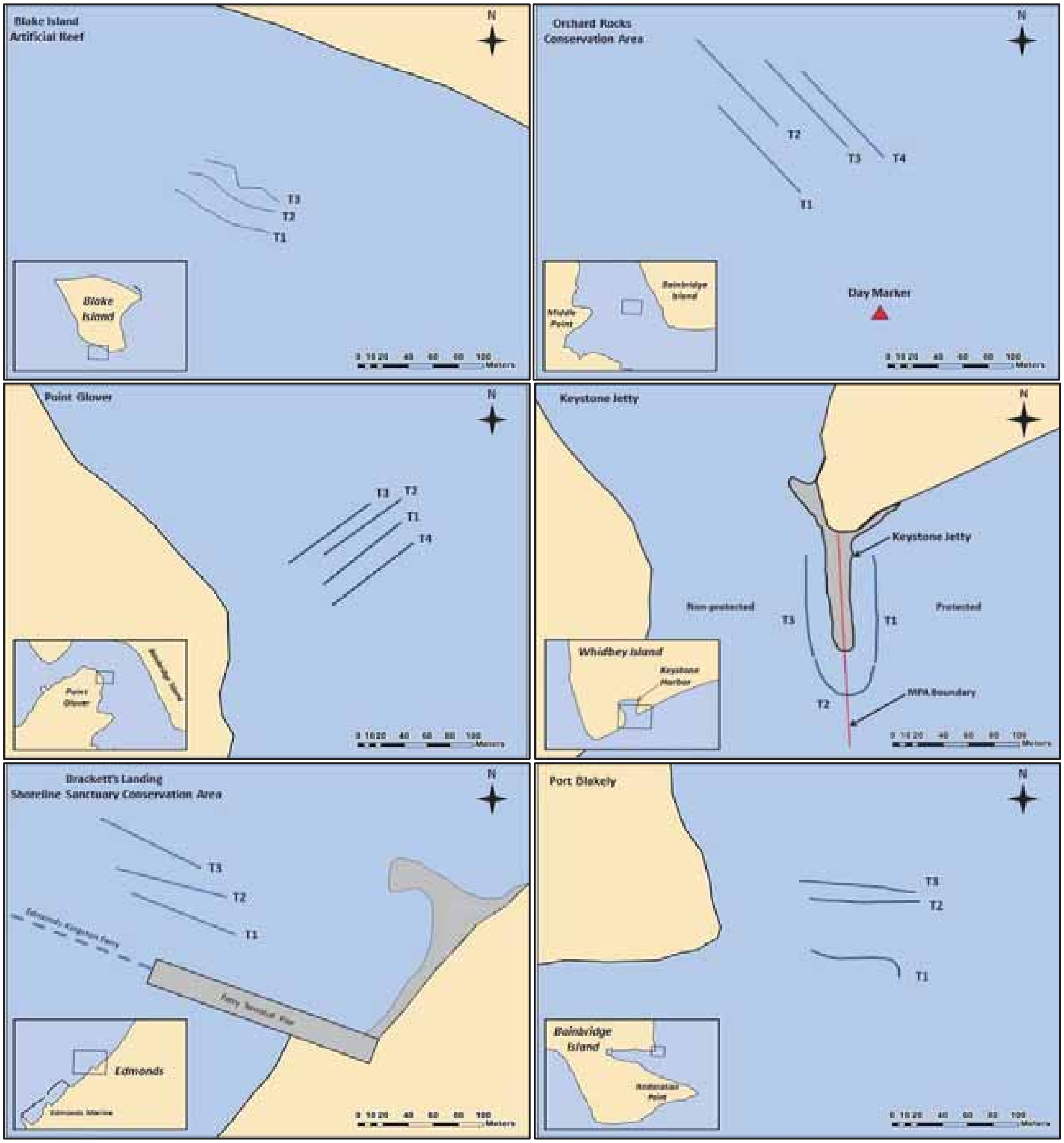

Figure 3. Locations of transects at each of six surveyed sites in central Puget Sound.

Surveys[2] were conducted during daylight hours in the spring (April - June) and fall (October-December) from 1995-2010; however, not all sites were surveyed in all years or both seasons, and the total number of surveys conducted and the total area surveyed varied among sites (Table 2)[3]. In most years, each site was surveyed at least three times per season on a three to four week

[2] In this study, we define a survey as the sampling of all transects in a single day at a single site.
[3] Due to weather conditions, the “fall” surveys at several sites were conducted in January/early February.

rotation. With a single exception (ORCA, Table 2 footnote “a”), all transects were surveyed at each site in a single dive. Due to staffing shortages and constraints imposed by competing WDFW priorities, no surveys were conducted at any of the six sites in 1998. Sampling in 2006 was very limited; no spring surveys were conducted and only a single survey was conducted at five sites in the fall (KJ excluded). The Keystone jetty was the least sampled site, with about half the number of surveys (and survey area) as the other five sites (Table 2). Some results from surveys up to 2002, and preliminary surveys conducted in 1993-94 at five of the six sites (KJ not included), have been summarized by Palsson and Pacunski (1995), Palsson (1998), and Palsson *et al*. (2004).

Table 2. Number of surveys conducted (left of slash) and total area surveyed in m^2 (right of slash) by year and season at each of six surveyed sites in Puget Sound. Blank = no surveys were conducted.

	Blake Island (BIAR)		Orchard Rocks (ORCA)		Point Glover (PG)		Keystone Jetty (KJ)		Brackett's Landing (BLCA)		Port Blakely (PB)	
Year	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
1995	3/810	3/810	3/810	3/810			3/810	2/540	3/810	3/810	3/810	3/810
1996	3/810	3/810	3/810	3/810			3/810	2/540	3/810	3/810	3/810	3/810
1997	3/810	3/810	3/810	3/810			3/810	3/810	3/810	3/810	3/810	3/810
1998												
1999	5/1,350	5/1,350	7[a]/2,070	5/1,800	5[b]/1,440	5/1,800				5/1,350	5/1,350	5/1,350
2000	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080			3/810	3/810	3/810	3/810
2001	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080			3/810	3/810	3/810	3/810
2002	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080	1/270		3/810	3/810	3/810	3/810
2003	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080	2/540	3/810	3/810	3/810	3/810	3/810
2004	3/810	3/810	3/1,080	3/1,080	3/1,080	2/720	3/810	2/540	3/810	3/810	3/810	2/540
2005	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080	2/540		3/810	3/810	3/810	3/810
2006		1/270		1/360		1/360				1/270		1/270
2007	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080	2/540	2/540	3/810	3/810	3/810	3/810
2008	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080	1/270	3/810	2/540	3/810	3/810	3/810
2009	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080	2/540	3/810	3/810	3/810	3/810	3/810
2010	3/810	3/810	3/1,080	3/1,080	3/1,080	3/1,080	3/810	2/540	3/810	3/810	3/810	3/810
Total # of surveys	44	45	46	44	35	35	25	22	38	45	44	44
Cumulative area surveyed (m^2)	11,880	12,150	15,300	15,390	12,240	12,600	6,750	5,940	10,260	12,150	11,880	11,880

[a] A fourth transect was added at Orchard Rocks Conservation Area on 28 April, 1999, and it was the only transect surveyed on that date. Surveys included all four transects on all subsequent dates.

[b] A fourth transect was added at Point Glover on 21 June, 1999. All four transects were surveyed on that and on all subsequent dates.

Estimates of Bottomfish Biomass, Density, Mean Length, and Frequency of Occurrence

We used the standard allometric equation $W = A \cdot L^B$ (LeCren, 1951) to estimate biomass (kg per m^2) for most bottomfish species, where W is weight, L is length, and A and B are, respectively, scale and shape parameter constants. The estimates are inherently imprecise due to our grouping of fish into pre-established length-classes, and therefore provide only relative measures of biomass. We used the mid-point lengths (*i.e.*, the medians) from each length-class to compute weights. We obtained length-weight (L-W) regression coefficients from a variety of sources (Table 3), and most of the relationships were derived from data that were neither contemporaneous nor sympatric with our surveys. However, and particularly when relative measures of biomass are needed, the error induced by using relationships from other time periods or other areas is typically small when compared to sampling error (Kimmerer *et al*., 2005).

Rockfish that could not be identified to species were recorded as "unidentified rockfish" and were not included in the biomass estimates. This category included juvenile rockfish that could not be identified based solely on the gross morphological features apparent to the survey divers, and rockfish partially obscured from the divers view (*e.g.*, in a crevice). Across all sites and years, nearly all unidentified rockfish were in the smallest length-class (only three were not). The greatest number of unidentified rockfish occurred at BLCA, and all were in the smallest length-class. These fish contributed fewer than 4% to the total number of rockfish seen at BLCA, and their summed total biomass was less than 4 kg when computed using L-W regression coefficients for any of the positively identified rockfish species observed in this study. Therefore, at sites where unidentified rockfish occurred, their impact on biomass estimates when summed over all years or for any single year would have been inconsequential. Wolf-eel (*Anarrichthys ocellatus*) were also excluded from the biomass estimates because they were rarely seen outside their den and their lengths could not be accurately estimated.

Table 3. Length-weight regression coefficients (A and B) used to generate estimates of bottomfish biomass. FL = fork length, TL = total length, SL = standard length, and SVL = snout to vent length.

Bottomfish common and (scientific) name	Source	A	B	Length Unit	Weight Unit	*N*	R^2
Copper Rockfish (*Sebastes caurinus*)	Wildermuth (1983)	6.18E-08	2.79	mm (FL)	kg	922	0.83
Brown Rockfish (*S. auriculatus*)	Wildermuth (1983)	3.39E-08	2.89	mm (FL)	kg	546	0.71
Quillback Rockfish (*S. maliger*)	Wildermuth (1983)	2.51E-08	2.95	mm (FL)	kg	905	0.88
Black Rockfish (*S. melanops*)	Wildermuth (1983)	3.75E-08	2.86	mm (FL)	kg	2,478	0.87
Yellowtail Rockfish[a] (*S. flavidus*)	Love *et al*. (1990)	3.23E-02	2.78	cm (TL)	g	272	0.97
Vermillion Rockfish (*S. miniatus*)	Love *et al*. (1990)	2.16E-02	2.92	cm (TL)	g	637	0.98
Bocaccio[a] (*S. paucispinis*)	Love *et al*. (1990)	1.22E-02	2.97	cm (TL)	g	1,011	0.98
Puget Sound Rockfish (*S. emphaeus*)	WDFW Puget Sound Trawl Survey[b]	3.00E-05	2.83	mm (TL)	g	45	0.71
Lingcod (*Ophiodon elongates*)	Wildermuth (1983)	5.60E-09	3.10	mm (FL)	kg	712	0.87
Kelp Greenling (*Hexagrammos decagrammus*)	Wildermuth (1983)	3.75E-08	2.83	mm (FL)	kg	891	0.79
Whitespotted Greenling (*H. stelleri*)	Wildermuth (1983)	1.02E-09	3.45	mm (FL)	kg	43	0.83
Painted Greenling (*Oxylebius pictus*)	Kelp Greenling used as proxy	3.75E-08	2.83	mm (FL)	kg	891	0.79
Cabezon (*Scorpaenichthys marmoratus*)	Wildermuth (1983)	2.78E-08	2.91	mm (FL)	kg	130	0.90
Red Irish Lord (*Hemilepidotus hemilepidotus*)	Wildermuth (1983)	6.19E-09	3.18	mm (FL)	kg	22	0.73
Buffalo Sculpin (*Enophrys bison*)	WDFW Puget Sound Trawl Survey[b]	5.00E-06	3.28	mm (TL)	g	41	0.95
Great Sculpin (*Myoxocephalus polyacanthocephalus*)	WDFW Puget Sound Trawl Survey[b]	4.00E-05	2.85	mm (TL)	g	102	0.94
Pacific Staghorn Sculpin (*Leptocottus armatus*)	WDFW Puget Sound Trawl Survey[b]	4.00E-06	3.24	mm (TL)	g	111	0.94
Plainfin Midshipman (*Porichthys notatus*)	Miller *et al*. (2008)	8.00E-06	3.07	mm (SL)	g	25	0.98
Kelp Perch (*Brachyistius frenatus*)	Miller *et al*. (2008)	5.00E-06	3.36	mm (SL)	g	22	0.93
Striped Seaperch (*Embiotoca lateralis*)	Wildermuth (1983)	6.82E-08	2.78	mm (FL)	kg	494	0.64
Pile Perch (*Rhacochilus vacca*)	Wildermuth (1983)	9.21E-08	2.74	mm (FL)	kg	116	0.65
English Sole (*Parophrys vetulus*)	Wildermuth (1983)	7.54E-08	2.65	mm (FL)	kg	105	0.72
Rock Sole (*Lepidopsetta polyxystra*)	Wildermuth (1983)	2.27E-08	2.88	mm (FL)	kg	633	0.65
Starry Flounder (*Platichthys stellatus*)	Wildermuth (1983)	4.57E-08	2.77	mm (FL)	kg	271	0.84
C-O Sole (*Pleuronichthys coenosus*)	WDFW Puget Sound Trawl Survey[b]	5.00E-06	3.2	mm (TL)	g	34	0.91
Gadid (unidentified)[c]	Wildermuth (1983)	1.86E-07	2.59	mm (FL)	kg	3,032	0.69
Spotted Ratfish (*Hydrolagus colliei*)	Barnett (2008)	2.46E-07	2.76	mm (SVL)	kg	711	0.94
Spiny Dogfish (*Squalus acanthias*)	Wildermuth (1983)	2.52E-09	3.13	mm (FL)	kg	81	0.96

[a] A significant difference in length-weight relationship between sexes was reported. We report coefficients and R^2 averaged between males and females.
[b] Length-weight data from annual trawl surveys conducted throughout Puget Sound between 1987 and 2015.
[c] Coefficients and R^2 are averaged over the three most common Gadids encountered in Puget Sound: Pacific Cod (*Gadus macrocephalus*), Walleye Pollock (*G. chalcogrammus*), and Pacific Tomcod (*Microgadus proximus*).

Mean lengths were computed using the equation:

$$\bar{L} = \sum_{1}^{i} (l_1 * n_1 + l_2 * n_2 + l_3 * n_3 + \ldots l_i * n_i)/N$$

where $\bar{L}$ is the overall mean length, l is the mid-point length of each length-class, n is the number of fish observed in each length-class, and N is the total number of fish observed. Where $l * n \neq \mathbb{Z}$ (integer), the product was rounded to the next greatest whole number. The breadth of our length-class intervals precluded us from producing accurate measures of variability and none are reported for mean lengths produced from our survey data; however, standard errors are reported for mean lengths from other data sources when fish lengths were recorded at least to the nearest cm.

Site densities by period (D_p) for each taxon were calculated as the sum of all individuals (C) observed in period (p) (entire study; year; season) divided by the total area surveyed in that period (A_p), as follows:

$$D_p = \frac{\sum C_p}{A_p}$$

Similarly, the site biomass by period (Bp) for each taxon was calculated as the sum of the individual survey biomass (B_p) estimates in period (p) divided by the total number of surveys in that period (N_p), as follows:

$$B_p = \frac{\sum B_p}{N_p}$$

While some taxa were necessarily excluded from the biomass estimates as noted above, all observed bottomfish were included in the density estimates.

Percent frequencies of occurrence (FO) for each species, rounded to the nearest whole number were computed as follows:

$$FO = \frac{n_{OBS}}{N} * 100$$

Where n_{OBS} is the number of surveys in which a species was observed, and N is the total number of surveys conducted over the course of the study.

Results

Species Composition

Based on density, the bottomfish species composition at each site was dominated by three taxonomic groups: rockfishes (Sebastids), surf perches (Embiotocids), and greenlings (Hexagrammids). The observed species compositions of these groups, as well as other observed bottomfish species, are listed in Table 4. Although the density of all other observed bottomfish species combined did not exceed any of the three dominant taxonomic groups at any of the six sites, the biomass of all other bottomfish species combined slightly exceeded that of surf perches at ORCA (due primarily to Red Irish Lords) and BLCA (due primarily to Cabezon) (Figure 4). However, perch likely composed a higher proportion of the fish community at BLCA than indicated due to the exclusion of Shiner Perch (*Cymatogaster aggregata*) from the legal definition of bottomfish[4] and, thus, from detailed consideration here. Although Shiner Perch were not targeted in the search effort, divers noted their presence and estimated their numbers when they occurred in high abundance, and they were sometimes seen numbering in the hundreds on a single transect at BLCA. By comparison, only four Shiner Perch were recorded at ORCA over the 16-year survey period.

While the species composition at most sites was dominated by the same three taxonomic groups, the relative proportions of those groups differed among sites (Figure 4). For example, the density of perch was more than twice that of rockfish at BIAR, while the converse was true at nearby ORCA. A presence-absence list of all observed bottomfish species and their percent frequency of occurrence, arranged by group, is presented in Table 4. Interestingly, the greatest number of species observed (23) was at PB, one of the most heavily fished sites, while the fewest number of species observed (15) was at BLCA, the most protected site. Effort, in terms of total number of surveys conducted and cumulative area surveyed, was slightly greater at PB (Table 2) than at BLCA. Most of the difference in the total number of observed species at the two sites can be attributed to four species of flatfish that were observed, albeit infrequently, at PB. No flatfish were observed at BLCA.

[4] Shiner perch are often used as live bait for bottomfish and, as such, are not considered bottomfish for management and regulatory purposes in Washington.

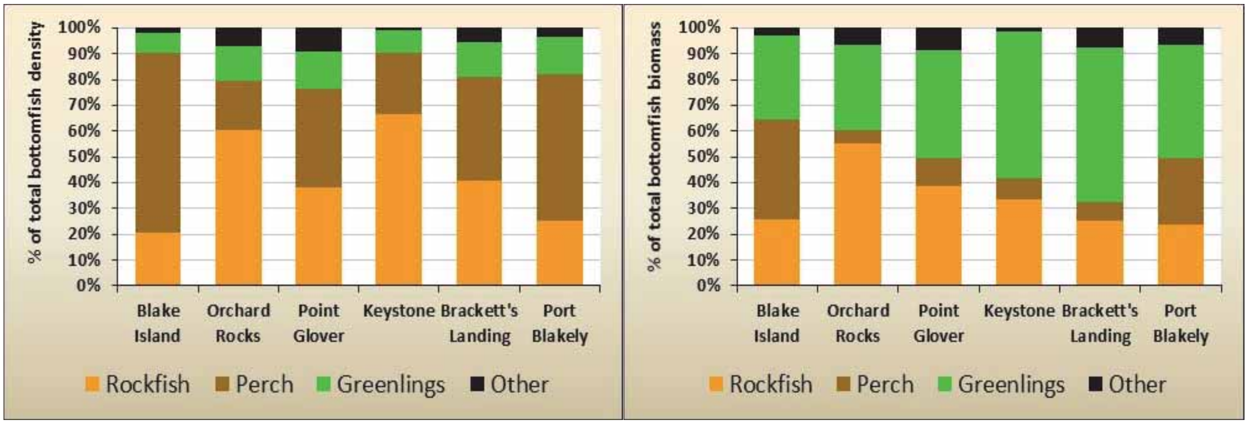

Figure 4. Percent total, summed over all years surveyed at each site, of the density (left) and biomass (right) for four bottomfish groups. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12).

Table 4. Mean percent frequency of occurrence for all bottomfish species/taxa observed at each of six survey sites. Blank = no fish observed. [orange] = Rockfish, [brown] = Perch, [green] = Greenlings, and [gray] = Other bottomfish.

Bottomfish species	Blake Island	Orchard Rocks	Point Glover	Keystone	Brackett's Landing	Port Blakely
Copper Rockfish	100	93	74	100	100	98
Brown Rockfish	100	100	100	21	74	92
Quillback Rockfish	70	9	23	74	99	43
Black Rockfish	24	64	26	100	98	23
Yellowtail Rockfish	1	1		89	2	7
Vermilion Rockfish		4				
Bocaccio				2		
Puget Sound Rockfish	6	1		98	6	3
Unidentified rockfish	2			51	27	11
Kelp Perch	38	6	30	17	55	55
Pile Perch	60	33	39	57	59	44
Striped Seaperch	82	64	87	83	96	84
Lingcod	97	99	100	100	100	93
Kelp Greenling	49	81	77	98	72	85
Whitespotted Greenling				2		
Painted Greenling	100	97	96	100	95	88
Cabezon	38	18	21	9	100	27
Red Irish Lord	83	88	90	13	6	65
Buffalo Sculpin	34	33	80	55		6
Great Sculpin	2		1	2	1	
Pacific Staghorn Sculpin						1
Plainfin Midshipman	1	1				
English Sole						1
Rock Sole	1	1	1			3
Starry Flounder		1				2
C-O Sole						1
Gadidae	1					1
Spotted Ratfish	3					14
North Pacific Spiny Dogfish		1	1	2		2
Wolf-eel	39	11	3	19		
# Species observed[a]	**21**	**21**	**17**	**20**	**15**	**23**

[a] Unidentified rockfish are not included in the total number of bottomfish species observed.

To examine differences in species composition among sites, we used PRIMER v6 (Clarke and Gorley, 2006) (hereafter P6) to produce a between-site Bray-Curtis resemblance matrix from the non-transformed mean site densities of all observed bottomfish. The P6 zero-adjusted function was applied to minimize destabilization of the Bray-Curtis algorithm that can occur when zero densities are observed for a species across multiple sites (Clarke *et al*., 2006). A non-metric 2-dimensional (2D) ordination of the resemblance matrix indicates a broad range of dissimilarity in species composition among sites, possibly occurring across a latitudinal gradient (Figure 5).

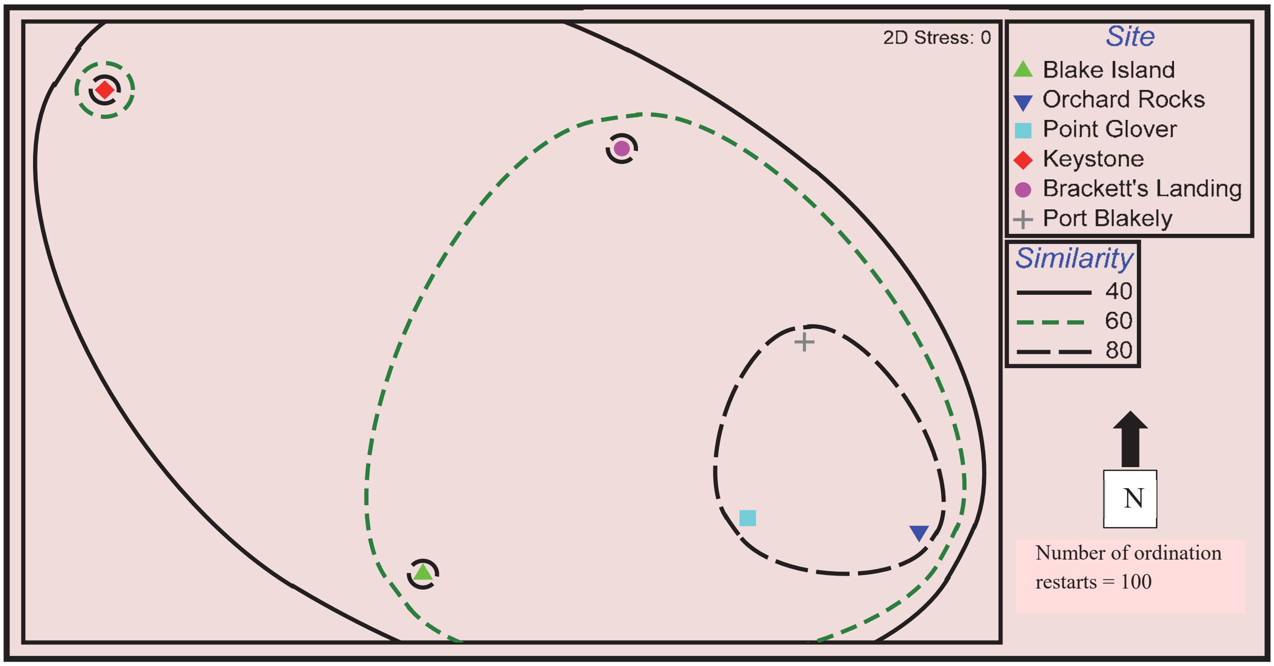

Figure 5. Non-metric 2-dimensional ordination of a zero adjusted Bray-Curtis resemblance matrix from non-transformed mean site densities of all observed bottomfish species at the six survey sites, with Group average similarity clusters (40%, 60%, and 80% similarity). The North arrow indicates that sites are plotted in order of increasing latitude, although no geographic scale is present or implied.

To test the null hypothesis of no significant differences in bottomfish species compositions within or between sites by season (*i.e*., similarities within groups were equal to similarities between groups), we generated a zero-adjusted Bray-Curtis resemblance matrix of the mean site-by-season densities and used the P6 one-way analysis of similarity (ANOSIM) function. The null hypothesis was rejected for nearly all 66 pairwise comparisons[5] (global $R = 0.59$ [see footnote 6], $p < 0.001$, $\bar{R}$ 0.72, *s.d.* 0.21, 999 permutations). Four comparisons were not significant ($p \geq 0.05$): ORCA fall did not differ from PG fall or spring; ORCA spring was not

[5] P6 does not implement a Bonferroni correction to pairwise significance levels. See Clarke and Gorley (2006), page 131 for explanation.

[6] $R > 0.75$ = groups well separated, $R > 0.5$ = groups overlapping but clearly different, $R < 0.25$ = groups barely (or not) separable (Clarke and Gorley, 2001).

different from PG spring; and PG fall was not different from BIAR spring. These similarities may be due to geographic proximity, as BIAR, ORCA, and PG are among the nearest of all six sites (Table 5). A 2D ordination of the group centroids from the resemblance matrix is presented in Figure 6.

Table 5. Approximate water-course distances (km) between six surveyed sites in Puget Sound.

	Blake Island	Orchard Rocks	Point Glover	Keystone	Brackett's Landing
Orchard Rocks	7				
Point Glover	8	1			
Keystone	75	74	76		
Brackett's Landing	34	32	34	44	
Port Blakely	9	8	9	66	26

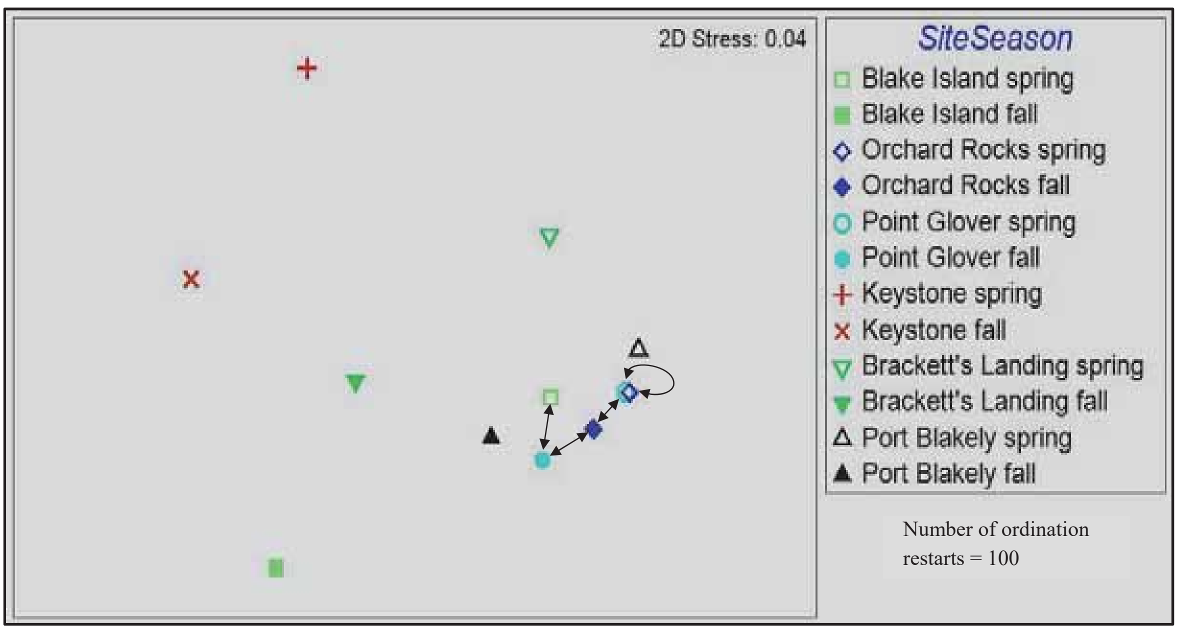

Figure 6. Non-metric 2-dimensional ordination of a zero adjusted Bray-Curtis resemblance matrix from non-transformed mean site densities by season of all observed bottomfish species at the six survey sites. For clarity, only the group centroids are depicted. Arrows indicate four pairwise comparisons that were *not* significantly different ($p \geq 0.05$) as determined by the ANOSIM test.

We conducted a P6 one-way similarity of percentages (SIMPER) analysis of the mean site densities to identify those species that contributed most to the pairwise dissimilarities between sites, and those species that contributed most to similarities within sites. The former provides a quantitative measure of which species are most influential in generating dissimilarities between paired sites. The latter determines the percent contribution of each species to the overall average pairwise similarities within sites, which provides a good indication of the species typifying a site. Only those species that, in sum, accounted for ≥ 70% of the (dis)similarity were identified. Three distinguishing species accounted for the majority of the dissimilarities between sites: Striped Seaperch was the most distinguishing species in 10 out of 15 comparisons, including all comparisons with BIAR; Puget Sound Rockfish was the most distinguishing species in all but one comparison with KJ, and; Brown Rockfish was the most distinguishing species between ORCA and PB (Table 6).

Table 6. Pairwise comparison matrix of the two top contributing species to each pairwise dissimilarity based on density (top contributor above, and second contributor below the diagonal). SS = Striped Seaperch, PP = Pile Perch, PSR = Puget Sound Rockfish, BR = Brown Rockfish, CR = Copper Rockfish.

	Blake Island	Orchard Rocks	Point Glover	Keystone	Brackett's Landing	Port Blakely
Blake Island		SS (55%)	SS (55%)	SS (26%)	SS (40%)	SS (52%)
Orchard Rocks	PP (11%)		SS (41%)	PSR (28%)	SS (23%)	BR (37%)
Point Glover	PP (11%)	BR (20%)		PSR (28%)	SS (24%)	SS (36%)
Keystone	PSR (25%)	SS (19%)	SS (19%)		PSR (27%)	PSR (29%)
Brackett's Landing	CR (12%)	CR (19%)	CR (20%)	SS (21%)		SS (28%)
Port Blakely	BR (12%)	SS (30%)	BR (26%)	SS (20%)	CR (20%)	

Relative to the number of bottomfish species seen at each site (see Table 4), a small number of species, ranging from just two to four, accounted for 70% or more of the average within-site similarities, and the highest contributors at each site were either rockfish or Striped Seaperch (Table 7). Brown Rockfish contributed more than 50% to the within-site similarity at both ORCA and PG, and this may account for the non-significant pairwise comparisons between those two sites previously noted.

Table 7. Bottomfish species that characterize each of six surveyed sites in Puget Sound by accounting for ≥ 70% of the average similarity within each site based on density. Shaded cells denote the highest contributing species at each site.

Bottomfish Species	Blake Island	Orchard Rocks	Point Glover	Keystone	Brackett's Landing	Port Blakely
Brown Rockfish	20%	68%	53%			20%
Copper Rockfish				10%	29%	17%
Puget Sound Rockfish				34%		
Black Rockfish				14%		
Striped Seaperch	48%	7%	17%	16%	21%	24%
Lingcod					14%	9%
Painted Greenling	11%		9%			
Cabezon					9%	
Total	79%	75%	79%	74%	73%	70%

Density and Biomass

We computed the survey density and biomass for all bottomfish at each of the six sites (Figure 7). The densities at BIAR, KJ, and BLCA were more than twice those observed at the other three sites, and a similar pattern was apparent for biomass, though less pronounced, at BIAR. A high number of Wolf-eel (*N*=58) was observed at BIAR (more than twice the number seen at any of the other five sites), but their biomass was not estimated. Most of the Wolf-eel seen at BIAR were adults estimated to weigh in excess of 10 Kg, and inclusion of these fish in the biomass estimate would likely have resulted in a sizeable increase in the estimate of bottomfish biomass at BIAR relative to the other five sites. While bottomfish density at KJ was more than twice that at BLCA, the biomass estimate was slightly greater at BLCA. We attribute this to two principle causes: 1) High numbers of Puget Sound Rockfish at KJ, and 2) relatively high numbers of adult Cabezon at BLCA. Puget Sound Rockfish accounted for 27% of the overall bottomfish density at KJ; however, due to their small size, they accounted for just 1% of the total KJ biomass. Conversely, Puget Sound Rockfish were nearly absent at BLCA (only seven observed throughout the study period). Cabezon are substantial biomass contributors and accounted for nearly 8% of the total bottomfish biomass observed at BLCA, whereas only four Cabezon were seen at KJ throughout the study.

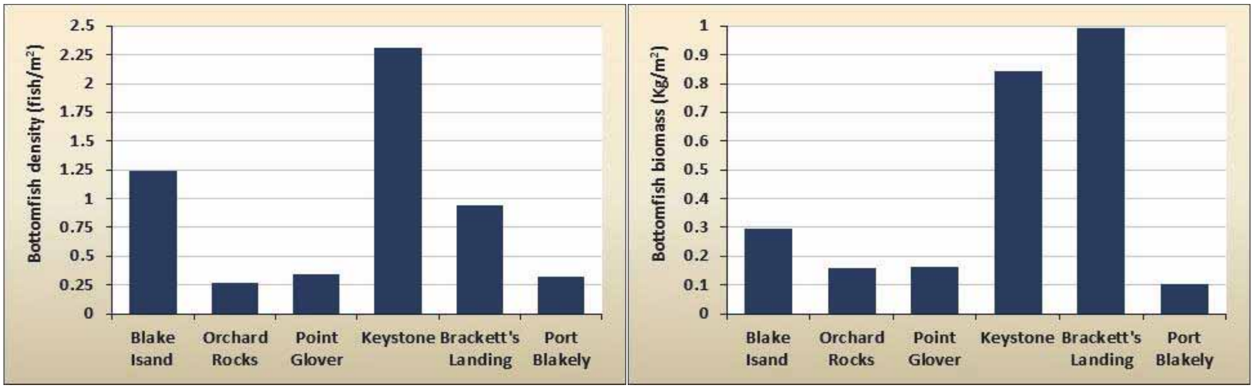

Figure 7. Bottomfish density (left) and biomass (right) at the six Puget Sound survey sites. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12).

Next, we computed the mean survey density and biomass for the three ichthyotypes identified in the species composition analysis (Figure 8). The density and biomass of rockfish and greenlings was greatest at KJ and BLCA. The relatively high overall density of rockfish at KJ can be attributed to high numbers of Puget Sound Rockfish, as noted above. The high rockfish biomass at KJ may be due to a relatively strong recruitment of juvenile Black and Yellowtail Rockfish during the final years of the monitoring period, which persisted as a strong year-class and grew rapidly (see below in this section). Perch density and biomass was greatest at BIAR, with both measures being more than twice those calculated for ORCA, PG, and PB.

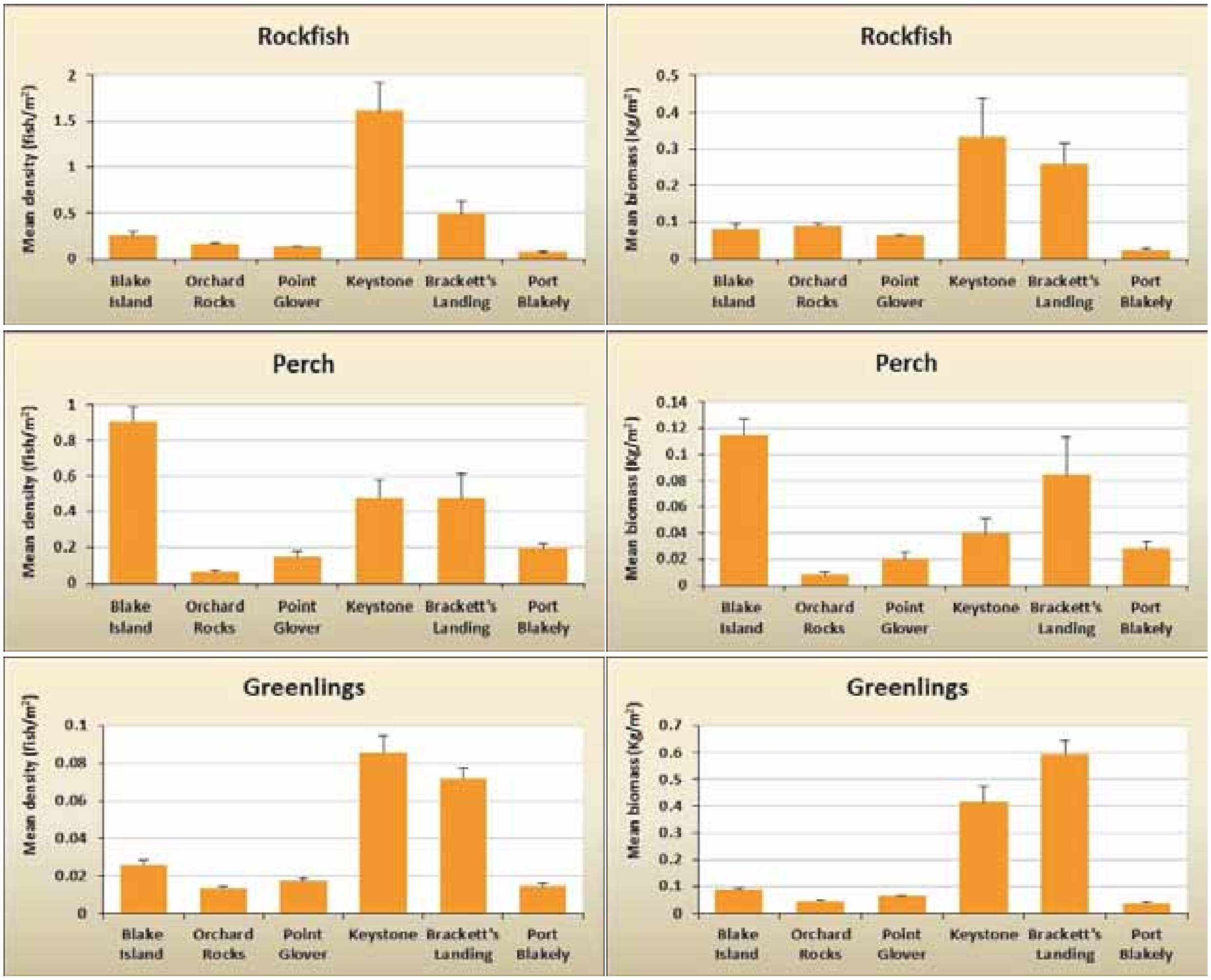

Figure 8. **Mean density (left) and biomass (right) (+1 *S.E.*) summed over all years surveyed at each site for three bottomfish groups. Unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12). Note different y-axis scales.**

We examined the relationship between density and biomass over time at each site for the three predominant ichthyotypes (rockfish, perch, and greenlings) (Appendix 6) and by species within each of those groups (Appendices 7, 8, and 9). When density and biomass profiles diverge over time, a change in demographics (age, size, sex, species composition) may be inferred. For instance, a trend toward increased biomass that is not accompanied by a similar increase in density could indicate growth and aging of individuals, or a change in sex ratio for sexually dimorphic species that exhibit substantial differences in size by sex. Conversely, an increase in density without an associated rise in biomass could indicate an increase in the proportion of smaller individuals in the population, such as might occur during a highly successful juvenile recruitment event.

At most sites, the density and biomass profiles over time were similar within each of the major taxonomic groups, though some exceptions occurred. Most notably, rockfish densities at BLCA and PB in 2006 increased substantially over the preceding years without a proportional increase in biomass (Appendix 6.E and F), with a similar but less apparent disparity at BLCA in 2007. An examination of rockfish density by species revealed that the increases in 2006 and 2007 at BLCA and PB were due primarily to increased densities of small Quillback Rockfish (Appendix 7.E). In 2006, a similar marked increase in perch density occurred at BLCA, though, unlike for rockfish, an accompanying increase in biomass was observed due to a substantial increase in Striped Seaperch of all length-classes (length data not shown) (Appendix 8.E).

We considered the possibility that the observed disparities might be explained by an inordinate recruitment of juveniles resulting in increased numbers of fish, but with a negligible impact on biomass. We evaluated this by examining densities by length-class over time at each site for the five numerically dominant rockfish species: Copper, Brown, Quillback, Black, and Yellowtail [7] (Appendix 10). For all but Brown Rockfish, we found compelling evidence of a juvenile rockfish recruitment event commencing in either 2006 or 2007 at one or more sites. This is best illustrated by the length-class densities for Copper Rockfish at BIAR (Appendix 10.A), where changes in density by length-class over time constitute a textbook example of a recruitment "pulse" moving through the population: an unusually high number of juvenile fish entered the population and, with growth, sequentially moved from smaller to larger length-classes over time. Similar patterns were observed for Copper Rockfish at each of the other five sites.

At all sites but KJ, there was also evidence of strong juvenile Quillback Rockfish recruitment in 2006 or 2007; however, with the exception of BIAR and PG, the cohort did not appear to persist over time (*i.e.*, no pulse was detected). This could be explained by emigration or mortality; fish may have left the site or perished before entering the subsequent length-class. There is at least one other tenable explanation, as it is likely that some misidentification of "positively" identified juveniles occurred. Visually, Copper and Quillback Rockfish are nearly indistinguishable during the earliest post-settlement phase of their life-history, and these two species probably accounted for the majority of all unidentified rockfish. As previously noted, all but three unidentified rockfish were placed into the smallest length-class. This could explain the lack of persistence over time of the relatively high numbers of Quillback Rockfish observed in the smallest length-class during 2006 and 2007 at BLCA and at PB in 2006 (Appendix 10.E and F). If those fish were in fact Copper Rockfish, they would have become discernable as such to the survey divers only after they entered the next larger length-classes (provided they remained and survived long enough to do so), and would then have become part of the Copper Rockfish pulse observed at BLCA and PB. If true, this suggests a bias toward misidentifying juvenile Copper Rockfish as Quillback Rockfish, rather than the converse. We also consider that behavioral differences

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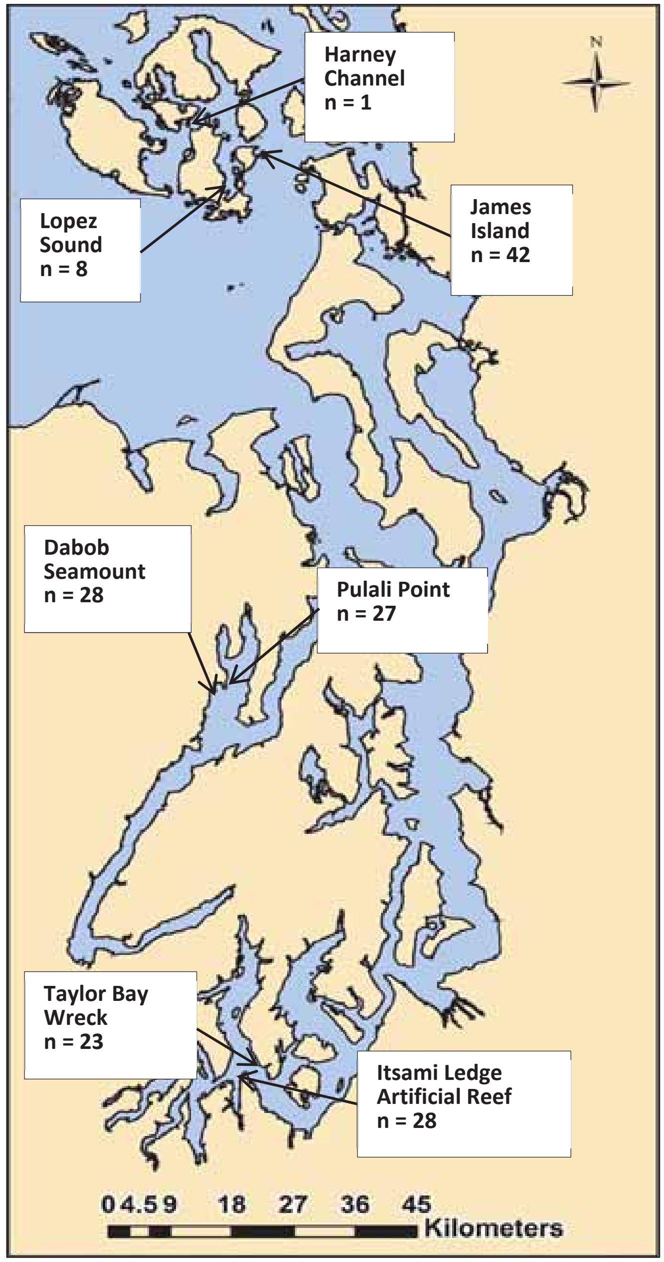
[7] Puget Sound Rockfish were numerically abundant at KJ; however, their small maximum length relative to other rockfish species resulted in all of them being placed into one of the two smallest length-classes. Further, KJ was not surveyed in 2006. Though potentially masked by the small number of length-classes for this relatively small-sized species, an examination of the proportions of the two length-classes over time gave no indication that a strong recruitment of juvenile Puget Sound Rockfish occurred during any year surveyed.

between the two species may result in different detection rates during the early post-settlement phase. While some uncertainty may exist around the apparent recruitment of juvenile Quillback Rockfish in 2006 at BCLA and PB, the evidence remains strong for BIAR and PG (and to a lesser extent, ORCA) in 2007, as a substantial increase in the numbers of Quillback Rockfish in the next-to-smallest length-class occurred subsequent to 2007 (*i.e.*, a pulse was detected).

A persistent year-class pulse commencing in 2007 was evident for Black Rockfish at all six sites (though less clearly defined at PB), and for Yellowtail Rockfish at KJ (Appendix 10.D). By 2008, presumably due to the rapid growth of cohort individuals, Black Rockfish had replaced Copper and Yellowtail Rockfish as the predominant source of rockfish biomass at KJ (Appendix 7.D). Of further note, prior to 2007, only one Black Rockfish had been observed at each BIAR and PG, compared to 667 and 121, respectively, after 2006 (Appendix 7.A and C). Although Black Rockfish exhibited evidence of a juvenile recruitment pulse at all sites (Appendix 10), the "strength" of the pulse was greater by about an order of magnitude at KJ (Appendix 10.D). There is weak evidence of juvenile Yellowtail Rockfish recruitment at BLCA in 2007, but with no apparent pulse (just one Yellowtail Rockfish was observed prior to 2007); 14 were noted in 2007, 12 of which were in the smallest length-class (< 15 cm) and two in the next-to-smallest length-class (15 < 25 cm), and no Yellowtail Rockfish were observed during subsequent years.

Curiously, at the five sites surveyed in 2006, Black Rockfish densities in the smallest length-class (< 15 cm) did not show an increase from previous years as they did at most sites for Copper and Quillback Rockfish. Rather, the apparent recruitment pulse appears to have commenced in 2007. Plausibly, the absence of Black Rockfish in the smallest length-class in 2006 could be explained by juveniles settling after the 2006 fall surveys and thus remaining undetected until 2007. Little is known about spawn timing for Black Rockfish in Puget Sound; however, along the outer coast, peak parturition occurs during March and April, sooner than Copper and Quillback Rockfish in Puget Sound. Black Rockfish are known to be less demersal than Copper or Quillback Rockfish and may have been present in 2006 but residing higher in the water column out of the divers' views. However, based on the behavior and distribution of Black Rockfish observed at all sites over the 16-year study period, we consider this an unlikely explanation.

Sidebar 1



Prompted by observations of increasing numbers of Black Rockfish in Puget Sound, the WDFW, between April and November of 2011, captured 157 Black Rockfish from seven nearshore sites in Puget Sound east of the Strait of Juan de Fuca (see inset) to determine if there was evidence of a dominant year-class in Puget Sound. Capture depths ranged from 12 m–20 m. The otoliths were removed from each fish and aged using a standard "break-and-burn" technique. Overall, 83% were determined to be age 5 fish from the 2006 cohort. Five-year-old fish accounted for 71%-100% of each sampled location (The Harney Channel, Lopez Island, and James Island sites were pooled into a single San Juan Islands sample.). The percent contribution of the 2006 cohort to each location increased with decreasing latitude. This suggests that the source of the recruits originated from somewhere outside the study area, possibly from the outer coast or the waters near or north of the San Juan Islands.

During the years leading up to 2006, few Black Rockfish were observed in our surveys of south Puget Sound (*e.g.*, remotely operated vehicles, scuba, trawl). Copper, Quillback, and Yellowtail Rockfish in south Puget Sound were also in low abundance, and they exhibited evidence of a strong 2006 cohort as well. We think it is unlikely that a strong recruitment event across multiple rockfish species would have originated from an area of relatively low abundance of mature fish. Further, many rockfish species are known to inhabit near surface waters during their larval phase, which would have occurred during the spring and summer. Surface waters would have been driven south by the northerly winds that prevail over Puget Sound during those seasons.

Tissue samples were also acquired from each fish and genotyped at ten microsatellite loci. To determine if there was evidence of genetic isolation between Black Rockfish from Puget Sound and from the outer coast, genetic pairwise comparisons between the five Puget Sound sample sites and five coastal sample sites (Cape Beale, B.C; La Push, WA; Pacific Beach, WA; Long Beach, WA; and Newport, OR) were conducted. The coastal samples were not aged, and it is not known what proportions of those samples (if any) were from the 2006 cohort. Nevertheless, of the total 28 pairwise comparisons, 21 were not significantly different ($p > 0.05$). The seven significant pairwise contrasts all involved the Newport sample.

We deduce that observed disparities between rockfish density and biomass over time were due to the recruitment of Copper, Quillback, Black, and Yellowtail Rockfish juveniles. The strength of the 2006/07 recruitment event appears to have been considerable, and, remarkably for some species, it was detected in 2006 in spite of a relatively modest survey effort. At all five sites surveyed in 2006 (KJ was not surveyed), the area surveyed was less than or equal to half the area surveyed in any other year, and no spring surveys were conducted (see Table 2).

In addition to the prominent juvenile rockfish recruitments observed in 2006/07, there is evidence that a weaker recruitment event occurred during or shortly before 1995 at some sites. For instance, Yellowtail Rockfish at KJ exhibited a weak, but clearly defined, modal progression in length from 1995-97 (Appendix 10.D). The site wasn't surveyed from 1998-2001; however, by 2002, Yellowtail Rockfish biomass was about three-fold greater than the first three years of the survey period (Appendix 7.D). This strongly suggests that a relatively weak recruitment pulse did occur and that the cohort persisted over time. Less strongly defined pulses were observed for Brown Rockfish at ORCA and BIAR, Copper Rockfish at ORCA and KJ, and Quillback Rockfish at KJ during the same period (Appendix 10.A, B, and D). Of note, even when recruitment was relatively weak, a pulse was still clearly discernable (*e.g.*, Quillback Rockfish at PG in 2007 and KJ in 1995, Appendix 10.C and D, respectively). Taken in total, this synchronous settlement success for a number of species indicates that at least one, and likely a suite, of environmental parameters were especially suitable for rockfish survival during this period. These could range from physical parameters such as temperature, dominant current direction, and upwelling intensity, to biological parameters such as prey biomass, reduced competitor biomass, and reduced predator biomass. Unfortunately, site-specific evaluation of such forcing factors did not occur, and identification of a causal mechanism for the settlement pulse remains speculative.

A decline in Copper and Quillback Rockfish densities from 1995-2002 was apparent at BLCA. For both species, a corresponding but more precipitous drop in biomass was also evident. Density and biomass decreased by factors of about 5 and 10, respectively, for both species over the eight-year period (Appendix 7.E). As noted by Palsson *et al*. (2004), Lingcod density and biomass increased slightly over the same period (Appendix 9.E).

Lingcod are high trophic-level feeders and are among the dominant fish predators on rocky reefs and other structurally complex habitats in Puget Sound. It has been suggested, though not confirmed, that Lingcod may exert top-down control over populations of some rockfish species through predation (Beaudreau and Essington, 2007), and that the removal of Lingcod (*i.e.*, predator culling) could aid in the recovery of localized rockfish populations (Oken and Essington, 2016). Tinus (2012), however, asserted that Lingcod are unlikely to be a primary source of mortality for any rockfish life history phase. We conducted a cursory examination to determine if there was evidence of an inverse relationship between the density or biomass of Lingcod and other bottomfish, which could be suggestive of a predator effect. Generally, both the density and biomass profiles over time were concordant and not inverse, suggesting that

Lingcod have no apparent impact on controlling other bottomfish at the coarsest spatial scale (all sites combined) (Figure 9). As described above, we attribute the prominent upsurge in the density of all other bottomfish in 2006/07 to juvenile rockfish recruitment observed at most of our study sites.

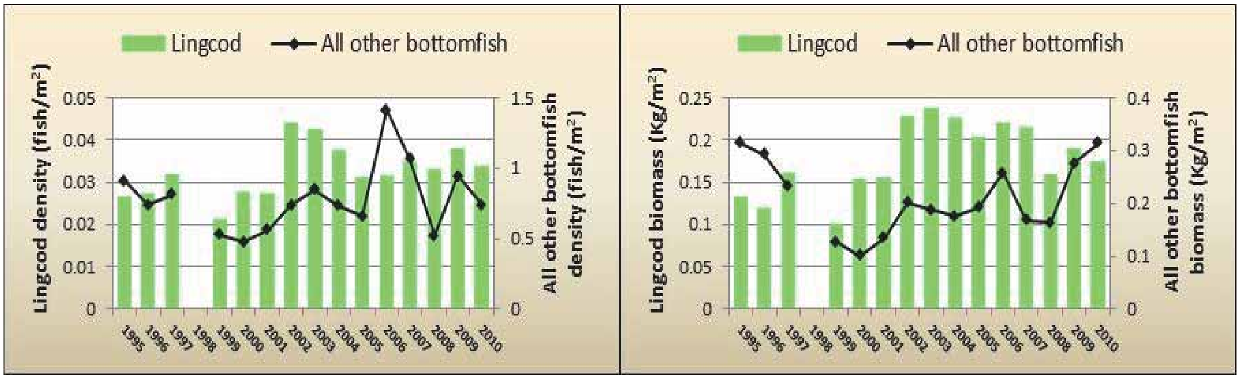


Figure 9. Density (left) and biomass (right) for Lingcod and all other bottomfish. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12).

To explore a possible predator effect at a finer spatial scale, we compared density and biomass between Lingcod, Puget Sound Rockfish, and all other rockfish species at KJ (Figure 10). Beaudreau and Essington (2007) reported that slightly fewer than half of the scorpaeniform fish that they sampled from Lingcod stomachs (and that could be positively identified to species) from the San Juan Islands were Puget Sound Rockfish. The remainder consisted of unidentified *Sebastes* spp., of which 11% were confirmed to be species other than Puget Sound Rockfish. They note from Love *et al*. (2002) that Lingcod > 34 cm in total length (TL) may ingest Copper Rockfish juveniles at a size of 7 cm TL; Lingcod > 54 cm TL are capable of consuming the entire size range of Puget Sound Rockfish (max recorded size of about 18 cm TL); and that Lingcod 95 cm TL are capable of consuming rockfish up to 40 cm TL. The Keystone jetty (KJ) exhibited a wide diversity of rockfish species and was the only site at which Puget Sound Rockfish occurred in abundance. That site also exhibited the highest overall densities of rockfish (see Figure 8) and the greatest number of juvenile rockfish recruits. Further, all Lingcod observed at KJ were ≥ 35 cm TL (*i.e*., capable of ingesting juvenile rockfish); 94% were ≥ 55 cm TL (*i.e*., capable of ingesting all sizes of Puget Sound Rockfish), while 8% were ≥ 95 cm TL (*i.e*., capable of ingesting rockfish up to 40 cm TL). We reasoned that if an inverse relationship between Lingcod and rockfish density or biomass existed in our data, KJ afforded the best opportunity to detect it. Because smaller rockfish are more heavily preyed upon by Lingcod than larger rockfish (Beaudreau and Essington, 2007), we included only rockfish < 25 cm TL (which includes all observed Puget Sound Rockfish) in order to further improve our ability to detect a relationship, should one exist. As with the Lingcod/all bottomfish comparison, a strong inverse relationship between Lingcod density and biomass with either Puget Sound Rockfish or all other rockfish was not apparent (Figure 10). We note, however, that the density of Puget Sound Rockfish more than doubled from 1996 to 1997 while Lingcod density increased only slightly during the same period. In spite of the increased density of Puget Sound Rockfish over other rockfish from 1995-97, their biomass matched nearly exactly that of all other rockfish for the same period. We further note that the greatest density, biomass, and frequency of occurrence of Lingcod in the largest length-classes at BLCA occurred in 2006, concurrent with juvenile rockfish recruitment (see following section).

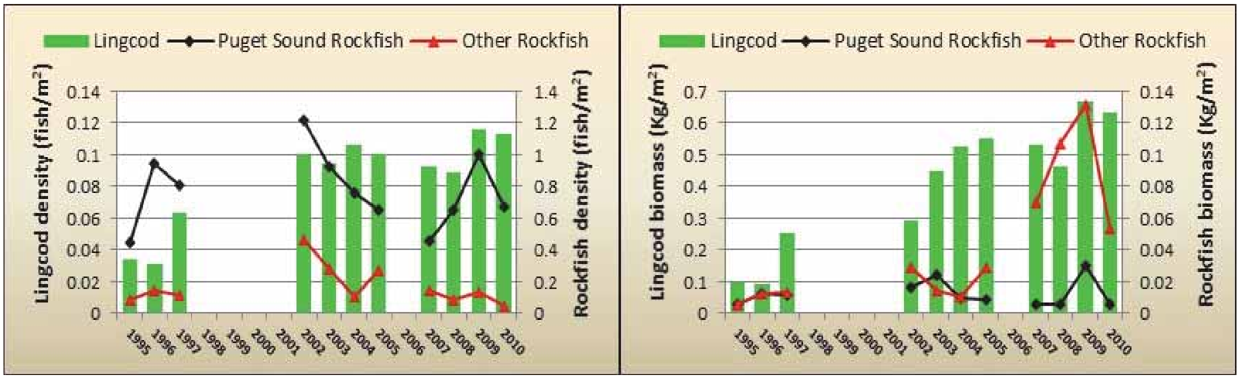


Figure 10. Density (left) and biomass (right) by year for lingcod, Puget Sound Rockfish, and all other rockfish at the Keystone jetty. Only rockfish < 25 cm TL are included (which includes all observed Puget Sound Rockfish). Unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12).

At KJ, Lingcod density in 2002 was slightly less than twice that observed in 1997, whereas biomass showed only a minimal increase over this period (Figure 10). This disparity clearly captures the change in the size structure of Lingcod at KJ, with a greater proportion of smaller fish in 2002, as evidenced by the decrease in average length from 1997 (Appendix 11.G). From 2002 onward, Lingcod density remained stable through the end of the monitoring period; however, biomass increased, and by 2010 it was slightly more than double that observed in 2002. When summed over all years, Lingcod density and biomass at KJ and BLCA were each greater than at any of the other four sites. Despite these changes in Lingcod population composition, a correlation with small rockfish abundance was not apparent, as noted above, thus failing to provide support to the hypothesis that Lingcod predation was a significant population-level driver for rockfish at any of the sites considered.

Frequency of Occurrence and Density by Size

We calculated percent frequency of occurrence and density by size in length (“small” and “large”) for bottomfish that: 1) are currently or were historically important in the recreational fishery; 2) were observed at all sites, and; 3) had overall frequencies of occurrence of at least 95% at one or more sites. Eight species met these criteria: Copper, Brown, Quillback, and Black Rockfish; Lingcod; Kelp Greenling; Cabezon; and Striped Seaperch (see Table 4). We defined the division between “small” and “large” for each species as that size class (see p 8) which came closest to capturing half the species’ maximum reported length (Table 8).[8]

For six species (Copper, Quillback, and Black Rockfish; Lingcod; Cabezon; and Striped Seaperch), large fish were more frequently observed at BLCA than at any of the other five sites, and BLCA was the only site at which Copper Rockfish in the 55 < 65 cm length-class ($N = 13$) and Quillback Rockfish in the 45 < 55 cm length-class ($N = 14$) were encountered. Additionally at BLCA, 89 Black Rockfish in the 55 < 65 cm length-class were observed; aside from a single individual encountered at ORCA, this was the only site where Black Rockfish in that length-class were observed. Likewise, Lingcod ≥ 115 cm were encountered only at BLCA ($N = 168$), and BLCA was the only site at which the density of large Lingcod exceeded small Lingcod.

[8] As reported for rockfish in Love *et al*. (2002); and in Love (2011) for the remaining four species.

Table 8. Mean percent frequency of occurrence and mean density (in parentheses) by size class (TL) and study site for eight bottomfish species (see page 29). The division between "small" and "large" is as defined in the text.

Site	Copper Rockfish		Brown Rockfish		Quillback Rockfish		Black Rockfish		Lingcod		Kelp Greenling		Cabezon		Striped Seaperch	
	< 35 (small)	≥ 35 (large)	< 35 (small)	≥ 35 (large)	< 35 (small)	≥ 35 (large)	< 35 (small)	≥ 35 (large)	< 75 (small)	≥ 75 (large)	< 35 (small)	≥ 35 (large)	< 55 (small)	≥ 55 (large)	< 25 (small)	≥ 25 (large)
Blake Island	99 (0.063)	91 (0.004)	100 (0.119)	62 (0.006)	70 (0.016)	4 (0.000)	24 (0.020)	12 (0.007)	96 (0.020)	73 (0.005)	21 (0.001)	43 (0.002)	19 (0.001)	28 (0.001)	79 (0.661)	74 (0.069)
Orchard Rocks	48 (0.006)	73 (0.004)	100 (0.123)	98 (0.022)	2 (0.000)	7 (0.000)	27 (0.005)	56 (0.004)	98 (0.012)	48 (0.002)	37 (0.002)	73 (0.005)	9 (0.000)	6 (0.000)	63 (0.040)	31 (0.006)
Point Glover	63 (0.004)	27 (0.001)	100 (0.103)	94 (0.014)	23 (0.001)	0 (0)	24 (0.004)	13 (0.001)	100 (0.014)	70 (0.004)	24 (0.002)	77 (0.005)	11 (0.000)	9 (0.000)	84 (0.109)	51 (0.014)
Keystone Jetty	100 (0.013)	87 (0.023)	19 (0.001)	4 (0.000)	74 (0.012)	0 (0.000)	100 (0.506)	77 (0.058)	100 (0.045)	91 (0.038)	83 (0.016)	98 (0.029)	6 (0.000)	2 (0.000)	83 (0.411)	51 (0.037)
Brackett's Landing	100 (0.083)	100 (0.100)	70 (0.014)	19 (0.001)	98 (0.149)	63 (0.017)	35 (0.020)	98 (0.022)	88 (0.011)	100 (0.060)	11 (0.001)	71 (0.006)	72 (0.006)	100 (0.037)	89 (0.218)	90 (0.069)
Port Blakely	98 (0.022)	50 (0.004)	92 (0.028)	25 (0.001)	43 (0.006)	0 (0.000)	20 (0.001)	3 (0.000)	93 (0.013)	10 (0.001)	50 (0.003)	76 (0.007)	11 (0.000)	16 (0.001)	77 (0.133)	61 (0.021)

A substantial downward trend in the density of large Copper and Quillback Rockfish was evident at BLCA during the first seven years of the monitoring period. Afterwards, a gradual rebound for large Copper Rockfish occurred, but no such trend was apparent for large Quillback Rockfish (Figure 10). The 13 Copper Rockfish in the 55 < 65 cm length-class, and 13 of the 14 Quillback Rockfish in the 45 < 55 cm length-class (see preceding paragraph) were all observed during the first four monitoring years. Due to their disproportionate size-at-length, the disappearance of large Copper Rockfish at BLCA accounts for the sharp overall decline in Copper Rockfish biomass and for the more precipitous decline in biomass relative to density as noted above (see Density and Biomass) (Appendix 7.E). A similar, though less protracted, decline in large Copper Rockfish was also observed at PB (large Quillback Rockfish were not observed at PB).

We consider the following possible explanations for the disappearance of large Copper and Quillback Rockfish from the BLCA surveys: 1) fishing mortality, 2) senescence, 3) marine mammal predation, and 4) emigration. Although the BLCA has been closed to fishing for decades, some fishing occurs in close proximity to the MPA boundary. The BLCA transects (along the *DeLeon*) were located adjacent to the southern boundary, about 100 m from the offshore boundary, and over 500 m from the northern boundary of the MPA. The southern boundary is demarcated by the Edmonds ferry terminal pier, from which fishing is prohibited. The area due south of the ferry pier contains an old (pre-1980) tire-bundle artificial reef structure, and although the area is open to fishing, few people are aware of the reef and virtually no fishing activity occurs there. However, considerable fishing effort occurs along the seaward boundary of the BLCA, especially during Lingcod season (May 1 – June 15). Vessels targeting Lingcod have been observed "crowding" the offshore boundary, with anglers casting terminal gear well into the BLCA, and some vessels have been seen entering the BLCA despite clear signage that vessels are strictly prohibited. Other submerged structures exist along the seaward boundary of the BLCA and are known to harbor large rockfish (WDFW unpublished data). If large rockfish made forays from these structures and/or the transect sites toward the seaward edge of the sanctuary (*e.g.*, in search of prey), they could have been vulnerable to harvest. It should be noted that WDFW divers have occasionally found terminal tackle from hook-and-line anglers well within the BLCA boundary (WDFW unpublished data), and therefore we cannot rule out the possibility that fishing was occurring within the sanctuary. Another potential source of mortality that cannot be ruled out is that from spearfishing, as WDFW biologists have received sporadic reports of suspected spearfishing occurring within the BLCA. The seaward boundary of the BLCA lies along the ~15m seafloor contour and is demarcated by large buoys anchored at regular intervals along the bottom. Little suspicion would be raised to a vessel that appears to be fishing along the boundary line and a vessel-based diver could make a quick descent to the bottom along one of the buoy lines and enter the park unseen and spearfish undetected (with the exception of possibly being seen by other divers). Diver guide-lines installed throughout the BLCA allow for easy navigation throughout the underwater park and would enable the diver to return to the exact point of entry. Although the density of large rockfish at the BLCA prior to their decline was greater than any other study site, the relative size of the population was small, numbering only a few hundred individuals. At this population size, the number of large rockfish at the transect sites could be quickly diminished over time by only a few persistent divers, thus we cannot discount this source of mortality as a possible cause for their decline.

Based on their relatively quick decline at the BLCA transect sites, senescence is considered to be a more plausible explanation for the decline of large Copper and Quillback Rockfish. Some rockfish populations are known to be dominated by a small number of year classes and, as evidenced in this study, strong recruitment events are sporadic. The length-at-age asymptote for both Copper and Quillback Rockfish in Puget Sound occurs at about 40 cm TL (West *et al*. 2014; Love *et al*. 2002), and the large fish (defined here as ≥ 35 cm TL) observed during our surveys could have been very old. Therefore, given the age and long-term protection status of the BLCA, we hypothesize that a strong cohort of Copper and Quillback Rockfish reached terminal age and perished over the course of several years. Some anecdotal evidence exists to support this hypothesis; during surveys conducted at the site the divers would occasionally encounter large dead rockfish and Lingcod, and this is the only site in our study where this was ever observed.

Seal and sea lion populations have increased as much as 10-fold in Puget Sound since the 1970s as a result of safeguards put in place by the Marine Mammal Protection Act (Jeffries *et al*. 2003), and these voracious predators are known to occasionally eat rockfish (Everitt *et al*., 1981; Lance *et al*. 2012). Because of this, it has been suggested that marine mammal predation could be responsible (in part or in full) for reducing the population of large rockfish at the BLCA site, although the available evidence does not support this hypothesis. Given that the majority of these mammals' diets consist of abundant and readily available species like forage fishes, Pacific Hake, and, seasonally, salmon, we presume this source of mortality is relatively minor for large, spiny-rayed prey such as adult Quillback and Copper Rockfish. Additionally, we note that from 1970 to 1988, floating docks were moored near the dry dock (see Site Descriptions) to provide a resting place for divers and spectators. The docks quickly became a popular haul-out site for sea lions and other pinnipeds, and divers frequently encountered them underwater. Anecdotal accounts from divers frequenting the area during that time suggest that no appreciable loss of rockfish, large or small, occurred during or subsequent to their presence (pinnipeds left the area once the docks were removed).

It is unclear what role emigration may have played in the decline of large rockfish at the BLCA survey site. By area, BLCA covers nearly 40 times the maximum reported home ranges for both Copper and Quillback Rockfish (ca. 4000 - 5000 m^2) (Matthews, 1990b; Tolimieri *et al*., 2009; Rankin *et al*., 2013). As we have no evidence to suggest that prey resources at the site were diminishing over time, there would appear to be no reason for large fish to leave the transect site, assuming they are more successful than smaller fish at defending and holding optimal habitat. However, the addition of other underwater structures in close proximity to the transect site during the period of decline may have been a contributing factor via the migration of large rockfish from the transect site to potentially higher suitability habitat. It should be noted that following most surveys at the transect site, the divers would visit other structures in the park to count and size rockfish, Lingcod, Cabezon, and other benthic fishes, although no attempt was made to quantify the area swept. These roving counts captured many large rockfish throughout the BLCA, some of which may have originated from the survey site.

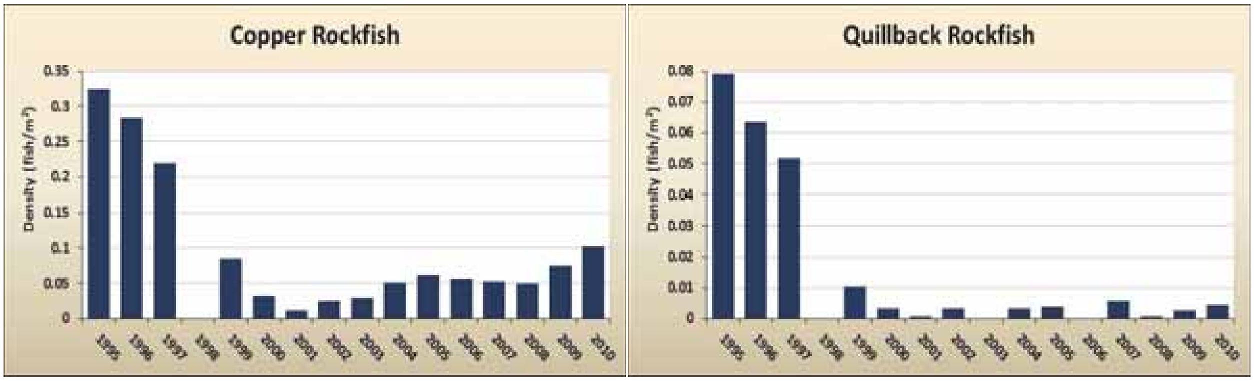


Figure 11. Annual density of large (≥ 35 cm) Copper and Quillback Rockfish at BLCA. No surveys were conducted in 1998. Note different y-axis scales.

For four species (Copper and Quillback Rockfish, Lingcod, and Cabezon), the highest frequencies of occurrence of large fish at BLCA coincided with the highest densities (which were near or greater than twice that observed at the other five sites), with one exception: for large Black Rockfish, the frequencies of occurrence and densities were incongruent at BLCA and KJ. Both sites exhibited relatively high frequencies of occurrence and densities of large Black Rockfish; however, while the frequency of occurrence of large Black Rockfish was greater at BLCA (98%) than at KJ (77%), the overall density of large Black Rockfish at KJ (0.058) was greater by a factor of nearly three. At KJ, large Black Rockfish were abundant during just one year (2010) and were represented primarily by a single length-class (35 < 45 cm) (Appendix 10.D); however, the density of those fish was nearly an order of magnitude greater than the highest annual density of fish in the same length-class at BLCA (which also occurred in 2010). Furthermore, large Black Rockfish ≥ 45 cm were seen consistently across all years at BLCA (Appendix 10.E) but rarely seen at KJ (no Black Rockfish ≥ 55 cm were observed at KJ). This accounts for the greater frequency of occurrence of large Black Rockfish at BLCA in spite of their overall lower density when compared to KJ. Large fish were observed at low densities at BLCA but were frequently encountered and consistently present over time; conversely, large fish were present at high densities at KJ, but for only a brief period of time (*i.e.*, less frequently observed).

Large Striped Seaperch were also observed most frequently at BLCA, but they were equal in density to those observed at BIAR, where large fish were observed slightly less frequently than small fish. Brown Rockfish and Kelp Greenling, the two species for which the large fish frequencies of occurrence were not greatest at BLCA, occurred in very low densities at BLCA relative to those sites where they were frequently encountered (see Table 8).

Lengths

Mean lengths by year are presented in Appendix 11 for each of the eight species of bottomfish that met the criteria identified at the beginning of the previous section, and for Yellowtail Rockfish at KJ (the only site at which Yellowtail Rockfish occurred in appreciable numbers). Length-frequency histograms for each of the nine species are presented in Appendices 12-20. For each of the five rockfish species, we present annual means summed over all length-classes, and means summed over all but the smallest length-class. The latter treatment ameliorates the effect of the 2006/07 recruitment event on the detection of length trends over time, which can be seen clearly for Copper and Quillback Rockfish at BIAR, and Quillback Rockfish at BLCA (Appendix 11.A and C).

At those sites where the density, biomass, and frequency of occurrence (see Table 4 and Appendix 7) were greatest for Brown Rockfish (BIAR, ORCA, PG, and PB), a remarkably stable length trend was observed, and there was little difference in annual mean lengths with and without the inclusion of the smallest length-class (this strengthens our view that Brown Rockfish juveniles did not heavily recruit in 2006/07) (Appendix 11.B). In Puget Sound, male and female Brown Rockfish reach 50% maturity at about the same length (24 and 26 cm TL for males and females, respectively) (Love and Johnson, 1998). At each of the four sites, summed over all years and both with and without the inclusion of the smallest length-class, the mean lengths of Brown Rockfish were within ±3 cm of the median male-female 50% maturity length (i.e, 25 cm). Relative to small fish, large fish occurred at very low densities at each site (see Table 8); therefore, although Brown Rockfish lengths remained stable over time, most Brown Rockfish remained at or below the length at which 50% of the population was sexually mature. This contrasts markedly with Cabezon at BLCA (the only site at which Cabezon occurred in appreciable numbers throughout the survey period), where length over time also remained stable; however, the mean length (63 cm) summed over all surveys and the lowest annual mean length (57 cm) (see Appendix 11.I) were both above any 100% maturity lengths reported for this species. Furthermore, nearly every Cabezon encountered was over any reported 50% maturity length; the frequency of occurrence of large fish was 100%; and the overall density of large fish was 5 times that of small fish (see Table 8).

At KJ, although the mean length (78 cm) of Lingcod summed over the last three survey years increased 20% over the mean of the first three survey years, we cannot characterize the change as a trend because there were too many intervening years in which no surveys were conducted. Nevertheless, the site was afforded MPA status approximately midway through the monitoring period, and we cannot dismiss the possibility that the increase in length is linked to harvest restrictions. The increase in Lingcod mean lengths also accounts for the stable density, accompanied by increased biomass, over the course of the last half of the monitoring period, as noted above (see Density and Biomass, page 21).

Sidebar 2

Between April 2005 and November 2009, 71 Brown Rockfish were live-captured using hand-held nets by WDFW scuba divers at the Orchard Rocks Conservation Area in connection with a rockfish genetics study. All fish were measured underwater to the nearest cm (total length) and immediately released at the point of capture. The live-capture sampling occurred near, but not over, the transects used in our study, and were temporally out of phase with the transect surveys in order to eliminate any impact on survey fish counts. The effort was directed toward live-capturing as many Brown Rockfish as possible during each dive, without regard for size. Summed over the years 2005-2009, the mean length of Brown Rockfish observed on transect was 30 cm; over the same period, the mean length of the live-captured fish that were measured to the nearest cm was also 30 (*s.e.* 3.30). While this comparison does not provide a statistically robust validation of surveyor ability to accurately estimate fish lengths (nor was it intended to do so), the fish-in-hand length data provide at least some assurance that survey divers were reasonably accurate in assigning rockfishes to the appropriate length-classes.

Comparable Studies

Study Synopses

Four of our sites (BIAR, ORCA, BLCA, and PB) were used in previous studies that entailed the use of scuba surveys to characterize fish populations. Those studies generated comparable data that may add further perspective to our survey results and can be briefly described as:

1) In 1975, the WDFW (then, Washington Department of Fisheries) contracted with the University of Washington to study fish associations with anthropogenic structures at the Port of Edmonds to help inform the placement and construction of a proposed fishing pier and artificial reef at that location. For a two-year period beginning in June 1975, Walton (1979) conducted monthly strip transect surveys near the Edmonds Marina and within the BLCA Edmonds Underwater Park. Surveys within the underwater park were conducted monthly from July 1975 to June 1976. Although the dry dock *DeLeon,* which was surveyed in our study, was not explicitly mentioned in the report, the author's description of the underwater park study site and survey method strongly suggests that it *was* included, as well as the nearly adjoined *M/V Alitak*.

2) Over a 15-month period beginning in October 1980, Laufle (1982) conducted monthly counts of fish, both day and night, on or adjacent to the BIAR to test for differences in habitat preferences between natural and artificial substrates, and between the different materials used to construct the artificial reef (*i.e*., concrete rubble and various configurations of automobile tires). The study included 15 monthly surveys of three delineated 6 x 6 m areas of the nearshore rubble patch, and 12 monthly surveys (no surveys were conducted in October or December 1980, and December 1981) of the entire offshore rubble patch (see Site Descriptions).

3) From December 1986 through October 1988, Matthews (1990a) conducted periodic rockfish strip transect surveys using scuba at eight central Puget Sound sites, including BIAR, ORCA, and PB, to evaluate habitat usage by different rockfish life-history stages. As noted in the above Surveys section, our transect locations at the BIAR, ORCA, and PB sites coincide approximately with those used by Matthews.

4) From July 1986 through June 1988, Matthews (1990c) tagged and released 512 Copper, Brown, and Quillback Rockfish from six sites, including BIAR, ORCA, and PB. A total of 248 fish (193 of which were from BIAR, ORCA, and PB) were displaced prior to release, and resightings during monthly scuba surveys were noted in order to determine whether habitat association affected movement patterns for these species. Lengths were recorded for each fish tagged and mean lengths for each species were reported for each sight.

Study Comparisons

Compositionally, our results from the BIAR, ORCA, BLCA, and PB bottomfish surveys were in general agreement with the aforementioned studies, though with some notable exceptions. Perhaps the most striking was the complete absence of Lingcod observed by Walton (1979) in 1975-76 at the Edmonds Underwater Park, and the near complete absence from seven other surveyed sites adjacent to the park (six of which contained anthropogenic structure). Only five Lingcod were seen throughout the entire study, with an overall frequency of occurrence of just 2%.[9] In our study, Lingcod frequency of occurrence at BLCA was 100%, and the mean count per year was 105 (*s.d.* = 40.07). Walton noted that, "Cabezon, observed on almost every dive [at Edmonds Underwater Park], were by far the largest fish species present…." Cabezon were observed on every dive in our study as well and, as noted above, accounted for 8% of the total biomass observed at BLCA (see Density and Biomass). This is in close agreement with Walton's finding of Cabezon contributing 10% to the total average biomass observed at the park in 1975-76. Lingcod, however, were the largest fish (in length) observed in our study. Additionally, no Painted Greenling were noted by Walton, but this species was observed in 95% of our surveys with a mean count of 57 per year (*s.d.* = 25.37). A list of targeted species was not presented by Walton, only that "potentially valuable sport species" were recorded. While it remains possible that Painted Greenling were present but not recorded (*i.e.*, not regarded as potentially valuable), other species of questionable importance to recreational fishers were recorded, such as Snake Prickleback and Pacific Staghorn Sculpin. We surmise that had Painted Greenling been frequently observed and abundant, as they were in our study, they would have been reported.[10] The frequency of occurrence of Pacific Tomcod during the 1975-76 surveys at the Edmonds Underwater Park was 64% (Pacific Tomcod was the only Gadid observed within the park at that time). Over the entire area surveyed by Walton at the Port of Edmonds, frequencies of occurrence for Pacific Cod, Walleye Pollock, and Pacific Tomcod were 16%, 3%, and 9%, respectively. No Gadids were observed during our surveys at BLCA.

In further contrast to our study, Walton found the density and biomass of Copper and Black Rockfish to be nearly equal, and the two species accounted for the majority of the total rockfish density and biomass at the Edmonds Underwater Park[11]. While the frequency of occurrence for Black Rockfish in our study was near 100%, their contribution to density and biomass was less than half that of Copper Rockfish for nearly all years; only after the 2006/07 juvenile recruitment event did Copper and Black Rockfish approach (but not attain) unity in proportions. Lastly, the mean site density (0.18 fish/m^2, *s.d.* = 0.09) and biomass (0.18 kg/m^2, *s.d.* = 0.17) estimates for

[9] Table 1 of Walton (1979).

[10] The absence of Painted Greenling and Lingcod, and inclusion of the *DeLeon,* in the 1975-76 Edmonds Underwater Park surveys was confirmed by personal communication on 29 March 2016 with R. M. Buckley (WDFW, retired) who participated in many of the Walton (1979) survey dives.

[11] Table 13 of Walton (1979).

Copper Rockfish at BLCA in our study were each six-times greater than those reported by Walton.

During the nine years prior to the fishing closure within the Edmonds Underwater Park, up to three Lingcod and 15 rockfish could legally be retained daily by anglers and spearfishers, and Cabezon could be harvested without limit. It is possible that fish aggregating on and near the *DeLeon*, the most prominent bottom structure present during that time, had been severely overfished prior to the harvest closure; indeed, the fishing closure was prompted by concerns about overfishing (see Site Descriptions). Walton's surveys may have occurred during a period of post over-exploitation recovery, thus accounting for the relatively low density and biomass of rockfish and the complete absence of Lingcod, fish that are highly prized by both anglers and spearfishers, within the underwater park.

Sidebar 3

Prior to 1953, spearfishing in Puget Sound was unlawful. On 30 March, 1953, the then Washington Department of Fisheries issued an order that legalized the activity. Afterwards, the sport burgeoned with the formation of several spearfishing clubs that regularly held spearfishing competitions throughout Puget Sound. The first competition (Pacific Northwest Underwater Spearfishing Championship) was held in June of 1955 with 35 divers, representing six clubs, participating. The use of scuba was prohibited in all Puget Sound spearfishing contests.

Tallman[1], through a questionnaire survey, determined that Lingcod was the most frequently speared fish in Puget Sound, followed by rockfish, and that Edmonds was visited by more spearfishers than any other site. He also remarked, "More fish have probably been speared at Edmonds than at any other site." Buckley[2], using a similar survey method, determined that spearfishing was the most popular reason for diving in Puget Sound during the winter months, and that Lingcod accounted for 56% of the spearfishing harvest in winter. The same author conducted creel surveys at seven spearfishing competitions in 1965, each of which was held at a different Puget Sound location. Two of those locations were surveyed in our study (Edmonds and Keystone). Effort during both competitions probably occurred both within and outside of areas now designated as Conservation Areas. The Edmonds Marina breakwater had not yet been constructed at the time of the competitions. The numbers of bottomfish harvested during each of the two single-day events (excerpted from Buckley[2], Tables 21 & 24) are presented in the accompanying table, and they provide some indication of the level of spearfishing pressure that was placed on local bottomfish populations during the sport's most active years.

	# of speared fish landed	
Species	**Edmonds (March 7, 1965)**	**Keystone (May 9, 1965)**
Lingcod	3	24
Cabezon	142	82
Black Rockfish	4	143
Copper Rockfish	138	74
Unidentified Rockfish	0	122
Kelp Greenling	28	8
Striped Seaperch	10	0
Pile Perch	1	0
Pacific Cod	2	0
Red Irish Lord	8	0
Buffalo Sculpin	7	0
Pacific Staghorn Sculpin	2	0
Flatfish	27	3
Total # bottomfish landed	**372**	**456**

As early as 1955, the director of the University of Washington's then School of Fisheries, in recognition of the winter movement of Lingcod spawners into nearshore habitat, remarked that Lingcod spearfishing should be discouraged during the winter spawning season. In 1964, a proposal by concerned fishers was advanced to close Lingcod spearfishing in all Puget Sound waters east of the eastern end of the Strait of Juan de Fuca from January 1 to March 1 in order to protect winter spawners in the nearshore environment. The proposal was rejected on the basis of a lack of supporting biological data. A winter spearfishing closure ultimately *was* implemented in 1966, and in 1978, similar seasonal restrictions were imposed on hook-and-line anglers.

[1] Tallman, J. D. 1956. The status of underwater spearfishing in the Puget Sound area of Washington. Master's thesis, 164 p, Univ. Washington, Seattle, WA.
[2] Buckley, R. M. 1967. Status report on skin diving and spearfishing in Puget Sound, January to June, 1965. Wash. Dept. Fish. Supp. Progress Rep., 64 p, Olympia, WA.

The overall assemblage of bottomfish species observed by Laufle (1982) during the daylight surveys in 1980-81 at BIAR was remarkably similar to our observations; however, the predominance of Copper Rockfish over other rockfish species contrasts with our findings of predominantly Brown Rockfish prior to the 2006/07 recruitment event (after which, Copper

Rockfish nearly equaled, or even exceeded, Brown Rockfish in density and biomass) (Appendix 7.A). The frequency of occurrence of Brown Rockfish observed by Laufle on the offshore rubble patch was 58% and did not exceed 7% on any of the three nearshore rubble-patch areas surveyed.[12] The frequency of occurrence of Brown Rockfish at BIAR in our study was 100%. Further, Quillback Rockfish were second numerically to Copper Rockfish at BIAR in 1980-81. Although Quillback Rockfish accounted for nearly 30% of the total rockfish density and biomass in 1995, they steadily declined afterwards and were nearly absent by 2000 but reappeared in greater numbers after the 2006/07 juvenile rockfish recruitment event. We note that the decline in Quillback Rockfish at BIAR coincides closely in both time and magnitude with the decline in Copper Rockfish observed at BLCA, as described above (see page 32).

We used data presented by Laufle[13] to compute mean densities for his 15-month study (1980-81) for the three rockfish species that were most frequently observed at BIAR by Laufle and in our study: Copper, Quillback, and Brown Rockfish. We compared those densities both to our mean densities from the 15 years surveyed between 1995 and 2010 (no surveys were conducted in 1998) and, in order to suppress the effect of juvenile rockfish recruitment in 2006, to the mean density for all years prior to 2006 (Figure 12). Over the 1995-2010 time period, Copper Rockfish density at BIAR was slightly greater than and Quillback Rockfish density slightly less than observed in 1980-81; however, with the omission of years after 2005, the density for both species dropped to less than half that observed in 1980-81. Brown Rockfish densities did not differ greatly between the overall and abbreviated time periods after 1981, and this further strengthens our conclusion that a major Brown Rockfish juvenile recruitment event did not occur in 2006/07 (at least not at BIAR) (see Density and Biomass). If it had occurred, we would have expected to see a more substantial difference in density between the two time periods, as observed for Copper Rockfish. Mean Brown Rockfish densities for each of the latter two time periods were nearly ten-times the mean density observed by Laufle in 1980-81. Of further interest is that Laufle recorded only a single Wolf-eel at BIAR in 1980-81, whereas in our study the frequency of occurrence of Wolf-eel at BIAR was 39%.

[12] Appendix Tables 17, 18, 19, and 23 (day only) of Laufle (1982).
[13] Appendix Tables 2, 5, 6, and 14 (day only) of Laufle (1982).

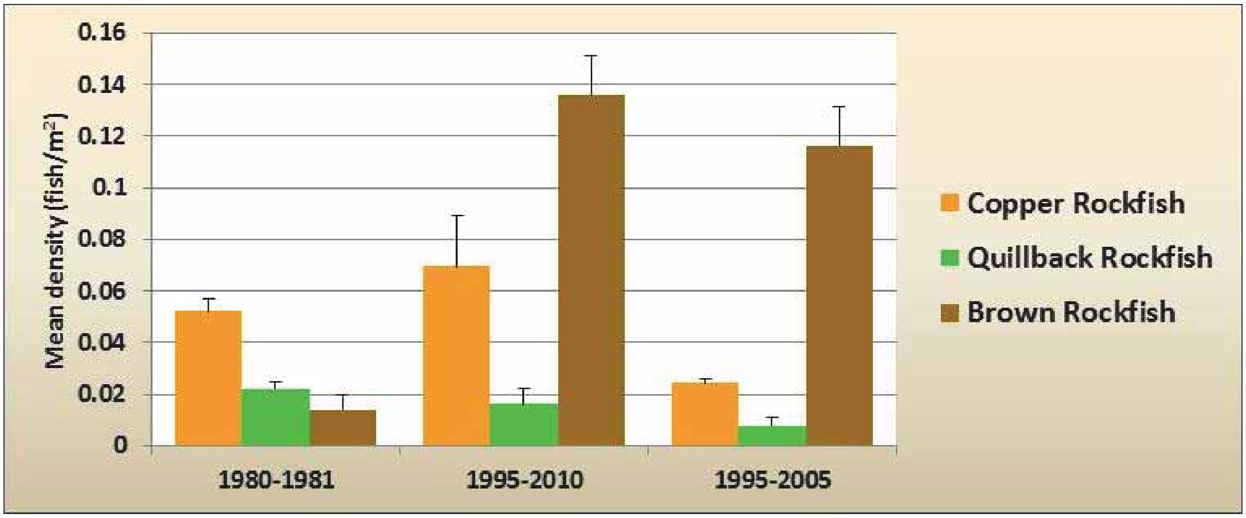


Figure 12. Mean densities (+ 1 S.E.) of the three most frequently observed rockfish species observed by Laufle (1982) over a 15-month period in 1980-81, and by WDFW over a 16-year period (1995-2010) and an 11-year period (1995-2005) at Blake Island Artificial Reef.

Laufle's study commenced in the fall of 1980, just months after BIAR was constructed, and thus offers an account of the reef's earliest fish inhabitants. The similarity in bottomfish species composition between immediate post-construction and 1995-2010 suggests that colonization and ecological succession on the reef occurred rapidly, and that the first rockfish colonizers were primarily Copper Rockfish, possibly arriving from the offshore escarpment described in the Site Descriptions for Blake Island.

Both of the studies conducted by Matthews (1990a and 1990c) corroborate Laufle's finding of a rockfish assemblage dominated by Copper and Quillback Rockfish at BIAR, and extends that finding to ORCA and PB. In both of the Matthews studies, Brown Rockfish were relatively scarce at each of the three comparable sites surveyed; indeed, no Brown Rockfish were observed at BIAR by Matthews (1990c) in 1986-88. Furthermore, Black Rockfish were not noted by either Laufle (who remarked that, "No schooling rockfish species were observed anywhere.") or Matthews. Matthews' survey method differed from ours in at least two important respects: just one surveyor, rather than two, counted fish within 3 m of the transect center-line, and they did so to a height of just 1 m off the bottom. Black Rockfish are less demersal than the rockfish species observed, and it remains possible that they were present but greater than 1 m off the bottom. We believe it to be likely, however, that had pelagic species of rockfish been observed, even if outside the survey area, Matthews would have mentioned it.

We compared the mean lengths of Copper, Brown, and Quillback Rockfish observed in our study to the mean lengths of those fish tagged by Matthews (1990c)[14] from 1986-88. As shown in

[14] Table 3 of Matthews (1990c).

Figure 13, two mean lengths are depicted for rockfish observed in our study: one that excludes the smallest length-class and one that includes all length-classes. We believe the former offers a better comparison with Matthew's observations as it minimizes the impact of the 2006/07 juvenile recruits to the overall mean. Additionally, although Matthew's did not report minimum lengths for the tagged fish, the use of anchor tags with an attached numbered disc 1.4 cm in diameter makes it highly improbable that juveniles, and possibly even small subadults, were tagged in that study.

Summed over the 1995-2010 time period, and excluding the smallest length-class, the mean lengths for Brown and Copper Rockfish were slightly less at PB, and Quillback Rockfish were approximately equal in length when compared to 1986-88. Copper and Quillback Rockfish mean lengths were slightly greater at BIAR during the latter time period. Copper Rockfish at ORCA were considerably greater in length when summed over the latter time period. Brown Rockfish mean lengths at ORCA were approximately equal during the two time periods (Figure 12).

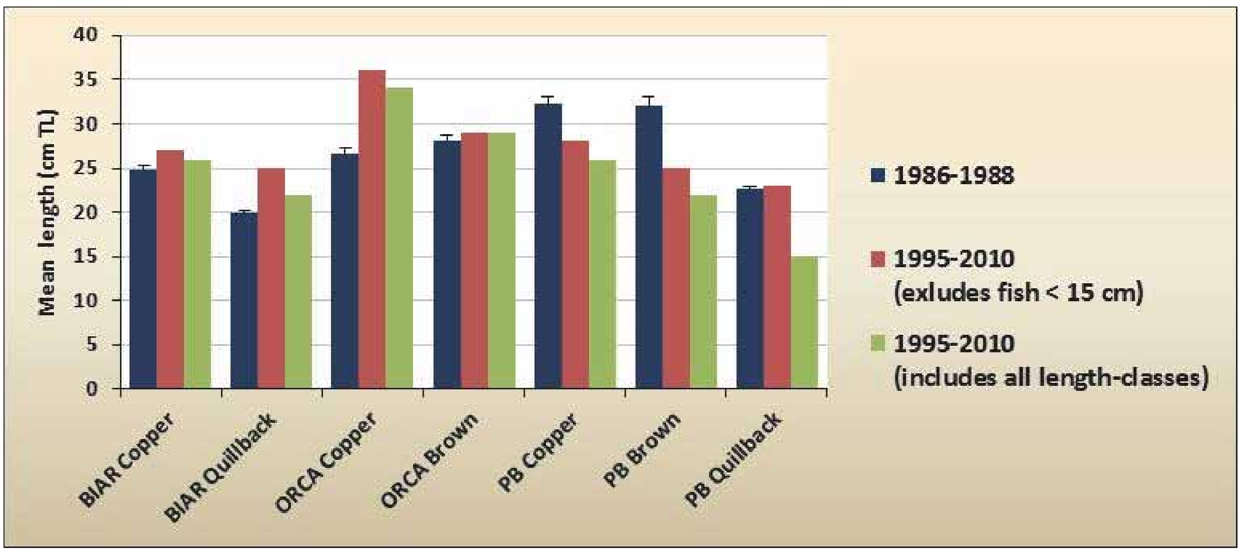


Figure 13. Mean lengths (cm TL) of rockfish by species at each of three Puget Sound sites. BIAR = Blake Island Artificial Reef, ORCA = Orchard Rocks Conservation Area, PB = Port Blakely. No Brown Rockfish were observed at BIAR from 1986-88, and only ten Quillback Rockfish were observed from 1995-2010 at ORCA; therefore, neither species is depicted for those sites. Standard errors (+ 1) are presented for 1986-1988 but not for 1995-2010 (see page 14).

Discussion and Recommendations

Our survey results provide an informative perspective on the recent status of several key bottomfish species at six nearshore sites in central Puget Sound and will serve as an important benchmark for future surveys. However, our ability to identify and interpret trends over time, particularly for rockfishes, was confounded by factors such as high interannual variability in juvenile recruitment, poorly understood post recruitment inter- and intraspecific interactions, and, at some sites, discontinuous sampling and changes in protection statuses. In comparing MPA sites to non-MPA sites, we were not able to discern any trends that could be unequivocally linked to harvest management actions; however, at least two phenomena suggest evidence of such a response: 1) At ORCA, subsequent to 1998 (the year ORCA was afforded MPA status), a persistent increase in rockfish density and biomass over the preceding survey years occurred that, unlike at other sites (*e.g.*, BIAR, KJ), did not appear to be as attributable to juvenile recruitment; and 2) The mean length, density, and biomass of Lingcod at KJ increased after 2002 (the year KJ was afforded MPA status). The latter observation ranks as the most notable potential direct population response to site protection. Prior to closure, KJ was popular among Lingcod anglers and spearfishers. Lingcod exhibit rapid ontogenetic growth, particularly during the first several years of their life (females may increase by nearly 10 cm/year through age five). The rapid growth, and accompanying rapid increase in fecundity, of Lingcod makes it a potentially valuable first-response species for detecting positive effects of conservation efforts as opposed to demersal rockfishes, which typically grow at substantially slower rates in Puget Sound (Palsson *et al*. 2009).

Though compelling, changes in the KJ Lingcod population remain equivocal as to cause. The primary habitat for structure-associated bottomfish (*i.e.*, the jetty) is contiguous and lies half within and half outside the MPA. Throughout this study, the survey divers observed fish moving from one side of the jetty to the other, likely in search of prey or in response to the strong tidal currents that occur at the site, but we have no data on cross-boundary movement rates. Fishing still occurs along the unprotected side of the jetty, but we have no data on the level of fishing effort or the catch per unit effort. Thus, while the fishable area has decreased, vulnerability to harvest pressure remains for those fish that cross the MPA boundary. While it is possible that fishing effort has decreased with the decrease in fishable area, it is also possible that effort remains substantially unchanged, or has even increased, but is now concentrated in a smaller area. If fishing effort along the jetty remains unchanged and if fish move freely from one side of the jetty to the other, affording protection to one side of the jetty would be of little consequence to the overall population of structure-associated bottomfish inhabiting the area. In the years immediately following designation of the KJ, WDFW divers received occasional reports of suspected spearfishing activities on the protected side of the jetty, whereby divers entered from the non-MPA side and were then free to swim anywhere along the jetty, including into the MPA. However, due to the popularity of the jetty with divers, many of whom supported the designation of the MPA, peer pressure may act to discourage this practice based on conversations between WDFW divers, recreational divers, and local dive shop staff.

Our survey results provide a valuable framework of useful indices that will improve our ability to assess the stock status of several nearshore bottomfish species and aid in identifying and diagnosing the causes of bottomfish population declines, should they occur. Furthermore, it establishes baselines for species-specific size distributions, cohort strength analysis, and response to place-based habitat management that can be compared to future survey data to evaluate direct biological impacts of management decisions. In coming years the WDFW will endeavor to resume comparable survey efforts on a periodic basis to allow systematic updates of how MPAs and other policy tools and decisions affect bottomfish populations. Moving forward, we recommend the following:

- Develop specific and pragmatic goals and objectives for future surveys that include collecting data on those population parameters that will most likely enable the identification of management action implications for key bottomfish species. For example, changes in size class distribution across time demonstrates the influence of various annual cohorts but must be accompanied by at least some definitive records of fish size-at-age. Biological samples must periodically be taken, even from MPAs, to evaluate age and growth.
- Survey frequency should be evaluated in light of our report findings and adjusted where it is deemed appropriate, and within the context of the specific goals and objectives identified for the surveys. For instance, if detecting juvenile rockfish recruitment is identified as an objective, biennial surveys may be sufficient. Although strong juvenile recruitment events that fail to persist over time may go undetected, recruits that persist as a strong year-class would likely remain detectable as length-class pulses over succeeding years as evidenced in this report; it is the persistence of strong year-classes that most influences long-term trends in species composition, density, biomass, and other demographics. Further, notwithstanding the effects of juvenile recruitment events, precipitous changes in species composition, density, biomass, and length were not detected in this study. Trends, such as the observed decline in large Copper and Quillback Rockfish abundance at BLCA, would likely remain detectable over more temporally coarse sampling scales.
- Based on extensive experience with both estimating and measuring juvenile rockfish lengths, we believe that survey divers can assign small rockfish to more finely subdivided length-classes, and do so within an acceptable margin of error. Dividing the smallest length-class (< 15 cm) into three length-classes (< 5, 5 < 10, and 10 < 15) would strengthen our ability to: 1) detect juvenile rockfish recruitment events when they occur; 2) determine spatial and temporal juvenile rockfish settlement patterns and their apparent preferred habitat(s); 3) predict year-class strength; and, 4) evaluate the influence of juvenile recruits on the structure of adult populations.

- Statistical and logistical efficiencies may be gained by concentrating survey efforts during times of peak bottomfish abundance. In the future, spring surveys should be reduced or eliminated, and available resources should be directed at increasing the number of replicate surveys conducted during the summer and fall periods of peak abundance in the nearshore environment for most bottomfish species. The periodicity of the surveys should be conducted over as protracted a time-scale as possible within those seasons to ensure that any late-settling juvenile rockfish are represented in the sample and thus accounted for within a given settlement cohort.
- A small-scale tagging study should be implemented at KJ to determine the extent of fish movement between the two sides of the jetty (protected and unprotected). If it is determined that one or more bottomfish species remains substantially segregated between sides year-round, then KJ could prove to be a highly valuable site for evaluating the impact of protection status on fished and unfished populations that are in close proximity to and occupy similar habitat. Transects at KJ should be repositioned so that they lie either entirely within or outside the MPA boundaries. The current transects were placed prior to the MPA designation and without foreknowledge of where the MPA boundaries would be established. Estimates of movement rates across the boundary is necessary in order to effectively evaluate the usefulness of, and possibly to augment, protection. That said, the WDFW may wish to consider a complete closure of the Keystone jetty to fishing. The WDFW has received anecdotal reports of poaching, whereby divers enter the water on the west (unprotected) side and swim to the east (protected) side to obtain their quarry. The Keystone jetty is a popular site for spearfishers, and enforcing the no-take rule over divers who swim to the jetty's east side is not practicable.
- Transects at BLCA should be repositioned over structures that are likely to endure substantially unchanged over a long period of time. The dry dock *DeLeon* has undergone significant structural collapses over the last two decades, reducing overhead and interstitial space and fundamentally changing its use by fishes of many species. Furthermore, the growing potential for collapse also poses a risk to diver safety such that WDFW divers no longer enter the wall of the drydock to search for fish in crevices and under material. To ensure that surveys conducted at various time intervals are comparable, habitat must remain largely consistent.
- Rockfish that are in late-stage gravid condition should be noted during the surveys. The prevalence of late-stage gravid fish can serve as an indicator of future larval, and possibly juvenile, abundance. Alternatively, if gravid females are plentiful but the resulting larval/juvenile cohort is weak, it could hint at causal factors for failed recruitment, such as environmental variables or predation. In order to connect various life stages in a meaningful way and better understand drivers of population dynamics, it will be crucial to develop a thorough understanding of temporal patterns of rockfish brooding and parturition.

- Survey results should be evaluated in a more timely manner than they have been historically in order to provide for responsive management and adaptive science. For example, had the rapid decline in large Copper and Quillback Rockfish at BLCA been detected earlier, our ability to evaluate the cause or causes behind the decline would have been enhanced (*e.g.,* if fishing mortality was suspected, Enforcement could have been involved and may have been able to limit the decline).

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Appendix 1. Policy Title: Marine Protected Areas (#C3013)

Effective Date: June 13, 1998

Marine Protected Areas (MPAs) are sites given long-term protection to protect and enhance some or all of the resources at the site and/or to facilitate some uses of the area. MPAs can serve a variety of purposes including:

Research and Education Areas
Protection of Unique or Sensitive Populations
Fish Production and Fishery Management
Protection of Habitats of Special Importance
Non-Consumptive Use Recreational Areas

A variety of fish and wildlife resources can benefit from establishment of MPAs. Some fish resources require major reductions in harvest pressure and protection from removal as by-catch to establish productive populations of adults. Establishing such areas may be important tools to recover from past over-harvest or prevent future overharvest (*e.g.*, rockfish in Puget Sound). MPAs can also provide areas for non-consumptive use of the resources, allow collection of baseline data on resources at the site, provide reference areas, and protect unique, sensitive, or important habitats and populations. They can facilitate integrated management of all resources within important habitats or areas.

General Policy: The Director of the Department of Fish and Wildlife will use marine protected areas as one of the agency's working tools for resource protection and management. The Director will be responsible for plan development and implementation to manage consumptive and/or non-consumptive uses.

The management objectives for the use of marine protected areas are:

- Preserve, protect, perpetuate and manage the living resources of the state.
- Provide refuges for stocks, substocks, or populations.
- Protect unique or important habitats or species.
- Foster stewardship of unique or important resources or habitats.
- Provide research and education areas.
- Provide baseline areas or reference sites.
- Provide non-consumptive recreational opportunities.

All sites will not meet all objectives by many sites will meet multiple objectives.

The following management principles will be used:

- Designed MPAs are needed in Puget Sound to protect a variety of species, to promote the recovery of some over-harvested species and to protect important habitats.
- To the extent possible, MPAs will be established based on scientific principles and available data.

- MPAs will not be delayed until all potential questions are answered since recovery of some depressed or declining resources will rely on the timely establishment of sites. The agency will rely on existing information to determine resources of concern and begin selection of areas.
- Regulations adopted will be as simple as possible at individual sites and throughout the network.
- Within the constraints of the above principles and objectives, uses compatible within the type of site and resource needs will be permitted.
- Opportunities will be made available for public involvement by consumptive and non-consumptive users during development of the network of areas and site selection.
- The agency will use adaptive management, including good neighbor practices, to modify the sites and the network as data is collected.

Appendix 2. WAC 220-303-050 Orchard Rocks Conservation Area

"Orchard Rocks Conservation Area" is defined as those waters and bedlands of Rich Passage within a 400-yard radius of Orchard Rocks day marker.

[Statutory Authority: RCW 77.12.047. WSR 00-17-106 (Order 00-149), § 220-16-590, filed 8/16/00, effective 9/16/00. Statutory Authority: RCW 75.08.080, 77.12.040. WSR 00-08-038 (Order 00-29), § 220-16-590, filed 3/29/00, effective 5/1/00; WSR 98-06-031, § 220-16-590, filed 2/26/98, effective 5/1/98.]

Appendix 3. WAC 220-303-030 Keystone Conservation Area

"Keystone Conservation Area" is defined as all bedlands and tidelands and the waters over these starting at the extreme high water line on the east side of the Keystone jetty in Fort Casey State Park then easterly along the extreme high water line to a line projected from shore through the easternmost row of pilings of the old military wharf, then offshore along that line southeasterly for 600 feet, then southwest parallel to the shoreline to a point due south of the southern tip of the jetty, then north to the extreme high water line on the southern tip of the jetty, then along the extreme high water line on the east side of the jetty to the point of origin.

[Statutory Authority: RCW 77.12.047. WSR 02-17-017 (Order 02-187), § 220-16-760, filed 8/9/02, effective 9/9/02; WSR 02-08-048 (Order 02-53), § 220-16-760, filed 3/29/02, effective 5/1/02.]

Appendix 4. WAC 220-303-010 Brackett's Landing Shoreline Sanctuary Conservation Area

"Brackett's Landing Shoreline Sanctuary Conservation Area" is defined as those bed lands and tidelands owned by the City of Edmonds at Brackett's Landing Shoreline Sanctuary, and the water column above these bed lands and tidelands including all of the area known as Edmonds Underwater Park.

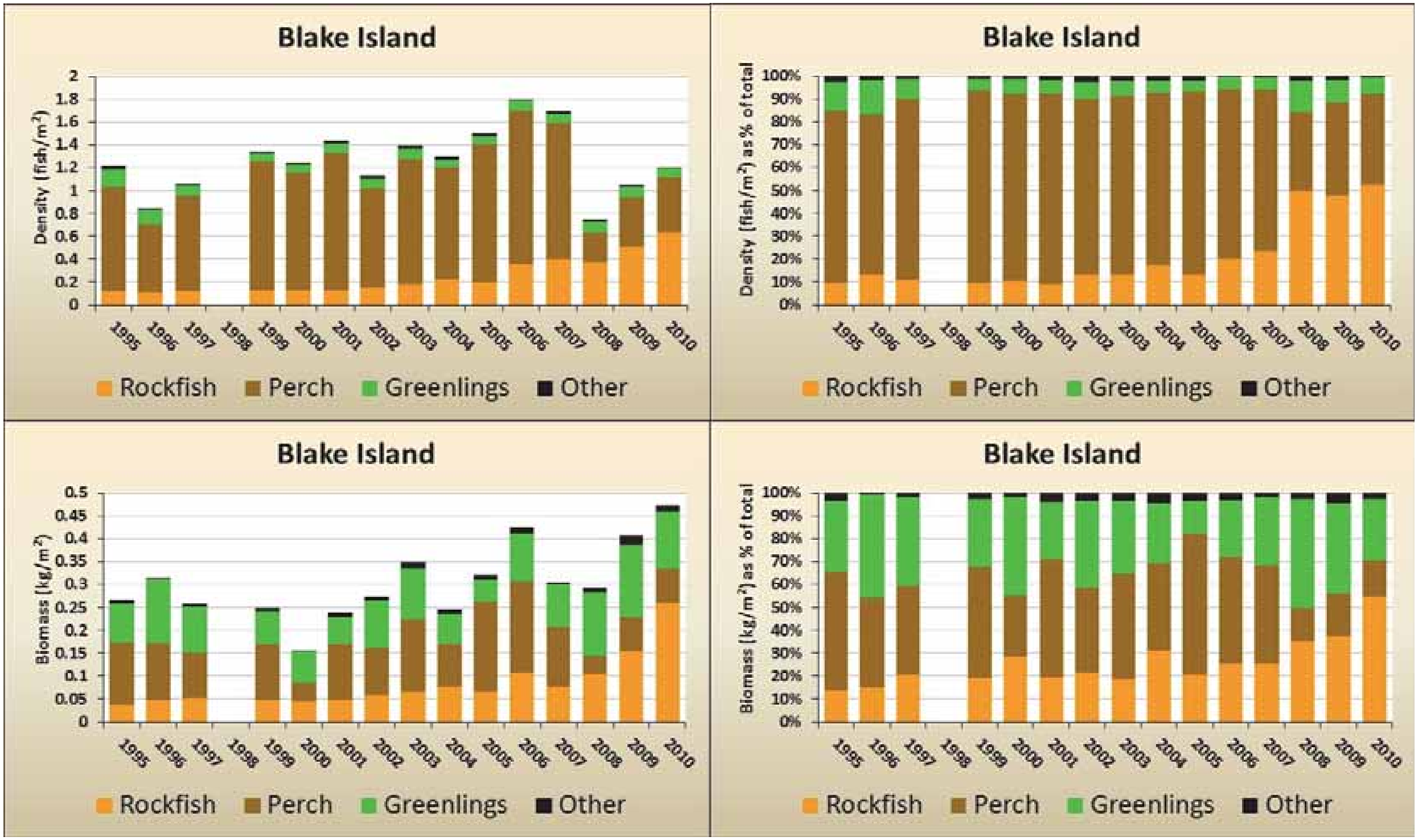
[Statutory Authority: RCW 75.08.080. WSR 00-01-103 (Order 99-215), § 220-16-720, filed 12/16/99, effective 1/16/00. Statutory Authority: RCW 77.12.040 and 75.08.080. WSR 98-06-031, § 220-16-720, filed 2/26/98, effective 5/1/98.]

Appendix 5. WAC 220-300-040 General Definitions – Bottomfish

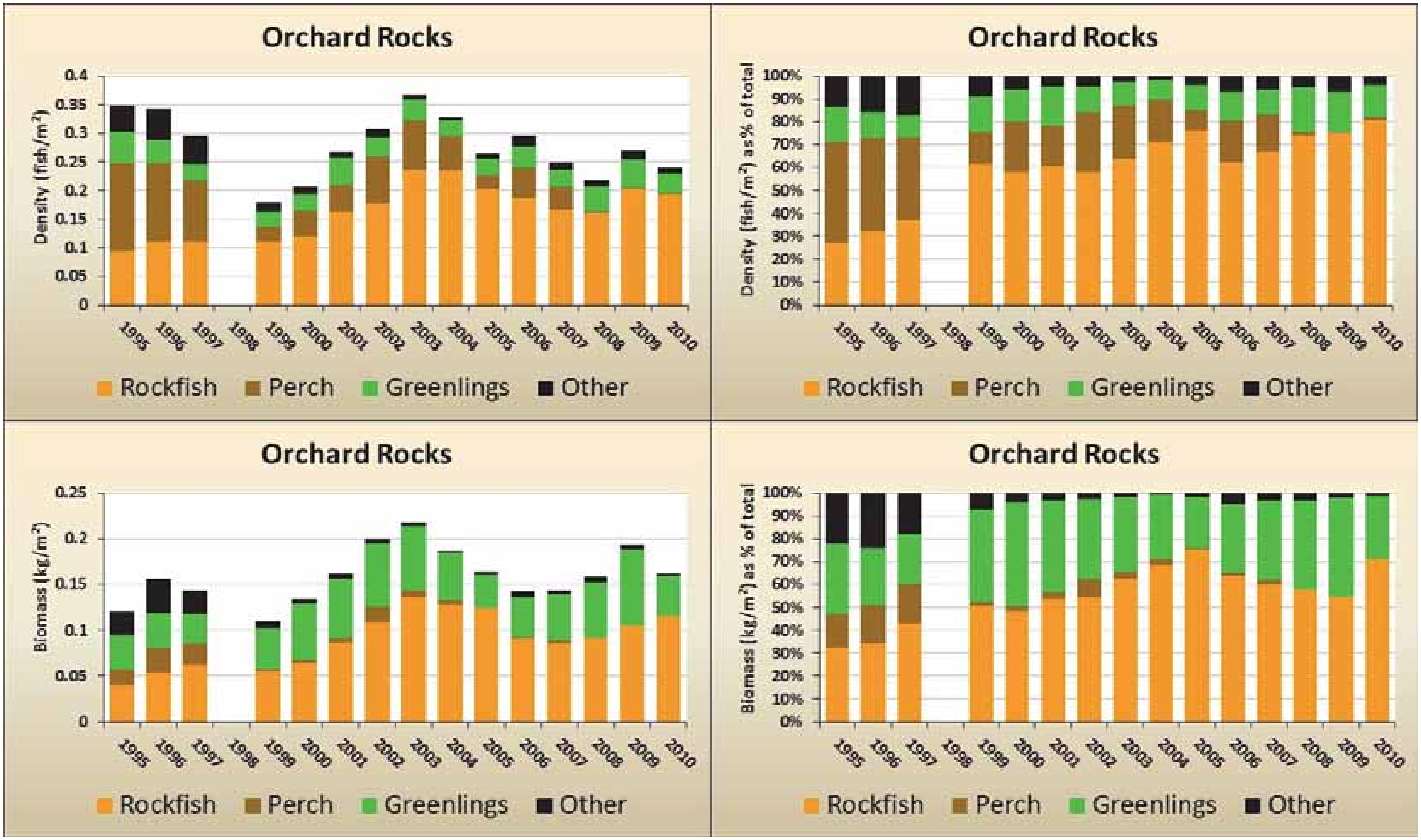
The term "bottomfish," unless otherwise provided, is defined as including Pacific cod, Pacific tomcod, Pacific hake, walleye pollock, all species of dabs, sole and flounders (except Pacific halibut), lingcod and all other species of greenling, ratfish, sablefish, cabezon, buffalo sculpin, great sculpin, red Irish lord, brown Irish lord, Pacific staghorn sculpin, wolf-eel, giant wry mouth, plainfin midshipman, spiny dogfish, six gill shark, soupfin shark and all other species of shark, and all species of skate, rockfish, rattails and surfperches except shiner perch.

[Statutory Authority: RCW 75.08.080. WSR 85-09-017 (Order 85-20), § 220-16-340, filed 4/9/85; WSR 83-24-024 (Order 83-200), § 220-16-340, filed 11/30/83, effective 1/1/84; WSR 82-07-047 (Order 82-19), § 220-16-340, filed 3/18/82; WSR 79-05-007 (Order 79-20), § 220-16-340, filed 4/11/79; Order 77-147, § 220-16-340, filed 12/16/77; Order 817, § 220-16-340, filed 5/29/69. Formerly WAC 220-16-030 (part).]

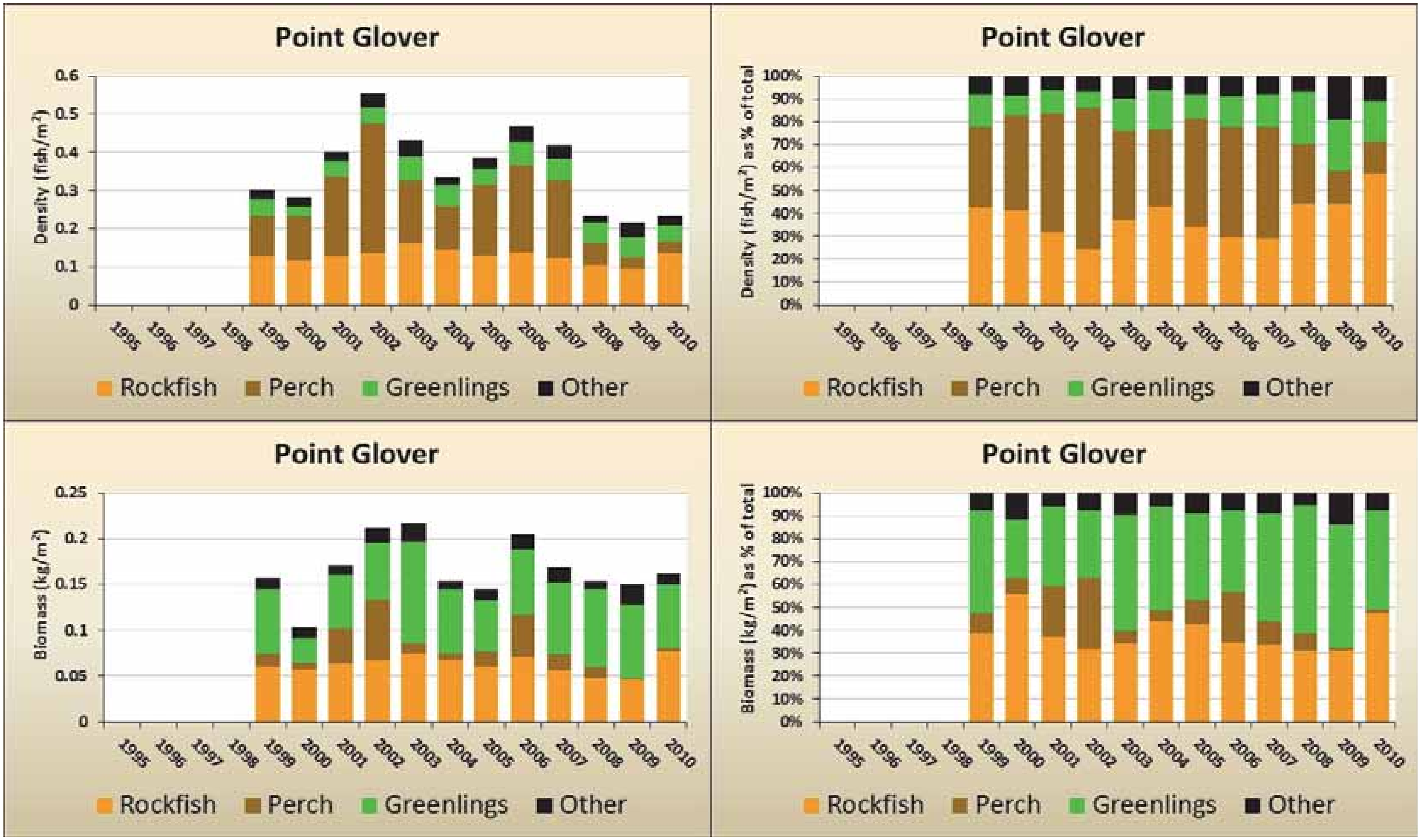
Appendix 6.A. Density (fish/m^2), estimated biomass (kg/m^2), and percent of total, grouped by the three numerically dominant bottomfish ichthyotypes and all other bottomfish at Blake Island Artificial Reef. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



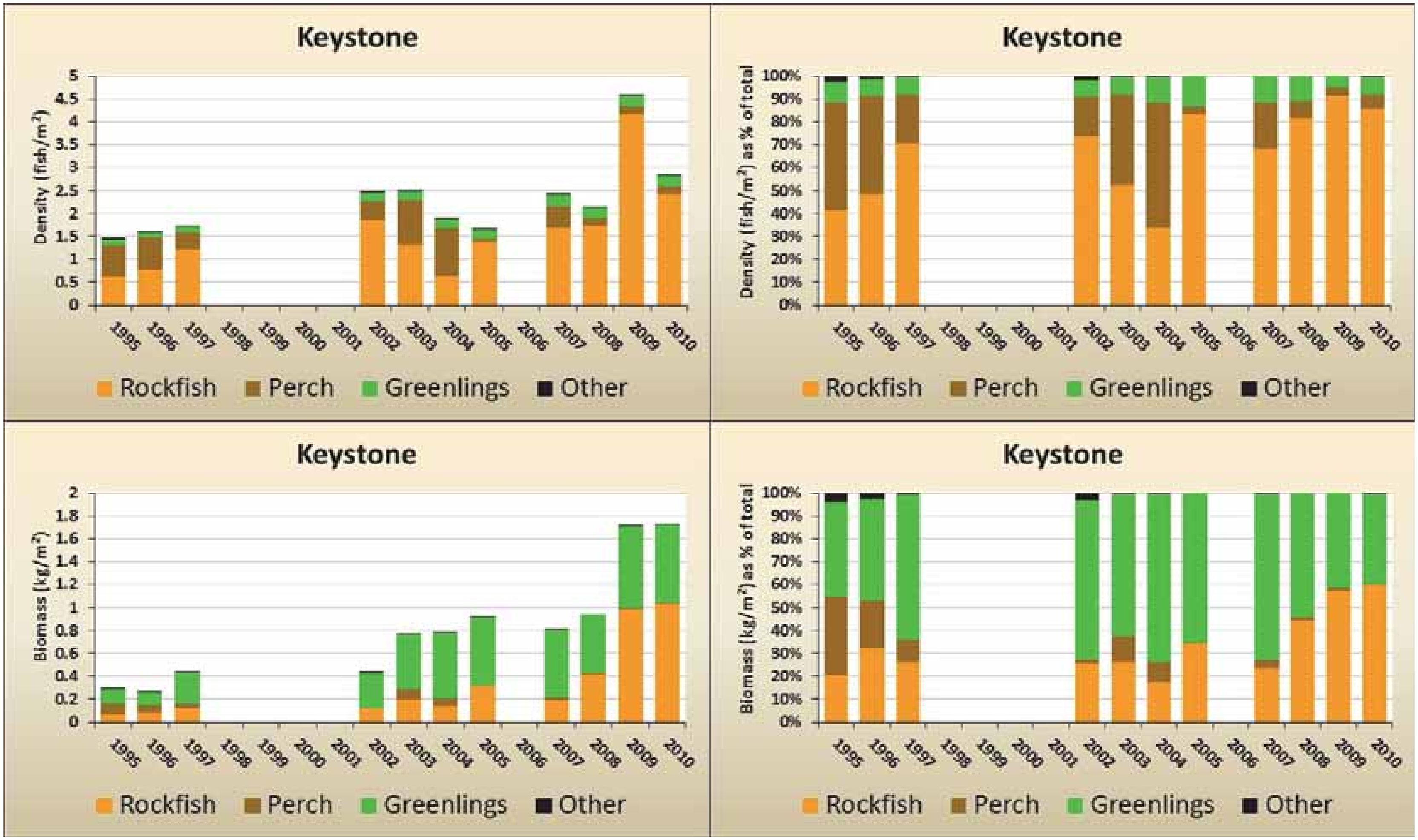
Appendix 6.B. Density (fish/m^2), estimated biomass (kg/m^2), and percent of total, grouped by the three numerically dominant bottomfish ichthyotypes and all other bottomfish at Orchard Rocks Conservation Area. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



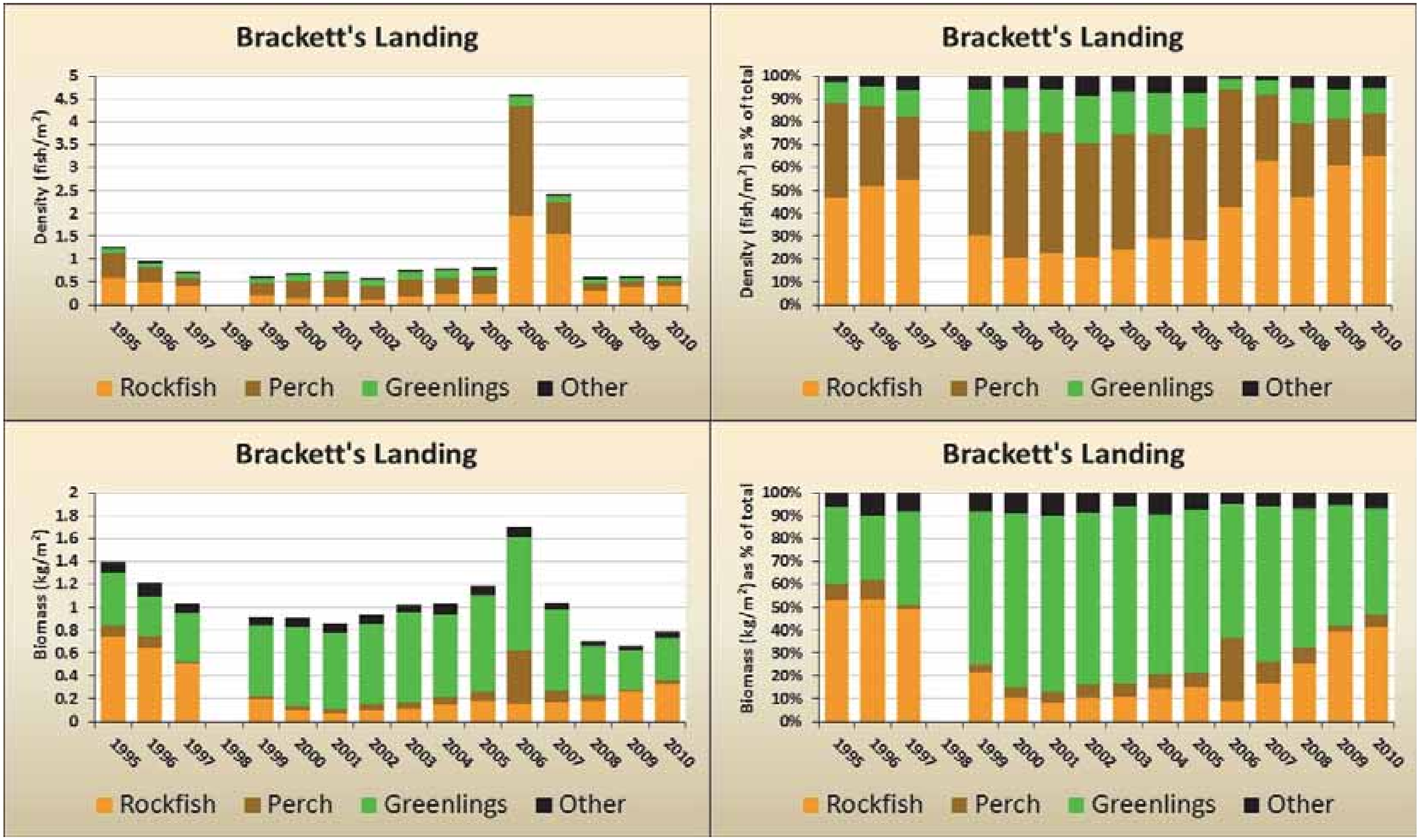
Appendix 6.C. Density (fish/m^2), estimated biomass (kg/m^2), and percent of total, grouped by the three numerically dominant bottomfish ichthyotypes and all other bottomfish at Point Glover. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



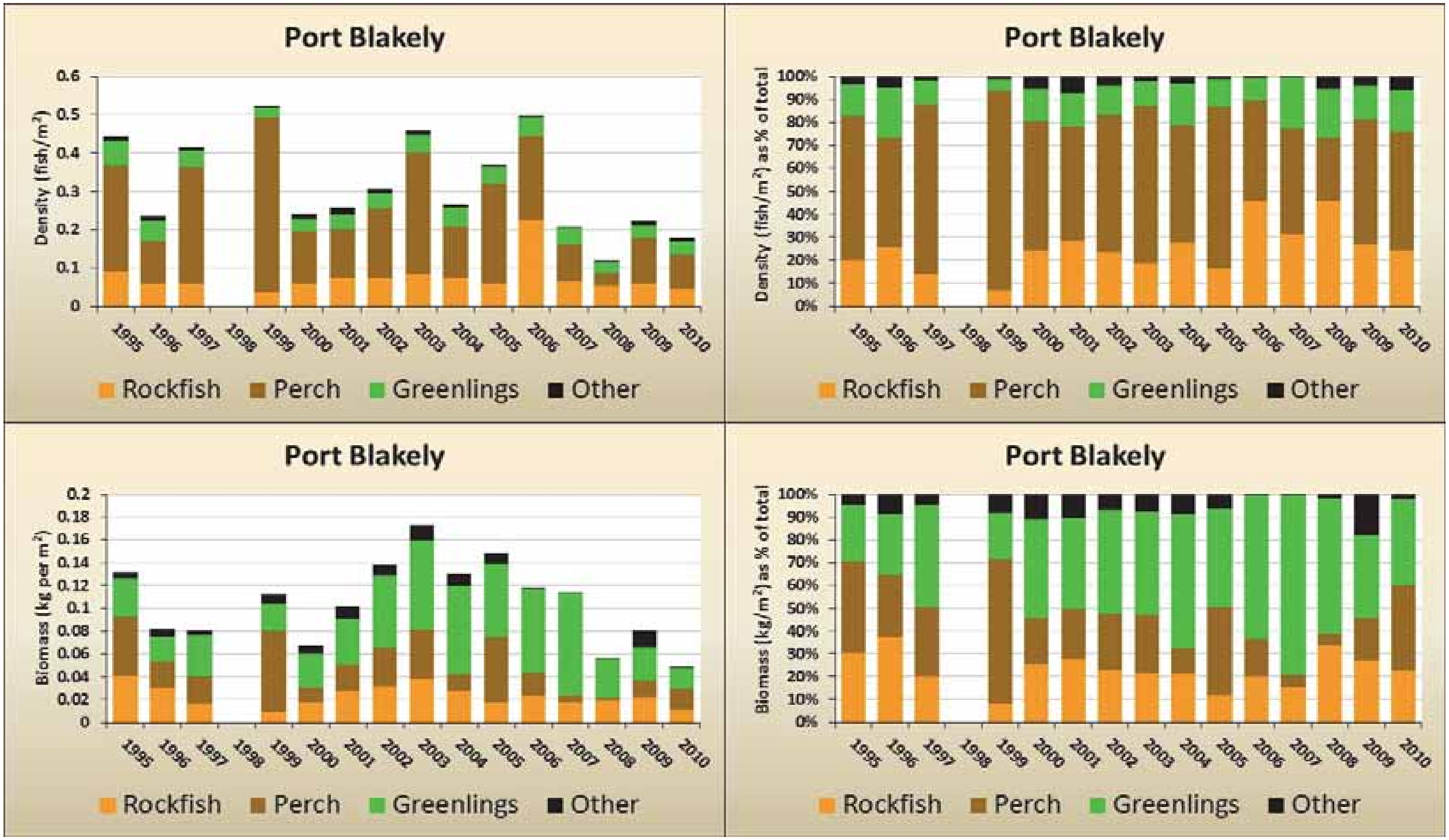
Appendix 6.D. Density (fish/m^2), estimated biomass (kg/m^2), and percent of total, grouped by the three numerically dominant bottomfish ichthyotypes and all other bottomfish at the Keystone jetty. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



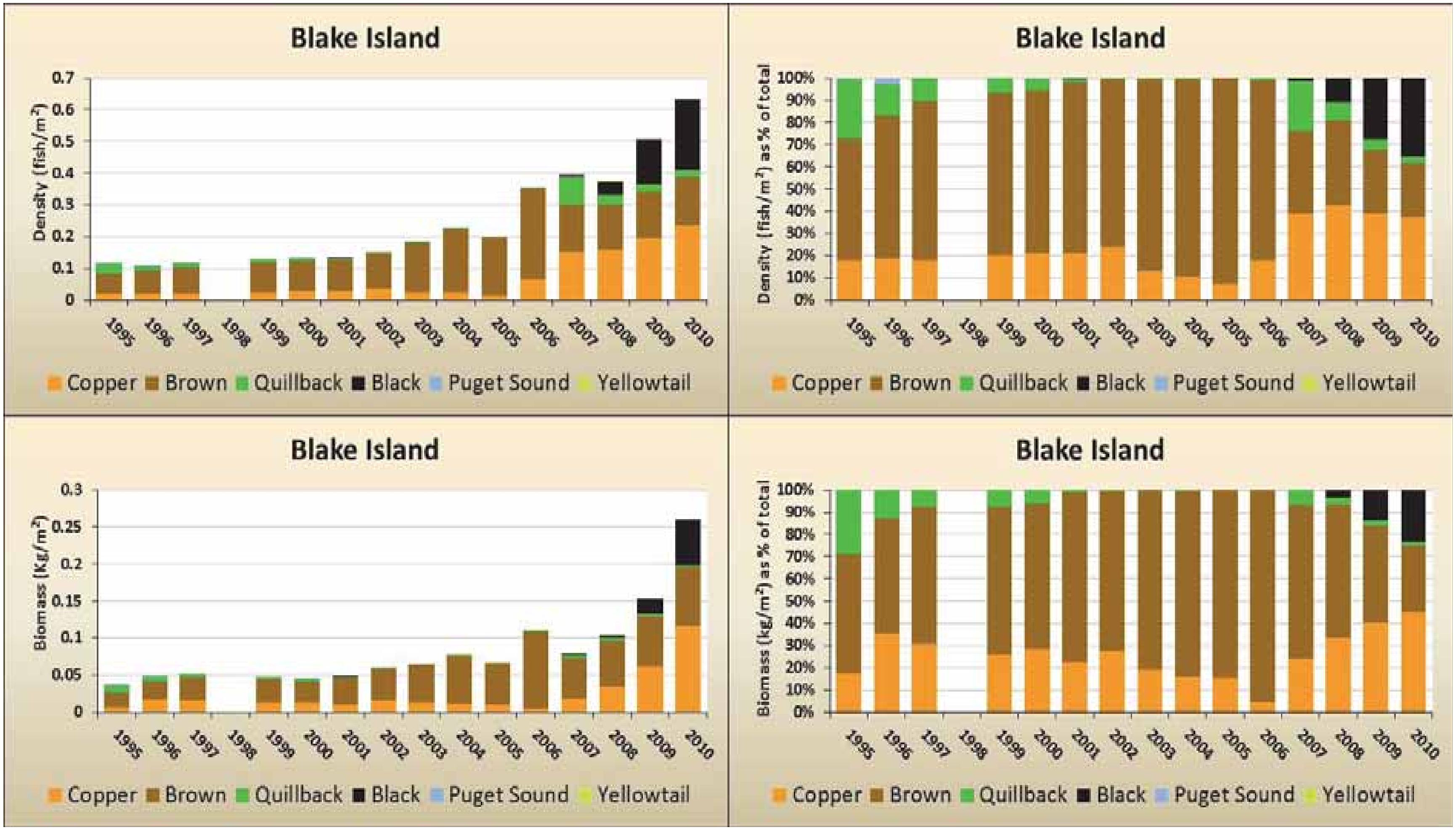
Appendix 6.E. Density (fish/m^2), estimated biomass (kg/m^2), and percent of total, grouped by the three numerically dominant bottomfish ichthyotypes and all other bottomfish at Brackett's Landing Shoreline Sanctuary Conservation Area. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



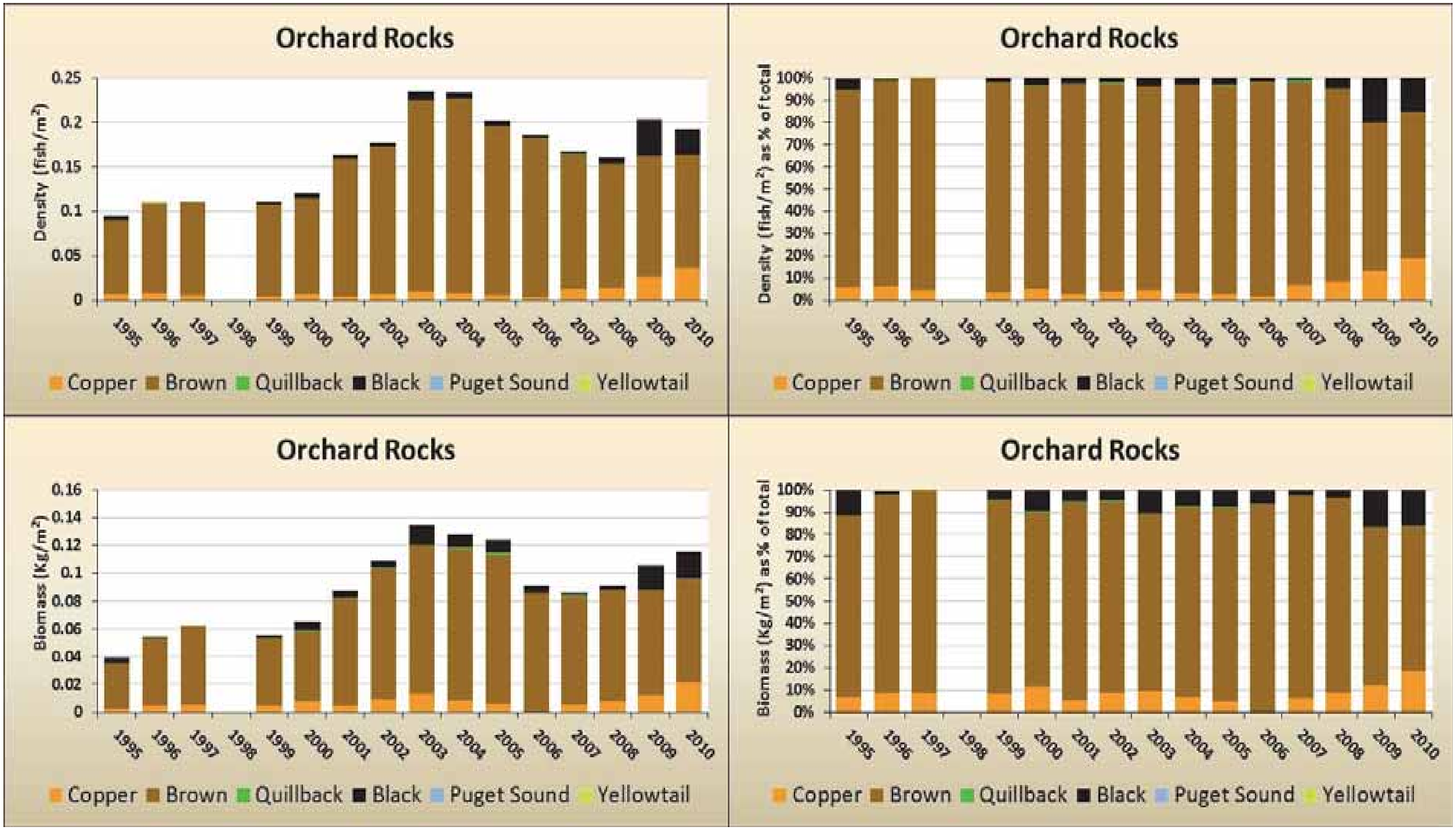
Appendix 6.F. Density (fish/m^2), estimated biomass (kg/m^2), and percent of total, grouped by the three numerically dominant bottomfish ichthyotypes and all other bottomfish at Port Blakely. Wolf-eel and unidentified rockfish were included in the density estimates but excluded from the biomass estimates (see page 12). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



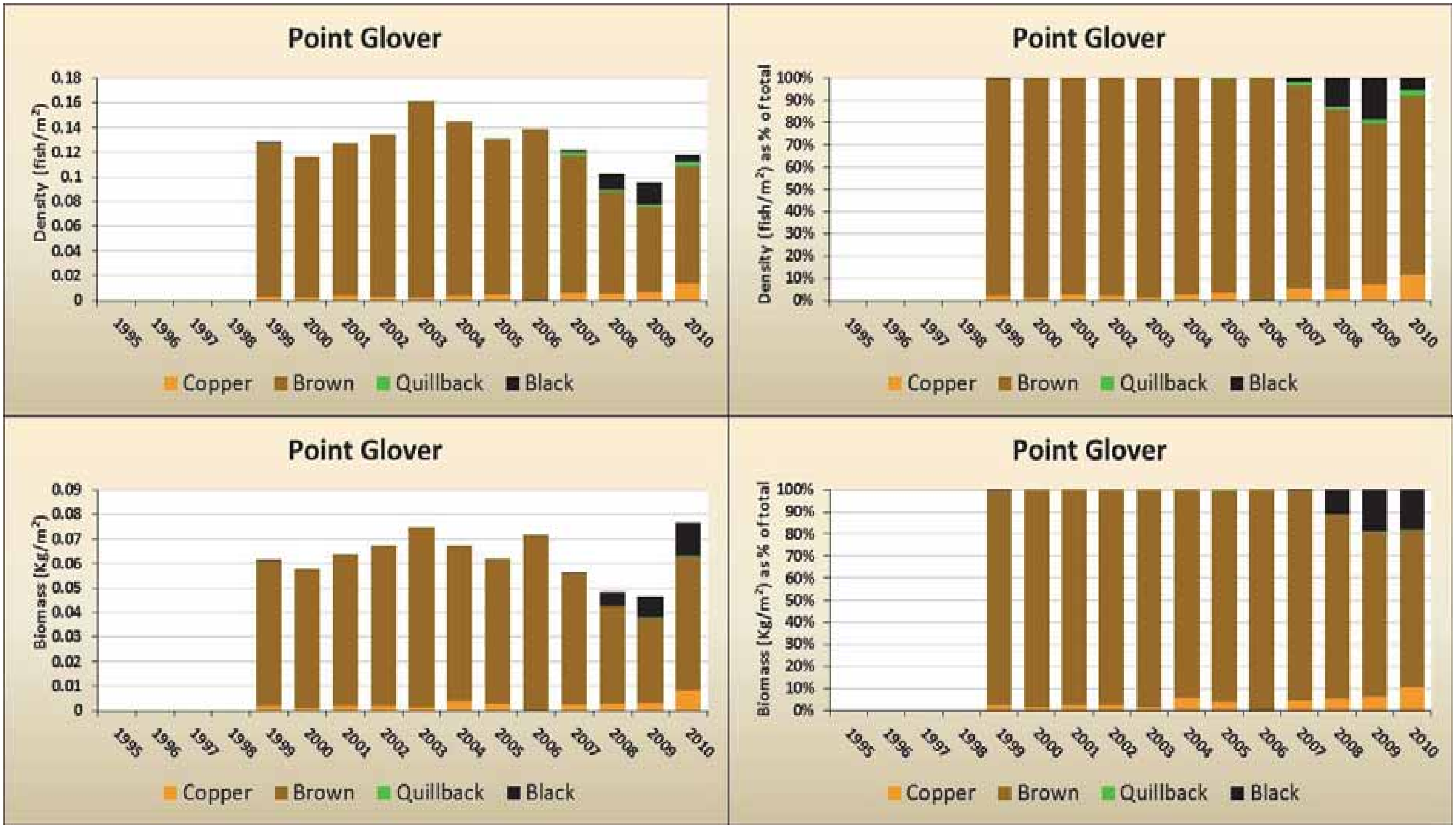
Appendix 7.A. Rockfish density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Blake Island Artificial Reef. Only those rockfish species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Copper, Brown, Quillback, Black, Puget Sound, and Yellowtail Rockfish). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



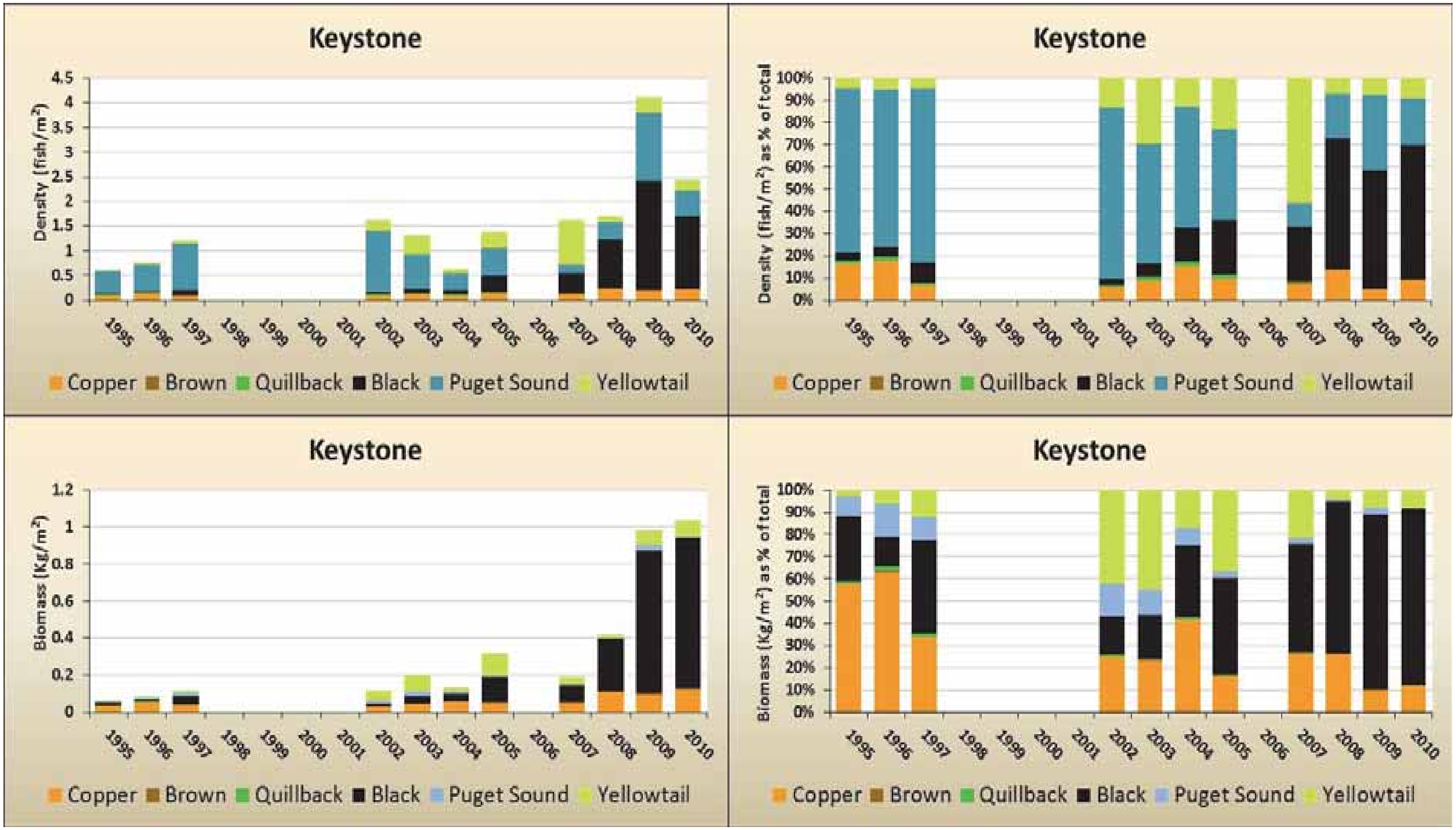
Appendix 7.B. Rockfish density (fish/m²), estimated biomass (kg/m²), and percent of total, by species, at Orchard Rocks Conservation Area. Only those rockfish species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Copper, Brown, Quillback, Black, Puget Sound, and Yellowtail Rockfish). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



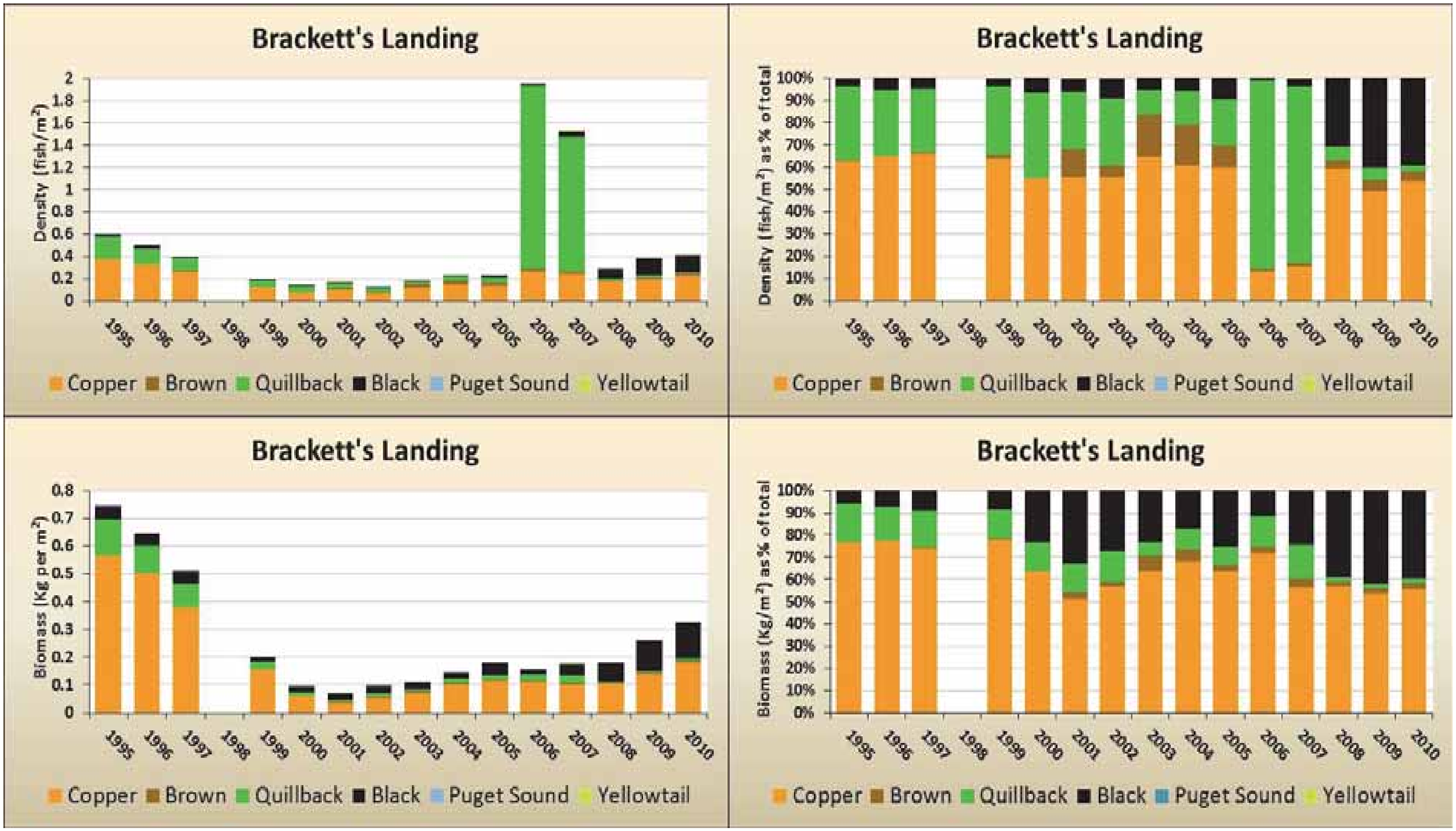
Appendix 7.C. Rockfish density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Point Glover. Only those rockfish species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Copper, Brown, Quillback, and Black Rockfish; note that no Puget Sound or Yellowtail Rockfish were observed at Point Glover). Years for which no data are presented were not surveyed. Note that y-axis scales may differ between among locations in this appendix.



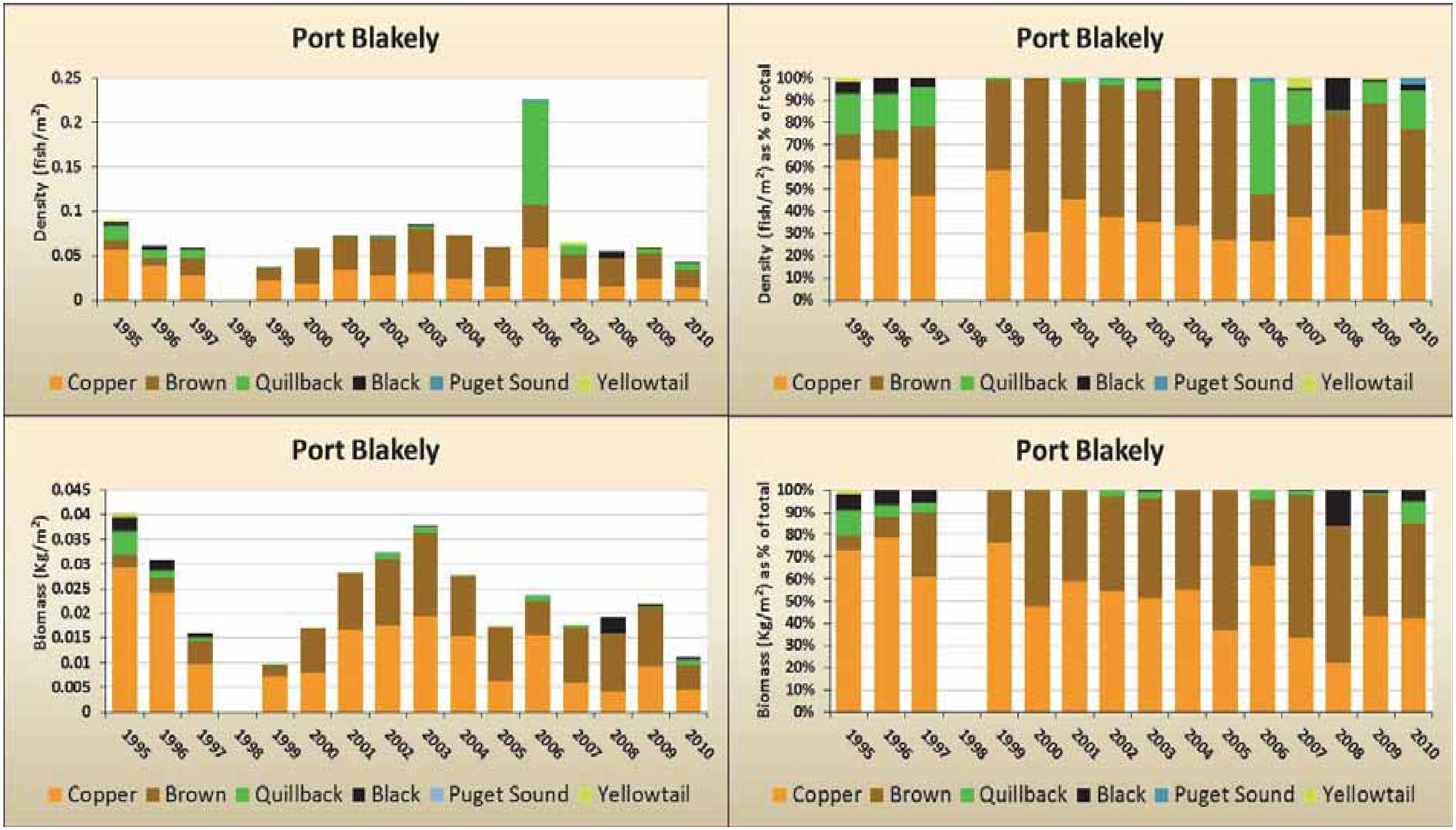
Appendix 7.D. Rockfish density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at the Keystone jetty. Only those rockfish species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Copper, Brown, Quillback, Black, Puget Sound, and Yellowtail Rockfish). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



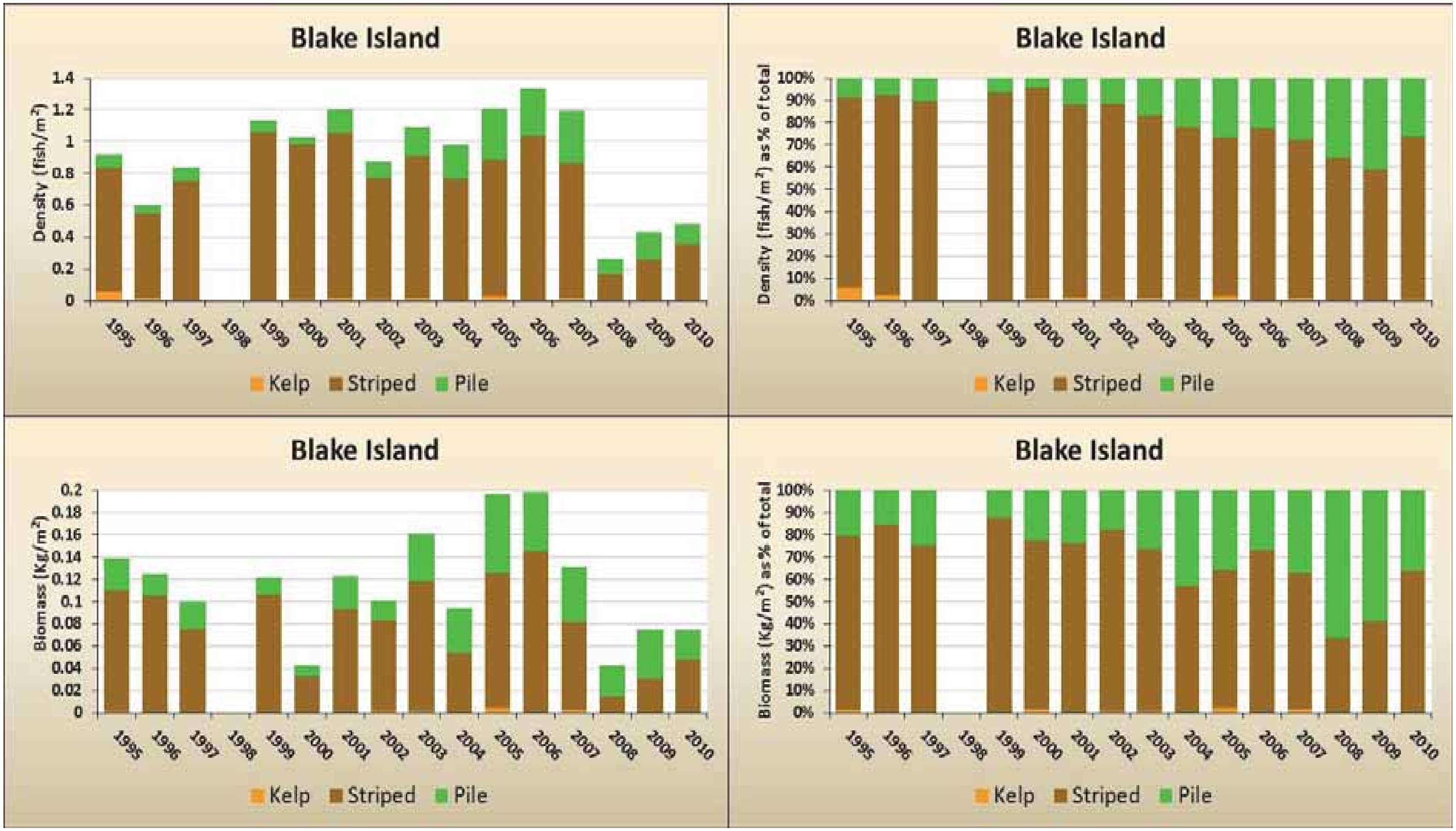
Appendix 7.E. Rockfish density (fish per/m²), estimated biomass (kg/m²), and percent of total, by species, at Brackett's Landing Shoreline Sanctuary Conservation Area. Only those rockfish species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Copper, Brown, Quillback, Black, Puget Sound, and Yellowtail Rockfish). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



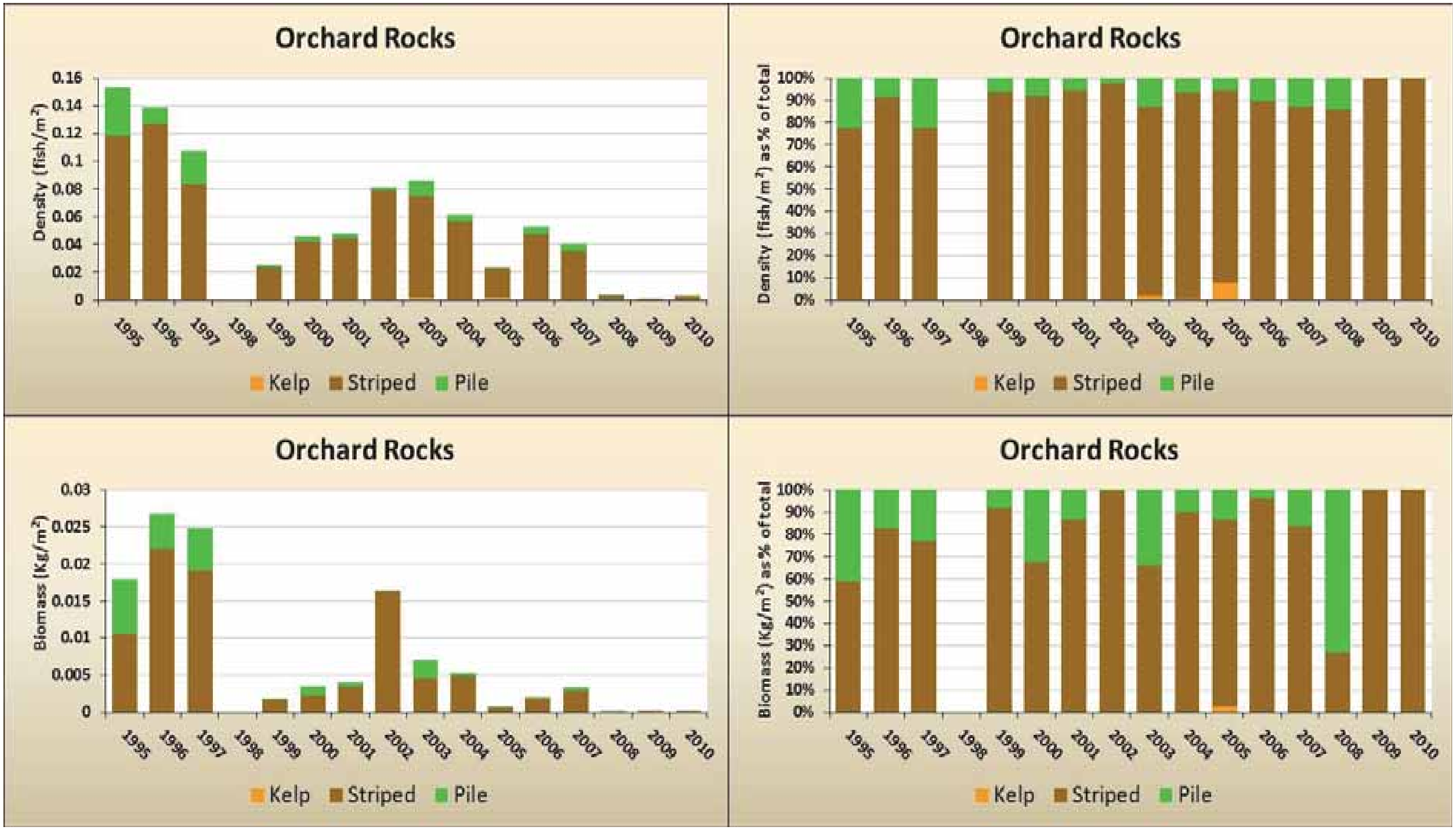
Appendix 7.F. Rockfish density (fish/m^2), estimated biomass (kg per/m^2), and percent of total, by species, at Port Blakely. Only those rockfish species for which the total biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Copper, Brown, Quillback, Black, Puget Sound, and Yellowtail Rockfish). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



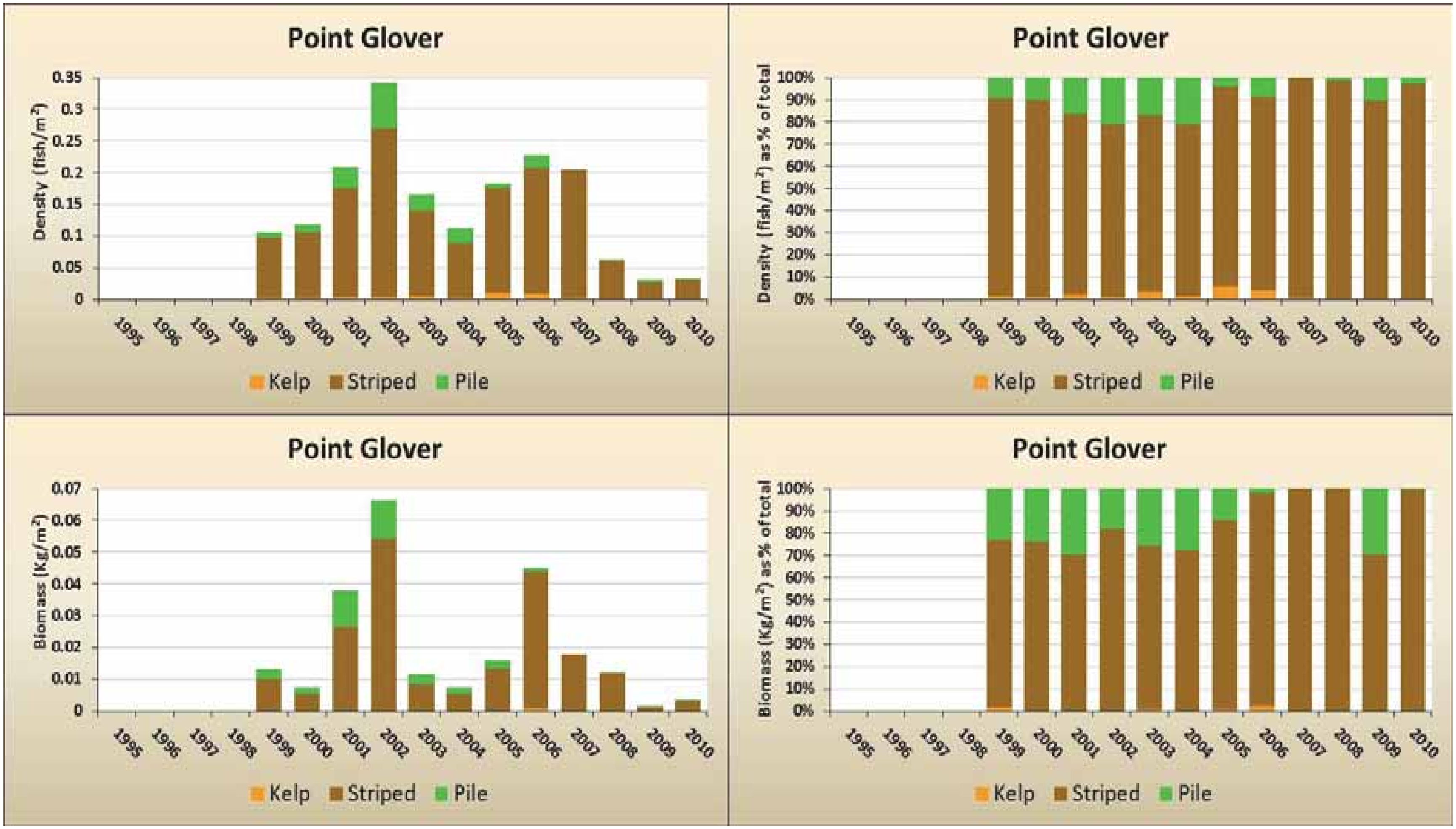
Appendix 8.A. Bottomfish perch density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Blake Island Artificial Reef. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



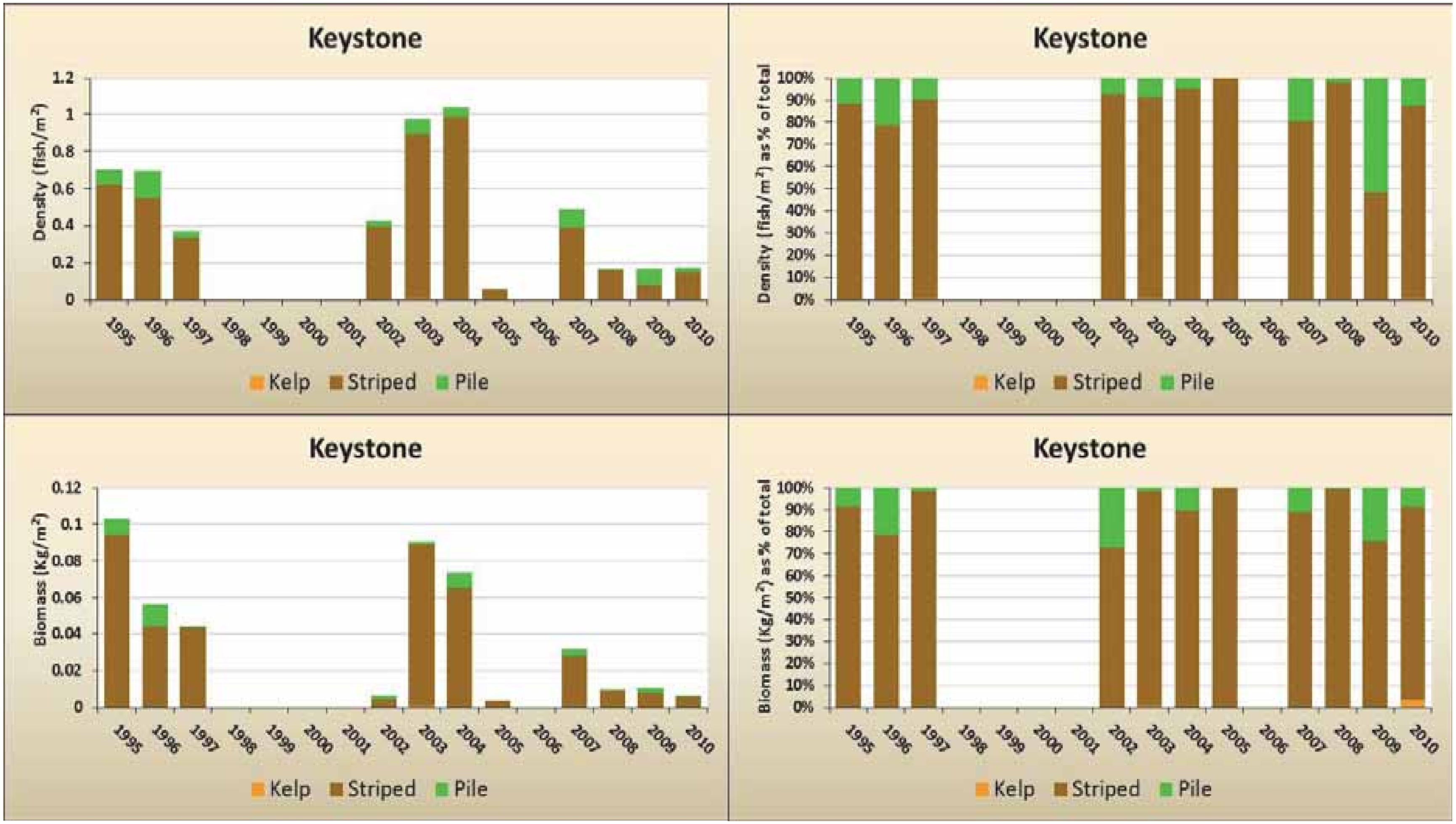
Appendix 8.B. Bottomfish perch density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Orchard Rocks Conservation Area. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



Appendix 8.C. Bottomfish perch density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Point Glover. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.

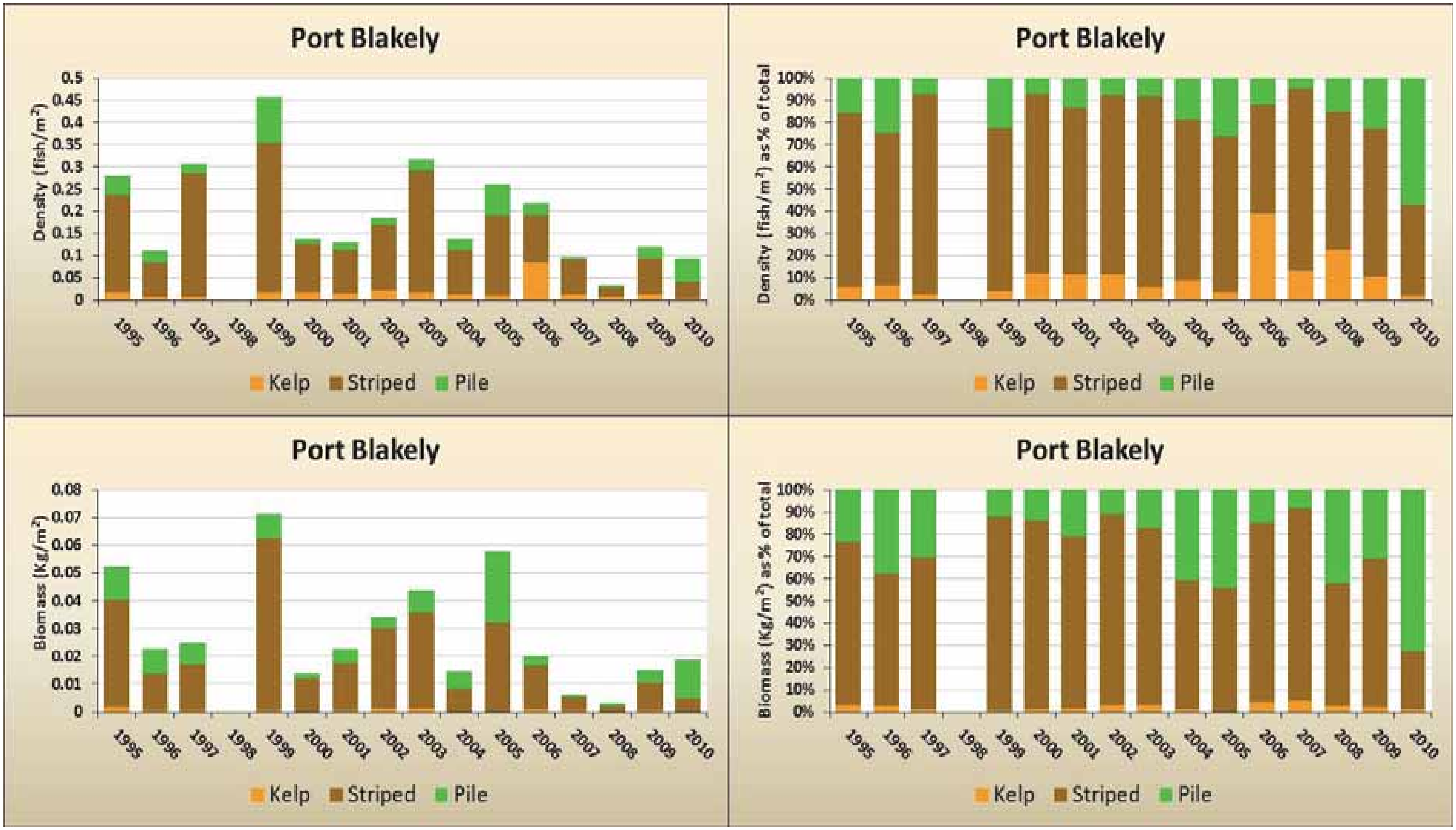


Appendix 8.D. Bottomfish perch density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at the Keystone jetty. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.

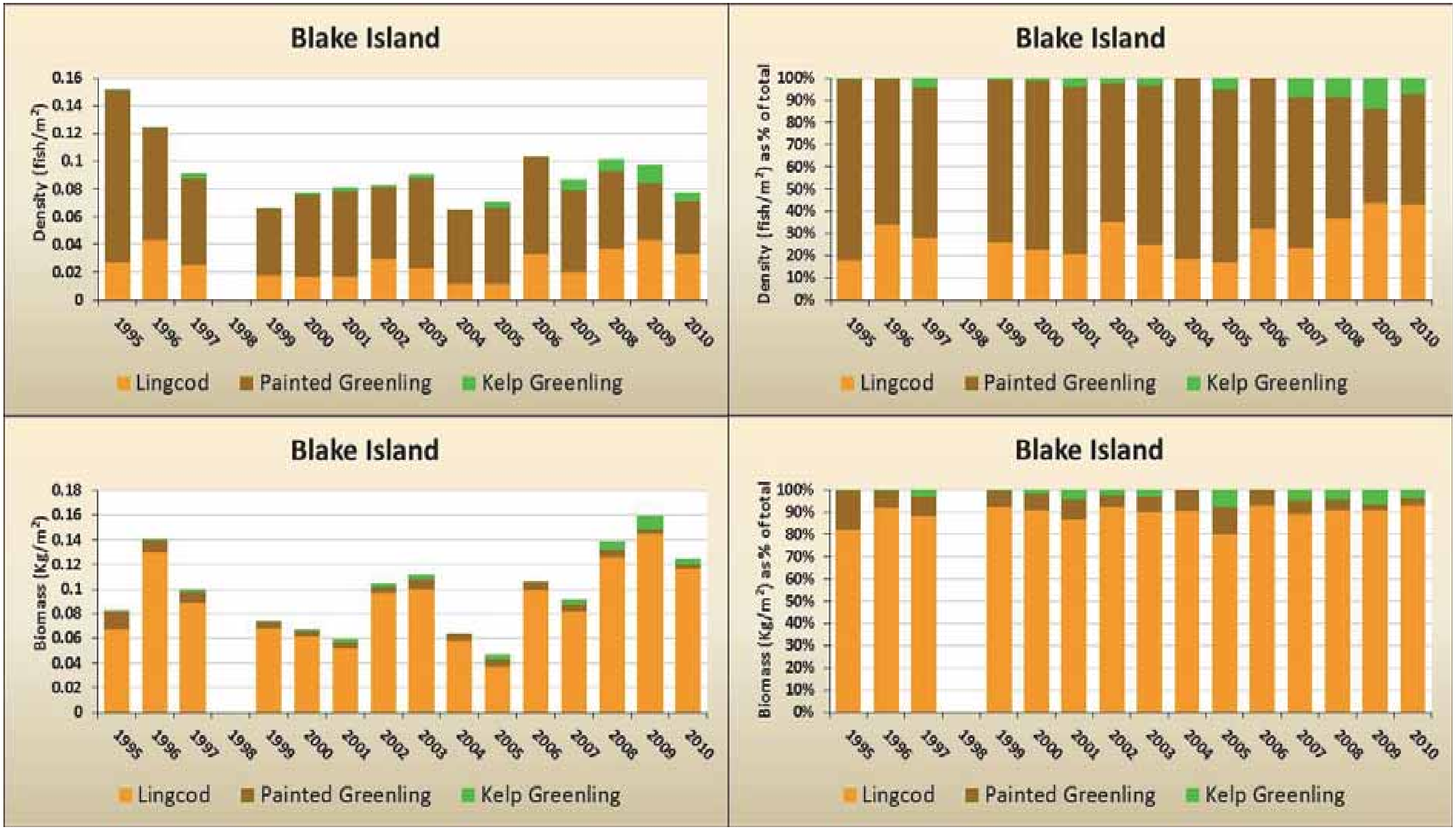


Appendix 8.E. Bottomfish perch density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Brackett's Landing Shoreline Sanctuary Conservation Area. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.

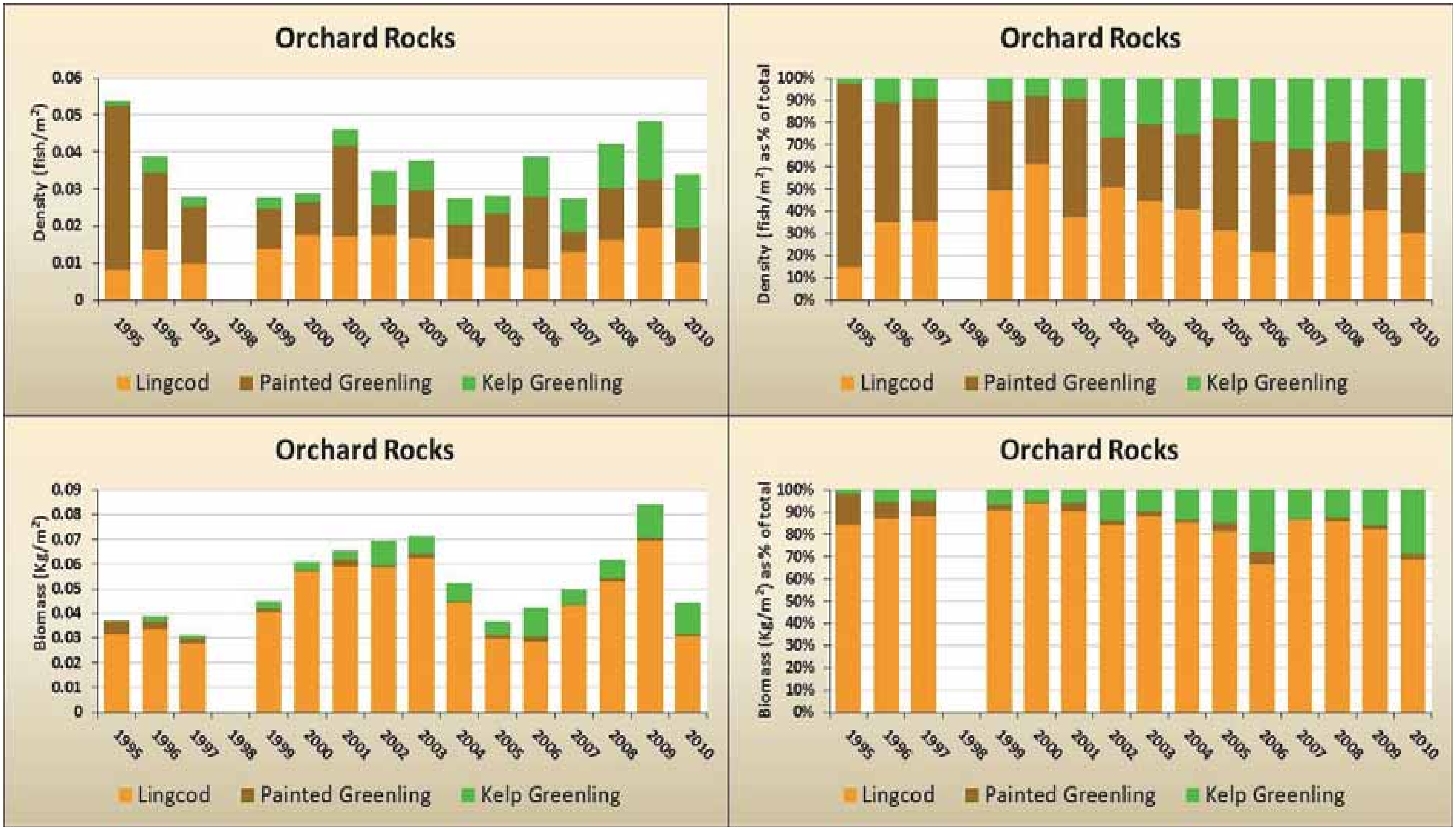
Appendix 8.F. Bottomfish perch density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Port Blakely. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



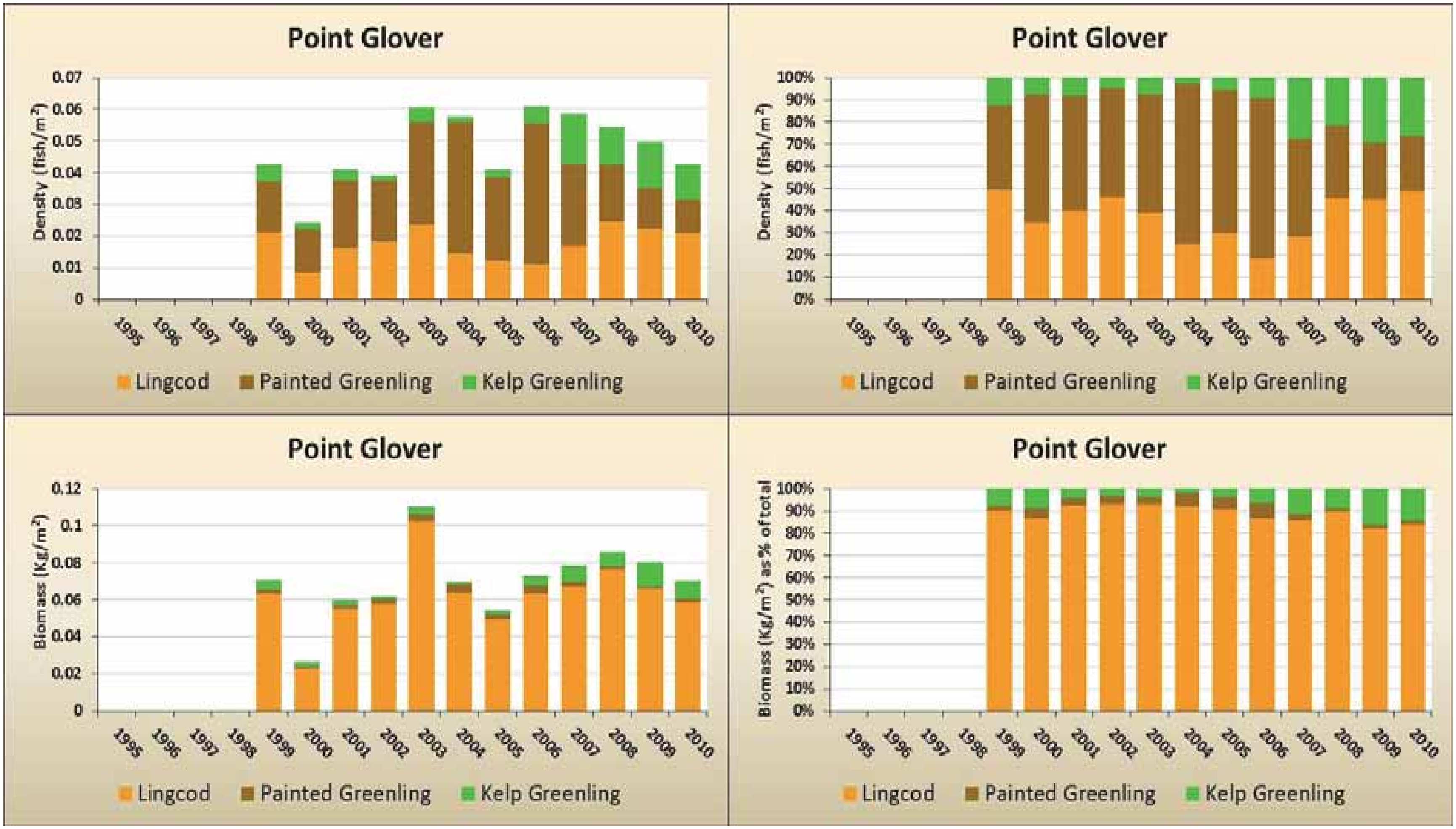
Appendix 9.A. Greenling density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Blake Island Artificial Reef. Only those greenling species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Lingcod, Painted Greenling, and Kelp Greenling). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



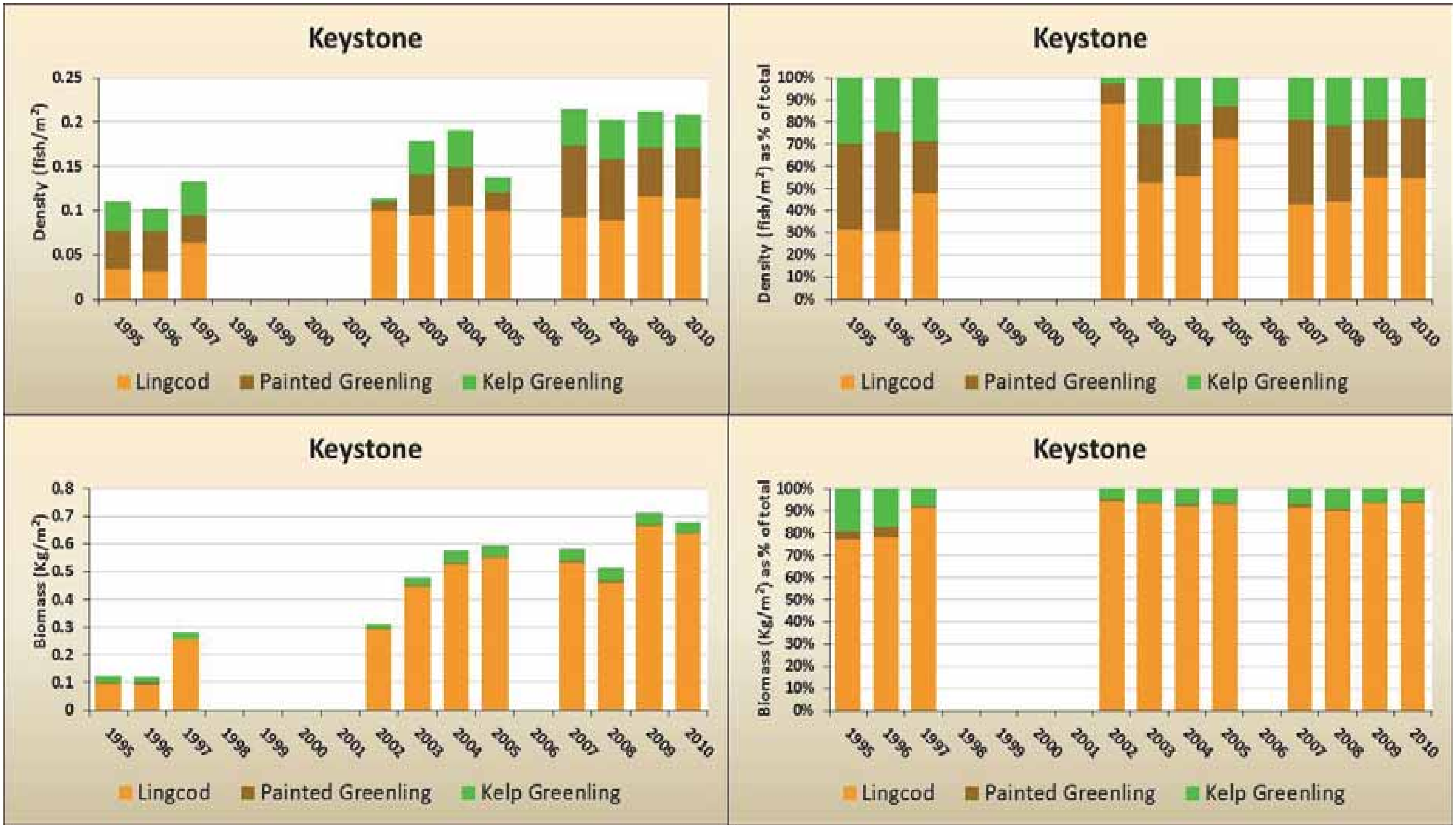
Appendix 9.B. Greenling density (fish/m²), estimated biomass (kg/m²), and percent of total, by species, at Orchard Rocks Conservation Area. Only those greenling species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Lingcod, Painted Greenling, and Kelp Greenling). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.



Appendix 9.C. Greenling density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Point Glover. Only those greenling species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (i.e., Lingcod, Painted Greenling, and Kelp Greenling). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.

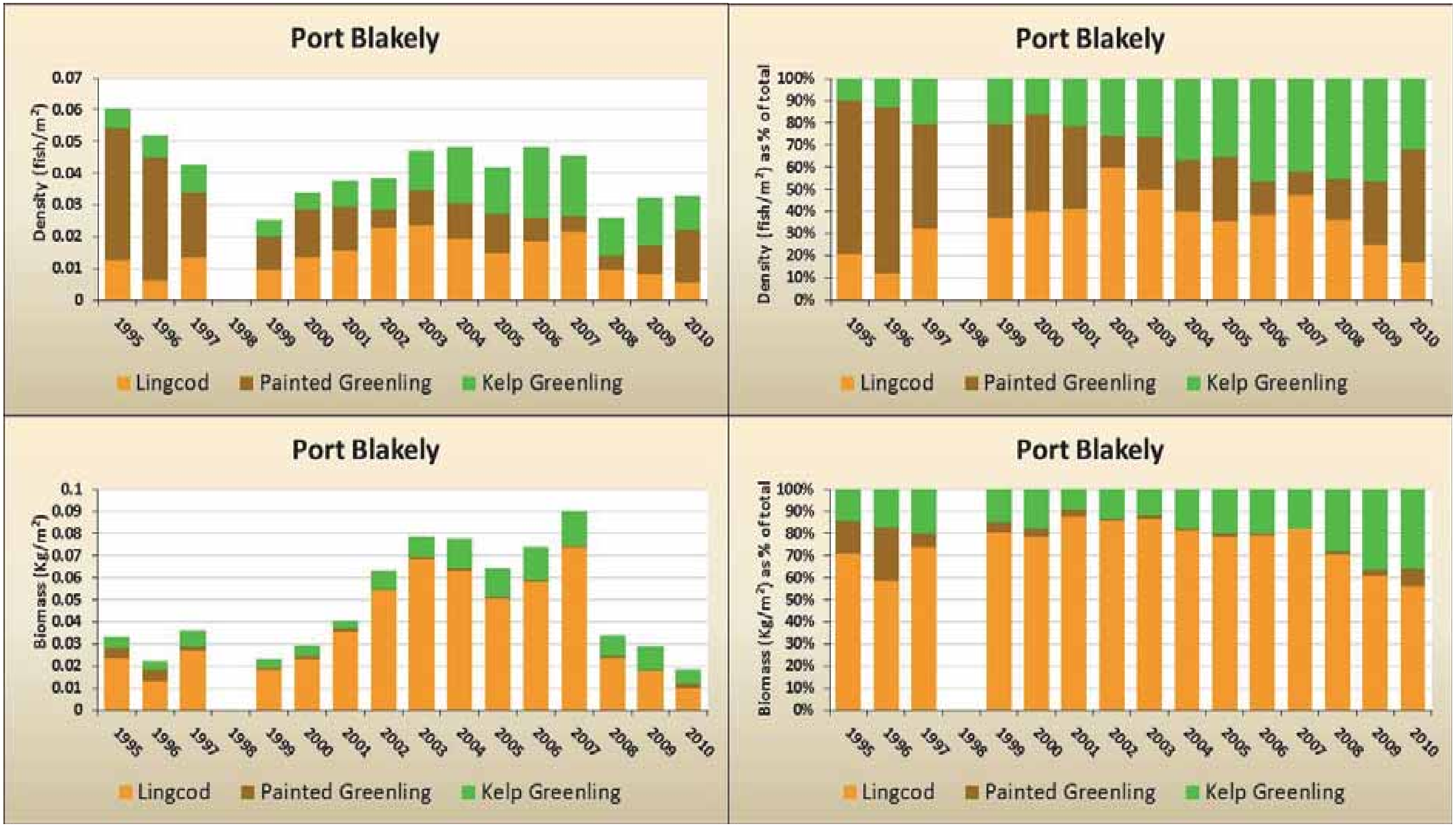


Appendix 9.D. **Greenling density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at the Keystone jetty. Only species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (*i.e.*, Lingcod, Painted Greenling, and Kelp Greenling). Years for which no data are presented were not surveyed. The east side of the jetty was afforded MPA protection in 2002. Note that y-axis scales may differ among locations in this appendix.**

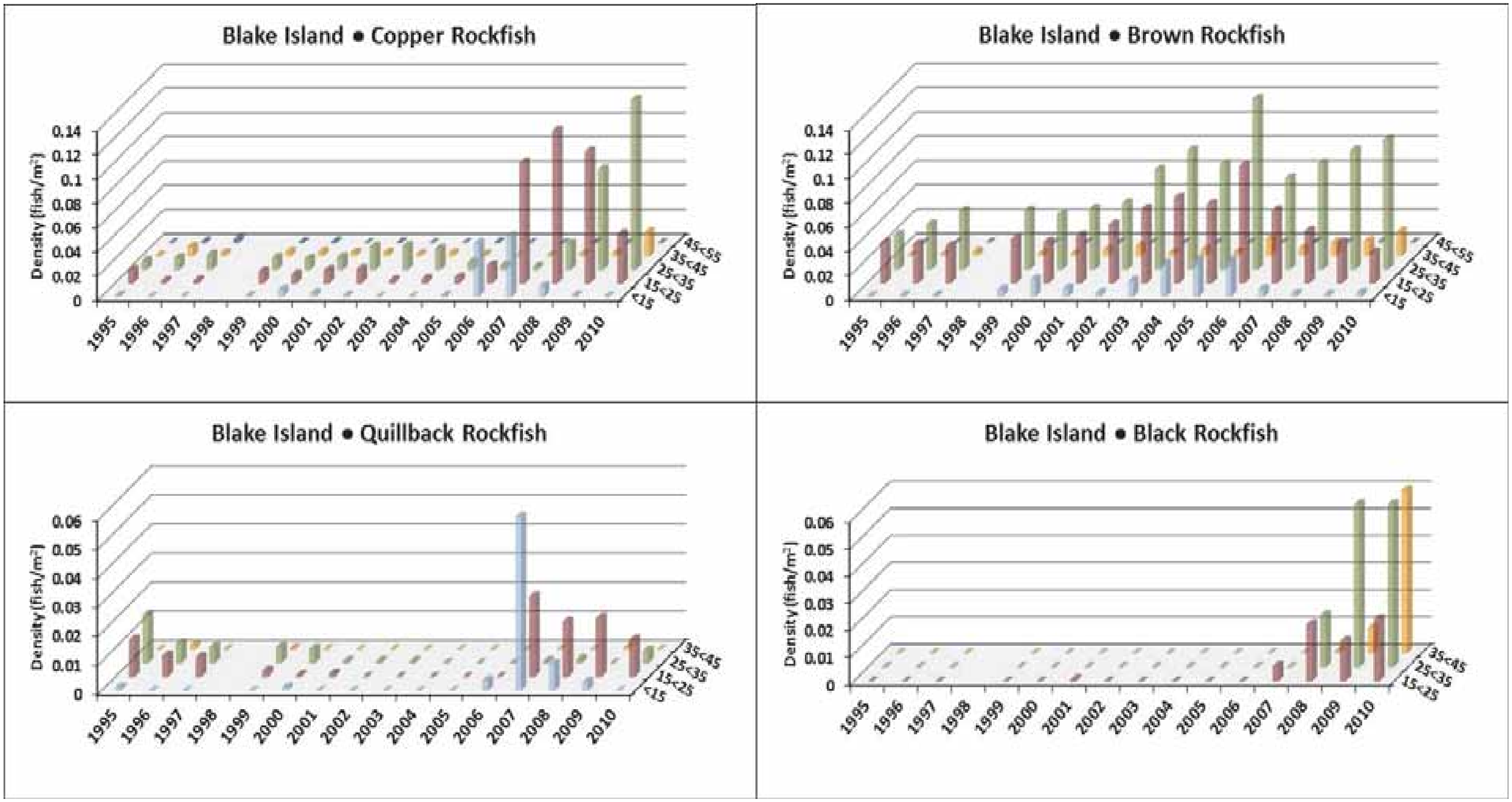


Appendix 9.E. Greenling density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Brackett's Landing Shoreline Sanctuary Conservation Area. Only those greenling species for which the total estimated biomass exceeded 10kg when summed over all surveys are included (i.e., Lingcod, Painted Greenling, and Kelp Greenling). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.

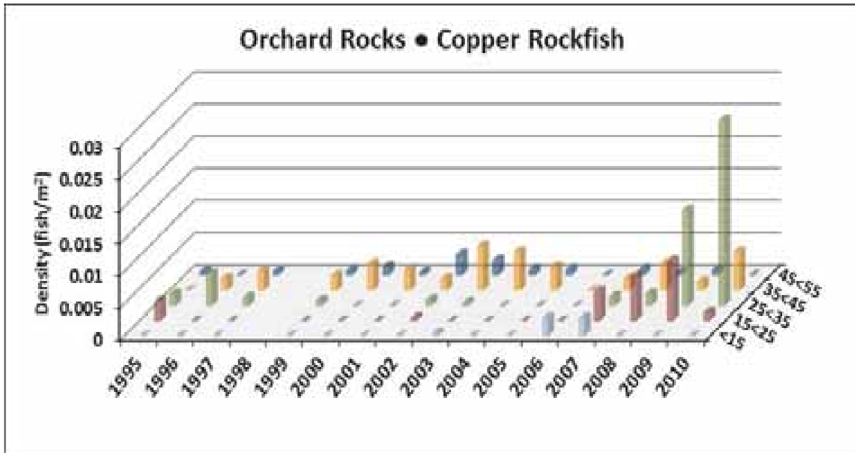
Appendix 9.F. Greenling density (fish/m^2), estimated biomass (kg/m^2), and percent of total, by species, at Port Blakely. Only those greenling species for which the total biomass exceeded 10kg when summed over all surveys are included (i.e., Lingcod, Painted Greenling, and Kelp Greenling). Years for which no data are presented were not surveyed. Note that y-axis scales may differ among locations in this appendix.

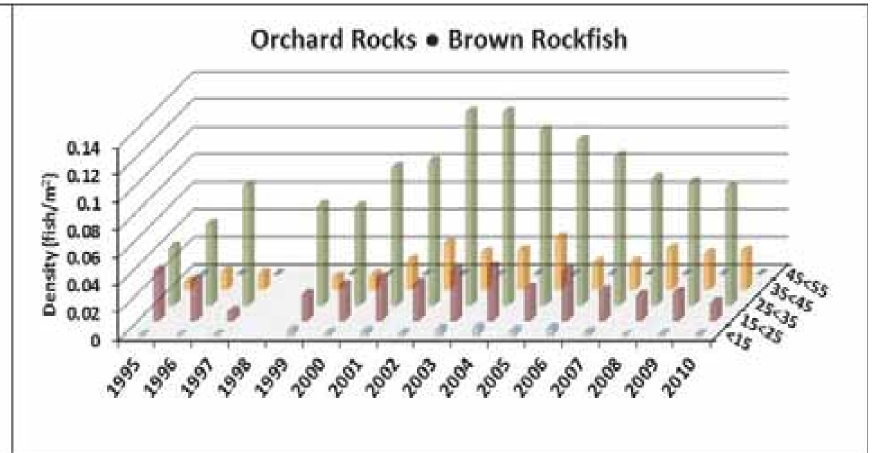


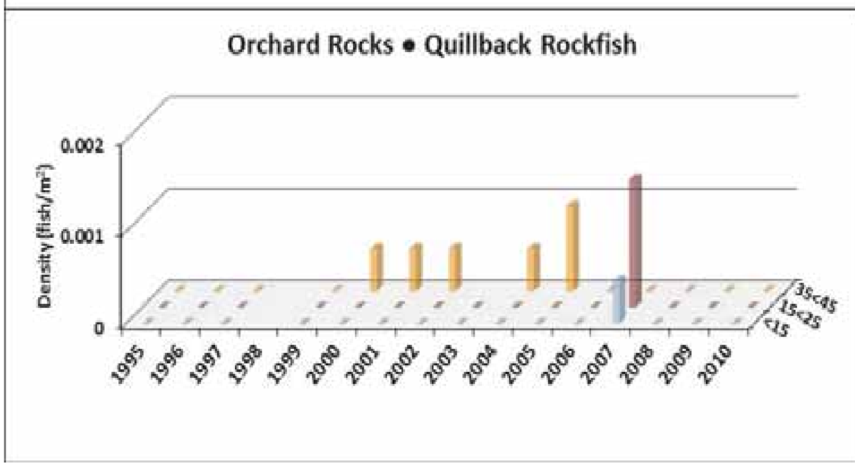
Appendix 10.A. Density (fish/m^2) by length-class (cm) for four rockfish species at Blake Island Artificial Reef. Length-classes for which no fish were observed in any year are not depicted. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among species and locations in this appendix.

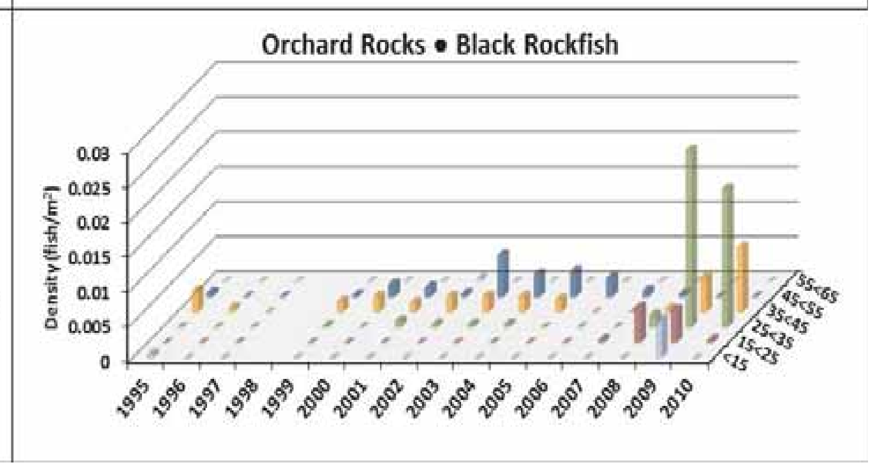


Appendix 10.B. Density (fish/m^2) by length-class (cm) for four rockfish species at Orchard Rocks Conservation Area. Length-classes for which no fish were observed in any year are not depicted. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among species and locations in this appendix.

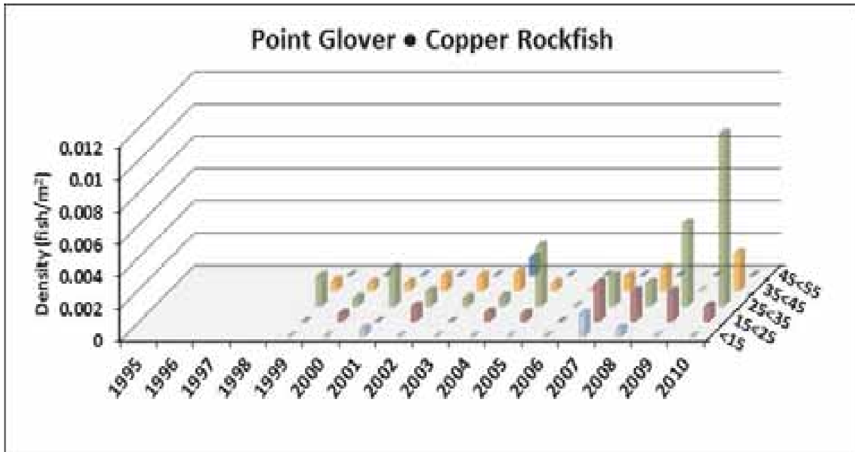


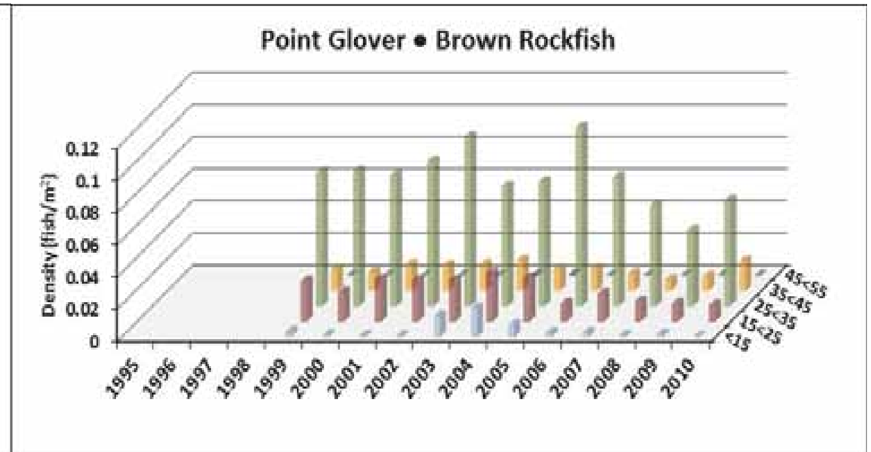


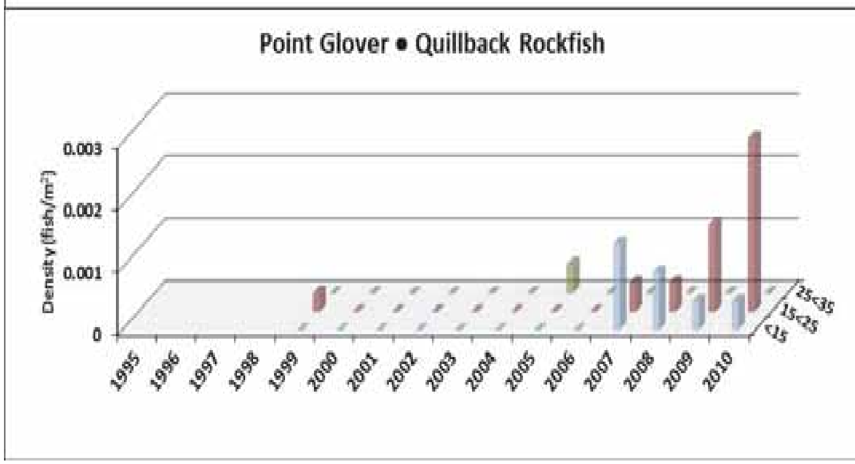


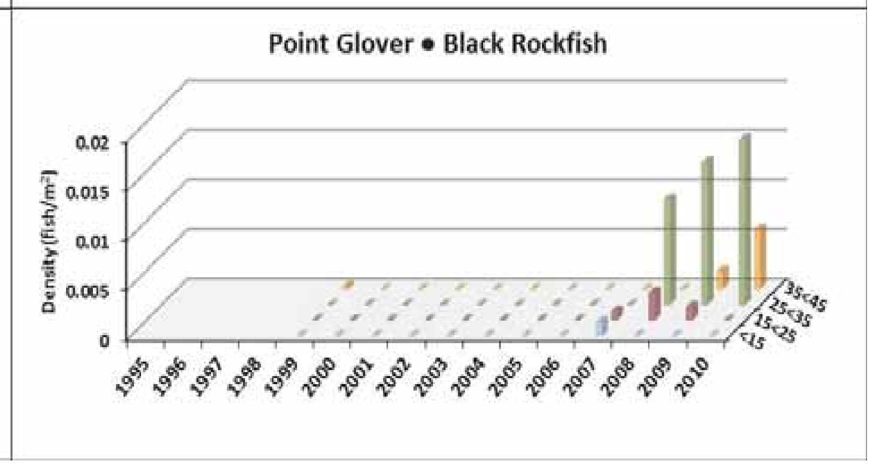


Appendix 10.C. Density (fish/m^2) by length-class (cm) for four rockfish species at Point Glover. Length-classes for which no fish were observed in any year are not depicted. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among species and locations in this appendix.

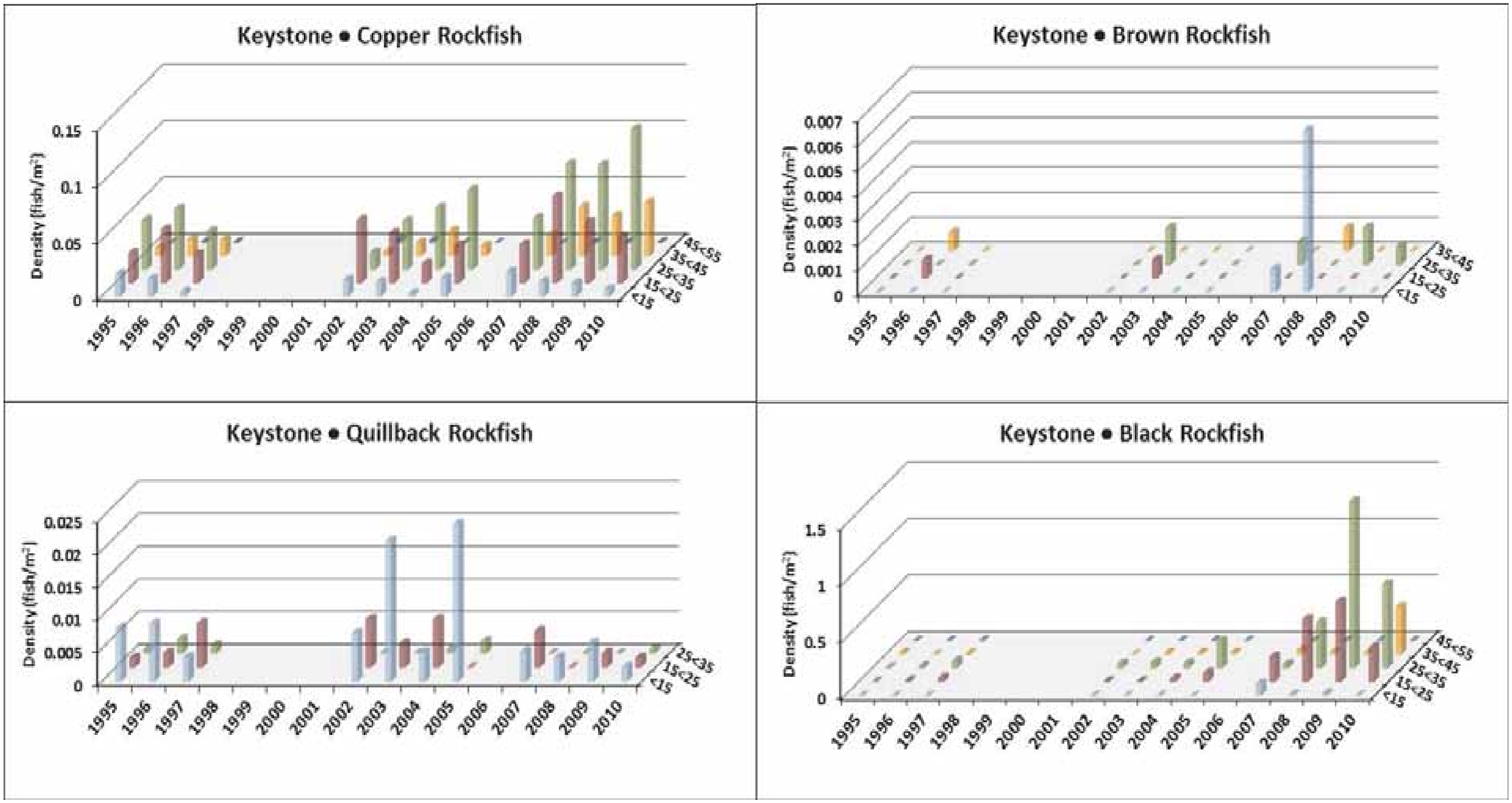




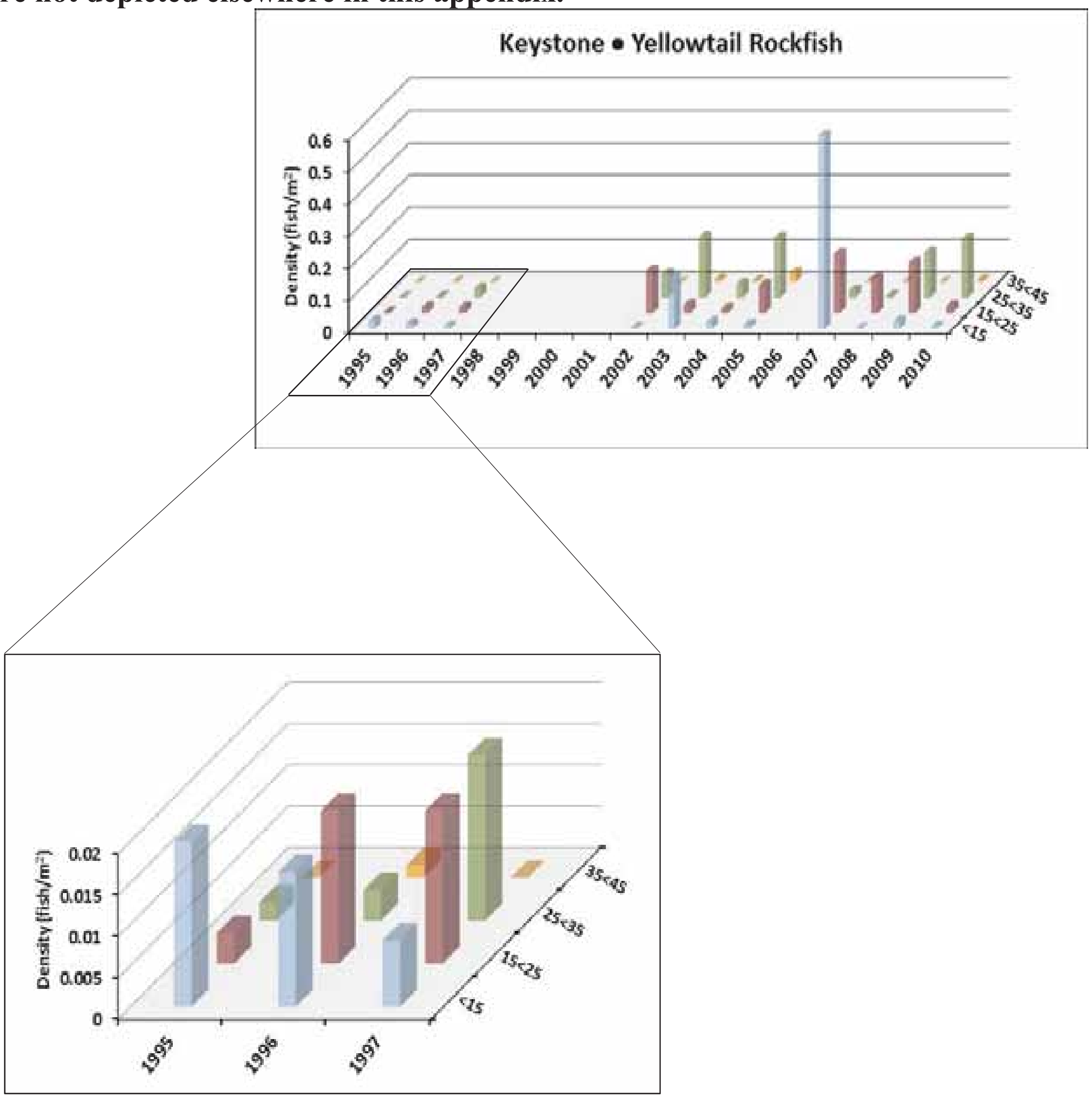




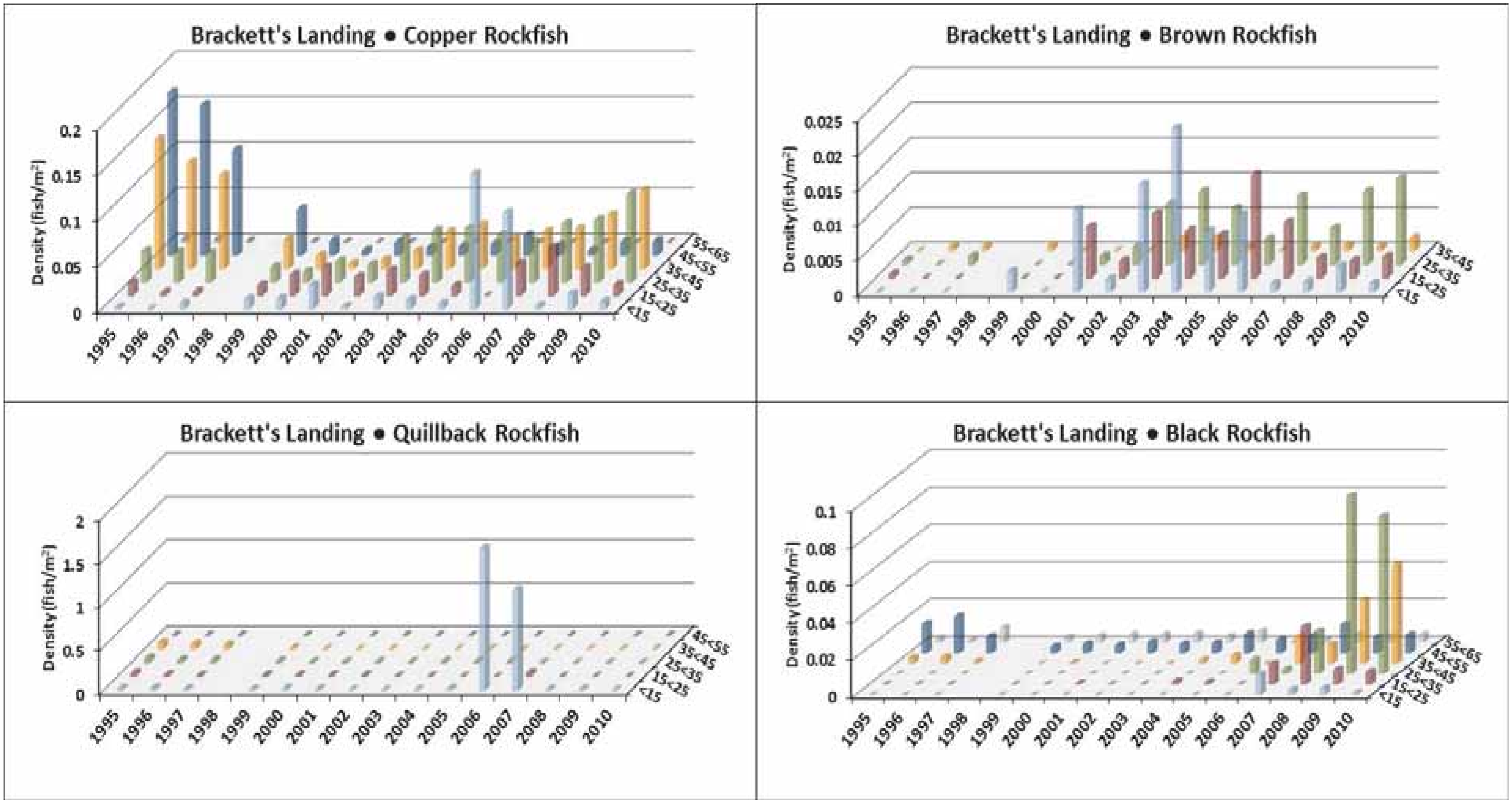
Appendix 10.D. Density (fish/m^2) by length-class (cm) for five rockfish species at the Keystone jetty. Length-classes for which no fish were observed in any year are not depicted. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among species and locations in this appendix.



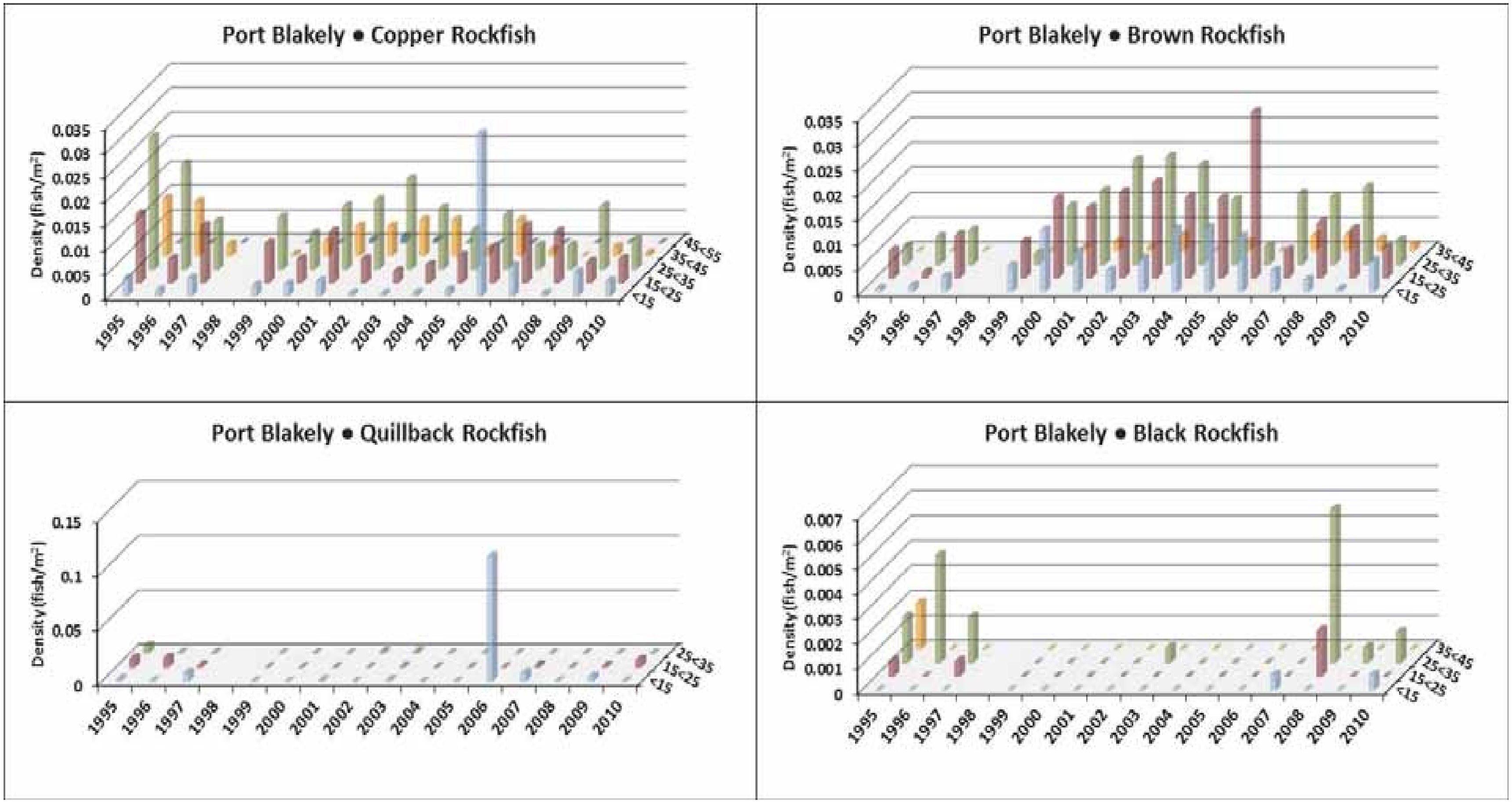
Appendix 10.D. Continued: Note that Yellowtail Rockfish occurred in appreciable numbers only at the Keystone jetty, thus they are not depicted elsewhere in this appendix.



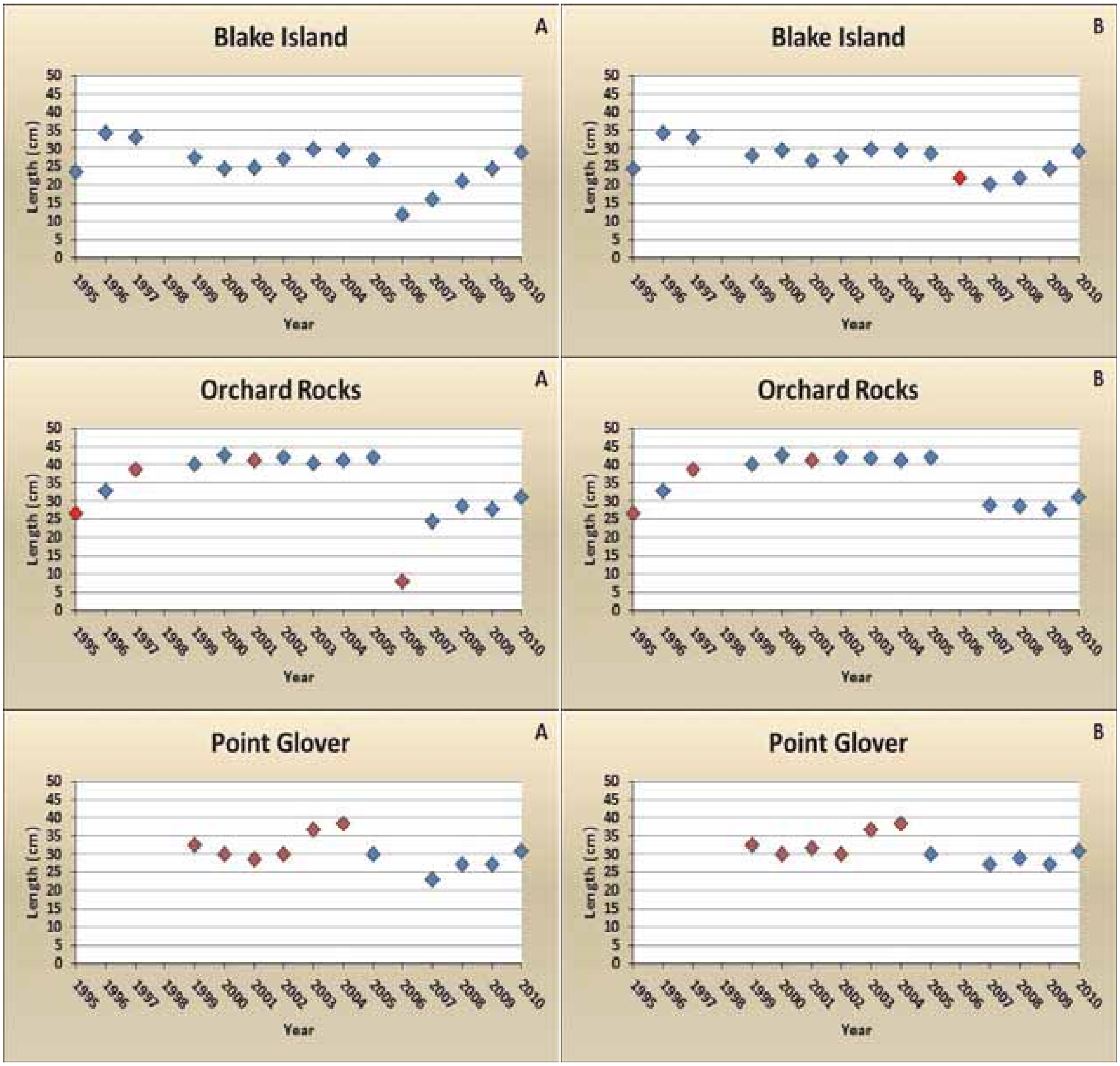
Appendix 10.E. Density (fish/m²) by length-class (cm) for four rockfish species at Brackett's Landing Shoreline Sanctuary Conservation Area. Length-classes for which no fish were observed in any year are not depicted. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among species and locations in this appendix.



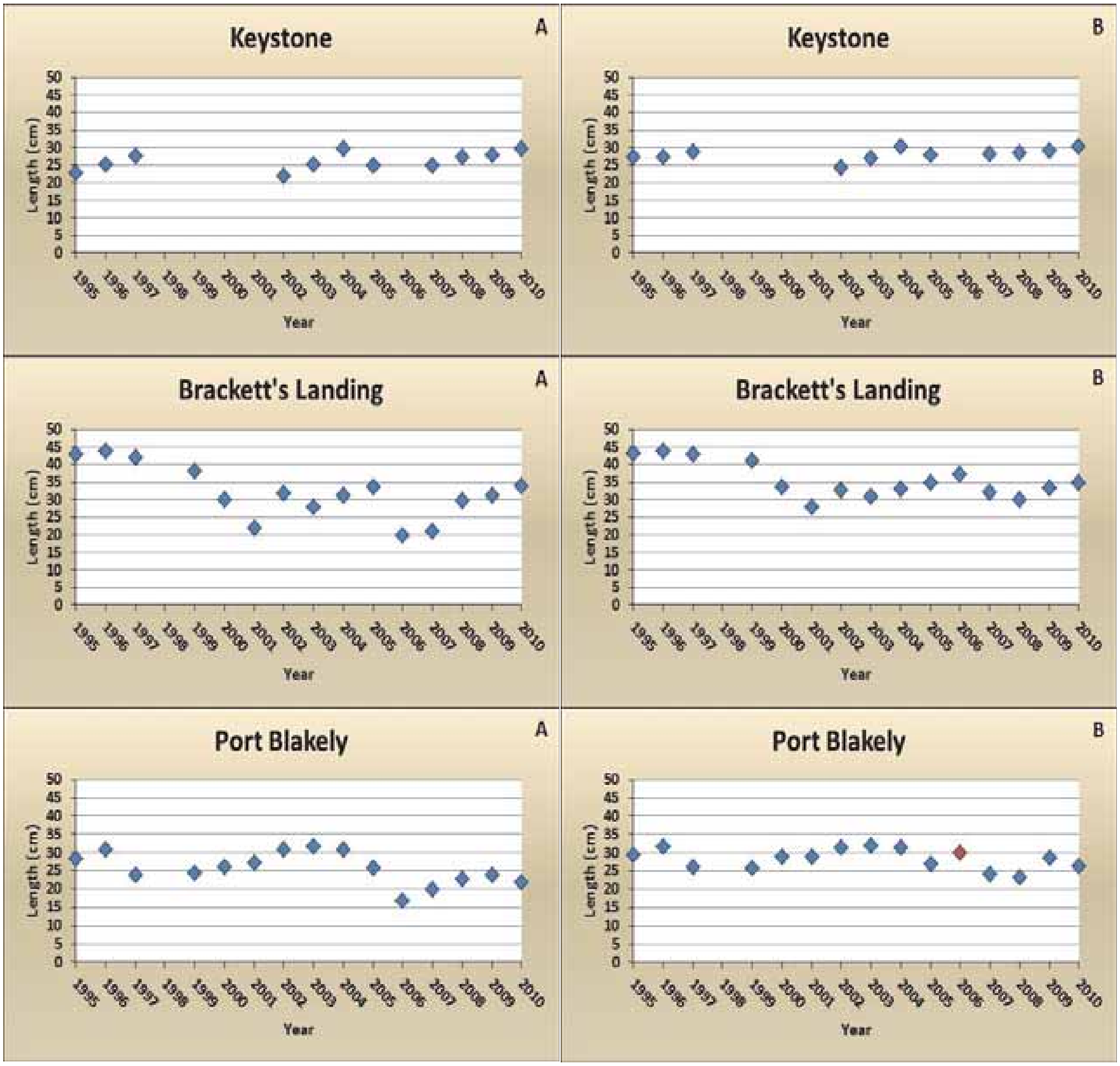
Appendix 10.F. Density (fish/m²) by length-class (cm) for four rockfish species at Port Blakely. Length-classes for which no fish were observed in any year are not depicted. Years for which no data are presented were not surveyed. Note that y-axis scales may differ among species and locations in this appendix.



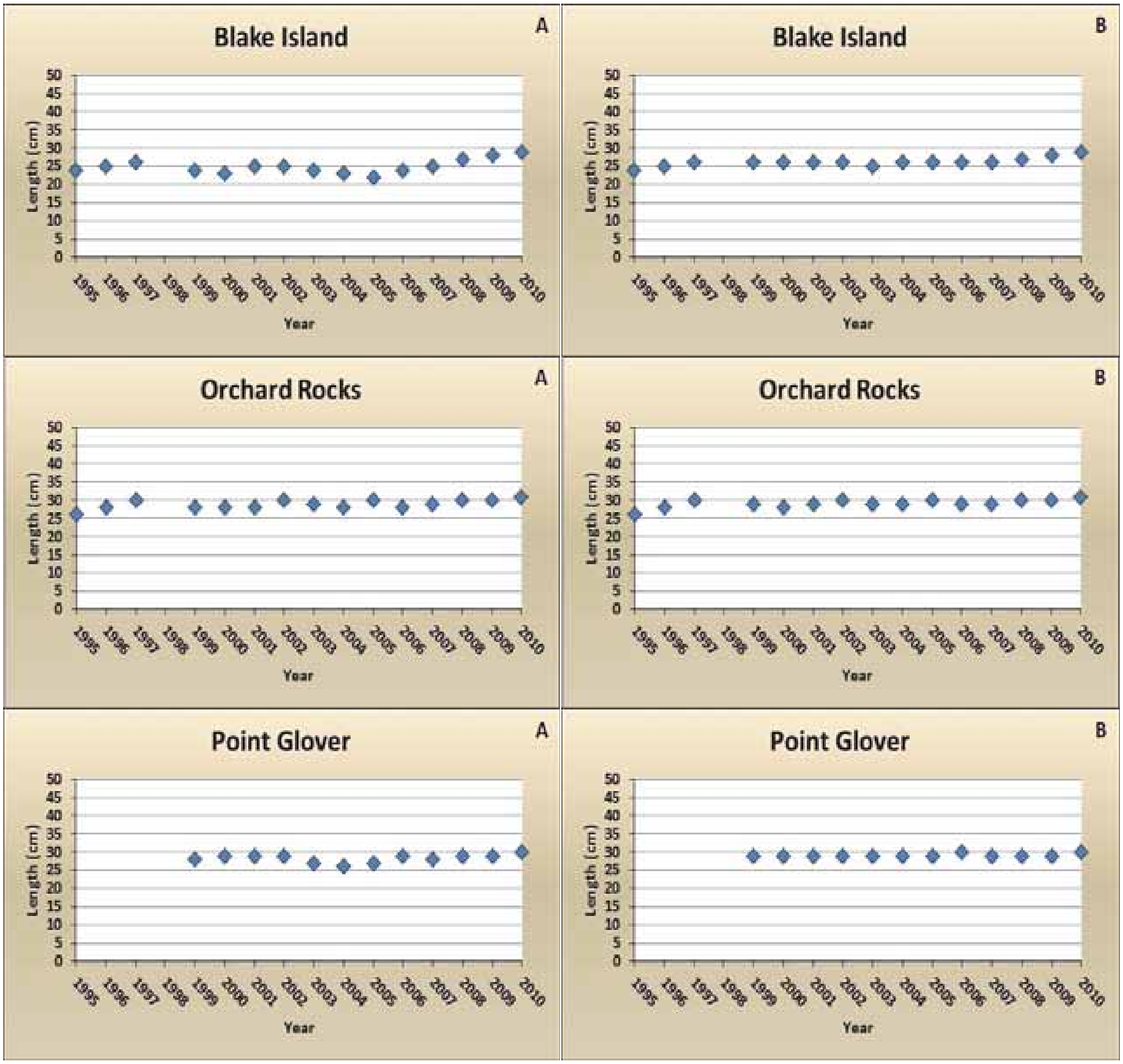
Appendix 11.A. Average length of Copper Rockfish summed over all spring and fall surveys by year at each of six surveyed sites in Puget Sound. “A” includes all length-classes. “B” includes all length-classes except < 15. Years for which no data are presented were either not surveyed, or no Copper Rockfish were observed (Orchard Rocks B & Point Glover B 2006). Red denotes years for which total N < 10. Refer to Appendix 12 for length-class frequency histograms by year.



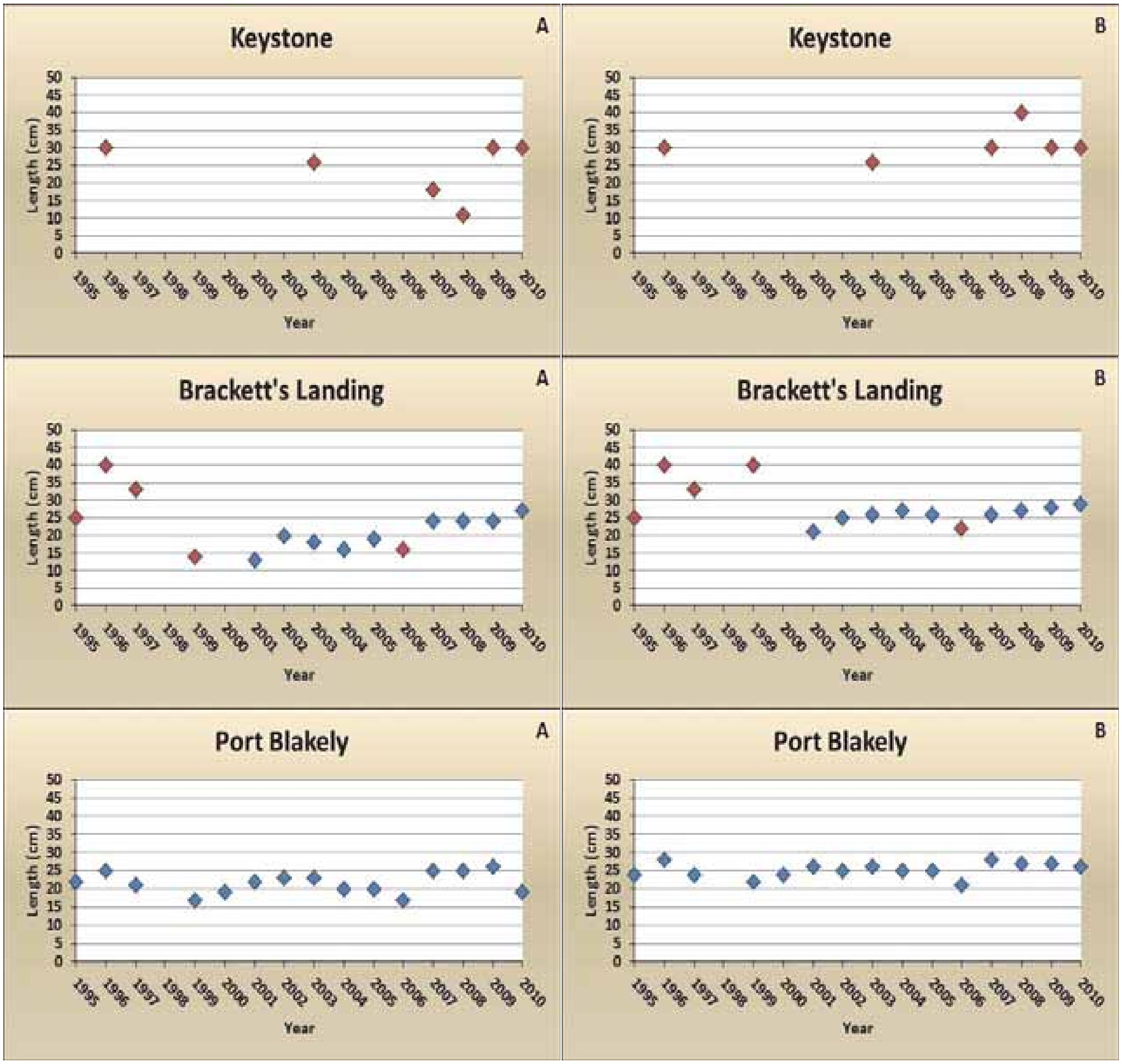
Appendix 11.A. Continued:



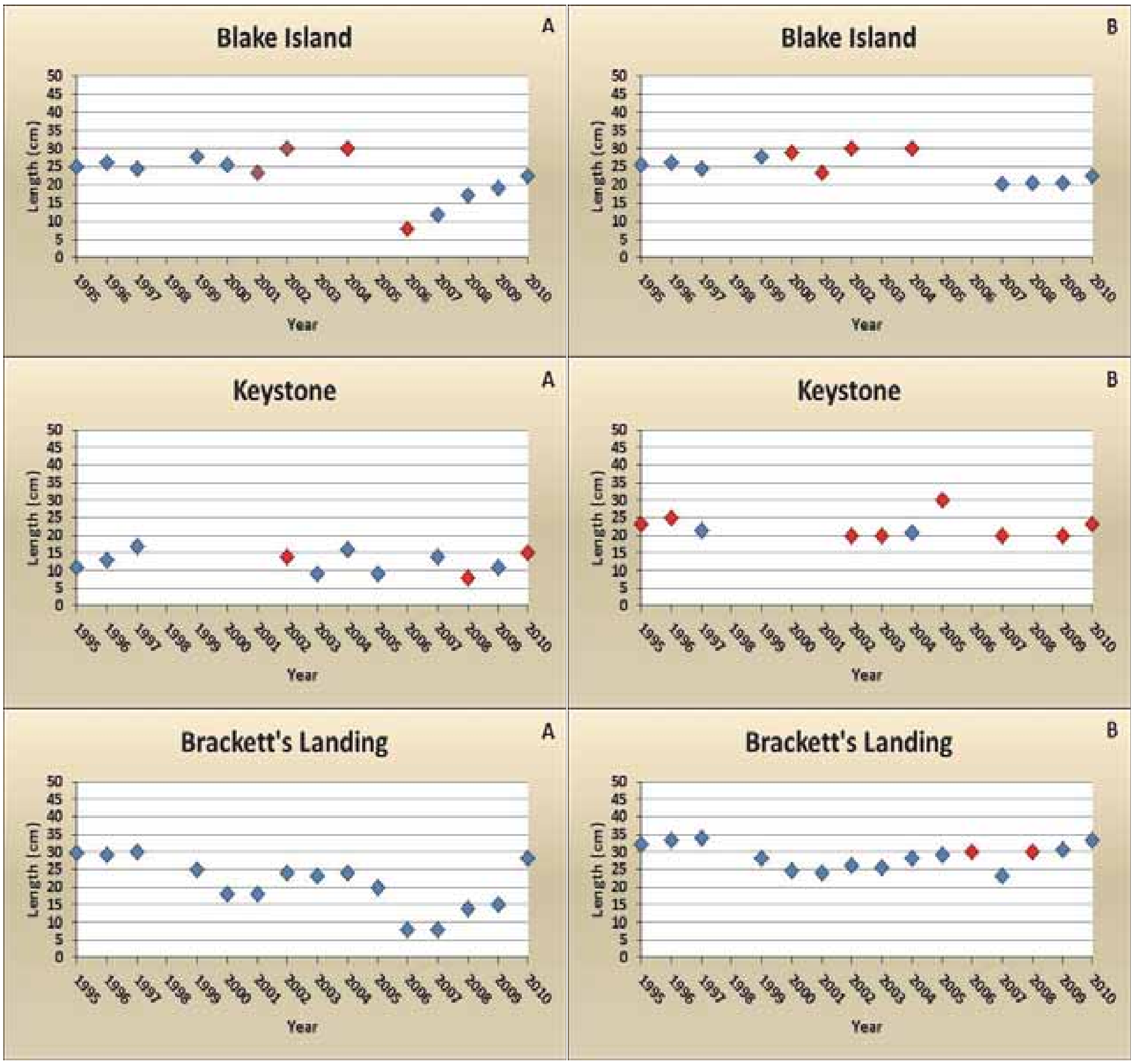
Appendix 11.B. Average length of Brown Rockfish summed over all spring and fall surveys by year at each of six surveyed sites in Puget Sound. "A" includes all length-classes. "B" includes all length-classes except < 15. Years for which no data are presented were either not surveyed, or no Brown Rockfish were observed (Keystone A & B 1995, 97, 2002, 04, 05; Brackett's Landing A & B 2000). Red denotes years for which total N < 10. Refer to Appendix 13 for length-class frequency histograms by year.



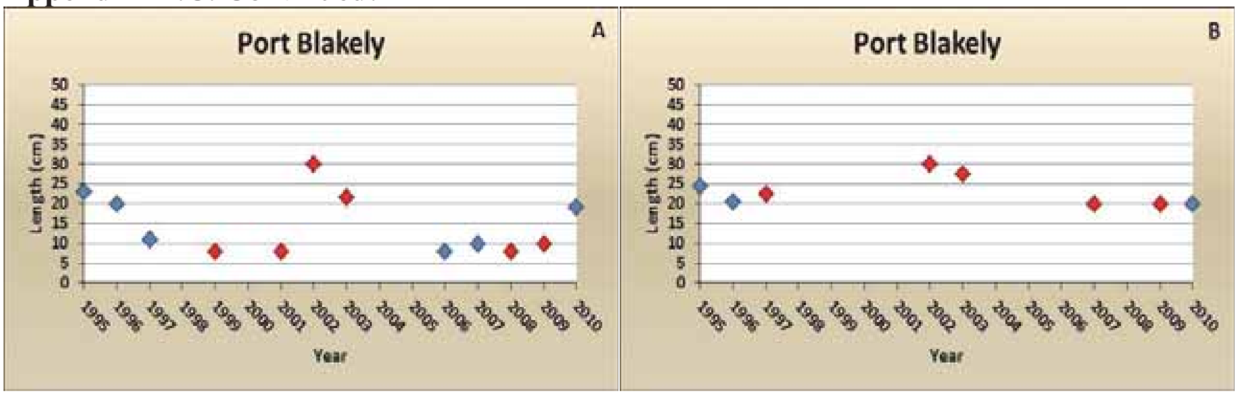
Appendix 11.B. Continued:



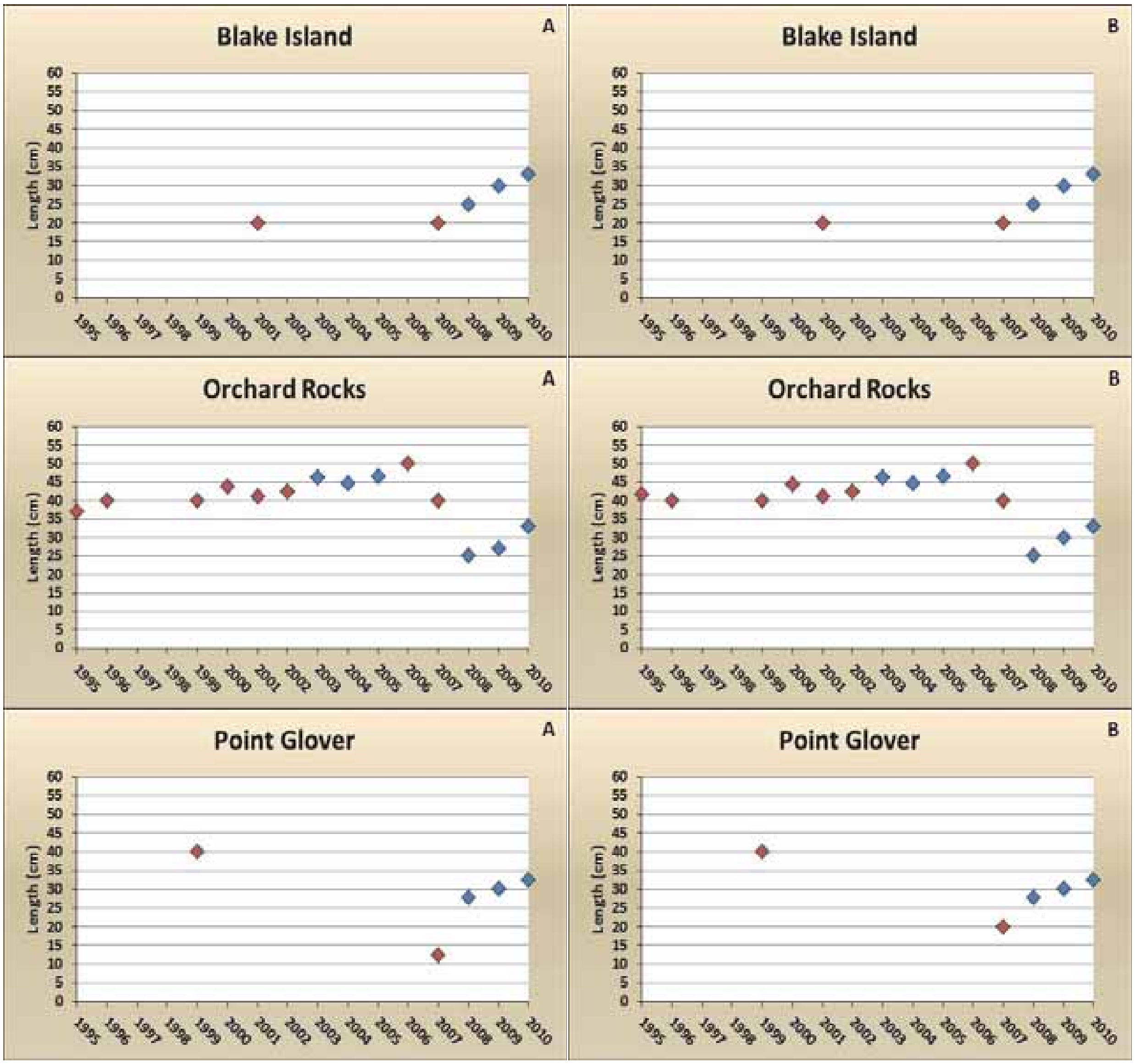
Appendix 11.C. Average length of Quillback Rockfish summed over all spring and fall surveys by year at each of four surveyed sites in Puget Sound. Note that the number of Quillback Rockfish at Orchard Rocks Conservation Area and Point Glover did not exceed seven in any one year and were only observed for half or less of the total number of years surveyed at either site, thus they are not depicted here. "A" includes all length-classes. "B" includes all length-classes except < 15. Years for which no data are presented were either not surveyed, or no Quillback Rockfish were observed (Blake Island A & B 2003, 05 & B 06; Keystone B 2008; Port Blakely A & B 2000, 04, 05 & B 1999, 2001, 06, 08). Red denotes years for which total N < 10. Refer to Appendix 14 for length-class frequency histograms by year.



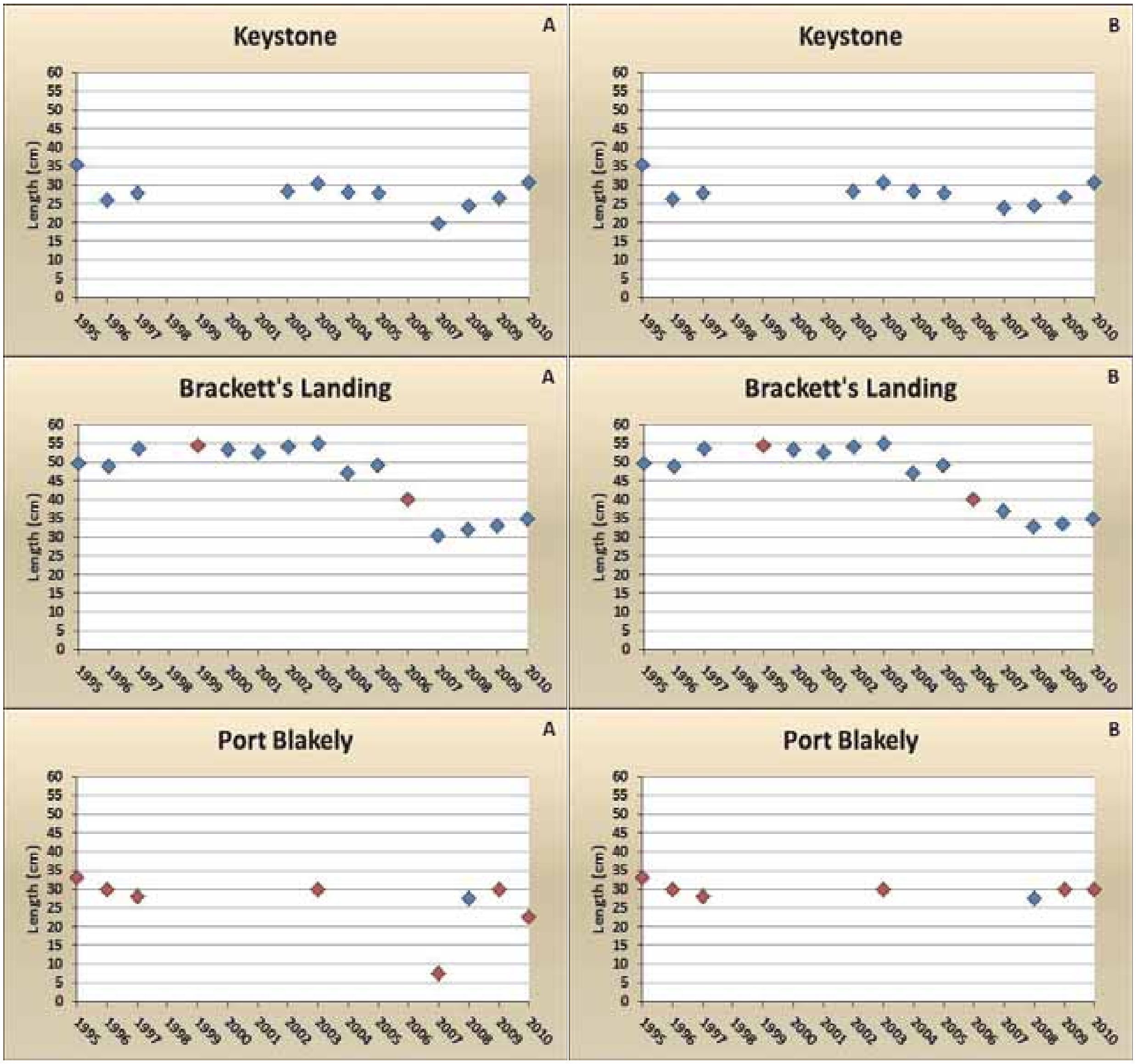
Appendix 11.C. Continued:



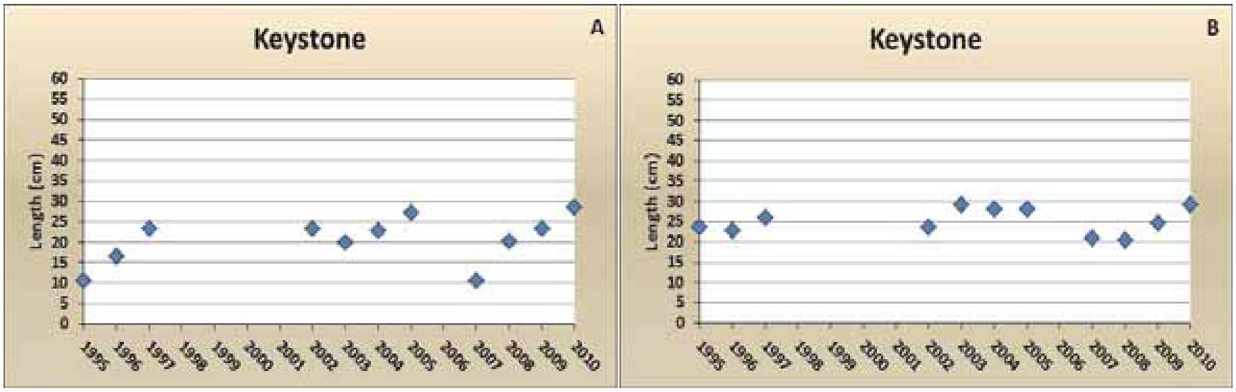
Appendix 11.D. Average length of Black Rockfish summed over all spring and fall surveys by year at each of six surveyed sites in Puget Sound. "A" includes all length-classes. "B" includes all length-classes except < 15. Years for which no data are presented were either not surveyed, or no Black Rockfish were observed (Blake Island A & B 1995-97, 1999, 2001-06 & B 2000, 2007-10); Orchard Rocks A & B 1997; Point Glover A & B 2000-06; Port Blakely A & B 1999, 2000-02, 2004-06 & B 2007). Red denotes years for which total N < 10. Refer to Appendix 15 for length-class frequency histograms by year.



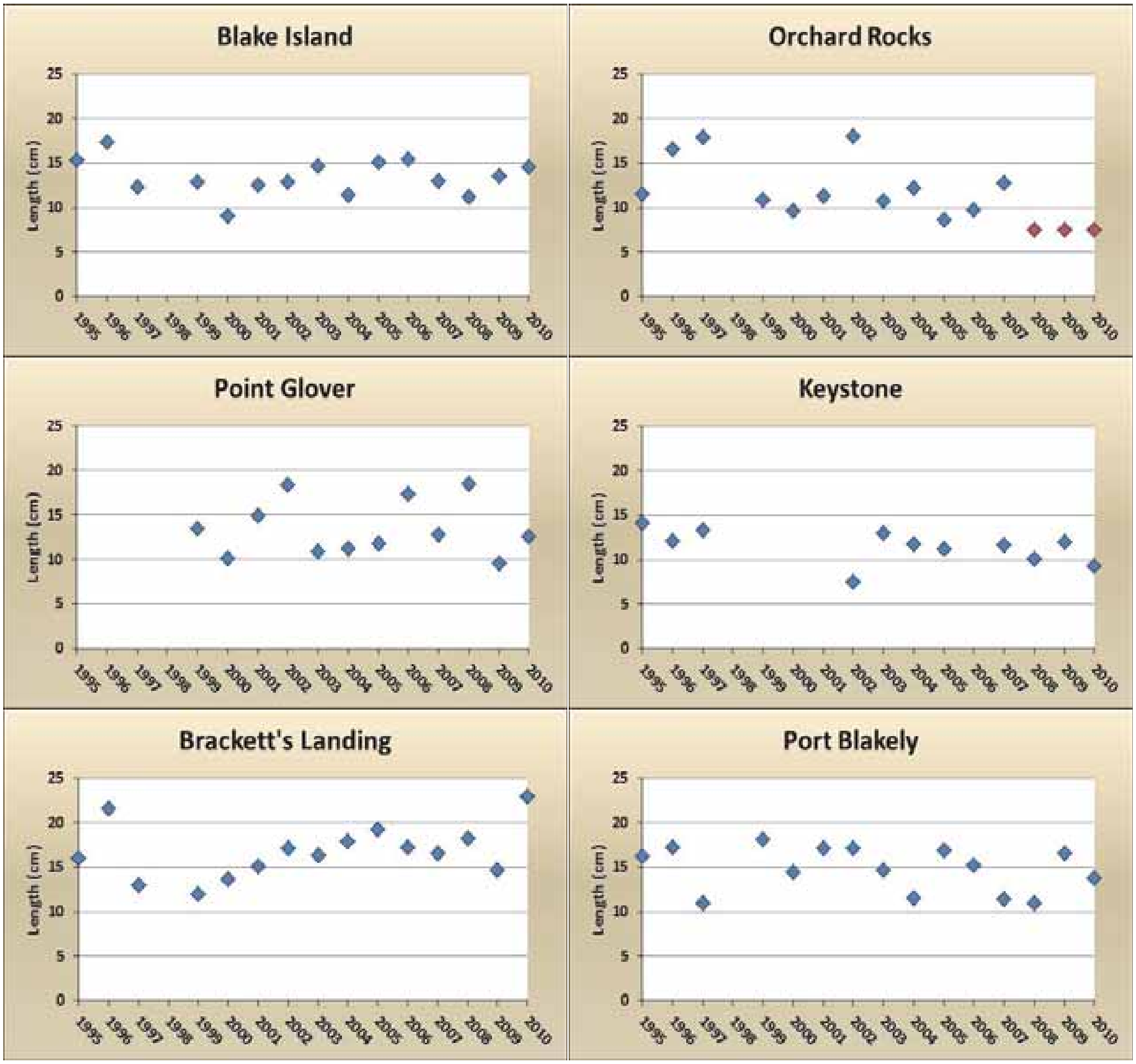
Appendix 11.D. Continued:



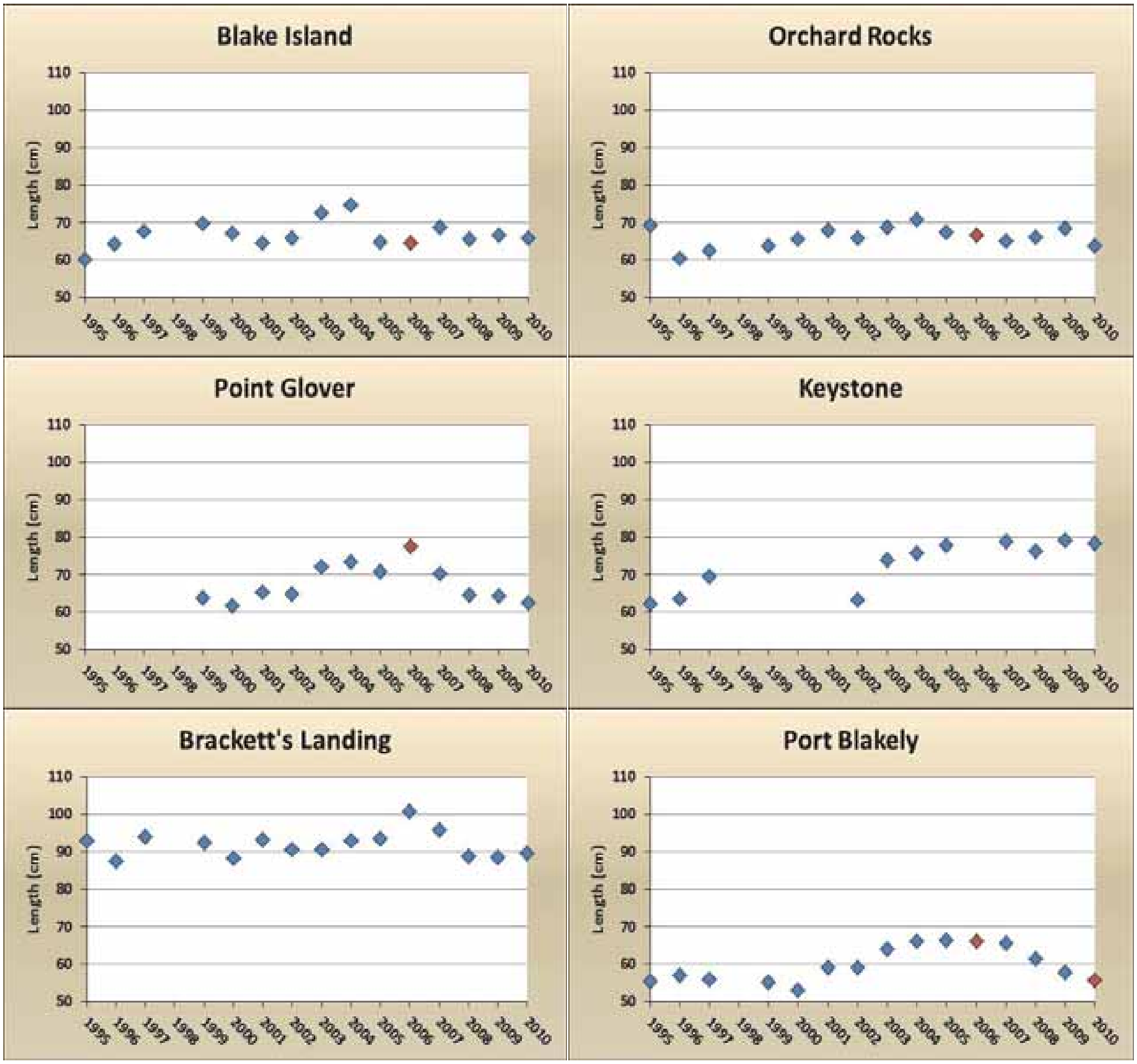
Appendix 11.E. Average length of Yellowtail Rockfish summed over all spring and fall surveys by year at the Keystone jetty (KJ). Note that Yellowtail Rockfish occurred in appreciable numbers only at KJ, thus the other five sites are not depicted here. "A" includes all length-classes. "B" includes all length-classes except < 15. Refer to Appendix 16.D for length-class frequency histograms by year.



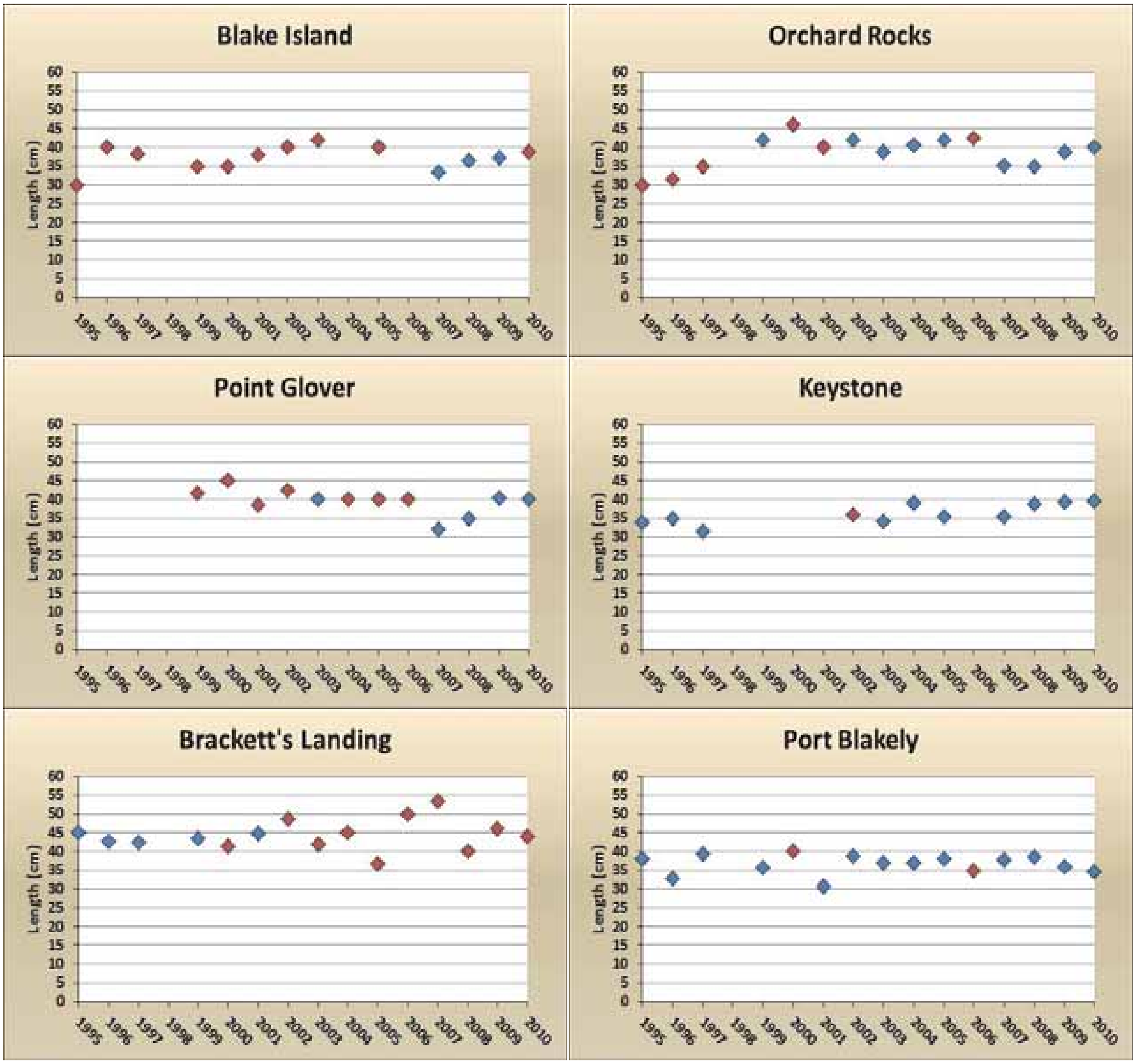
Appendix 11.F. Average length of Striped Seaperch summed over all spring and fall surveys by year at each of six surveyed sites in Puget Sound. Years for which no data are presented were not surveyed. Red denotes years for which total N < 10. Refer to Appendix 17 for length-class frequency histograms by year.



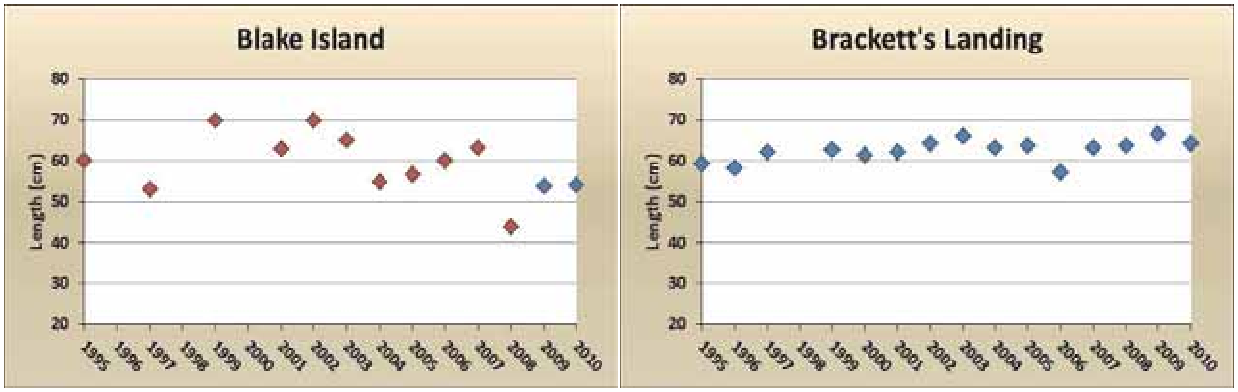
Appendix 11.G. Average length of Lingcod summed over all spring and fall surveys by year at each of six surveyed sites in Puget Sound. Years for which no data are presented were not surveyed. Red denotes years for which total N < 10. Refer to Appendix 18 for length-class frequency histograms by year.



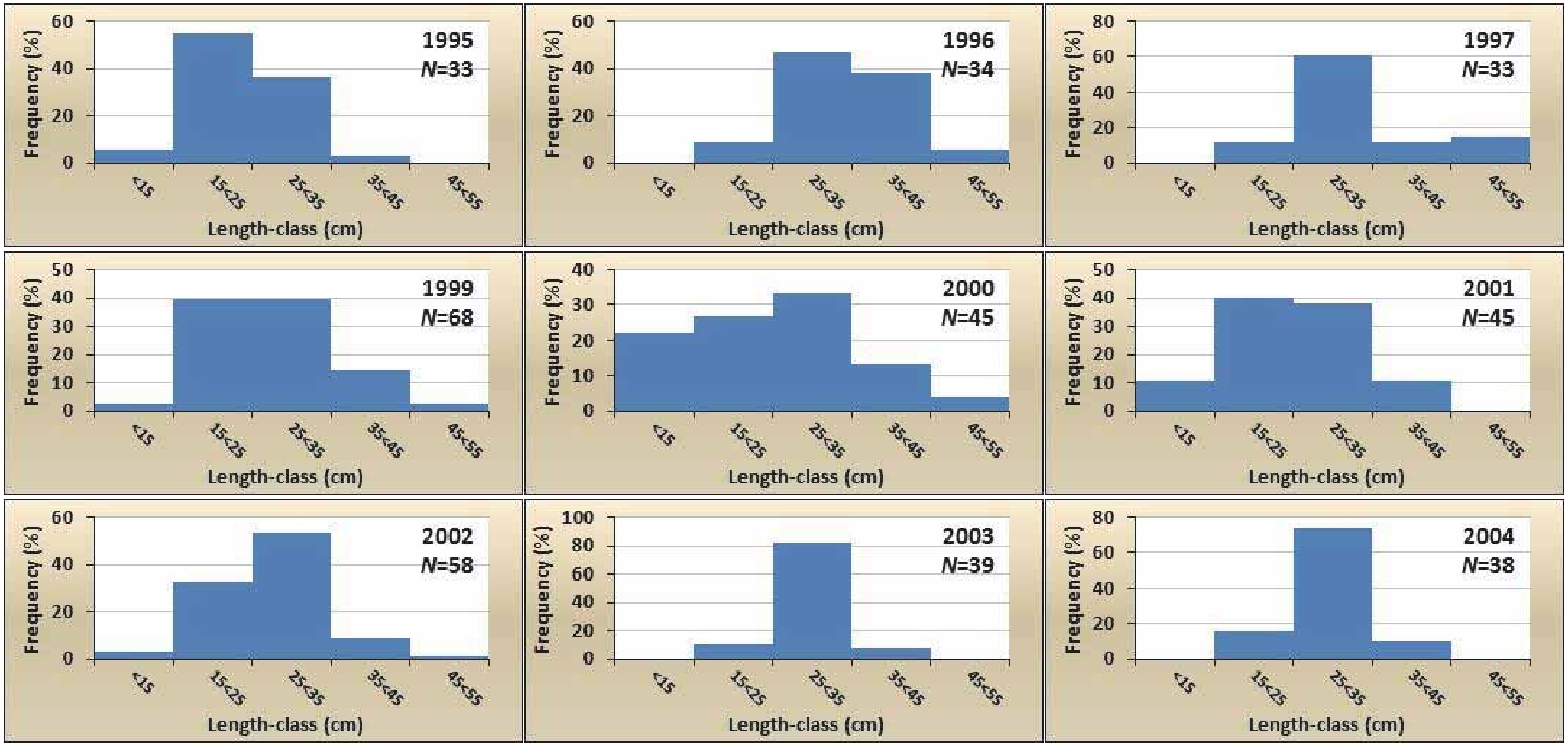
Appendix 11.H. Average length of Kelp Greenling summed over all spring and fall surveys by year at each of six surveyed sites in Puget Sound. Years for which no data are presented were either not surveyed, or no Kelp Greenling were observed (Blake Island 2004 & 2006). Red denotes years for which total N < 10. Refer to Appendix 19 for length-class frequency histograms by year.

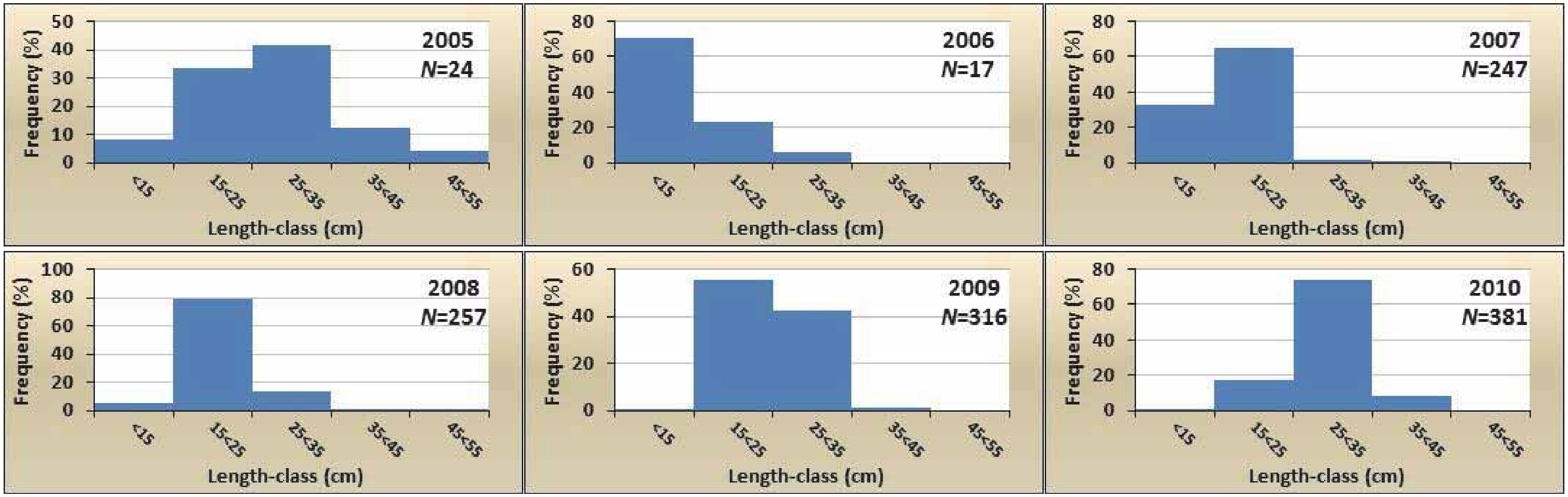


Appendix 11.I. Average length of Cabezon summed over all spring and fall surveys by year at each of two surveyed sites in Puget Sound. Note that the number of Cabezon at Orchard Rocks, Point Glover, Port Blakely, and Keystone did not exceed five in any one year, thus they are not depicted here. Years for which no data are presented were either not surveyed, or no Cabezon were observed (Blake Island 1996 & 2000). Red denotes years for which total N < 10. Refer to Appendix 20 for length-class frequency histograms by year.



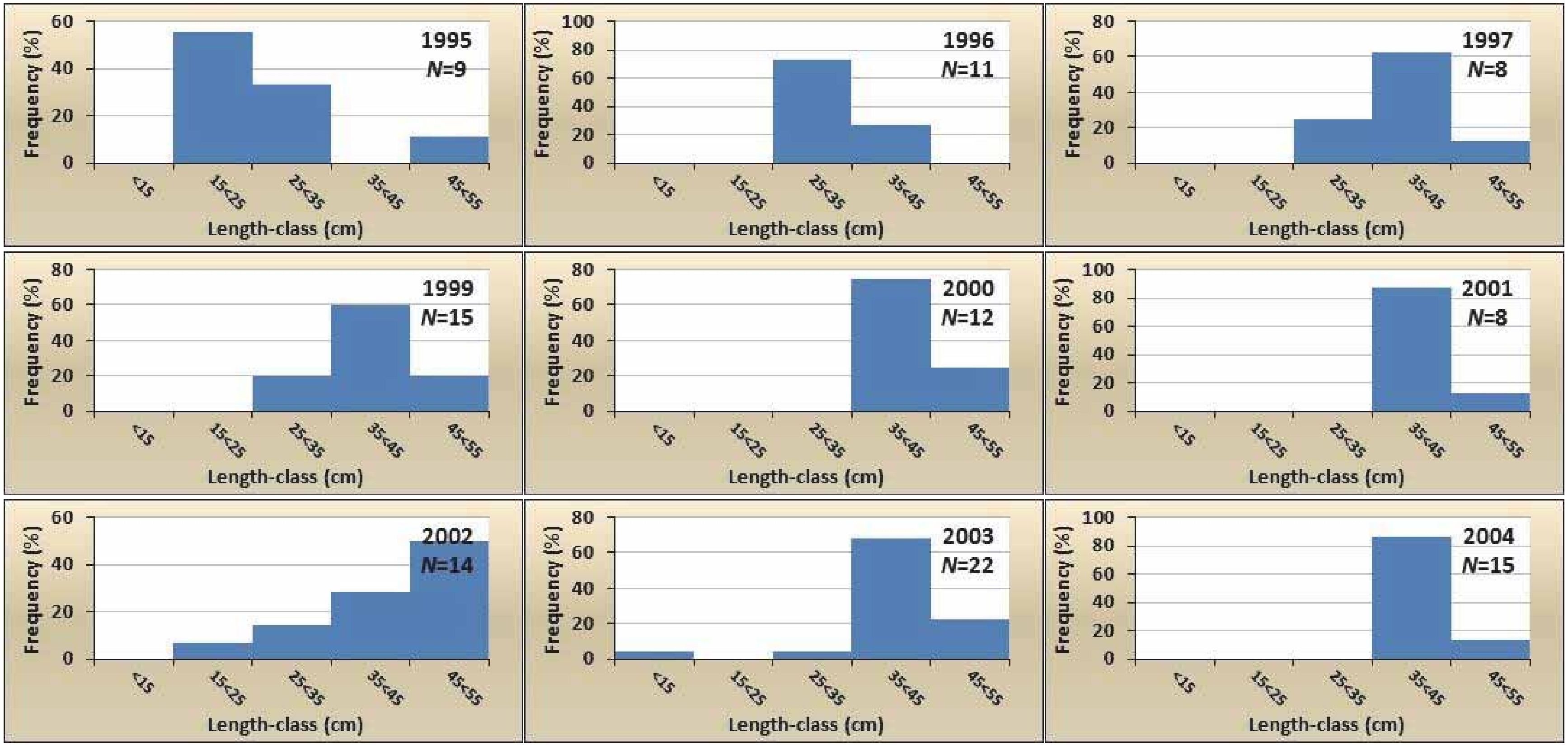
Appendix 12.A. Copper Rockfish length-class frequency histograms by year (expressed as percent of total N) at Blake Island Artificial Reef. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.

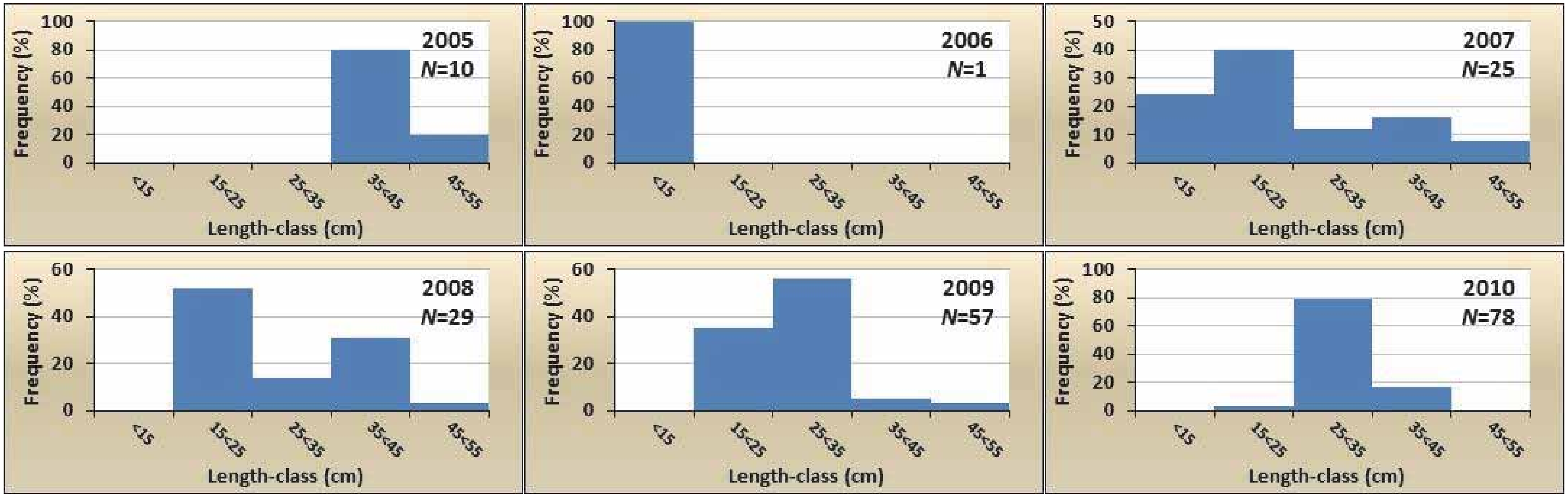




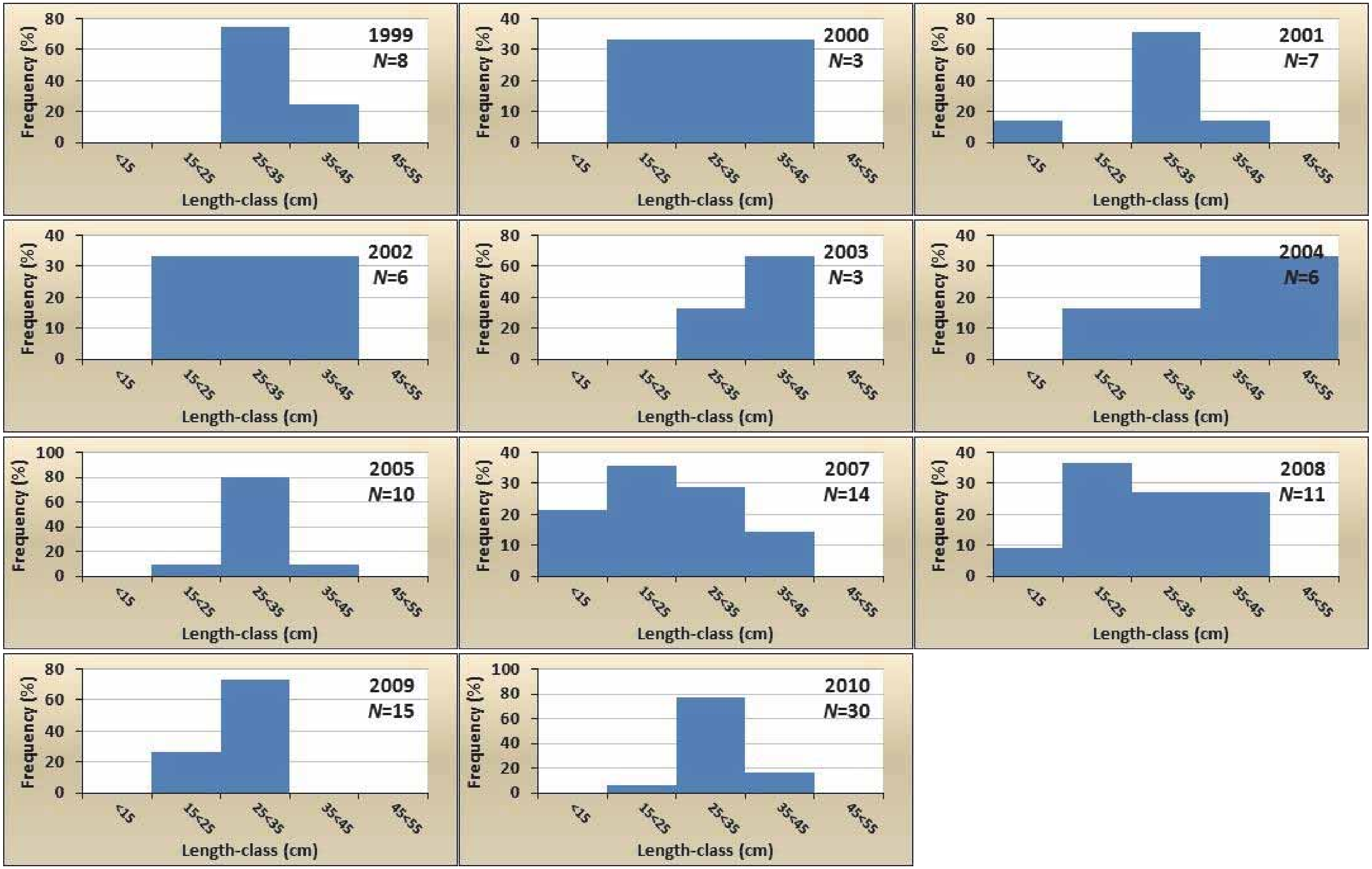
2005
N=24
2006
N=17
2007
N=247
2008
N=257
2009
N=316
2010
N=381
Frequency (%)
<15
15<25
25<35
35<45
45<55
Length-class (cm)

Appendix 12.B. Copper Rockfish length-class frequency histograms by year (expressed as percent of total N) at Orchard Rocks Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.

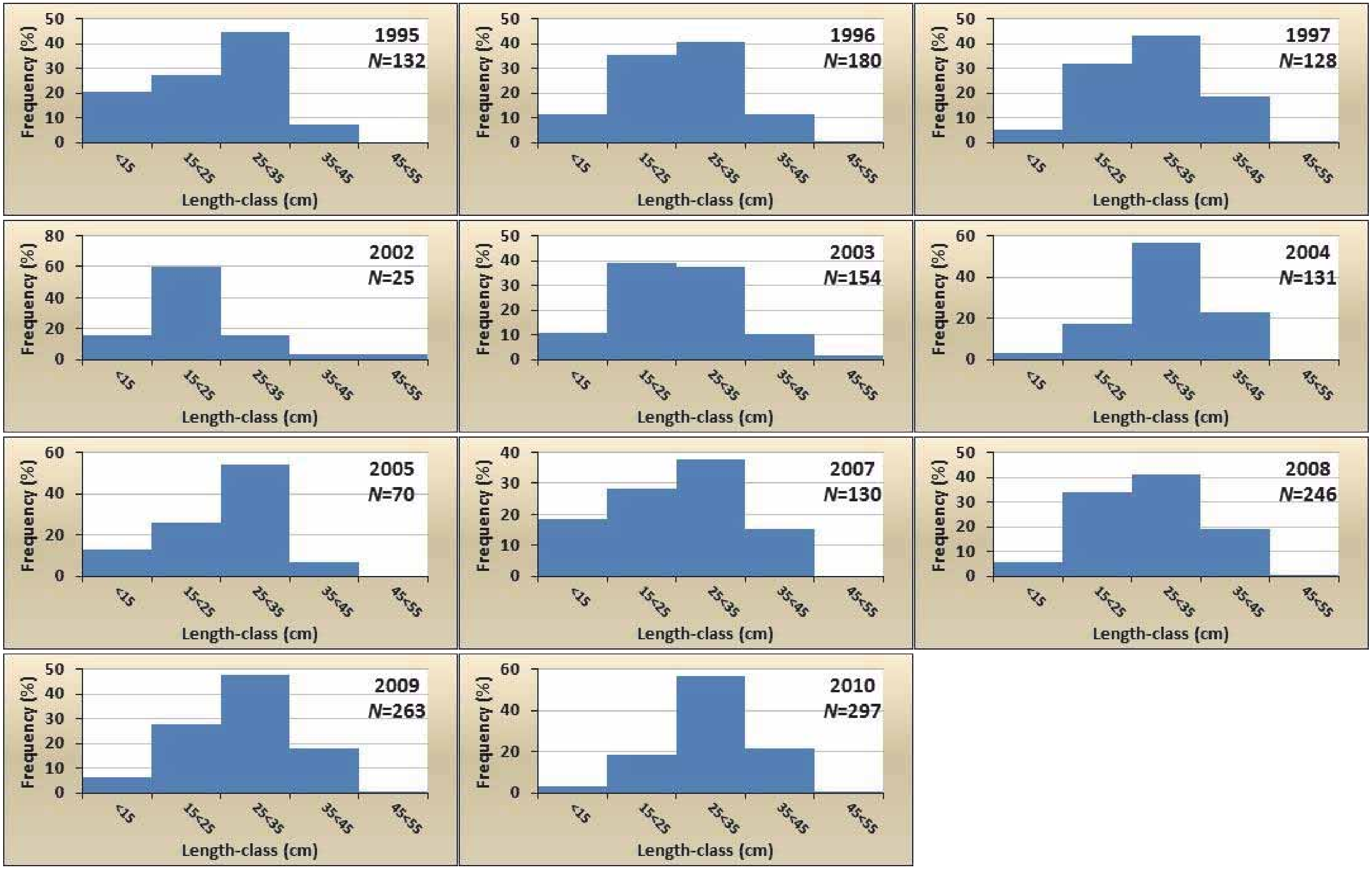



2005
N=10
2006
N=1
2007
N=25
2008
N=29
2009
N=57
2010
N=78
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

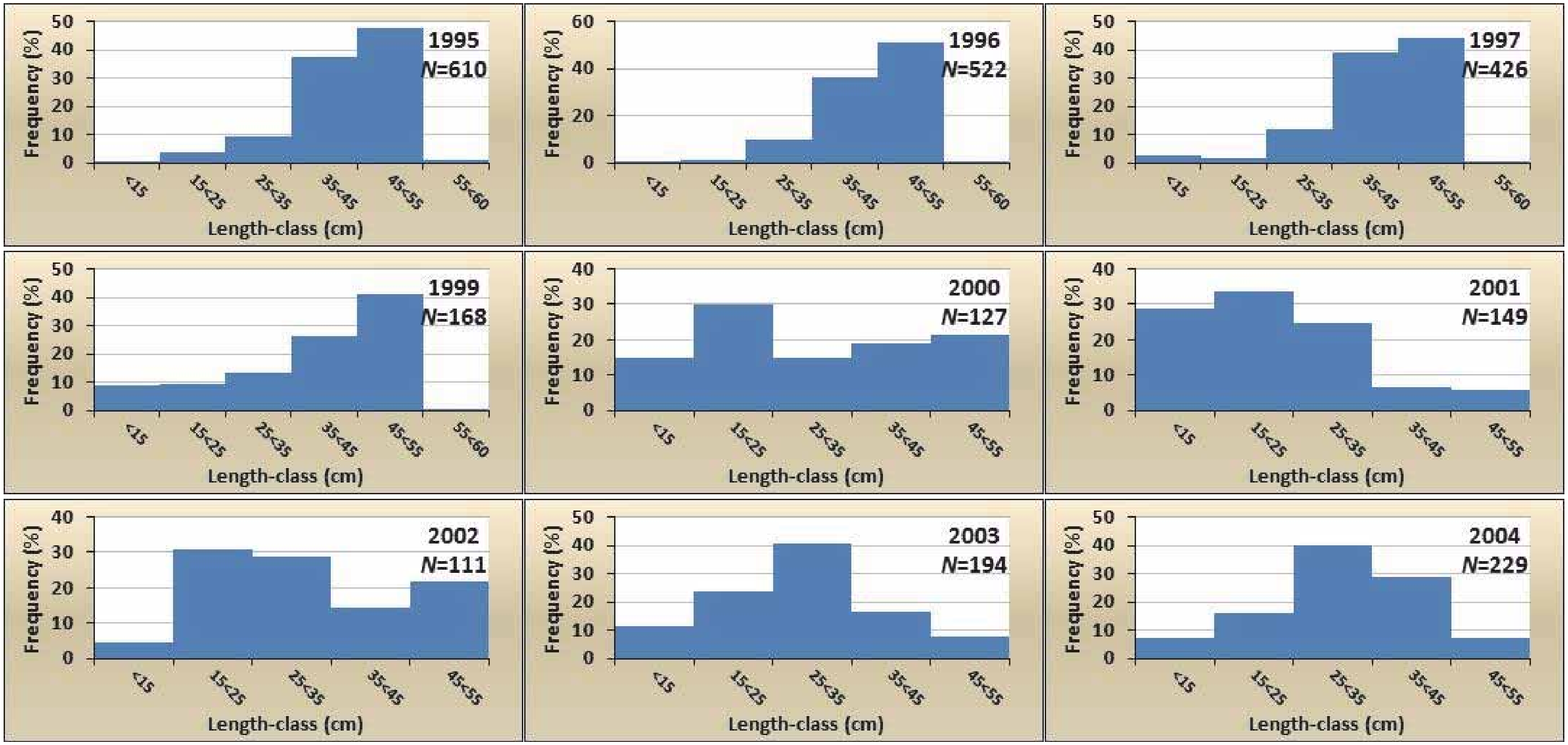
Appendix 12.C. Copper Rockfish length-class frequency histograms by year (expressed as percent of total N) at Point Glover. No surveys were conducted in 1995, 96, 97, or 98. No copper rockfish were observed in 2006. Note that y-axis scales may differ in this appendix.

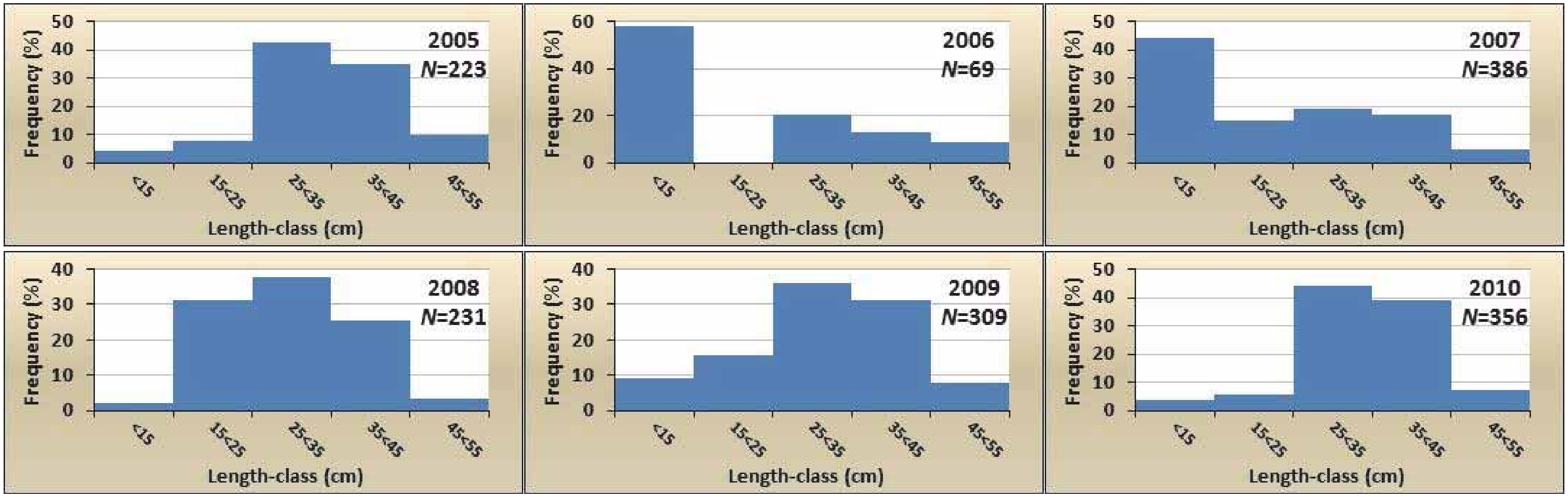


Appendix 12.D. Copper Rockfish length-class frequency histograms by year (expressed as percent of total N) at the Keystone jetty. No surveys were conducted in 1998, 99, 2000, 01, or 06. Note that y-axis scales may differ in this appendix.

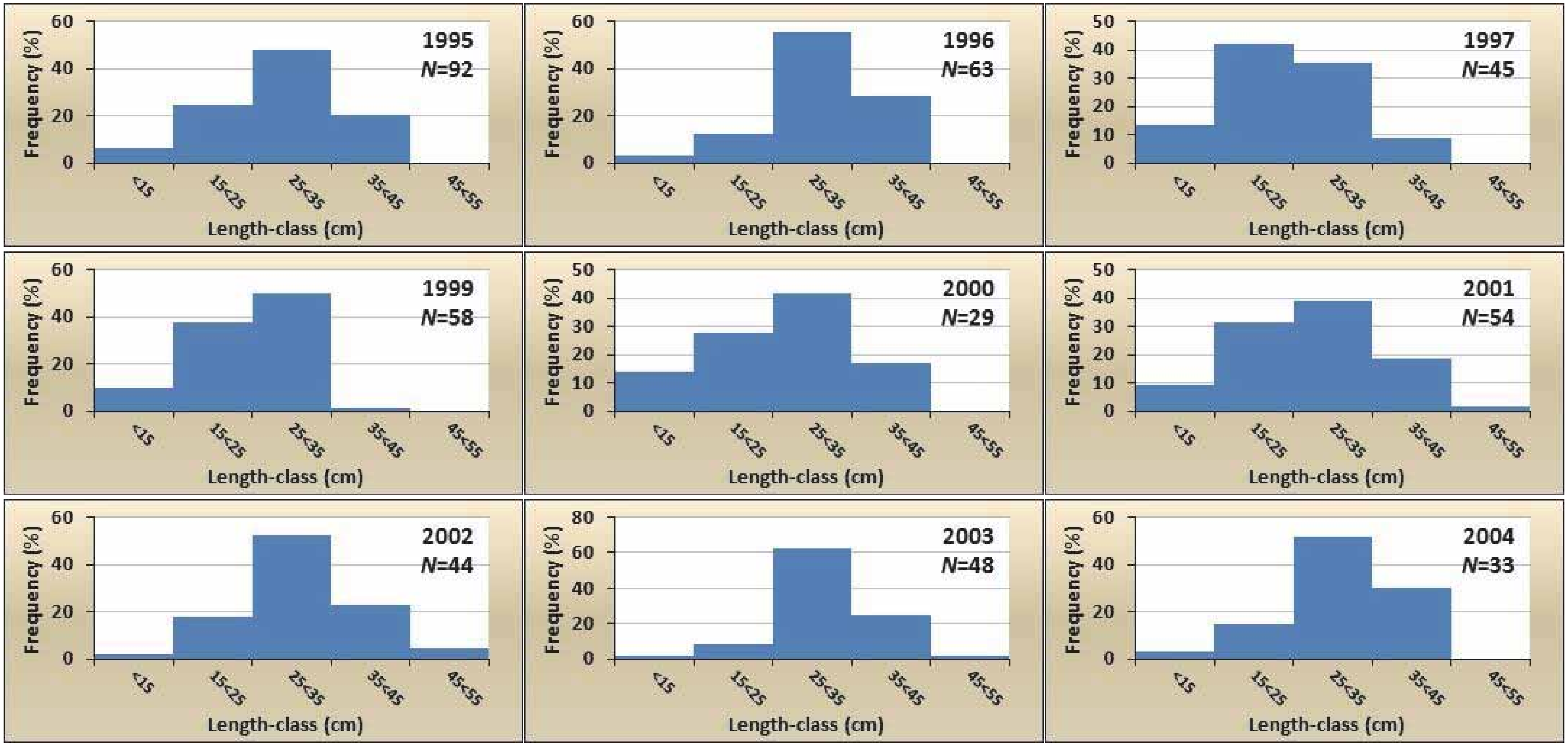


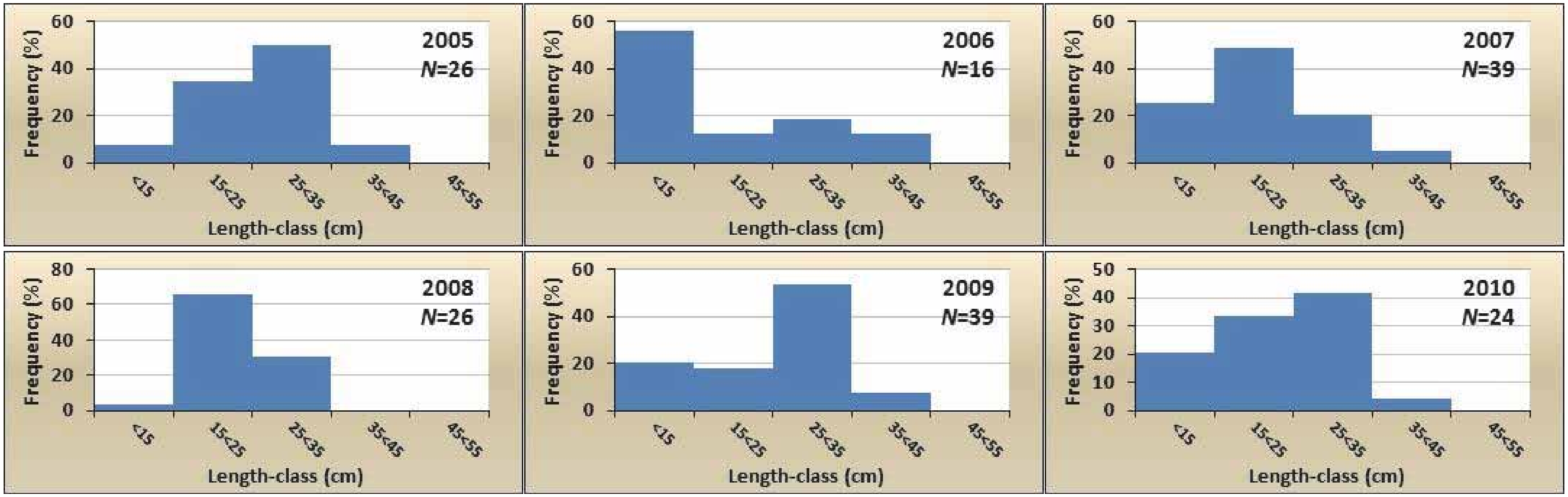
Appendix 12.E. Copper Rockfish length-class frequency histograms by year (expressed as percent of total N) at Brackett's Landing Shoreline Sanctuary Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.



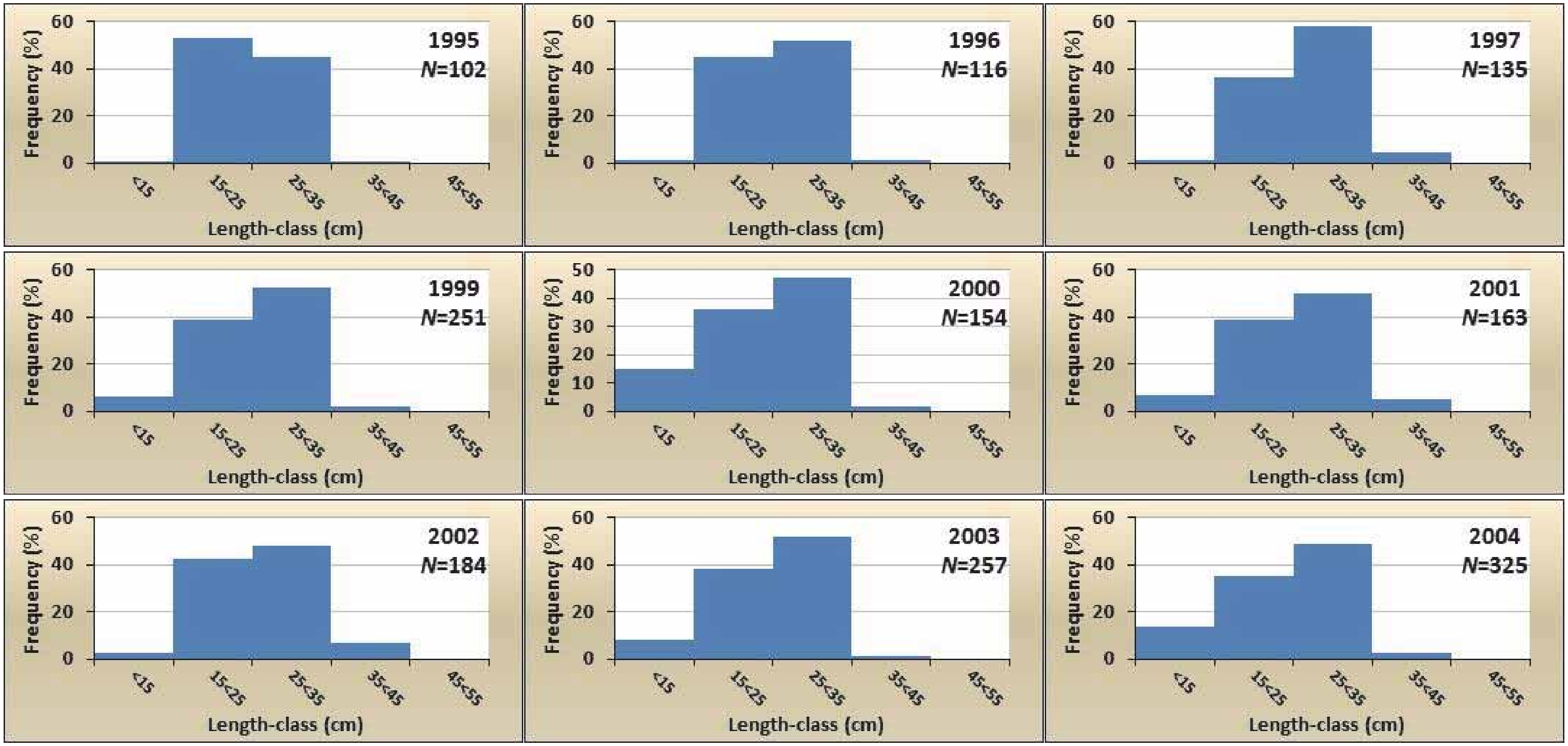

2005
N=223
2006
N=69
2007
N=386
2008
N=231
2009
N=309
2010
N=356
Frequency (%)
<15
15<25
25<35
35<45
45<55
Length-class (cm)

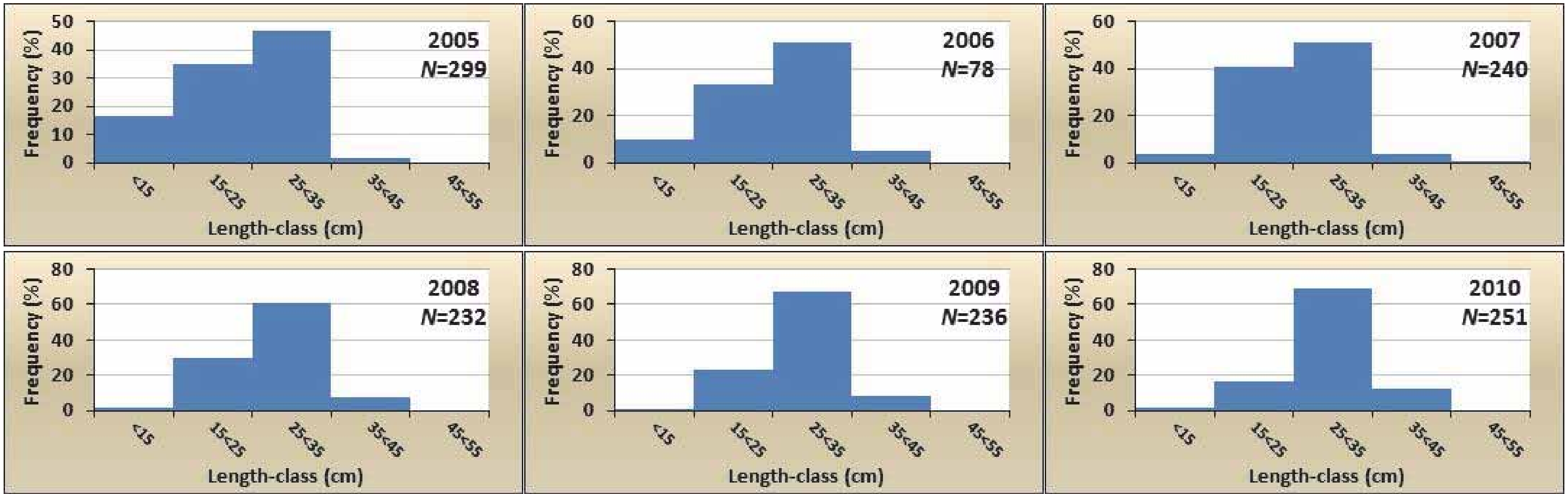
Appendix 12.F. Copper Rockfish length-class frequency histograms by year (expressed as percent of total N) at Port Blakely. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.




2005
N=26
2006
N=16
2007
N=39
2008
N=26
2009
N=39
2010
N=24
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

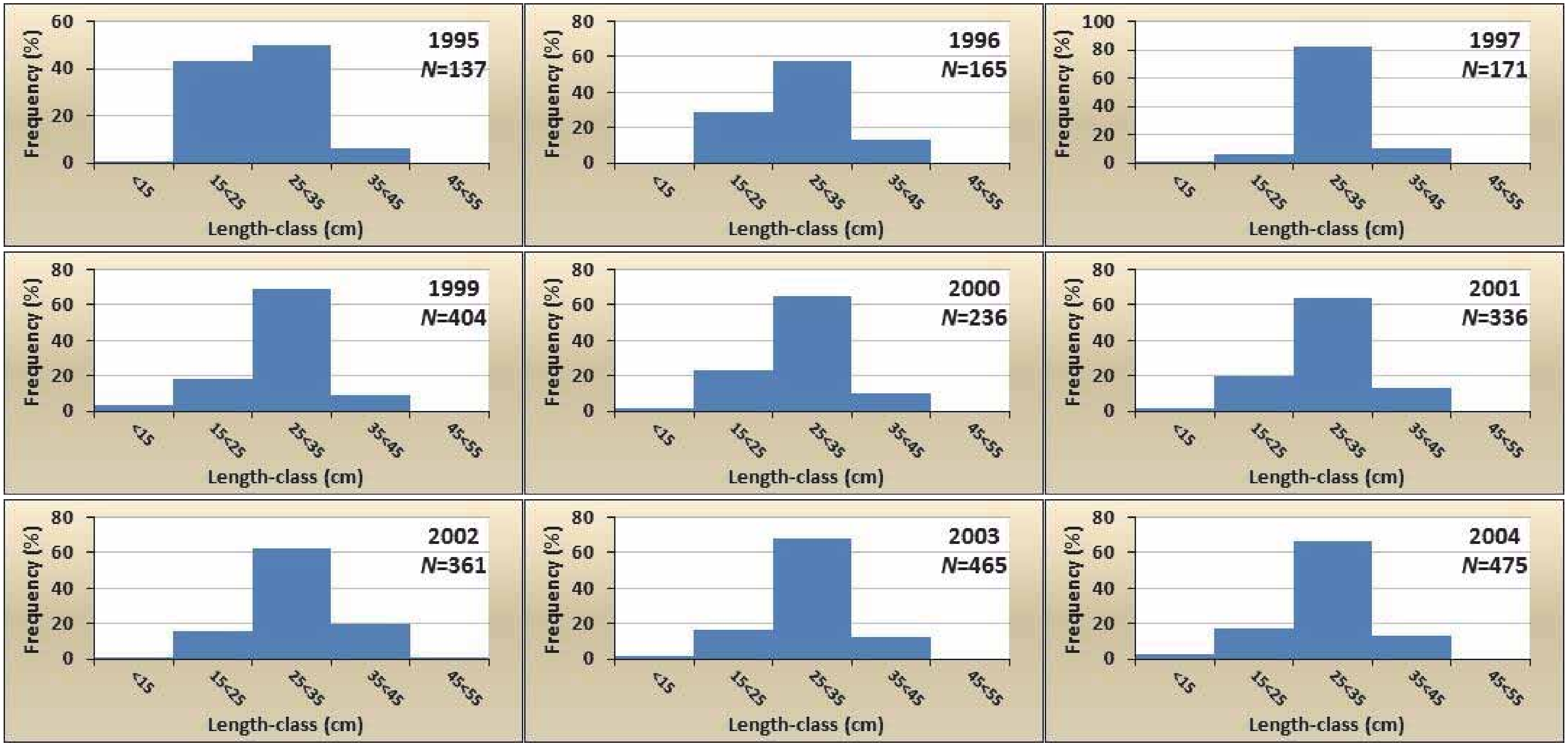
Appendix 13.A. Brown Rockfish length-class frequency histograms by year (expressed as percent of total N) at Blake Island Artificial Reef. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.

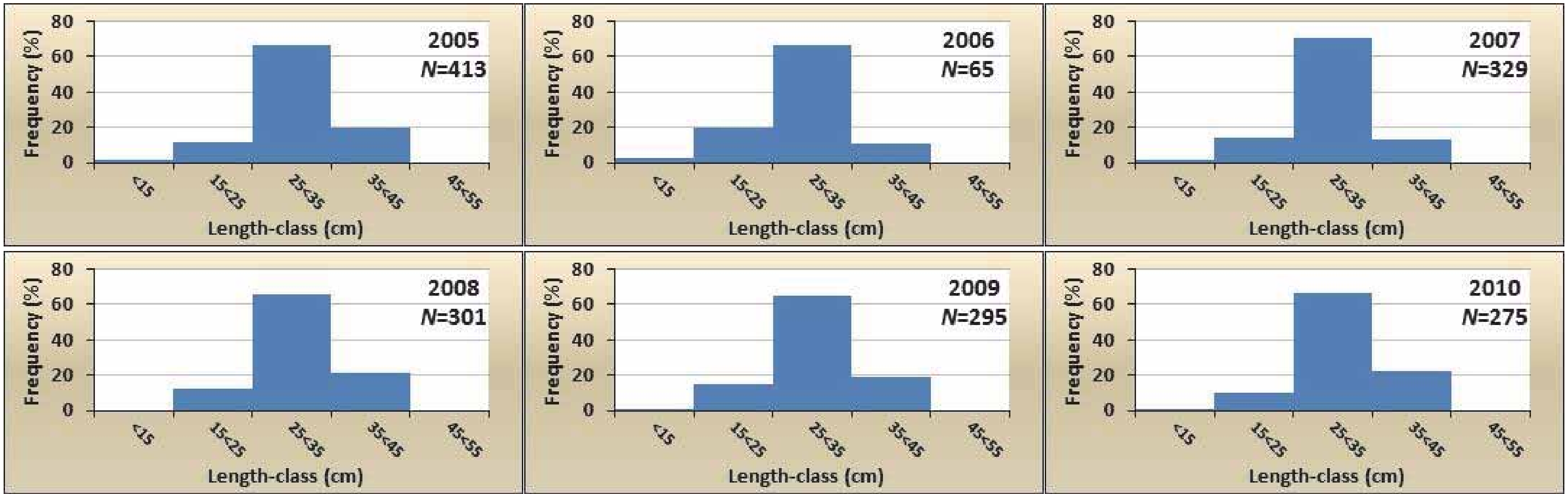




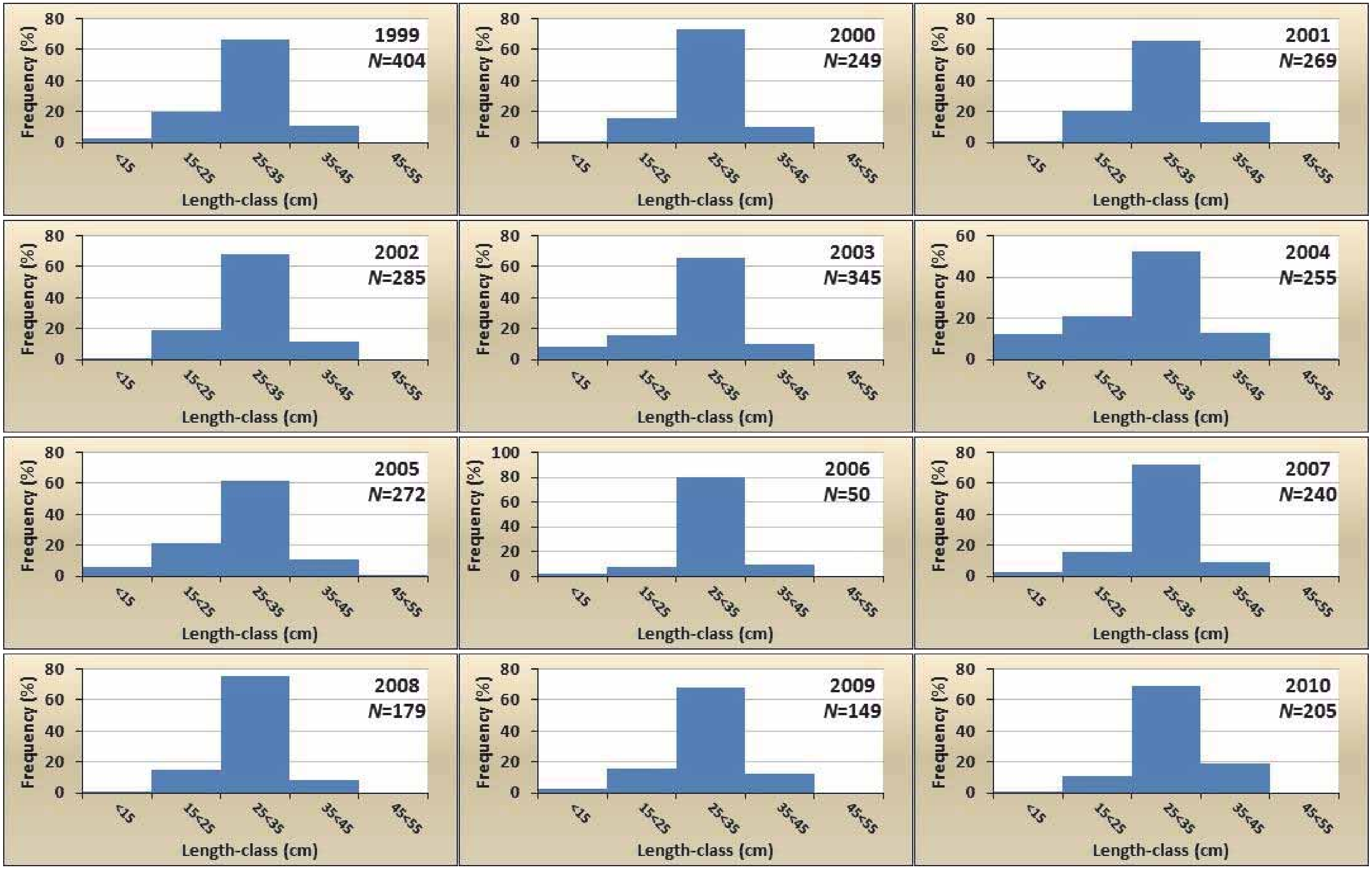
2005
N=299
2006
N=78
2007
N=240
2008
N=232
2009
N=236
2010
N=251
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

Appendix 13.B. Brown Rockfish length-class frequency histograms by year (expressed as percent of total N) at Orchard Rocks Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.



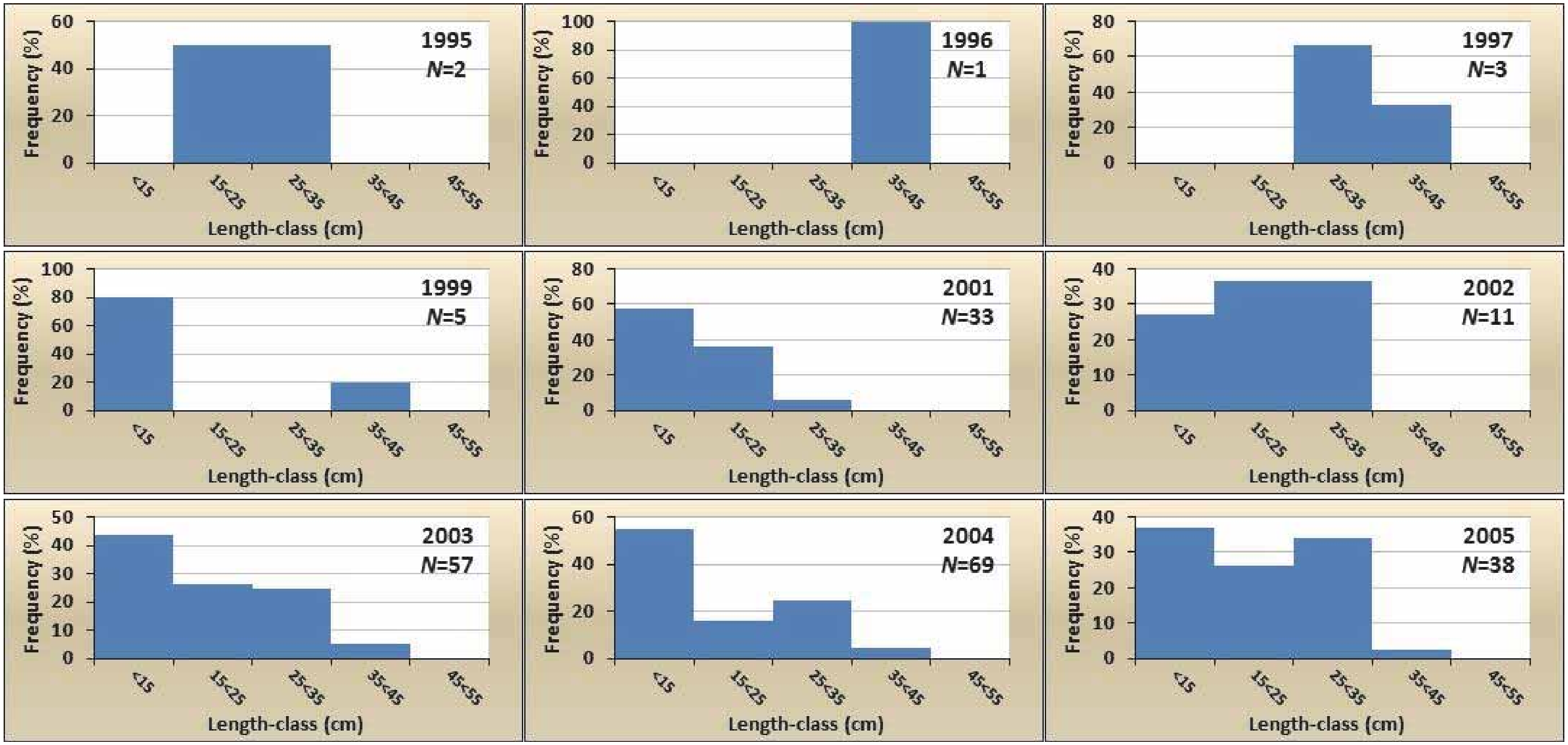

2005
N=413
2006
N=65
2007
N=329
2008
N=301
2009
N=295
2010
N=275
Frequency (%)
0
20
40
60
80
<15
15<25
25<35
35<45
45<55
Length-class (cm)

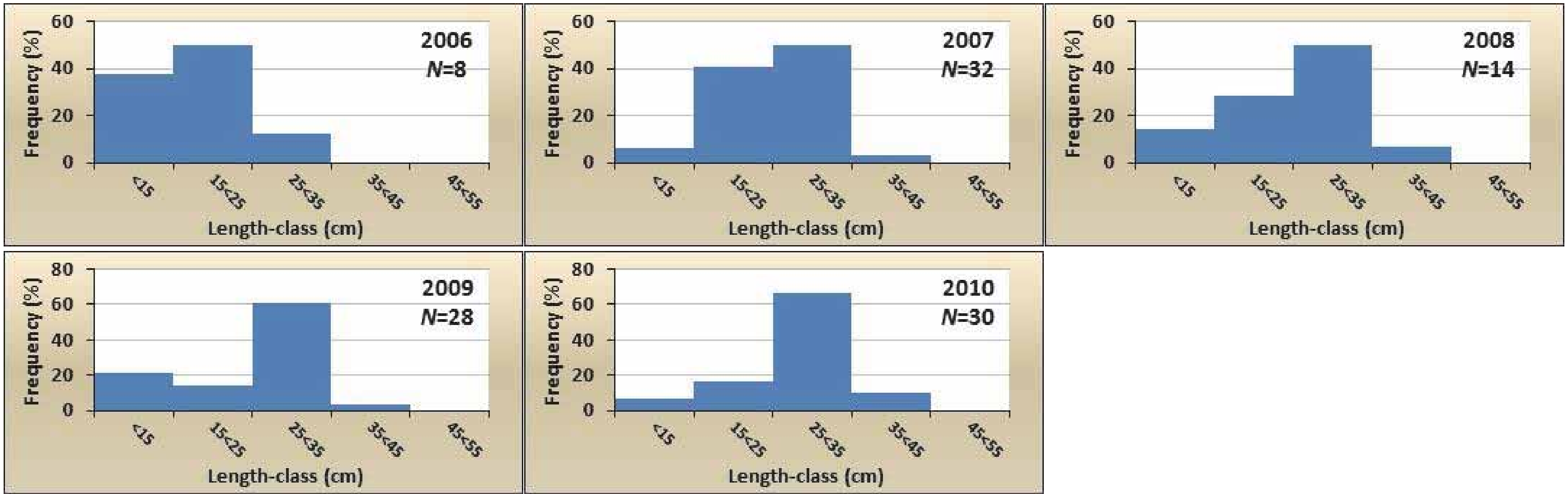
Appendix 13.C. Brown Rockfish length-class frequency histograms by year (expressed as percent of total N) at Point Glover. No surveys were conducted in 1995, 96, 97, or 98. Note that y-axis scales may differ in this appendix.



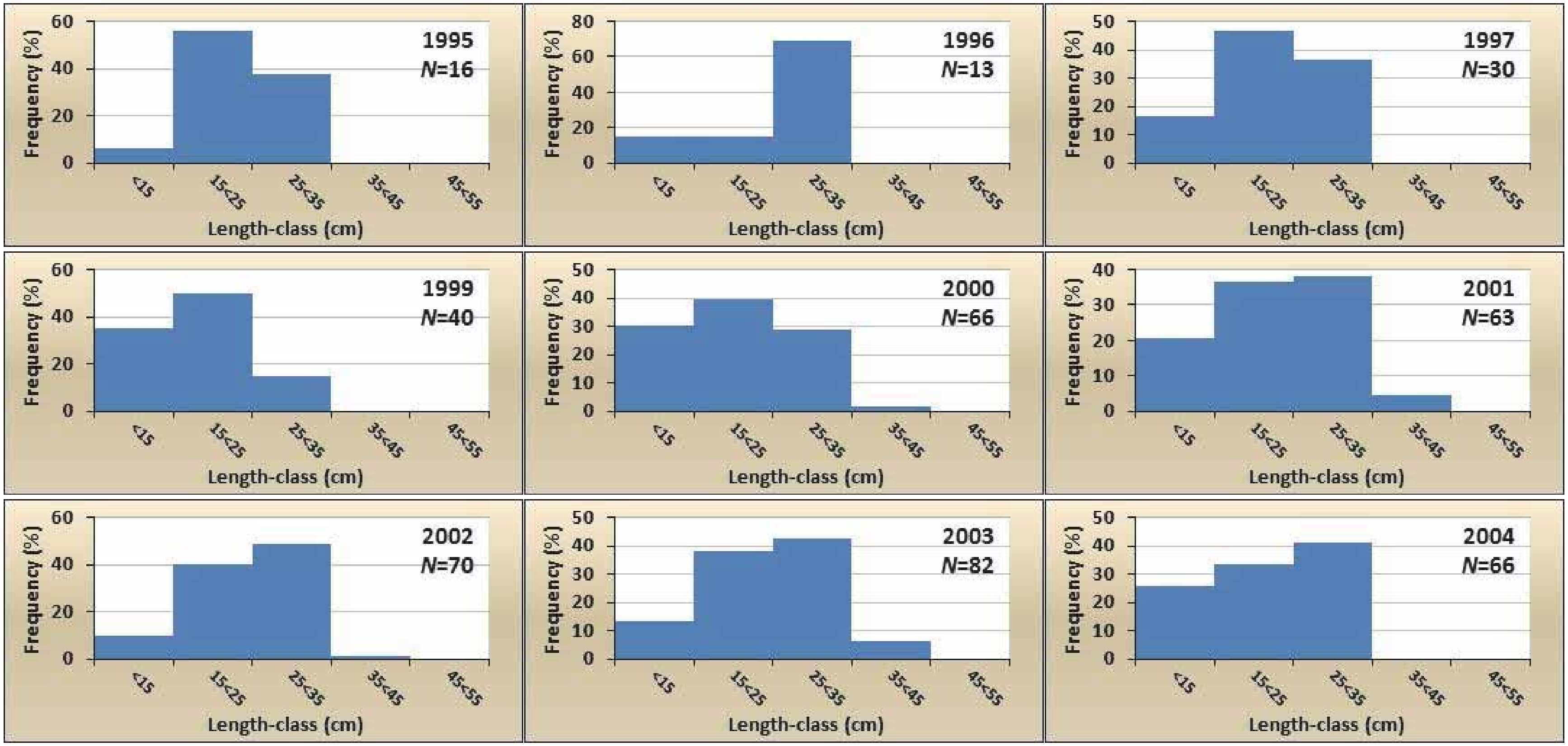
Appendix 13.D. The total number of Brown Rockfish observed at the Keystone jetty in any year did not exceed eight and they were observed in only six of the surveyed years, thus they are not depicted here.

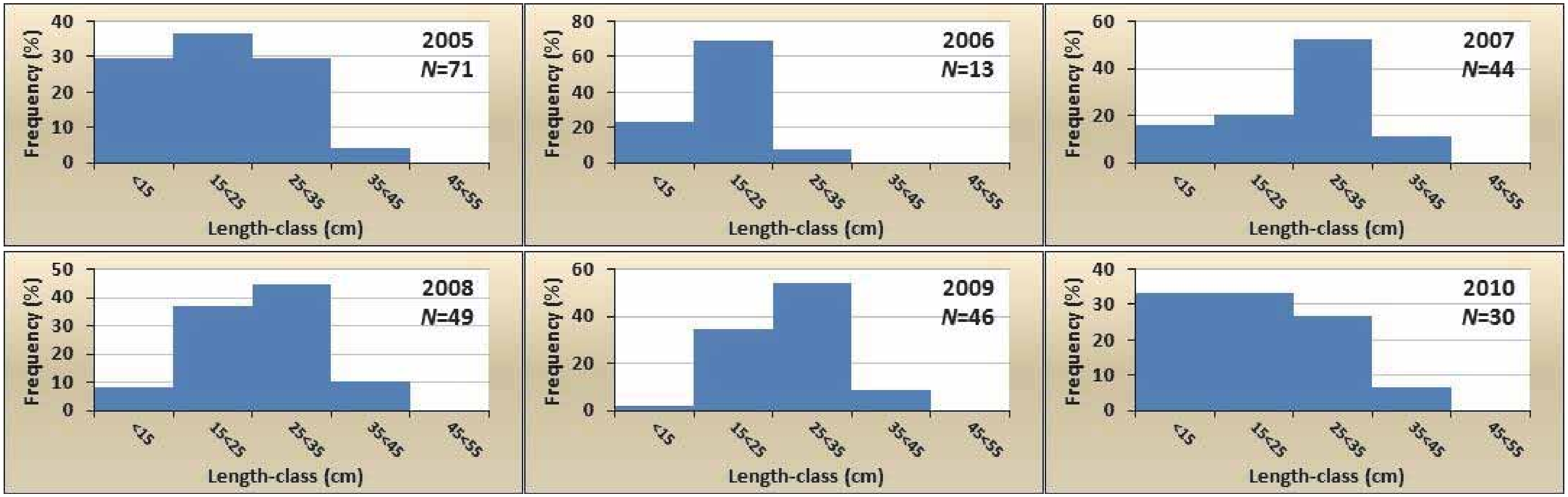
Appendix 13.E. Brown Rockfish length-class frequency histograms by year (expressed as percent of total N) at Brackett's Landing Shoreline Sanctuary Conservation Area. No surveys were conducted in 1998 and no Brown Rockfish were observed in 2000. Note that y-axis scales may differ in this appendix.



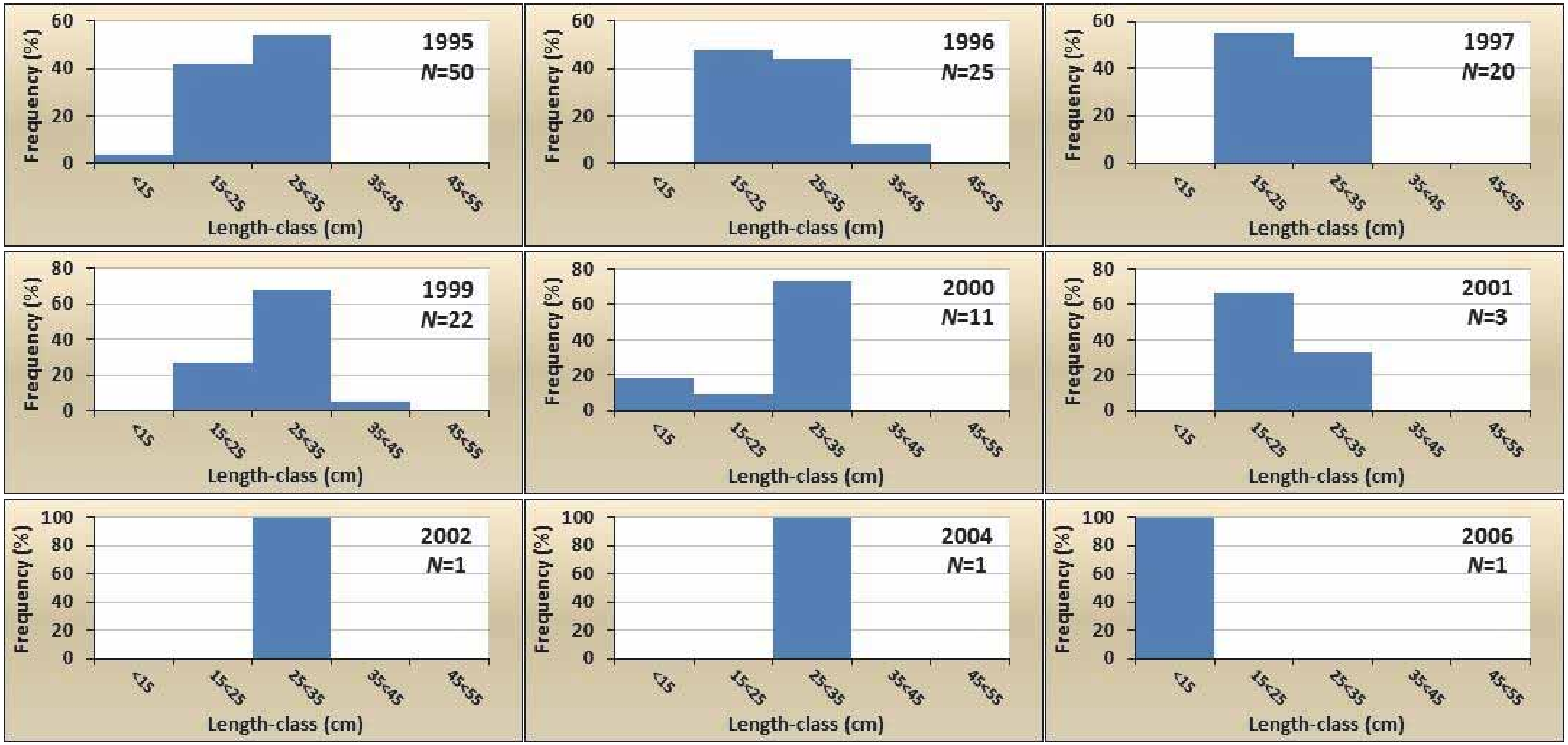

2006
N=8
2007
N=32
2008
N=14
2009
N=28
2010
N=30
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

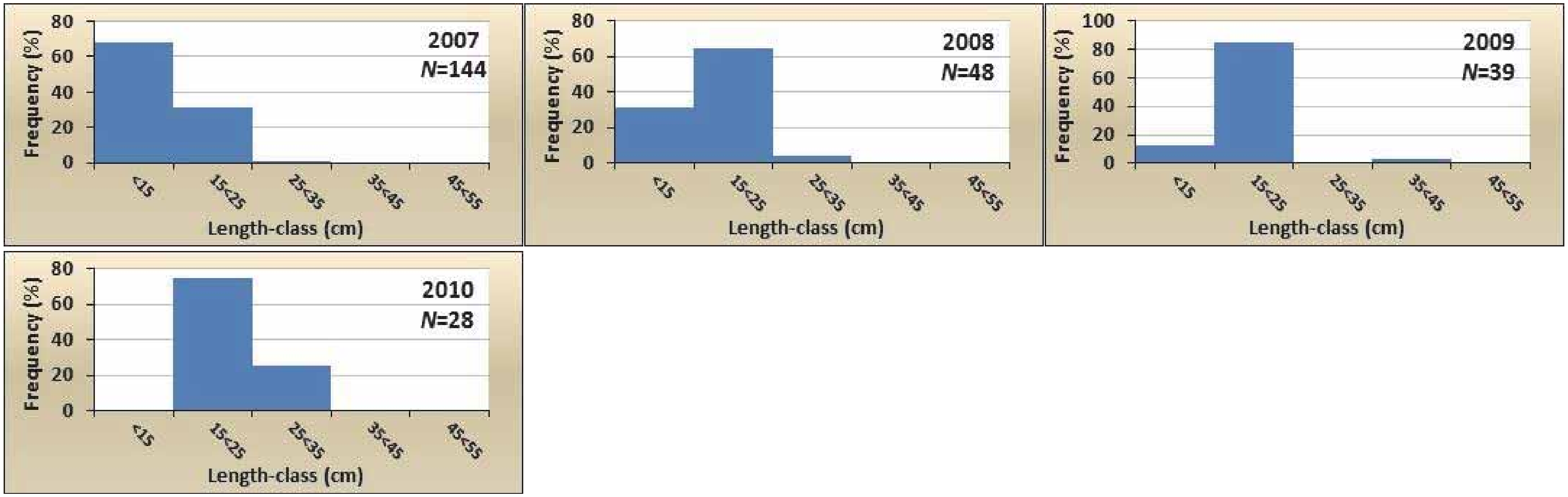
Appendix 13.F. Brown Rockfish length-class frequency histograms by year (expressed as percent of total N) at Port Blakely. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.




2005
N=71
2006
N=13
2007
N=44
2008
N=49
2009
N=46
2010
N=30
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

Appendix 14.A. Quillback Rockfish length-class frequency histograms by year (expressed as percent of total N) at Blake Island Artificial Reef. No surveys were conducted in 1998. No Quillback Rockfish were observed in 2003 or 2005. Note that y-axis scales may differ in this appendix.

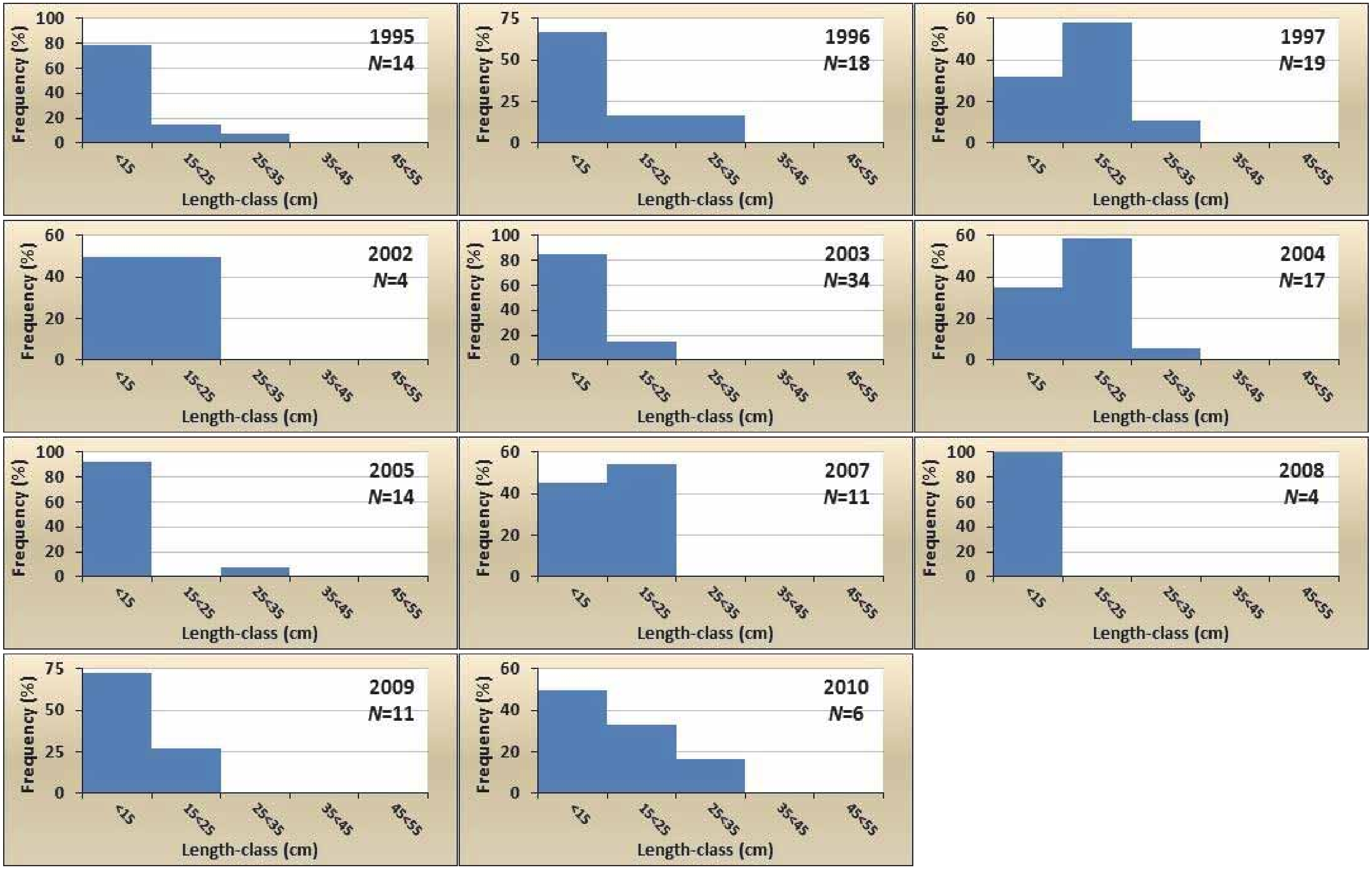



2007
N=144
2008
N=48
2009
N=39
2010
N=28
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
0
20
40
60
80
100

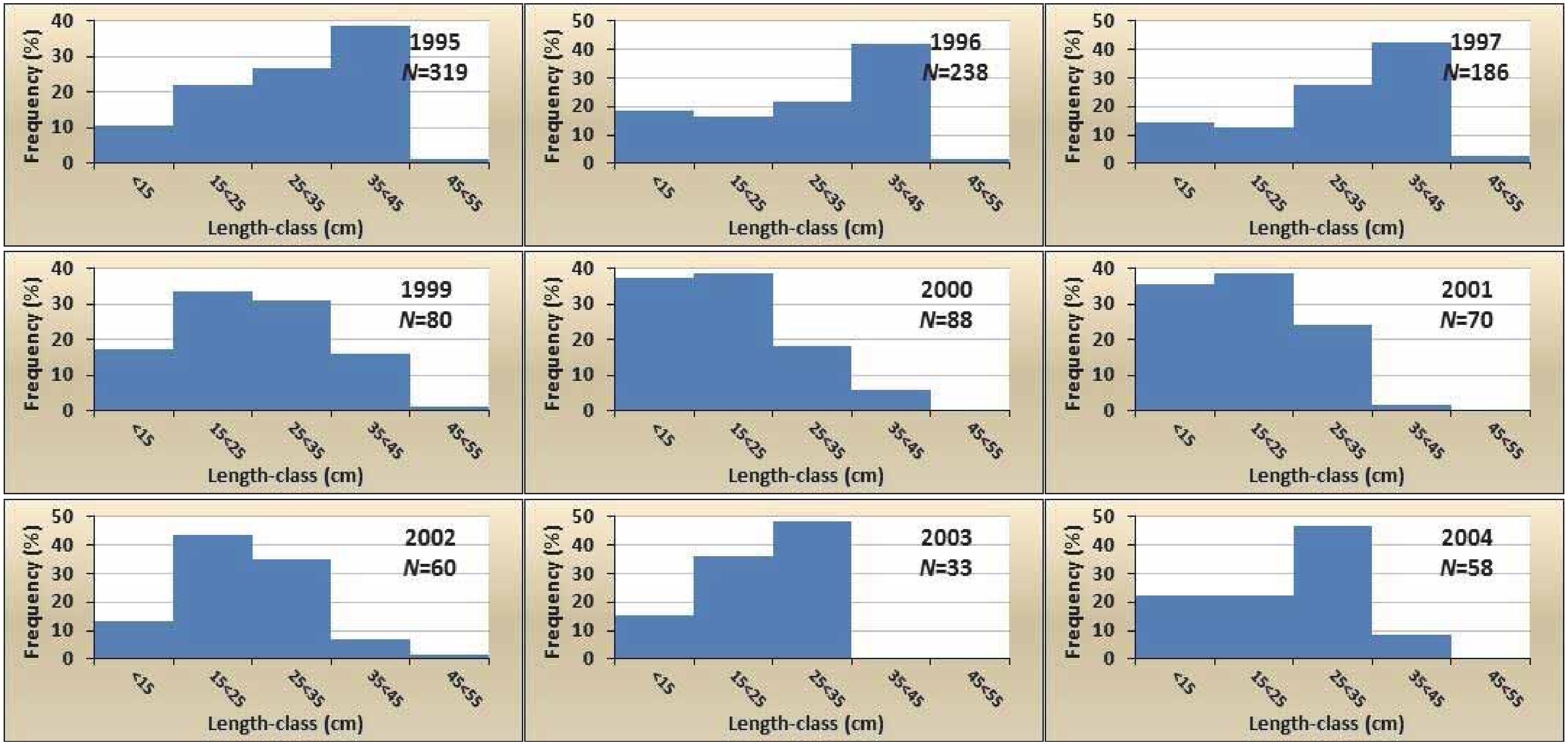
Appendix 14.B. The total number of Quillback Rockfish observed at Orchard Rocks Conservation Area in any year did not exceed four and they were observed in only six of the surveyed years, thus they are not depicted here.

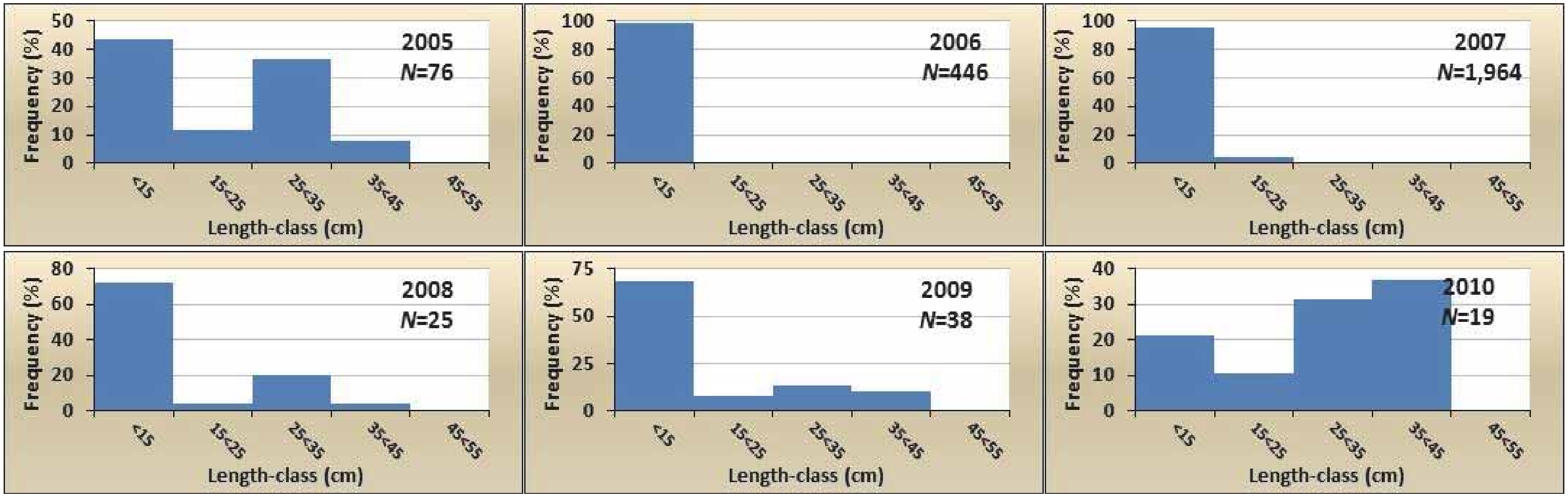
Appendix 14.C. The total number of Quillback Rockfish observed at Point Glover in any year did not exceed seven and they were observed in only six of the surveyed years, thus they are not depicted here.

Appendix 14.D. Quillback Rockfish length-class frequency histograms by year (expressed as percent of total N) at the Keystone jetty. No surveys were conducted in 1998, 99, 2000, 01, or 06. Note that y-axis scales may differ in this appendix.



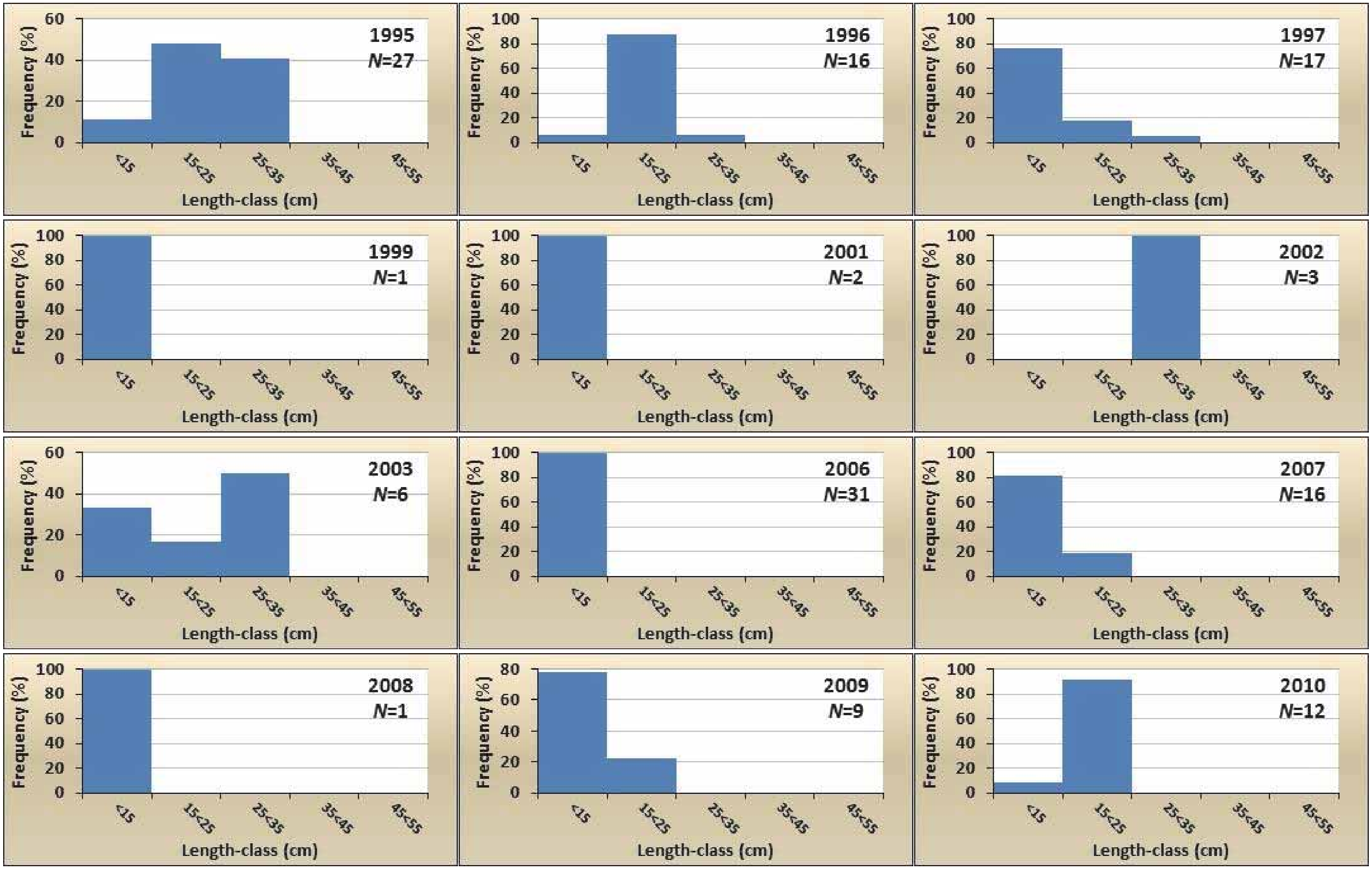
Appendix 14.E. Quillback Rockfish length-class frequency histograms by year (expressed as percent of total N) at Brackett's Landing Shoreline Sanctuary Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.



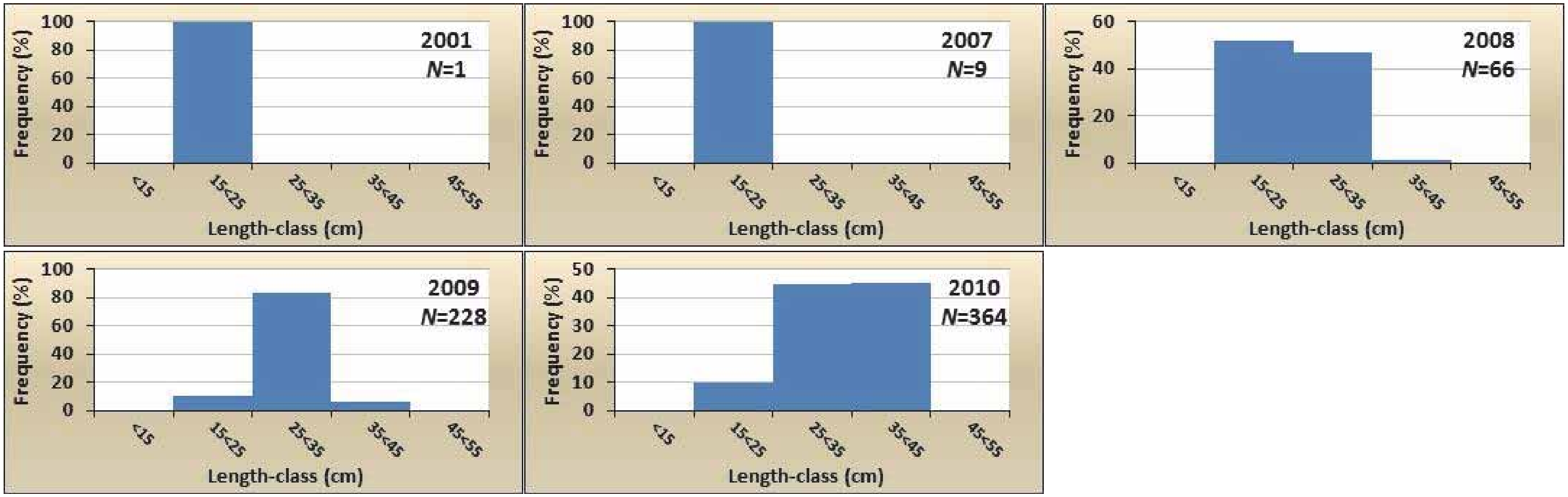


2005
N=76
2006
N=446
2007
N=1,964
2008
N=25
2009
N=38
2010
N=19
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

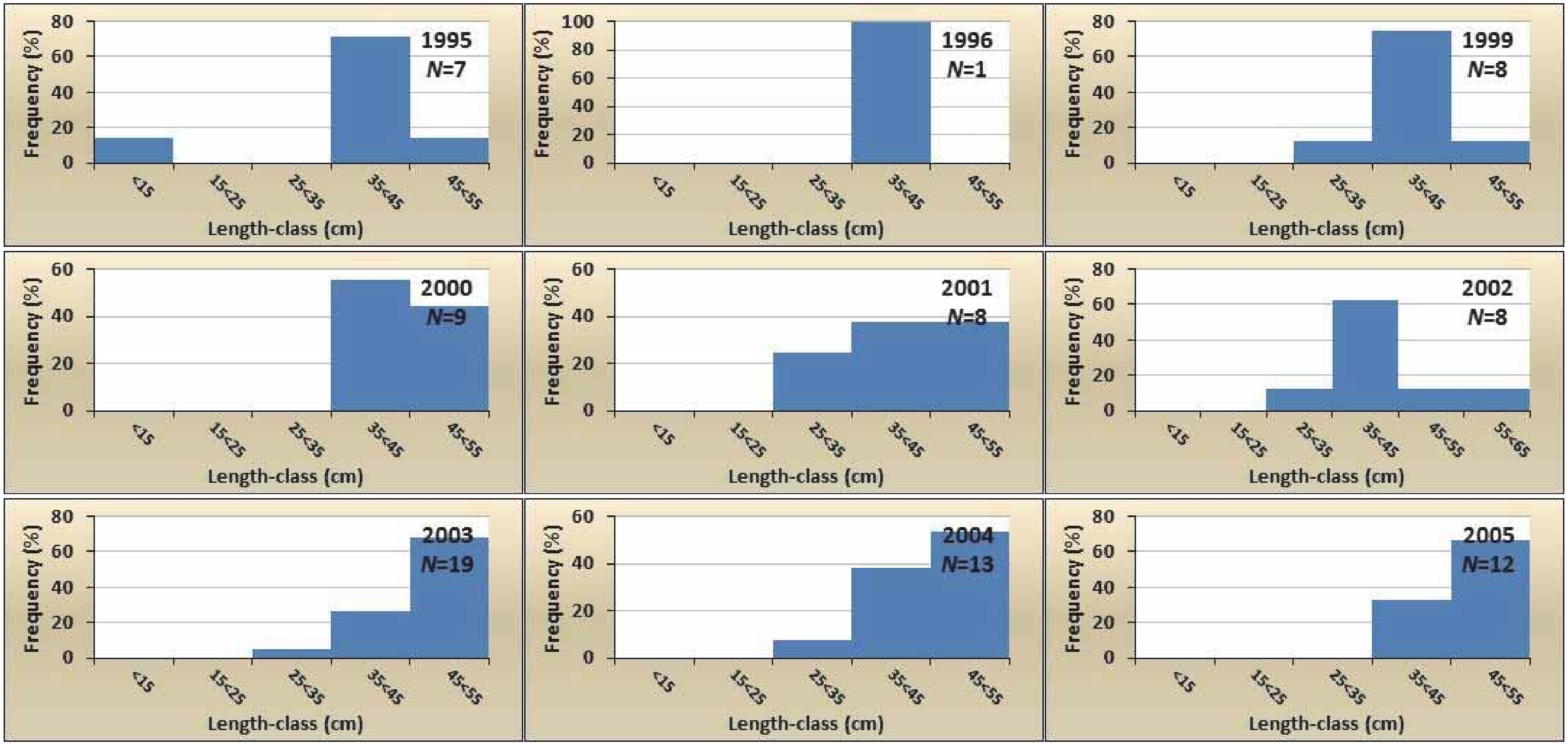
Appendix 14.F. Quillback Rockfish length-class frequency histograms by year (expressed as percent of total N) at Port Blakely. No surveys were conducted in 1998. No Quillback Rockfish were observed in 2000, 04, or 05. Note that y-axis scales may differ in this appendix.

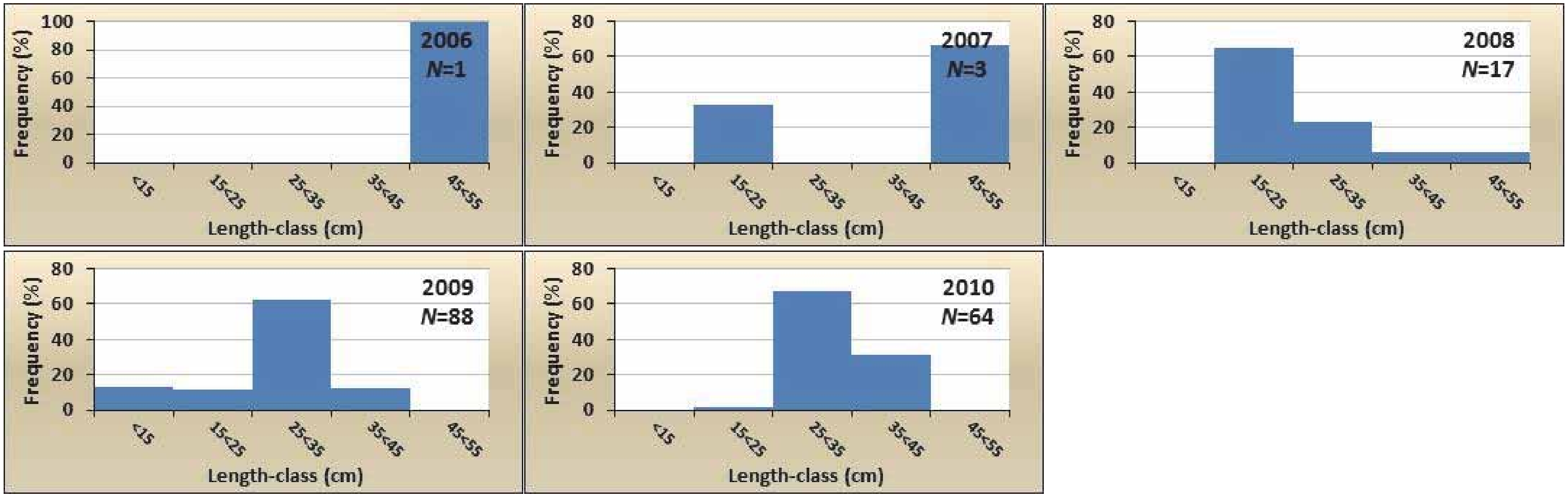


Appendix 15.A. Black Rockfish length-class frequency histograms by year (expressed as percent of total N) at Blake Island Artificial Reef. No surveys were conducted in 1998. No Black Rockfish were observed in 1995, 96, 97, 99, 2000, or 02-06. Note that y-axis scales may differ in this appendix.



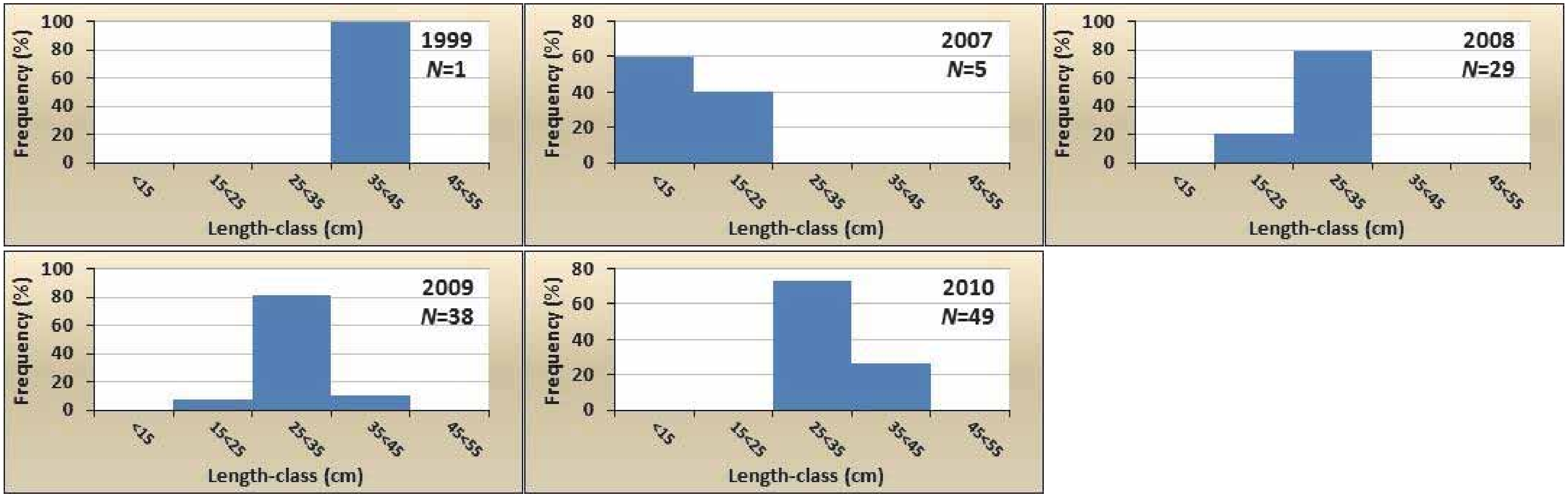
Appendix 15.B. Black Rockfish length-class frequency histograms by year (expressed as percent of total N) at Orchard Rocks Conservation Area. No surveys were conducted in 1998. No Black Rockfish were observed in 1997. Note that y-axis scales may differ in this appendix.



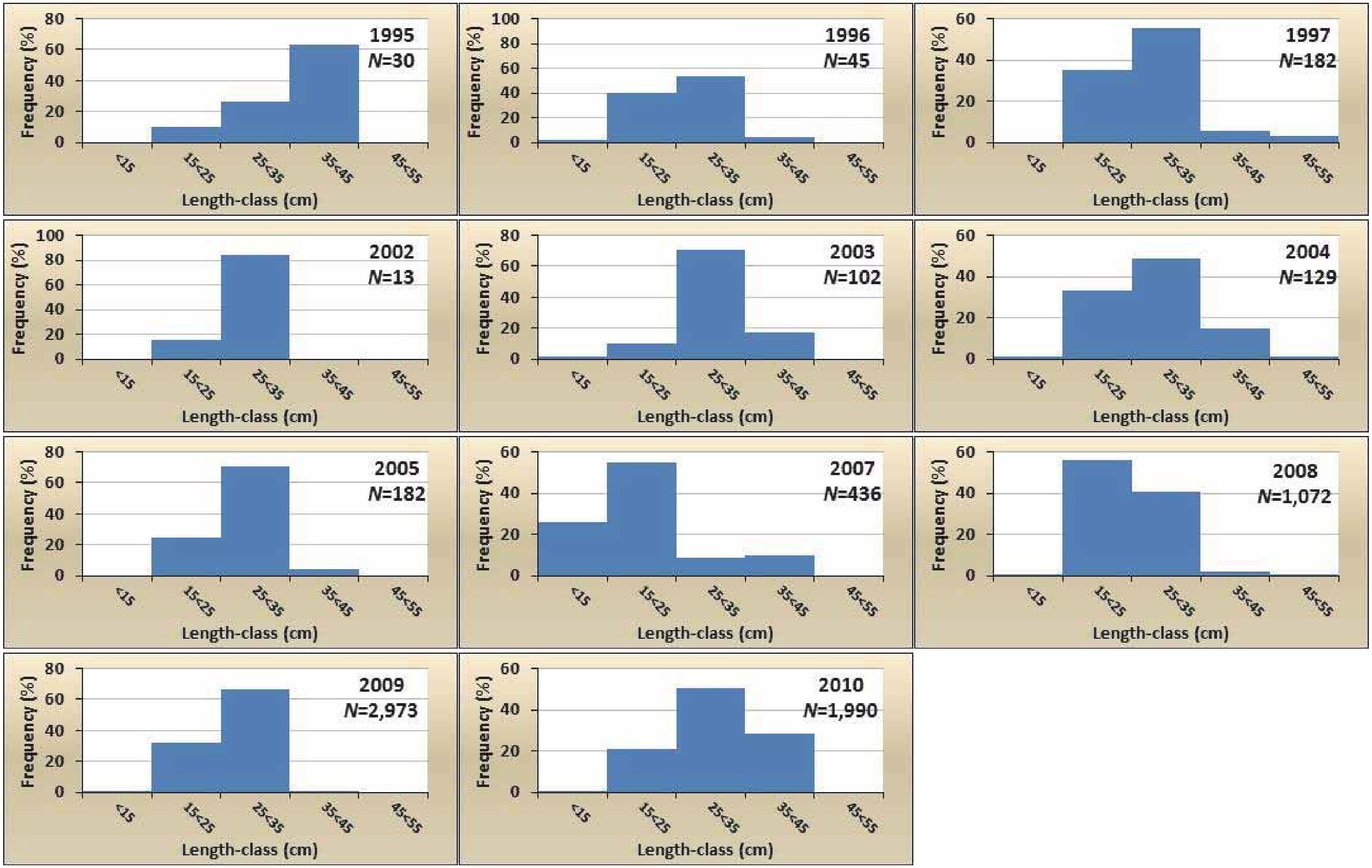


2006
N=1
2007
N=3
2008
N=17
2009
N=88
2010
N=64
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

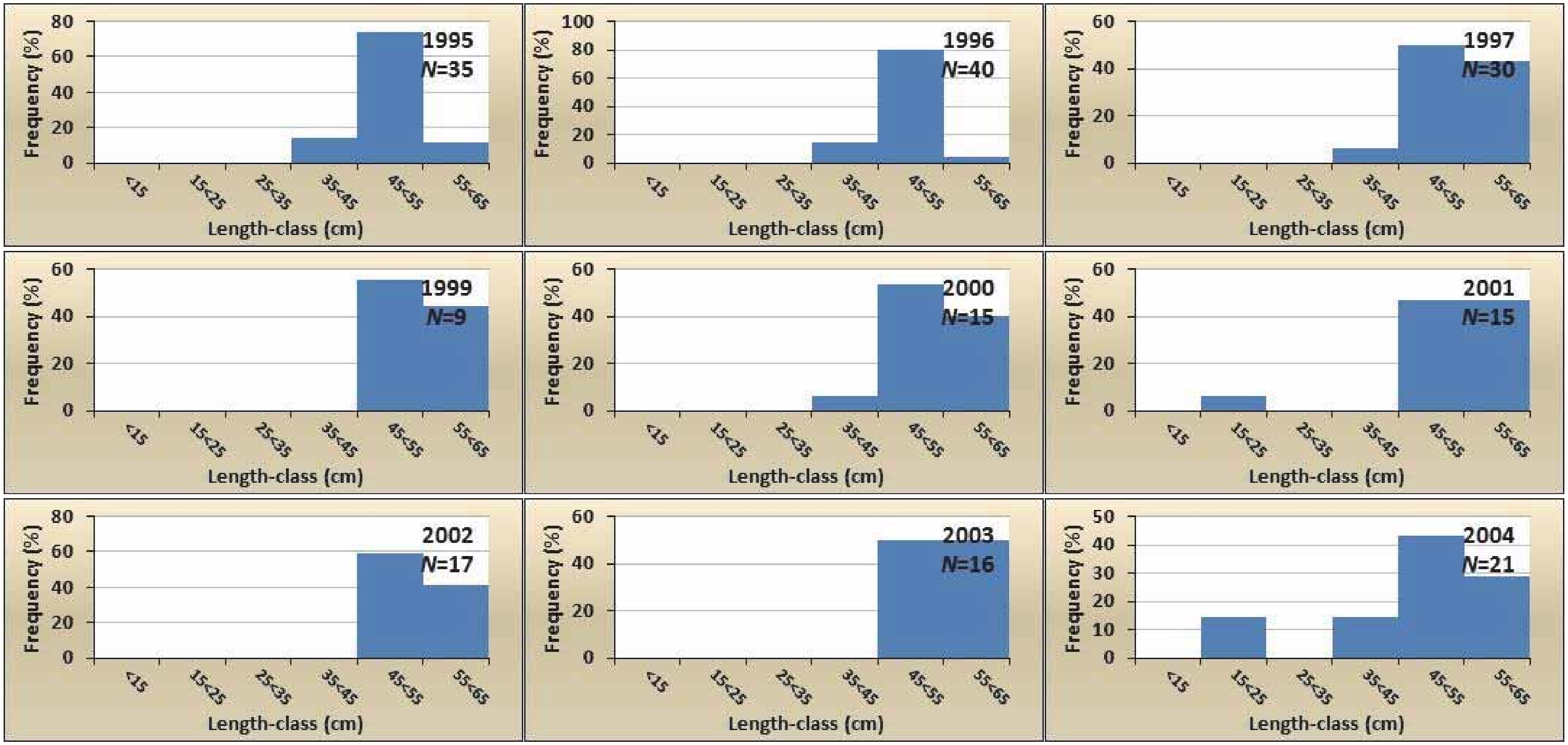
Appendix 15.C. Black Rockfish length-class frequency histograms by year (expressed as percent of total N) at Point Glover. No surveys were conducted in 1995, 96, 97, or 98. No Black Rockfish were observed in 2000-06. Note that y-axis scales may differ in this appendix.

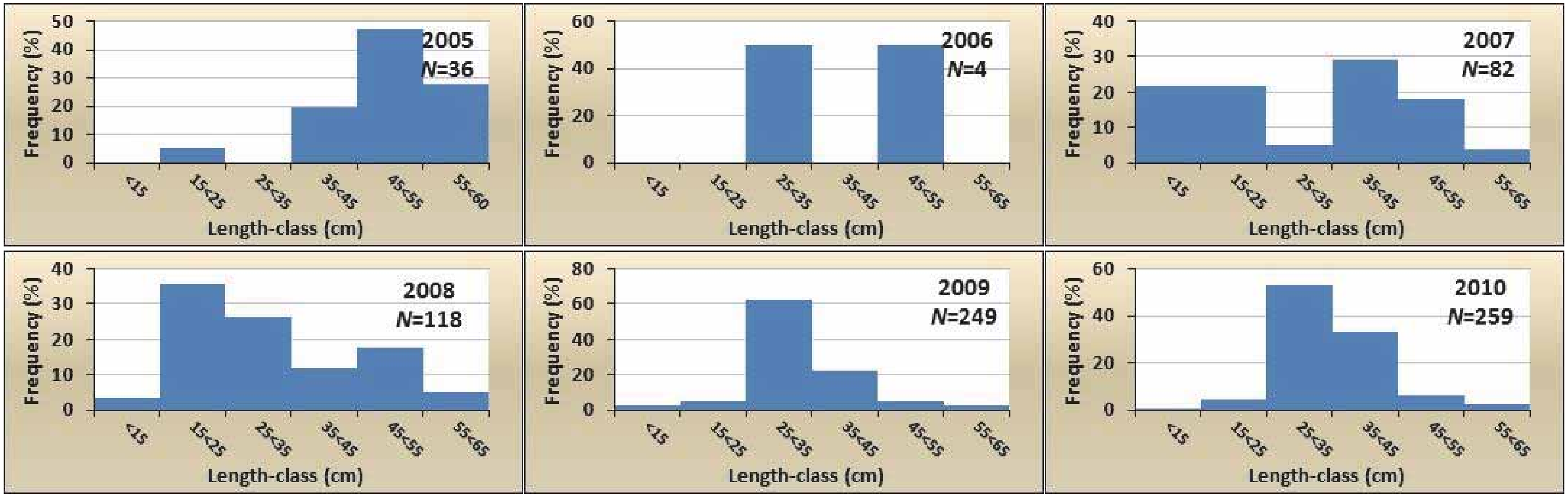


Appendix 15.D. Black Rockfish length-class frequency histograms by year (expressed as percent of total N) at the Keystone jetty. No surveys were conducted in 1998, 99, 2000, 01, or 06. Note that y-axis scales may differ in this appendix.

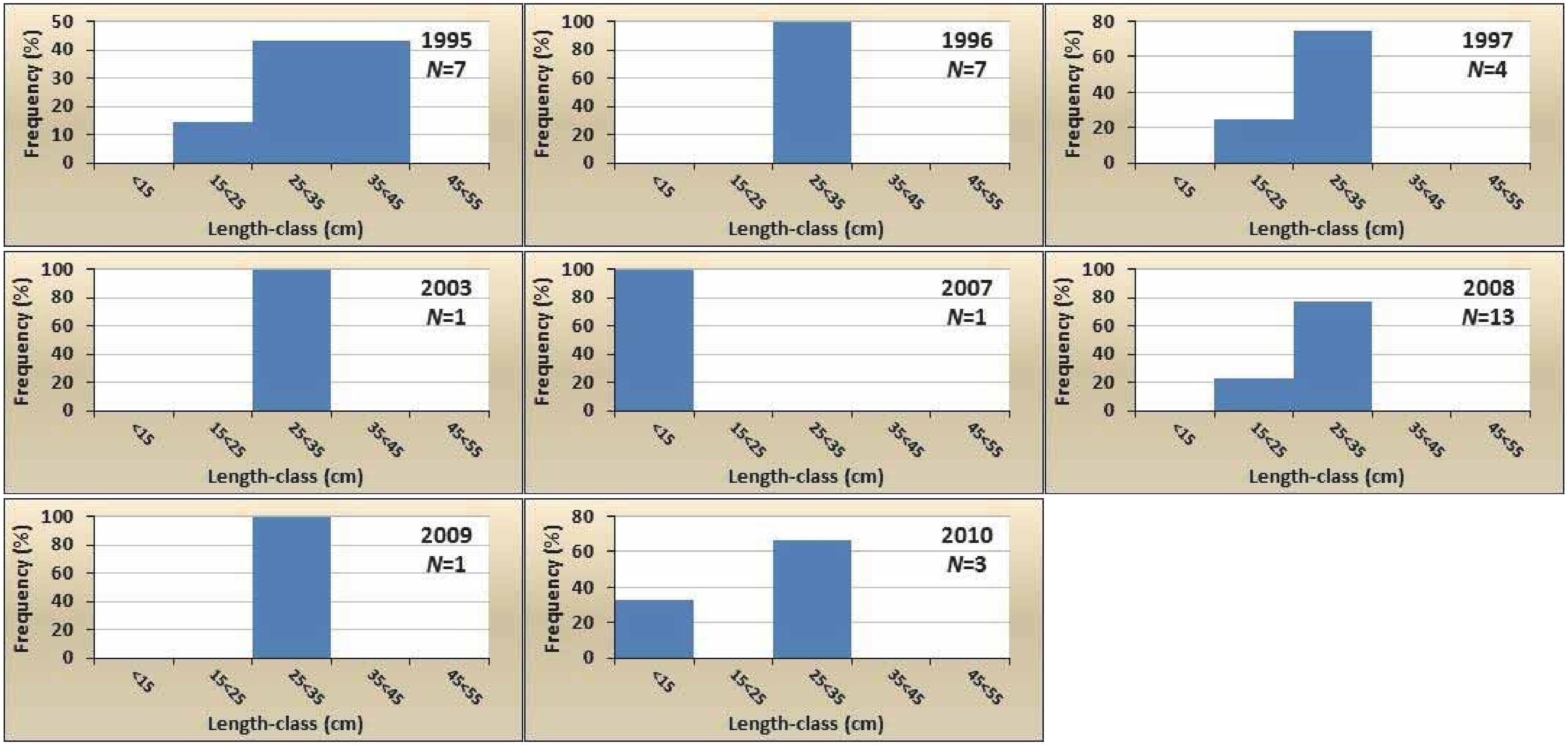


Appendix 15.E. Black Rockfish length-class frequency histograms by year (expressed as percent of total N) at Brackett's Landing Shoreline Sanctuary Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.




2005
N=36
2006
N=4
2007
N=82
2008
N=118
2009
N=249
2010
N=259
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
55<60
55<65

Appendix 15.F. Black Rockfish length-class frequency histograms by year (expressed as percent of total N) at Port Blakely. No surveys were conducted in 1998. No Black Rockfish were observed in 1999-2002, or 2004-06. Note that y-axis scales may differ in this appendix.

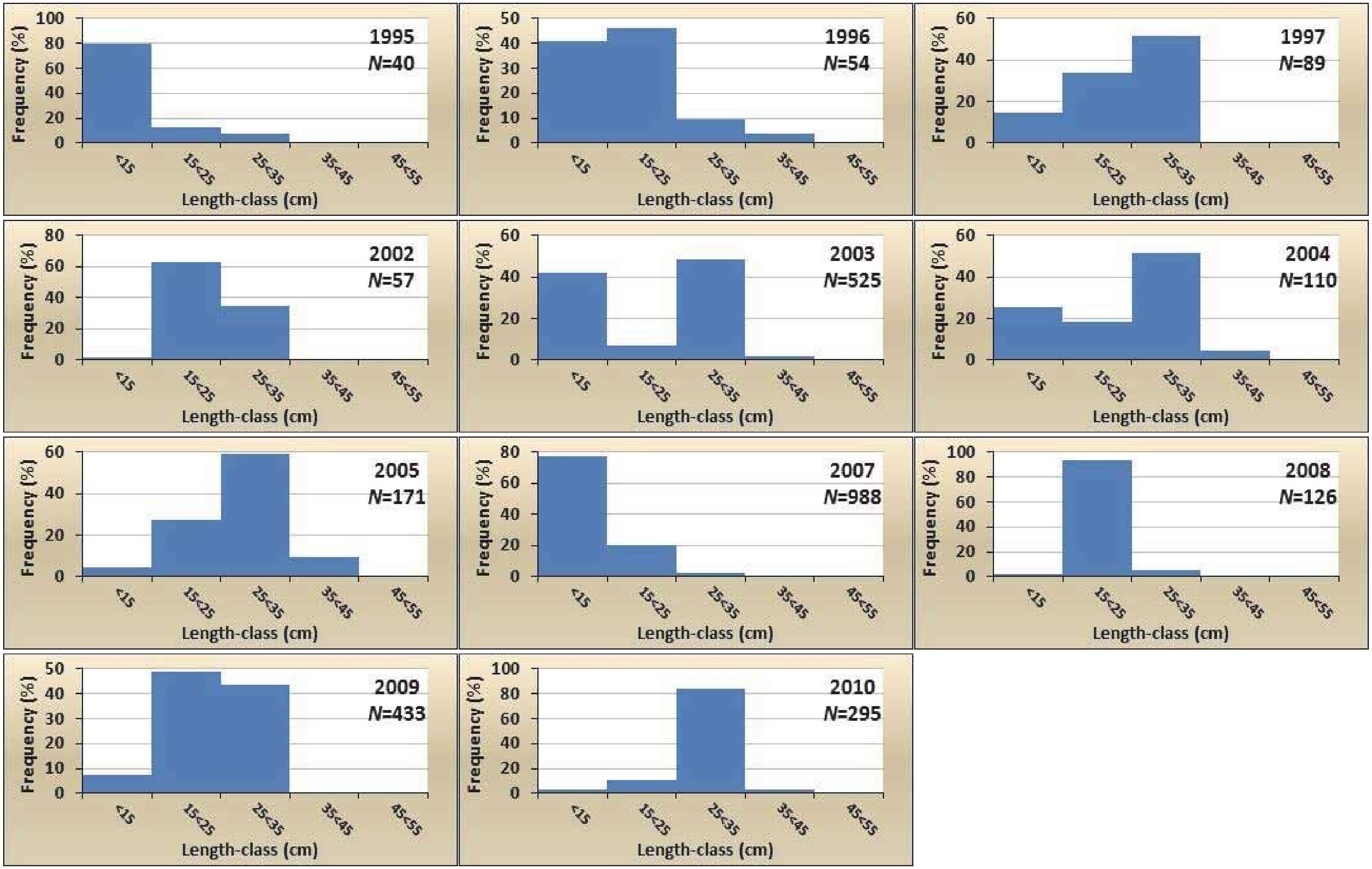


Appendix 16.A. Only one Yellowtail Rockfish was observed at Blake Island Artificial Reef, thus it is not depicted here.

Appendix 16.B. Only one Yellowtail Rockfish was observed at Orchard Rocks Conservation Area, thus it is not depicted here.

Appendix 16.C. No Yellowtail Rockfish were observed at Point Glover.

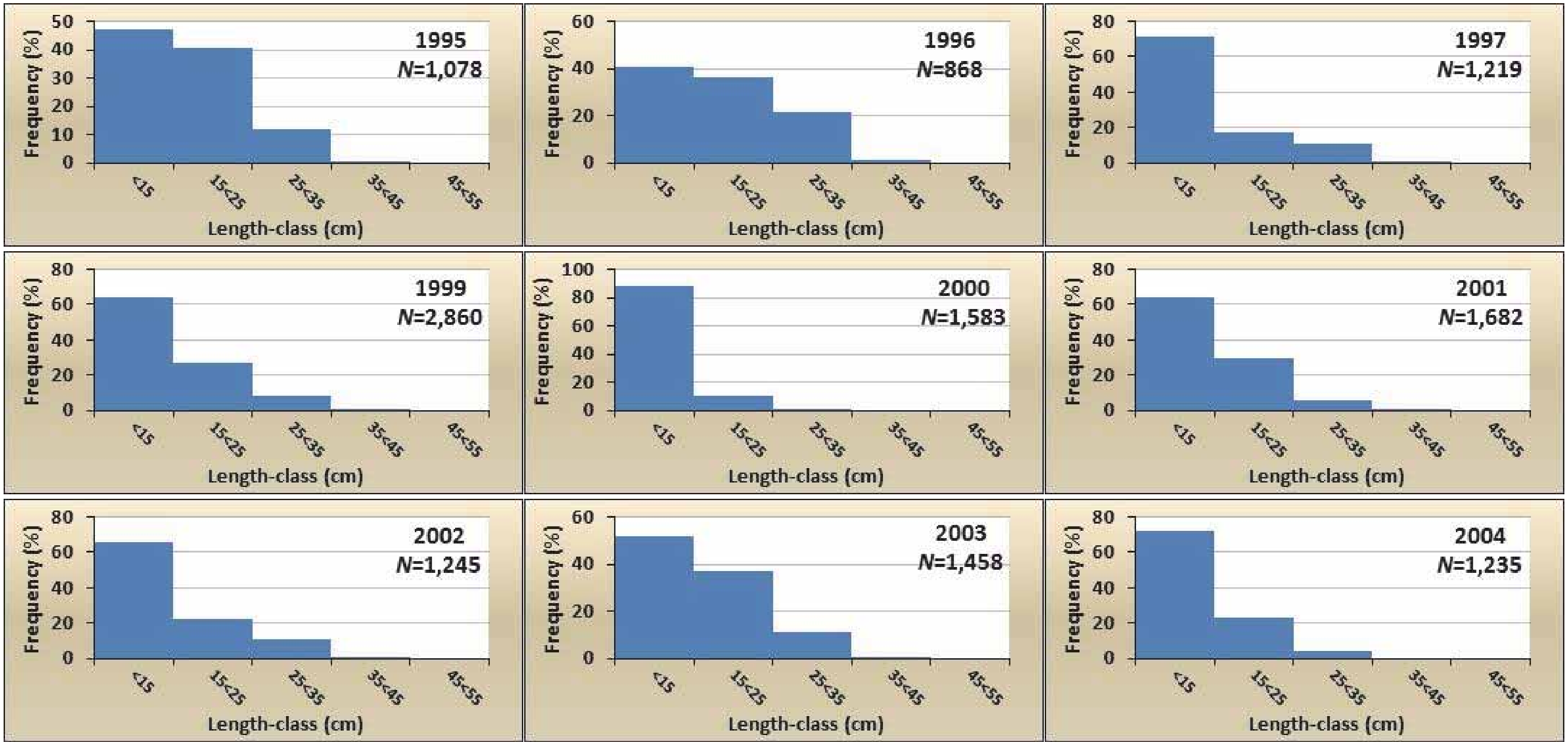
Appendix 16.D. Yellowtail Rockfish length-class frequency histograms by year (expressed as percent of total N) at the Keystone jetty. No surveys were conducted in 1998, 99, 2000, 01, or 06. Note that y-axis scales may differ in this appendix.

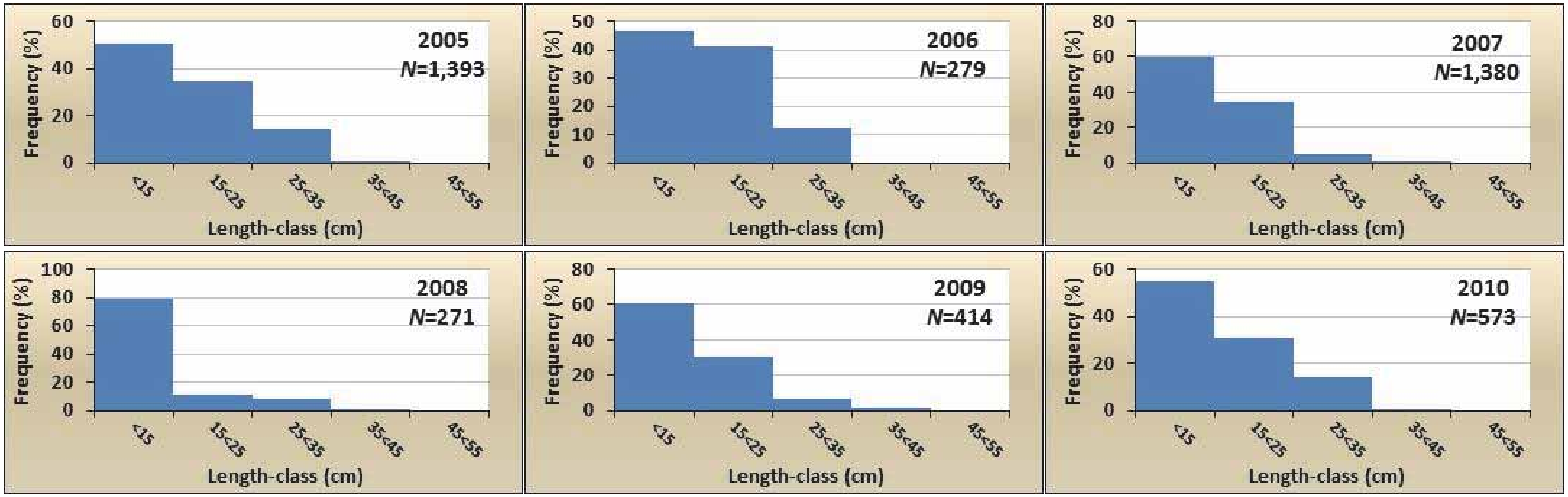


Appendix 16.E. The total number of Yellowtail Rockfish observed at Brackett's Landing Shoreline Sanctuary Conservation Area in any year did not exceed 14 and they were observed in only two of the six surveyed years, thus they are not depicted here.

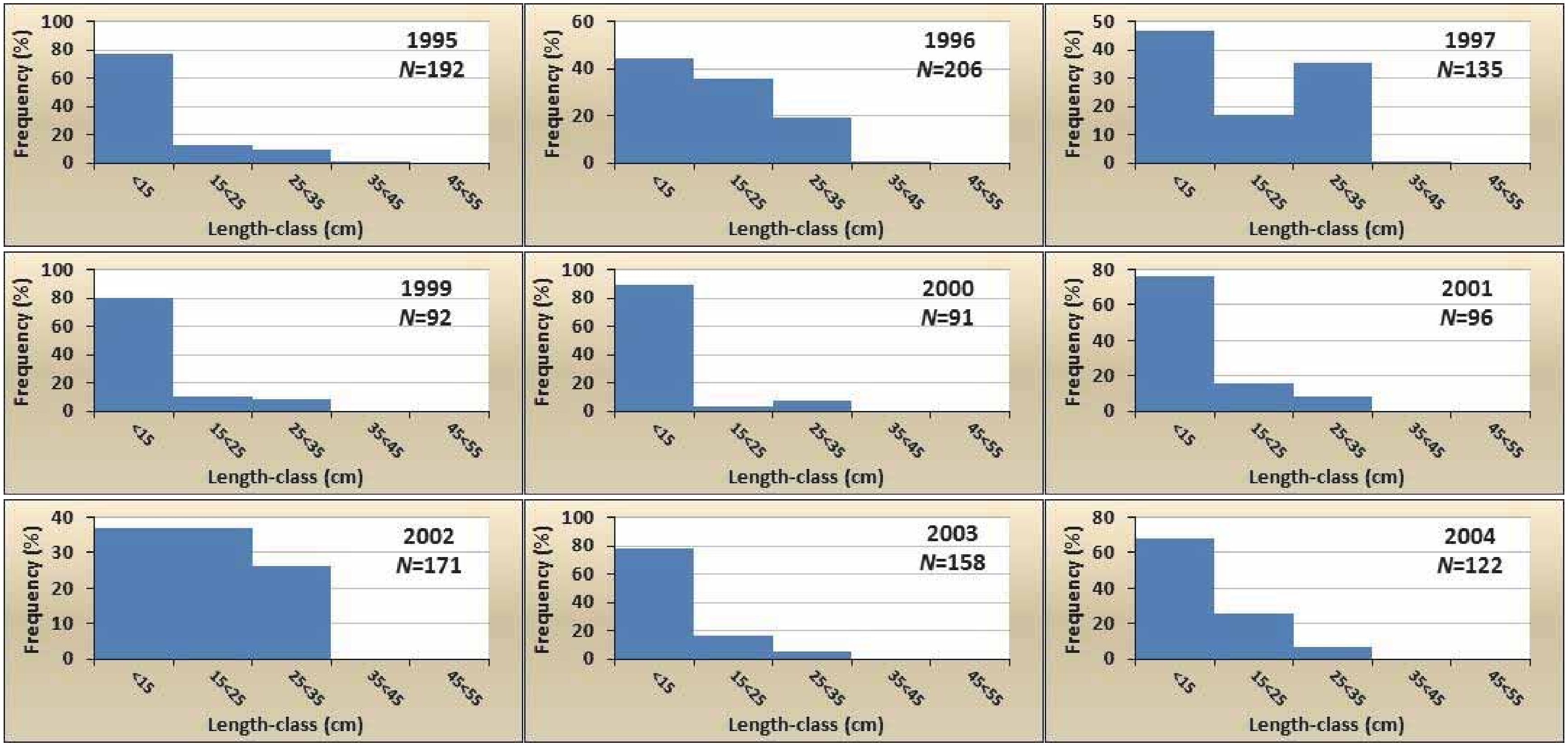
Appendix 16.F. The total number of Yellowtail Rockfish observed at Port Blakely in any year did not exceed five and they were observed in only three of the surveyed years, thus they are not depicted here.

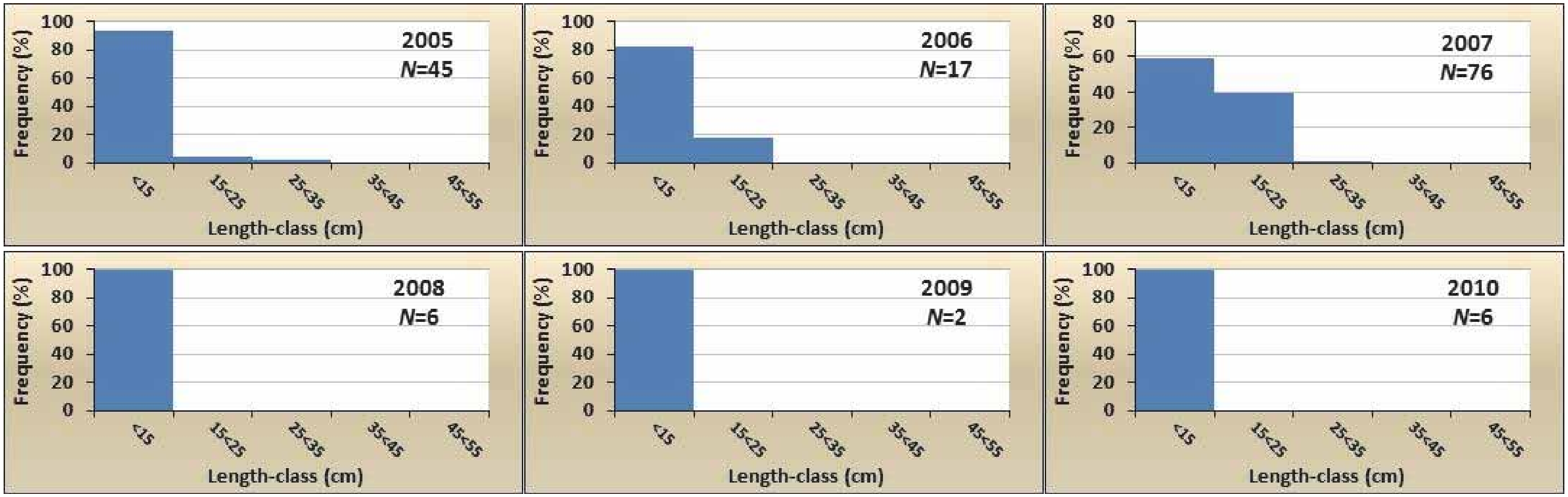
Appendix 17.A. Striped Seaperch length-class frequency histograms by year (expressed as percent of total N) at Blake Island Artificial Reef. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.



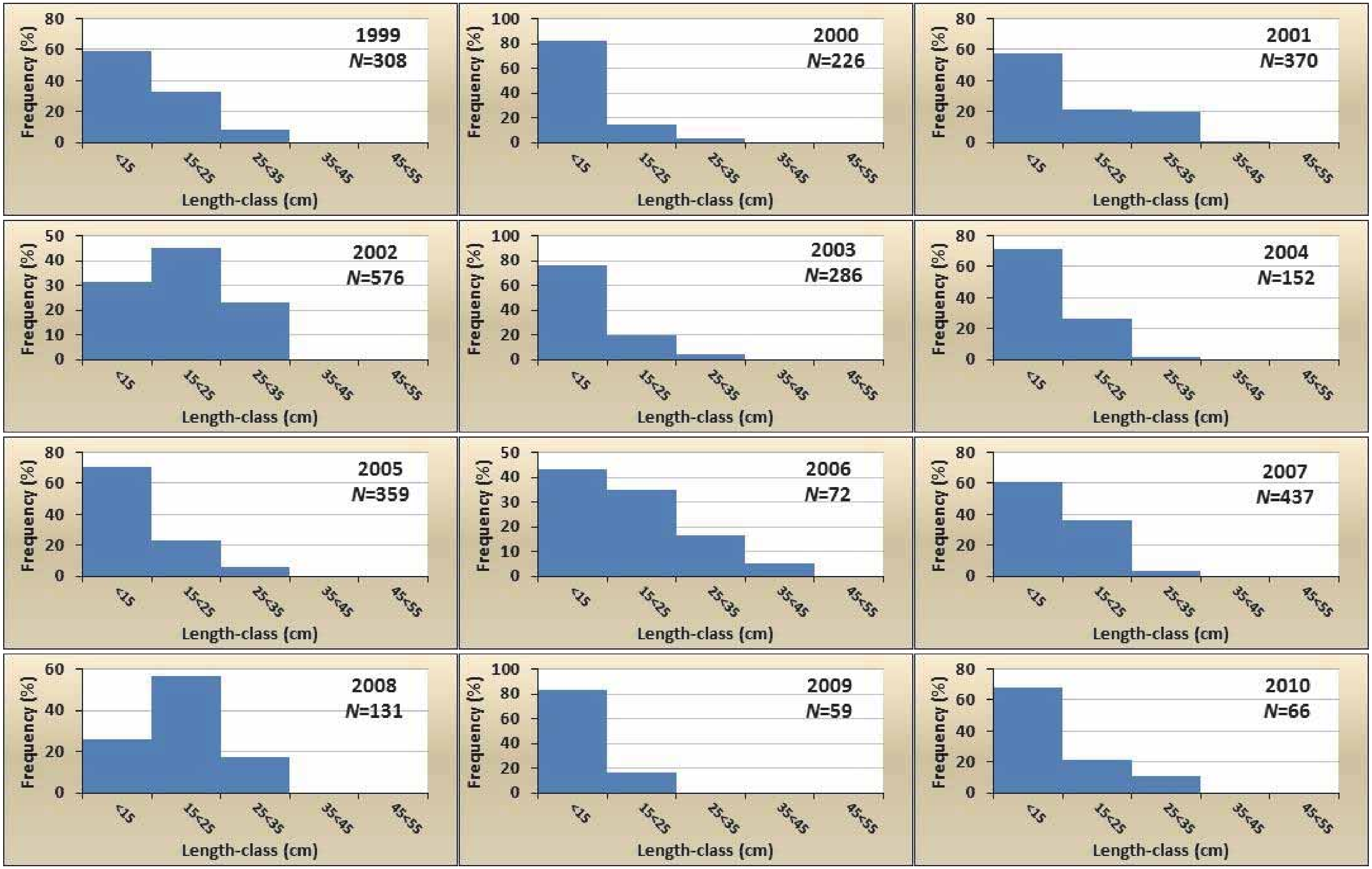

2005
N=1,393
2006
N=279
2007
N=1,380
2008
N=271
2009
N=414
2010
N=573
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

Appendix 17.B. Striped Seaperch length-class frequency histograms by year (expressed as percent of total N) at Orchard Rocks Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.

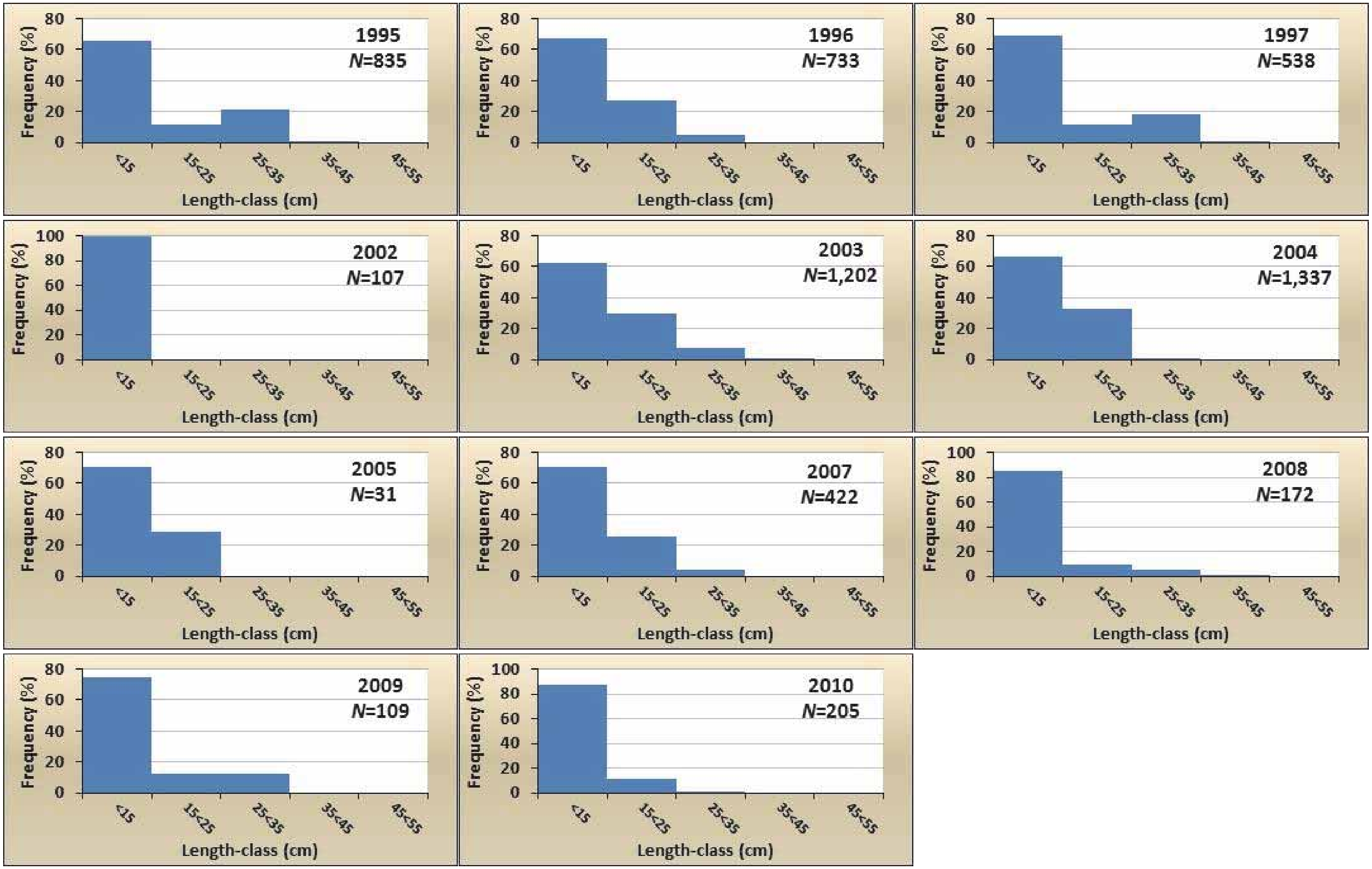



2005
N=45
2006
N=17
2007
N=76
2008
N=6
2009
N=2
2010
N=6
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

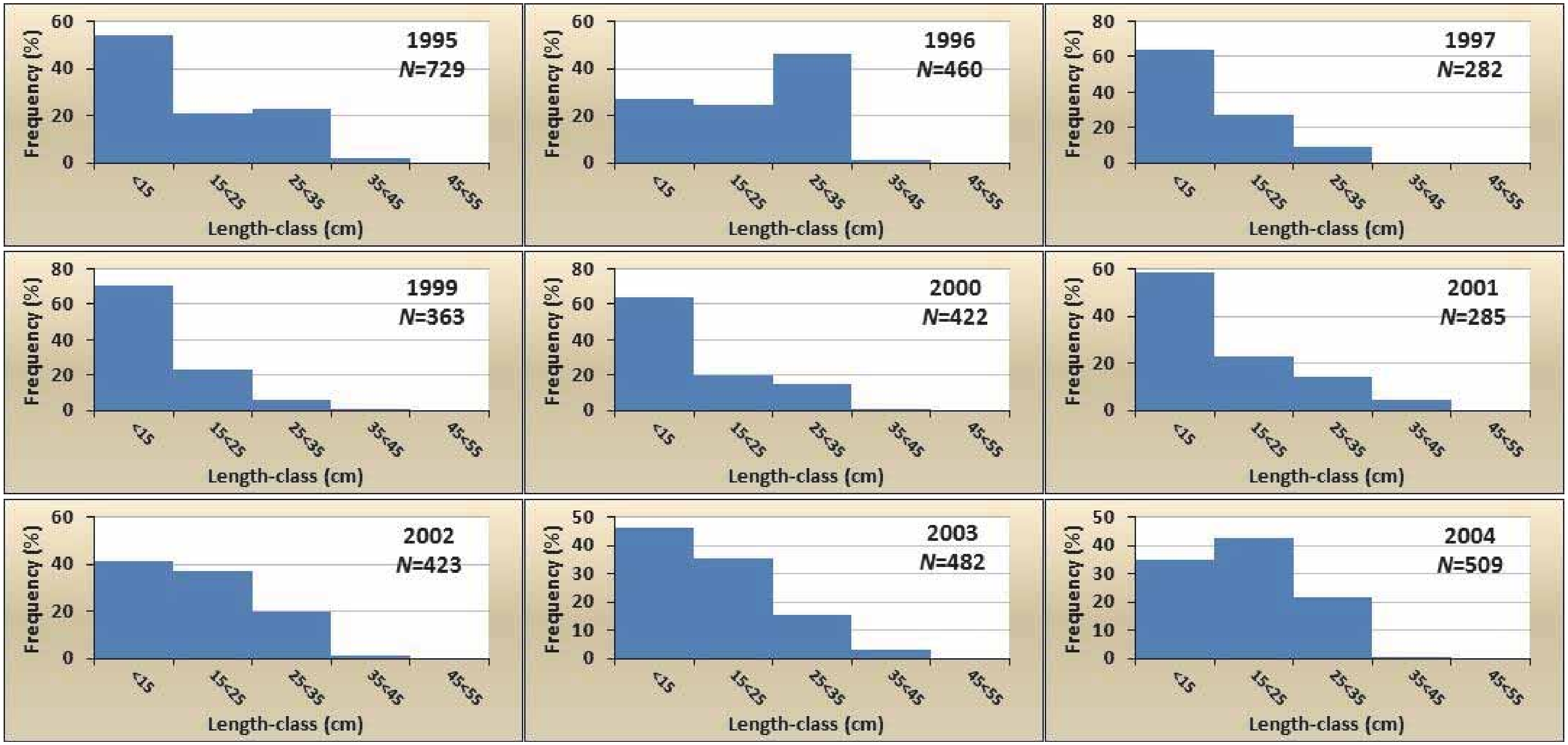
Appendix 17.C. Striped Seaperch length-class frequency histograms by year (expressed as percent of total N) at Point Glover. No surveys were conducted in 1995, 96, 97, or 98. Note that y-axis scales may differ in this appendix.

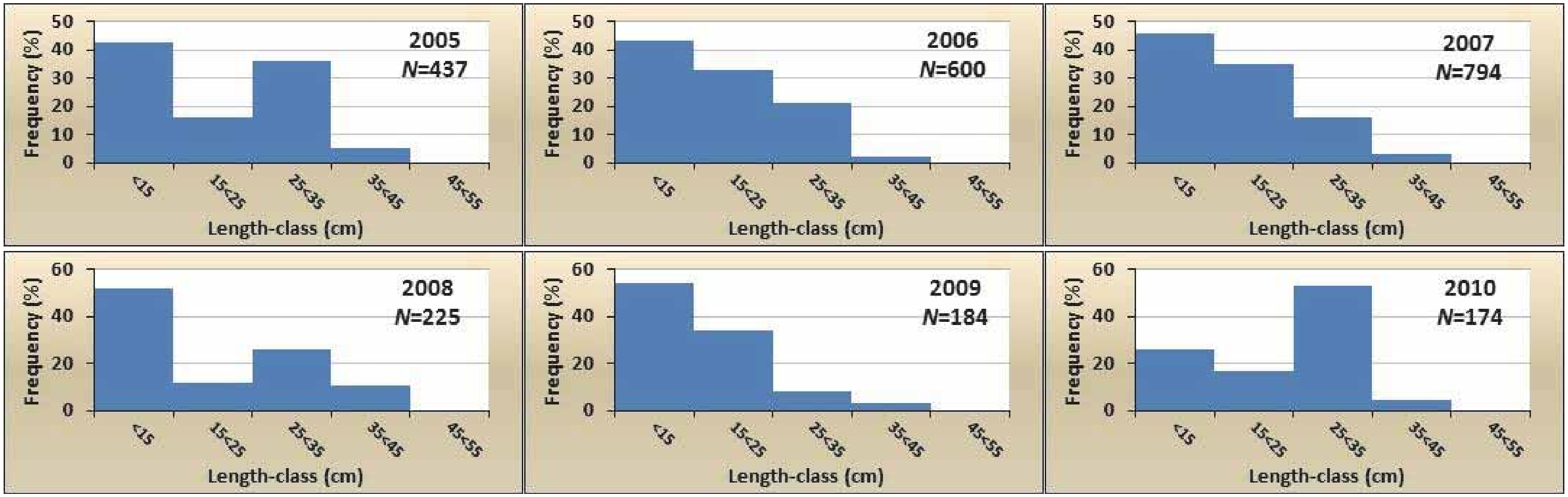


Appendix 17.D. Striped Seaperch length-class frequency histograms by year (expressed as percent of total N) at the Keystone jetty. No surveys were conducted in 1998, 99, 2000, 01, or 06. Note that y-axis scales may differ in this appendix.

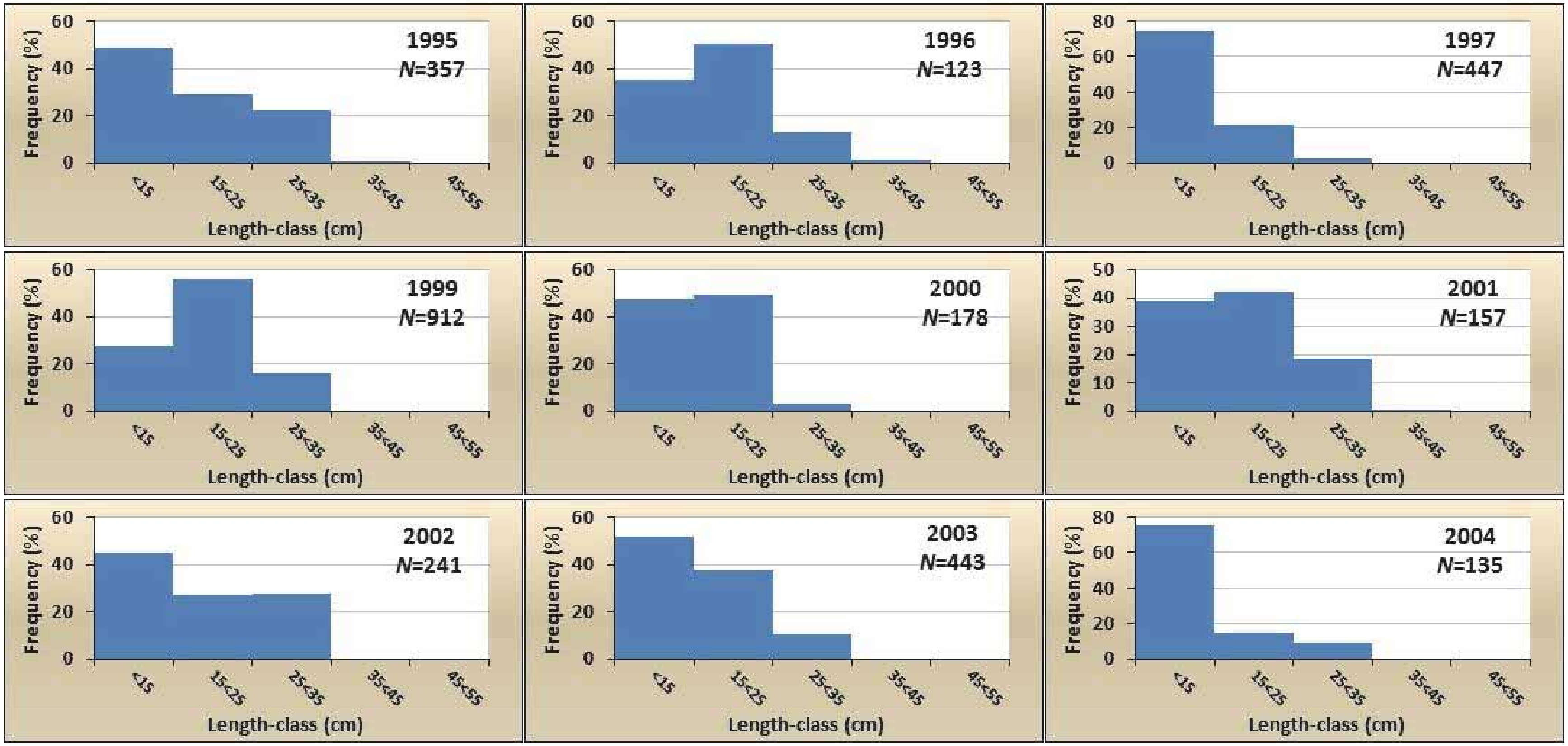


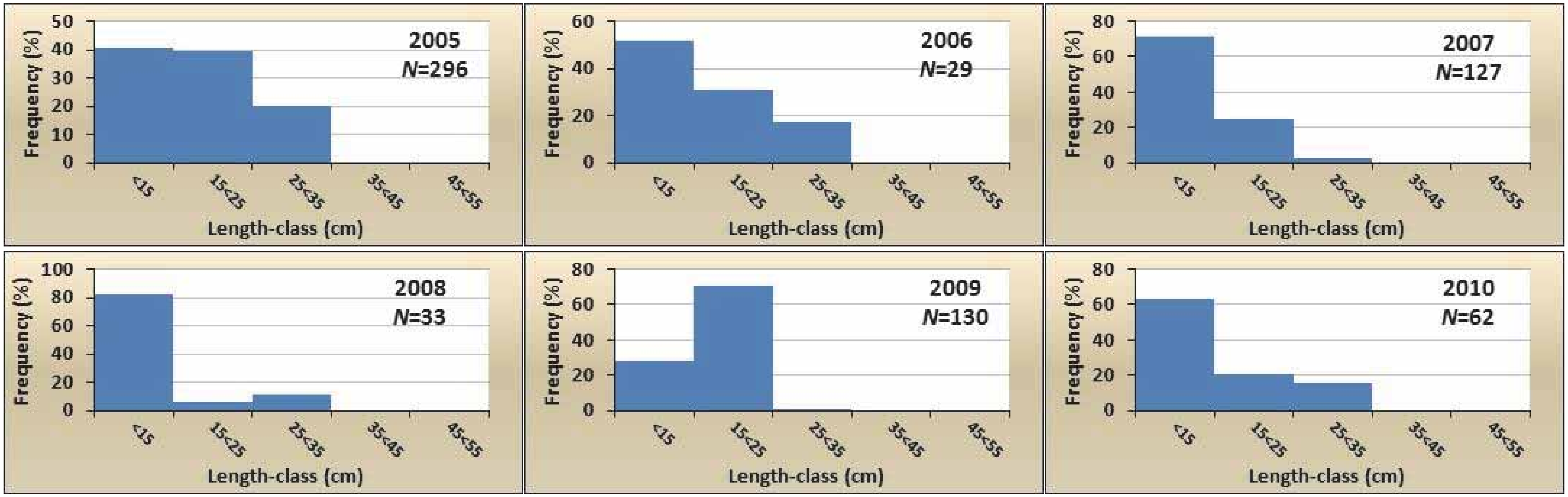
Appendix 17.E. Striped Seaperch length-class frequency histograms by year (expressed as percent of total N) at Brackett's Landing Shoreline Sanctuary Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.




2005
N=437
2006
N=600
2007
N=794
2008
N=225
2009
N=184
2010
N=174
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

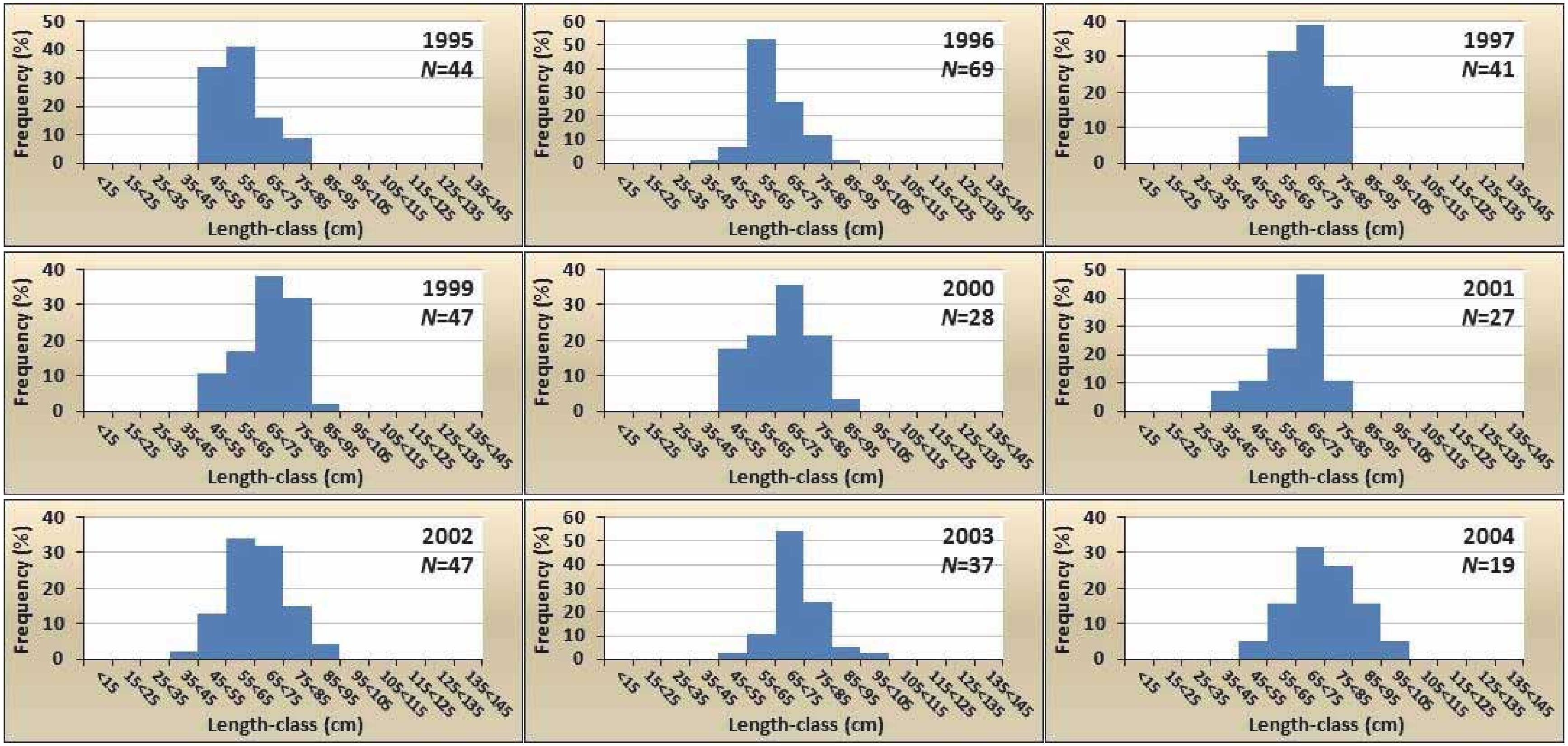
Appendix 17.F. Striped Seaperch length-class frequency histograms by year (expressed as percent of total N) at Port Blakely. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.

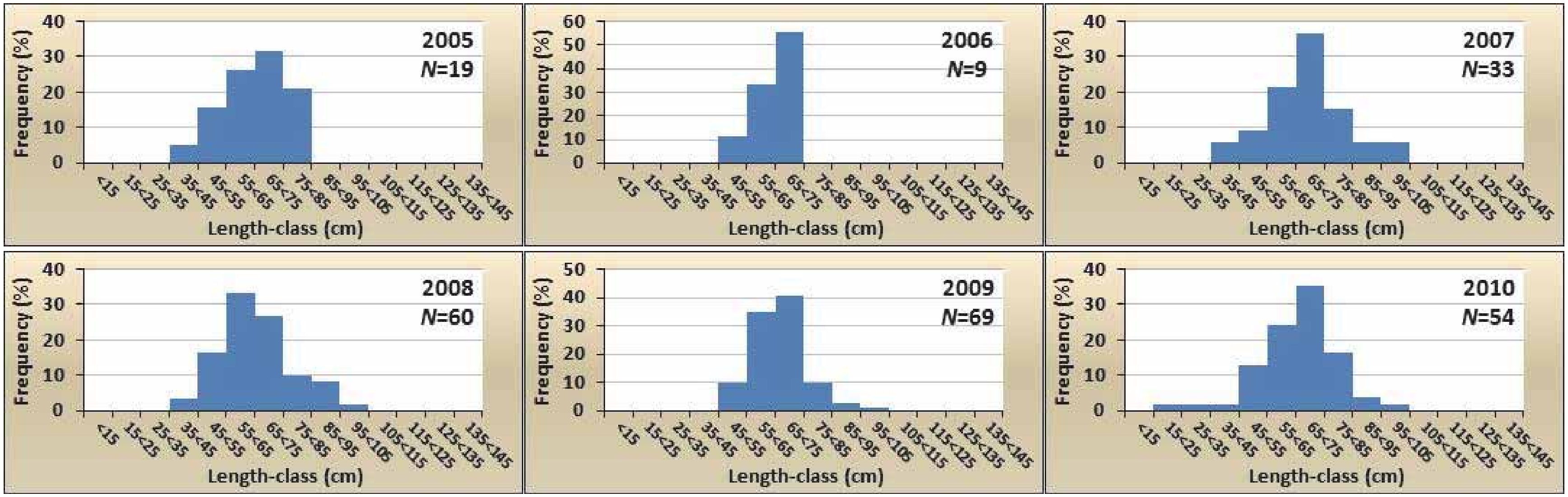




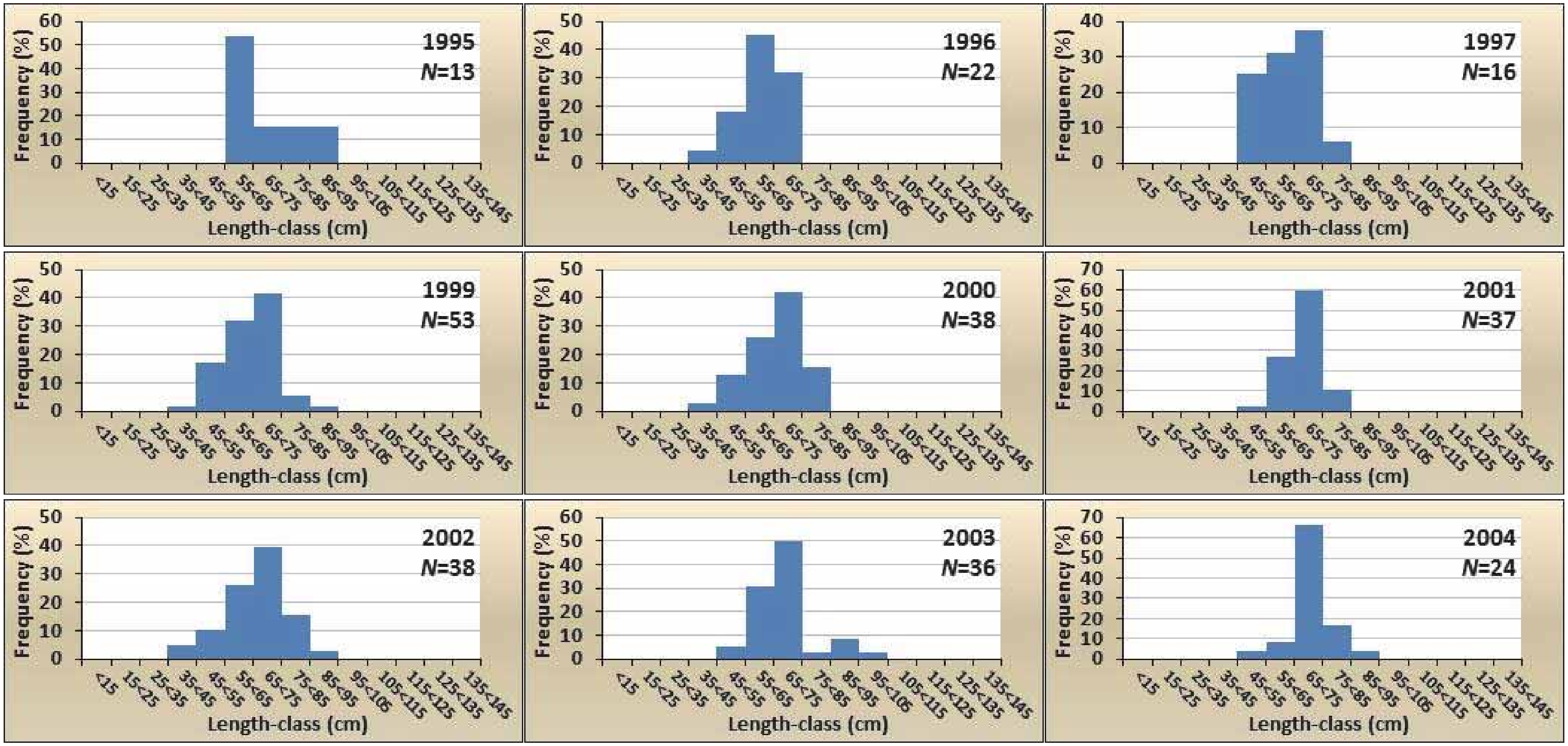
2005
N=296
2006
N=29
2007
N=127
2008
N=33
2009
N=130
2010
N=62
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

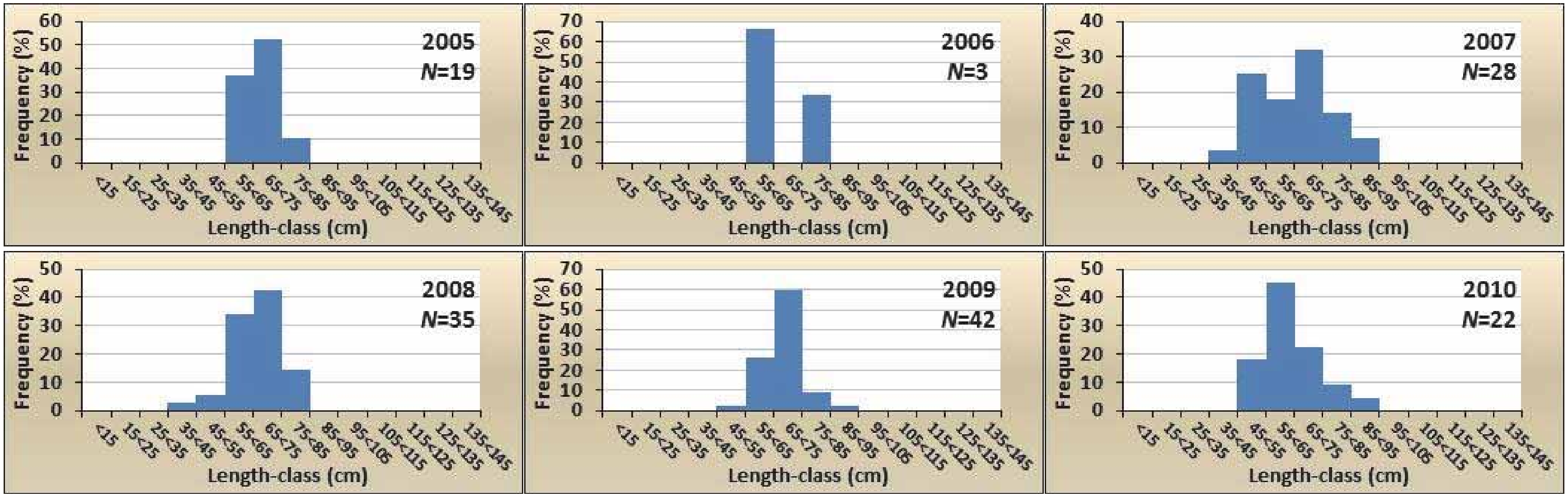
Appendix 18.A. Lingcod length-class frequency histograms by year (expressed as percent of total N) at Blake Island Artificial Reef. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.



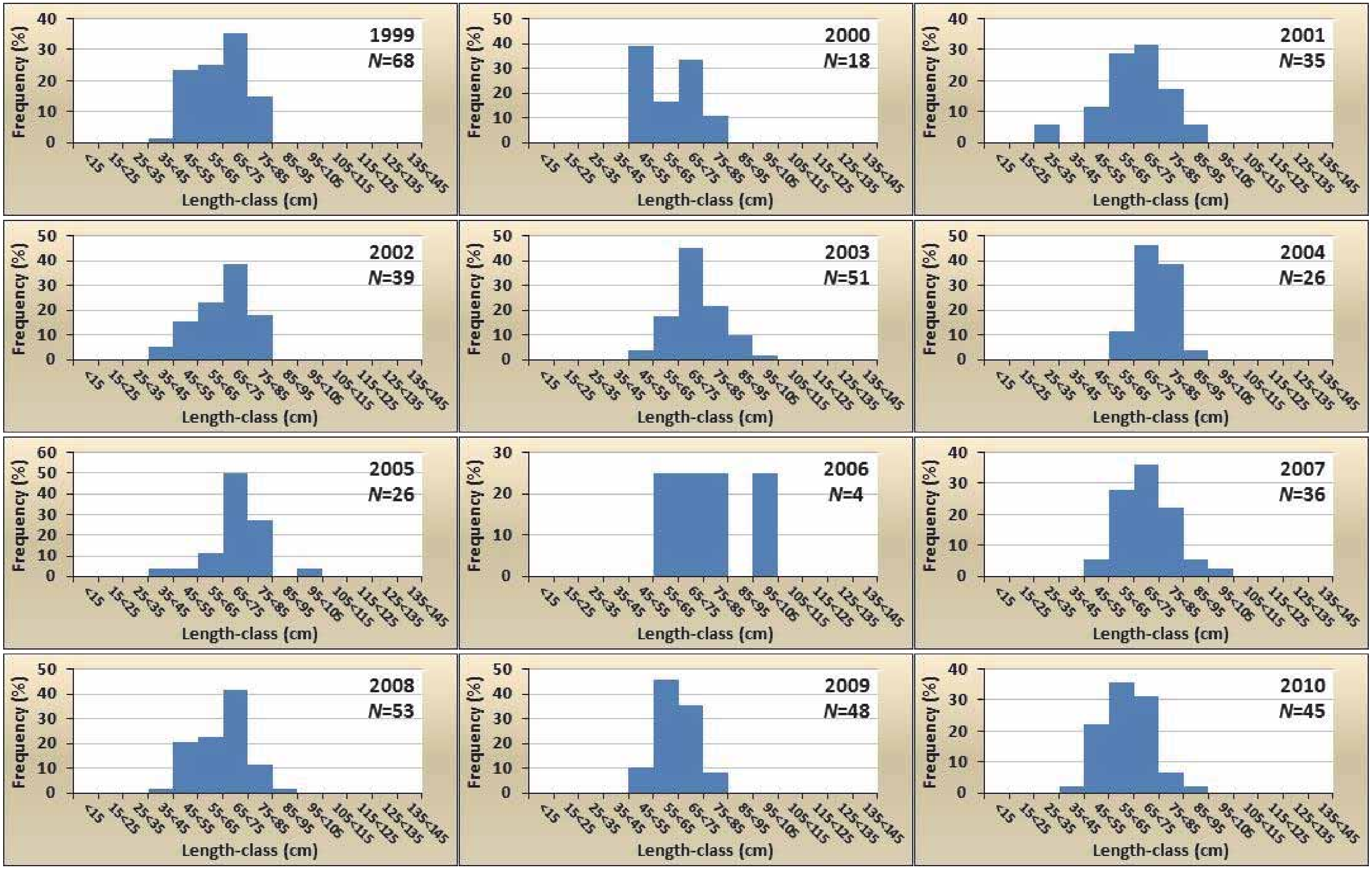

2005
N=19
2006
N=9
2007
N=33
2008
N=60
2009
N=69
2010
N=54
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
55<65
65<75
75<85
85<95
95<105
105<115
115<125
125<135
135<145

Appendix 18.B. Lingcod length-class frequency histograms by year (expressed as percent of total N) at Orchard Rocks Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.

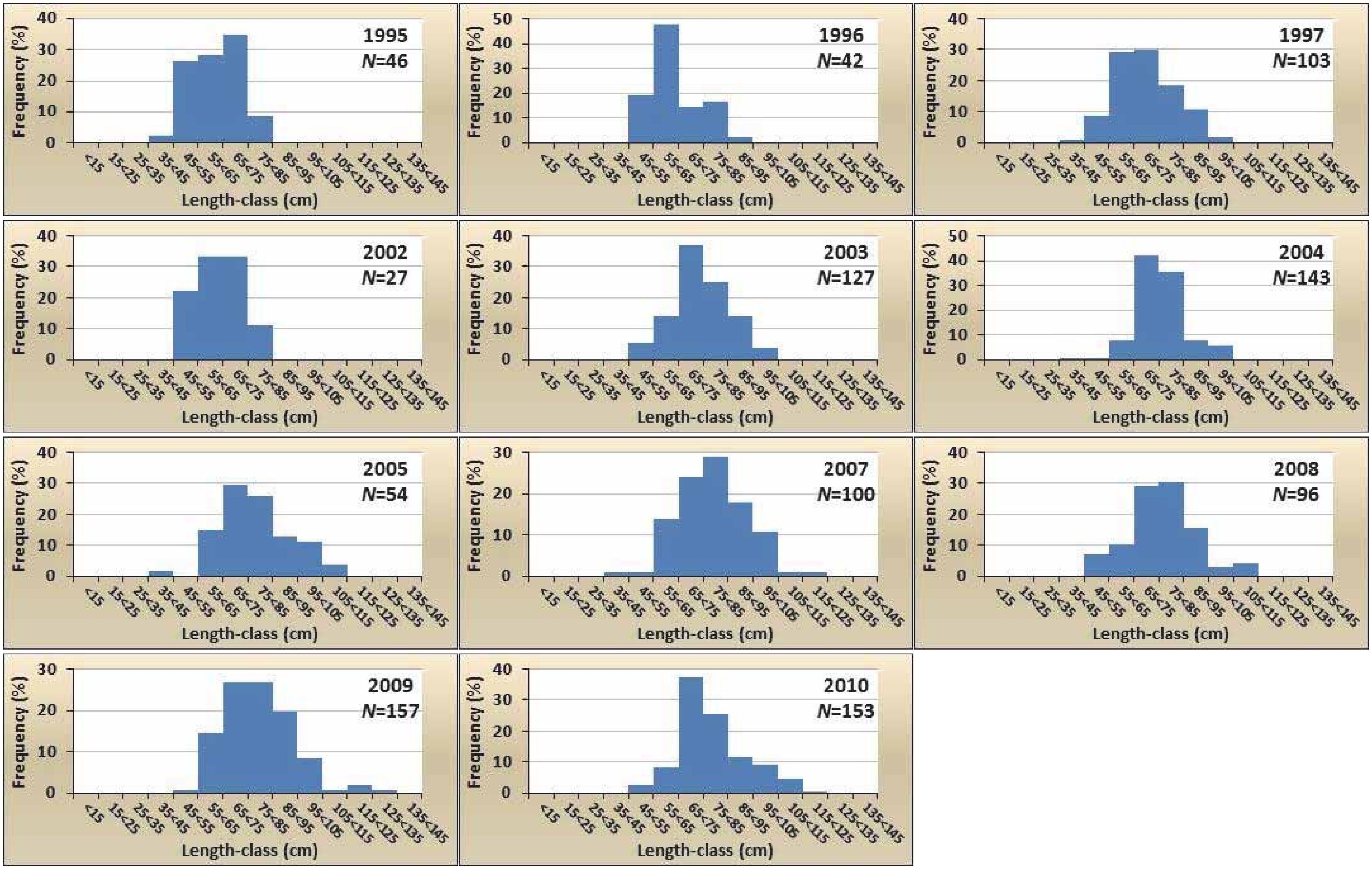



2005
N=19
2006
N=3
2007
N=28
2008
N=35
2009
N=42
2010
N=22
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
55<65
65<75
75<85
85<95
95<105
105<115
115<125
125<135
135<145

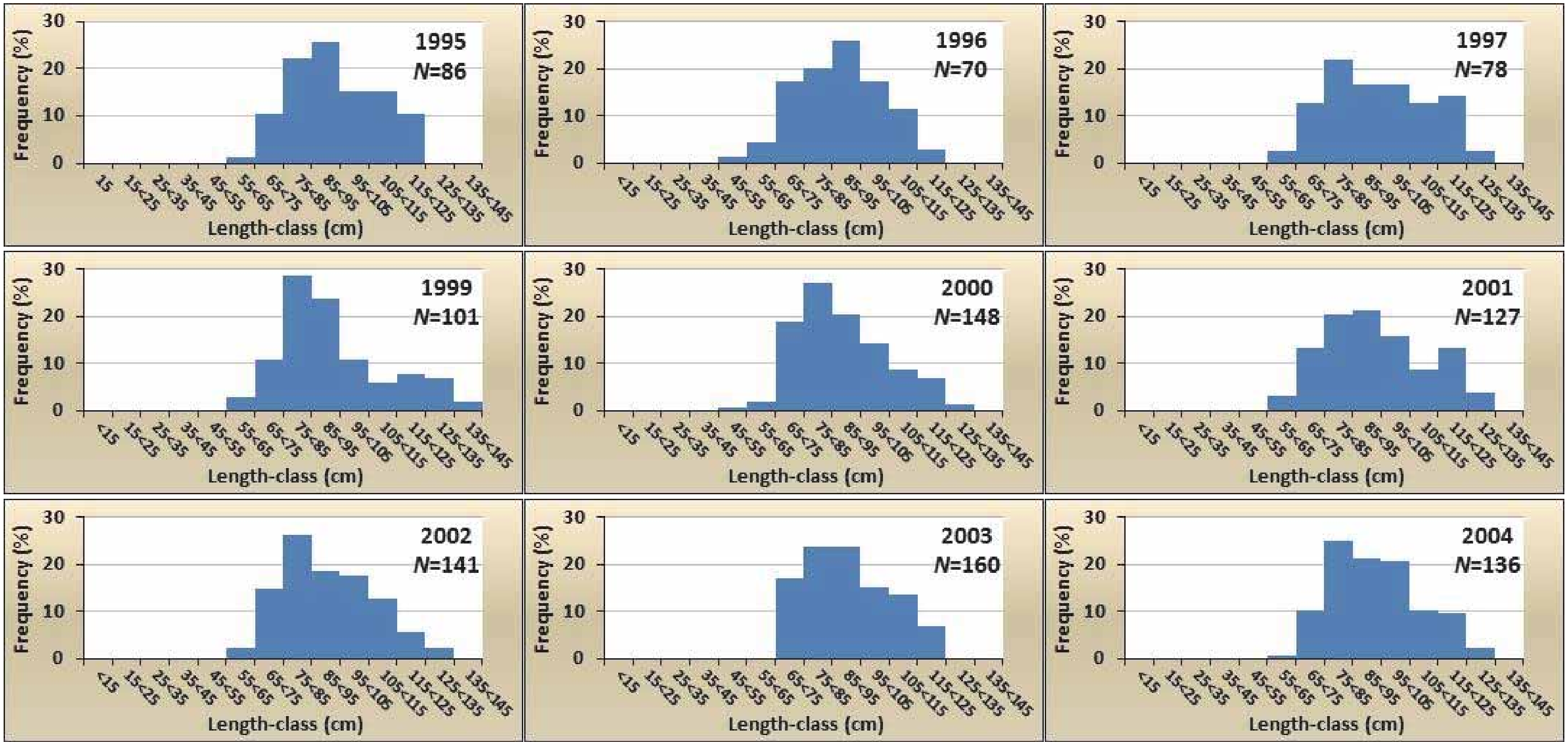
Appendix 18.C. Lingcod length-class frequency histograms by year (expressed as percent of total N) at Point Glover. No surveys were conducted in 1995, 96, 97, or 98. Note that y-axis scales may differ in this appendix.

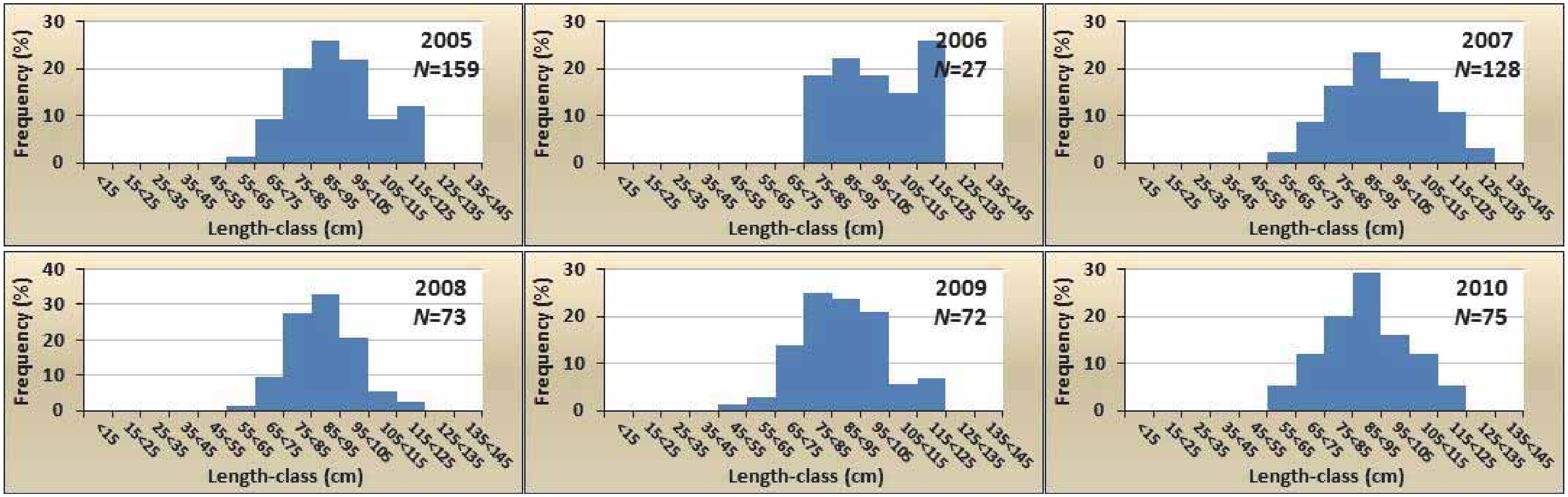


Appendix 18.D. Lingcod length-class frequency histograms by year (expressed as percent of total N) at the Keystone jetty. No surveys were conducted in 1998, 99, 2000, 01, or 06. Note that y-axis scales may differ in this appendix.

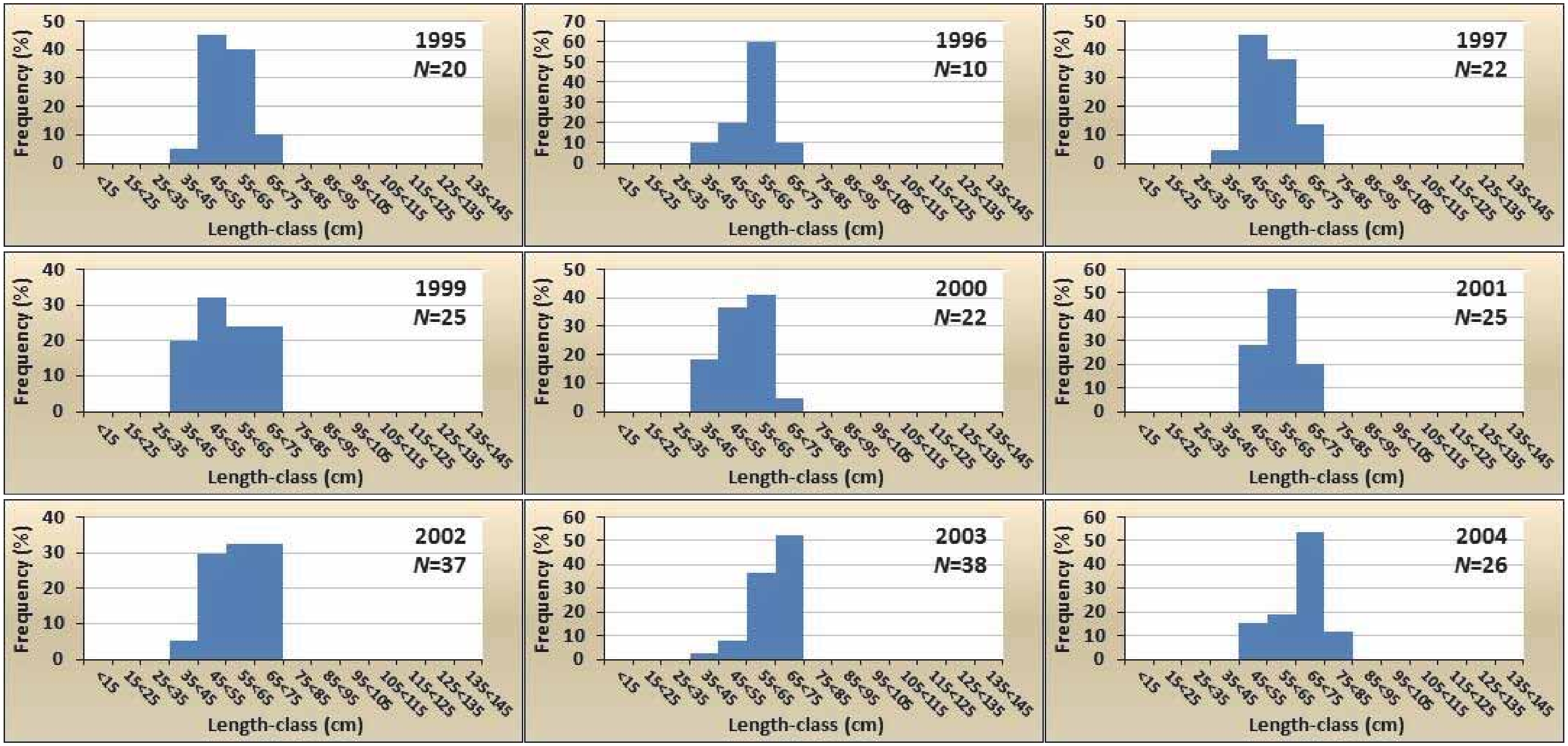


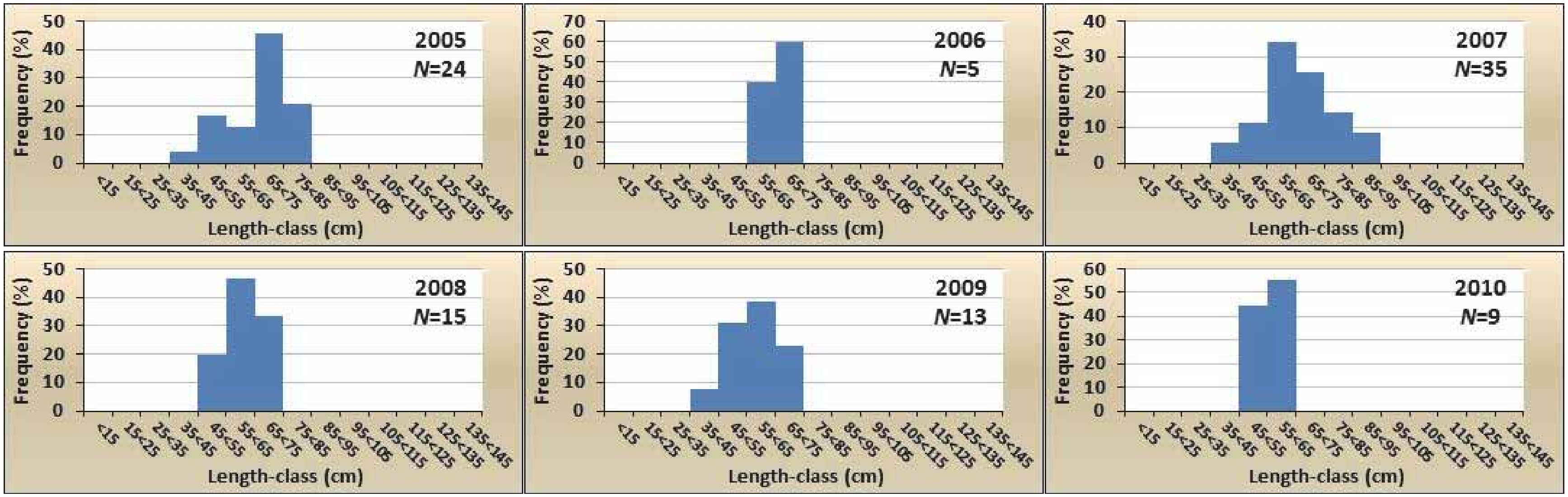
Appendix 18.E. Lingcod length-class frequency histograms by year (expressed as percent of total N) at Brackett's Landing Shoreline Sanctuary Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.



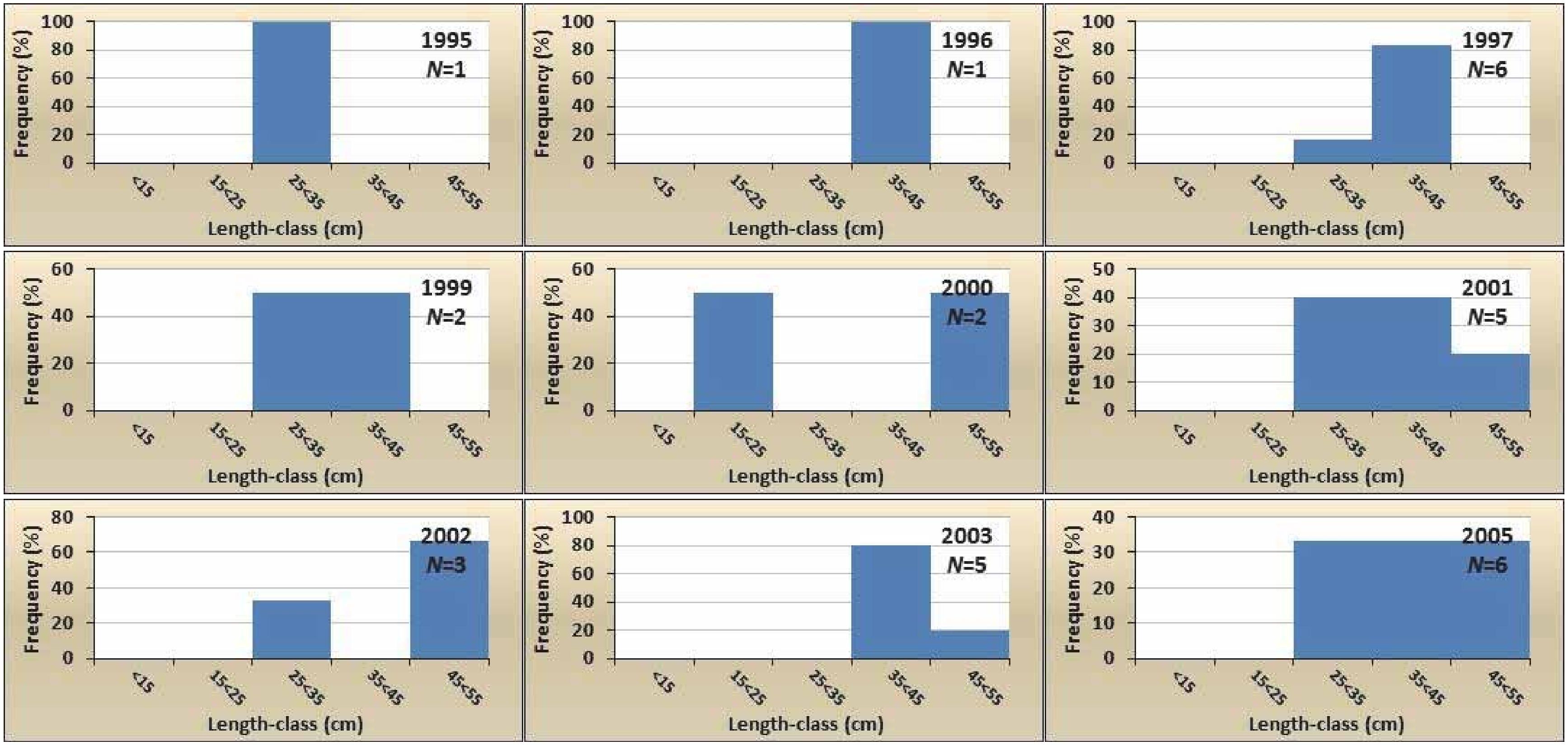

2005
N=159
2006
N=27
2007
N=128
2008
N=73
2009
N=72
2010
N=75
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
55<65
65<75
75<85
85<95
95<105
105<115
115<125
125<135
135<145

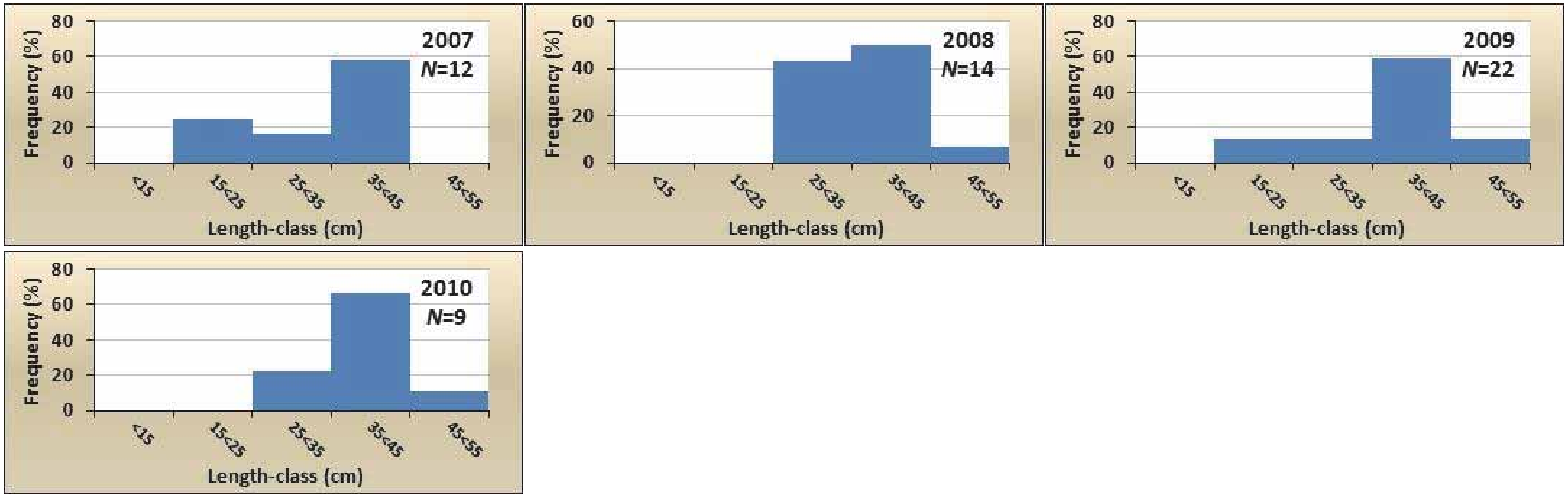
Appendix 18.F. Lingcod length-class frequency histograms by year (expressed as percent of total N) at Port Blakely. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.




2005
N=24
2006
N=5
2007
N=35
2008
N=15
2009
N=13
2010
N=9
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
55<65
65<75
75<85
85<95
95<105
105<115
115<125
125<135
135<145

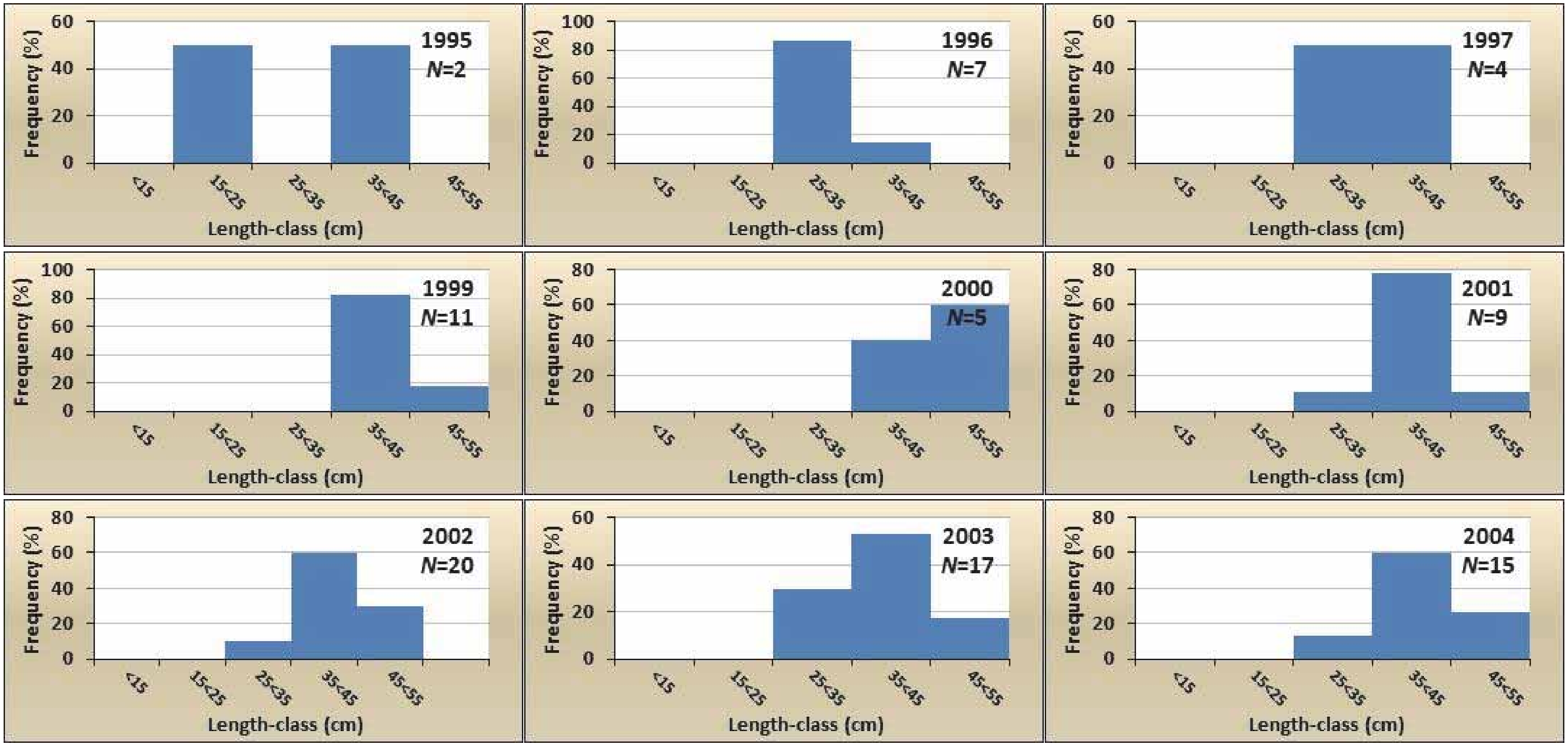
Appendix 19.A. Kelp Greenling length-class frequency histograms by year (expressed as percent of total N) at Blake Island Artificial Reef. No surveys were conducted in 1998. No Kelp Greenling were observed in 2004 or 2006. Note that y-axis scales may differ in this appendix.

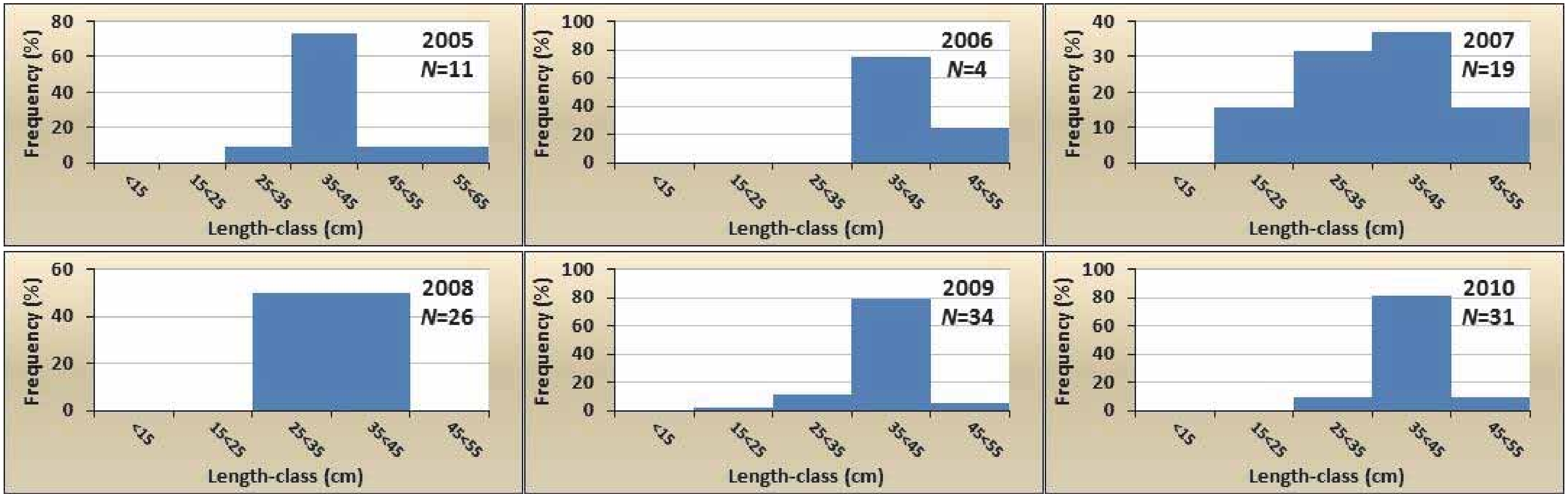




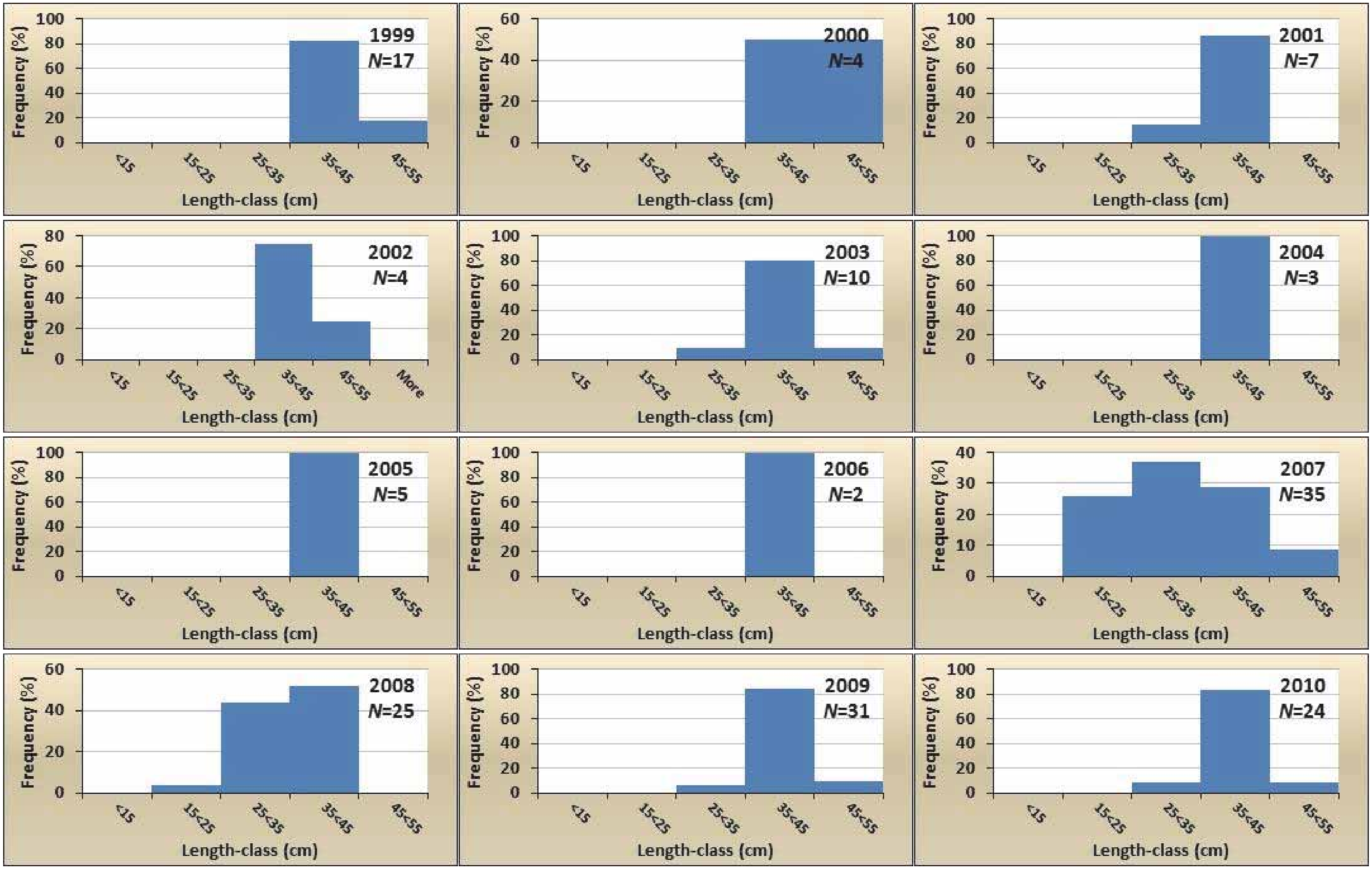
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
2007
N=12
2008
N=14
2009
N=22
2010
N=9

Appendix 19.B. Kelp Greenling length-class frequency histograms by year (expressed as percent of total N) at Orchard Rocks Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.

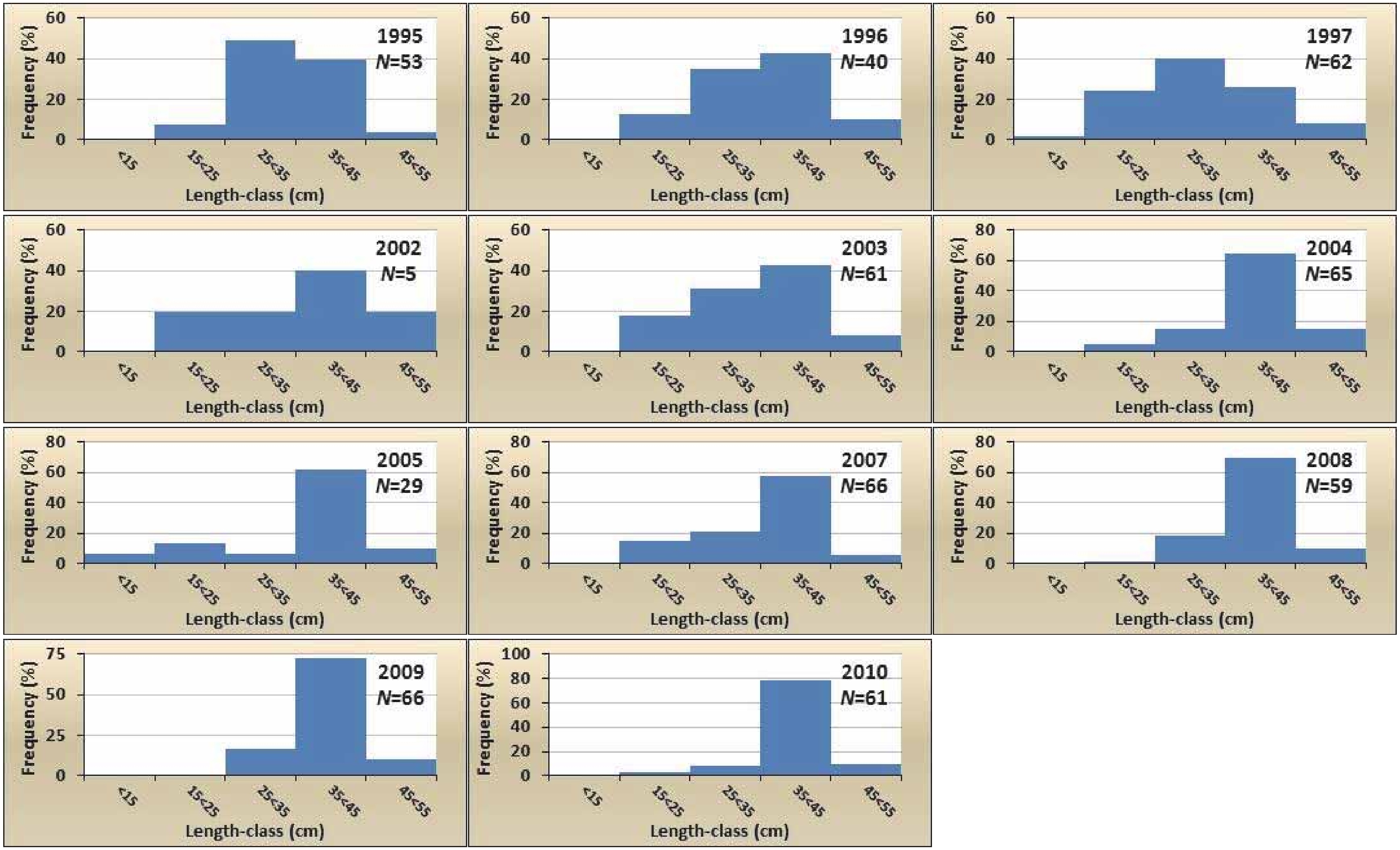



Frequency (%)
80
60
40
20
0
2005
N=11
<15
15<25
25<35
35<45
45<55
55<65
Length-class (cm)
Frequency (%)
100
80
60
40
20
0
2006
N=4
<15
15<25
25<35
35<45
45<55
Length-class (cm)
Frequency (%)
40
30
20
10
0
2007
N=19
<15
15<25
25<35
35<45
45<55
Length-class (cm)
Frequency (%)
60
40
20
0
2008
N=26
<15
15<25
25<35
35<45
45<55
Length-class (cm)
Frequency (%)
100
80
60
40
20
0
2009
N=34
<15
15<25
25<35
35<45
45<55
Length-class (cm)
Frequency (%)
100
80
60
40
20
0
2010
N=31
<15
15<25
25<35
35<45
45<55
Length-class (cm)

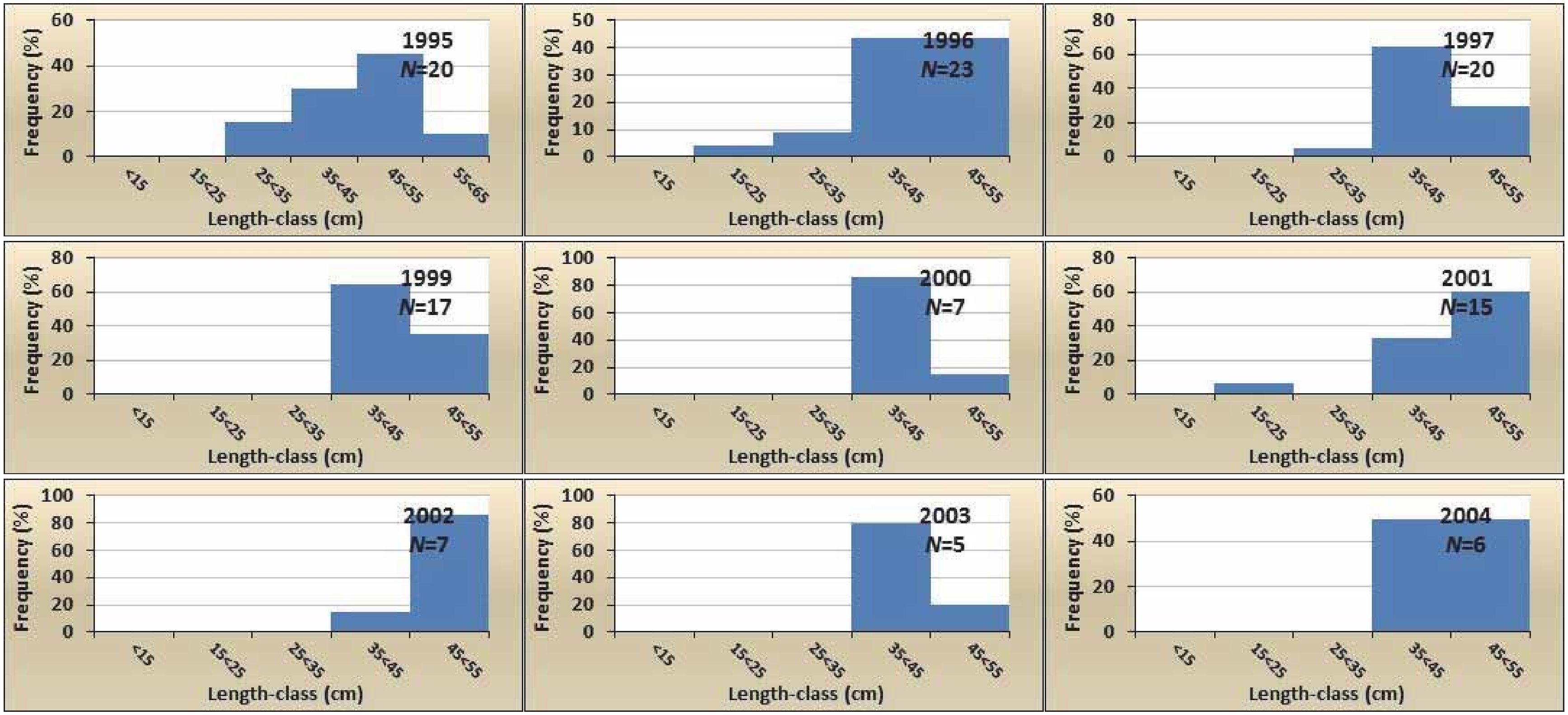
Appendix 19.C. Kelp Greenling length-class frequency histograms by year (expressed as percent of total N) at Point Glover. No surveys were conducted in 1995, 96, 97, or 98. Note that y-axis scales may differ in this appendix.

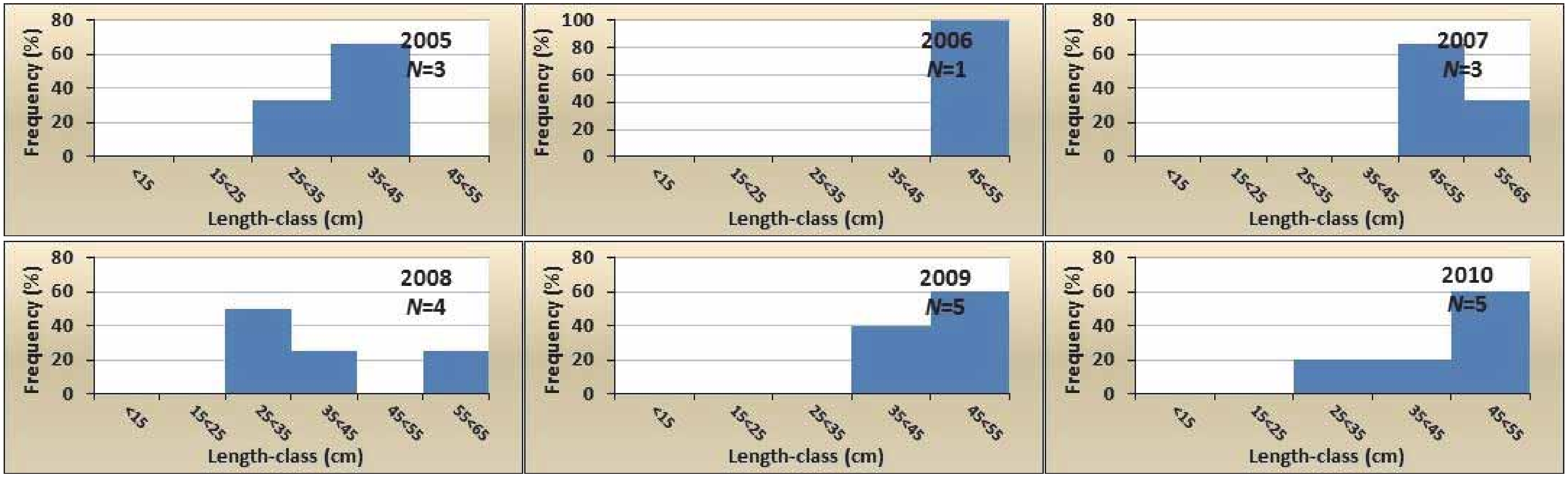


Appendix 19.D. Kelp Greenling length-class frequency histograms by year (expressed as percent of total N) at the Keystone jetty. No surveys were conducted in 1998, 99, 2000, 01, or 06. Note that y-axis scales may differ in this appendix.

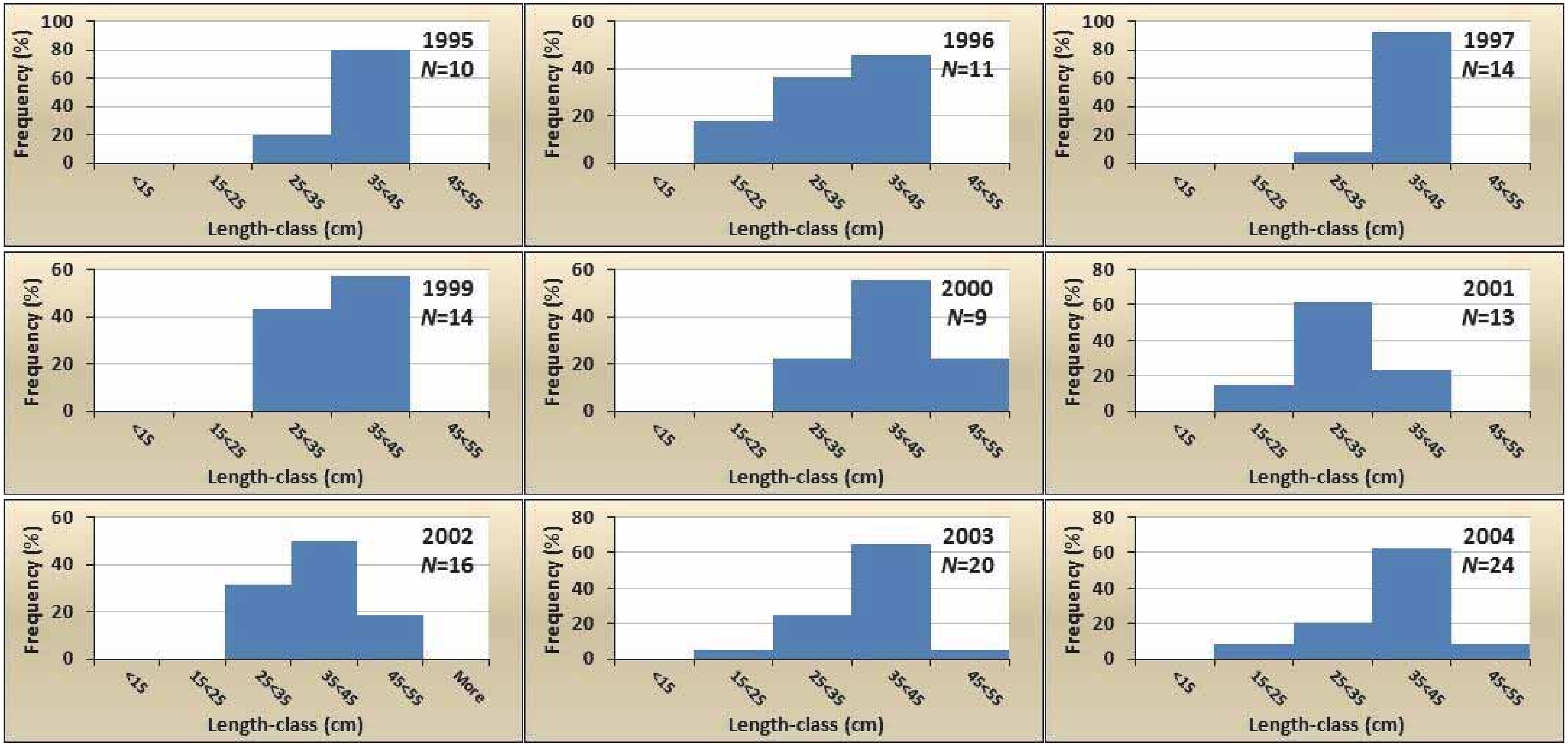


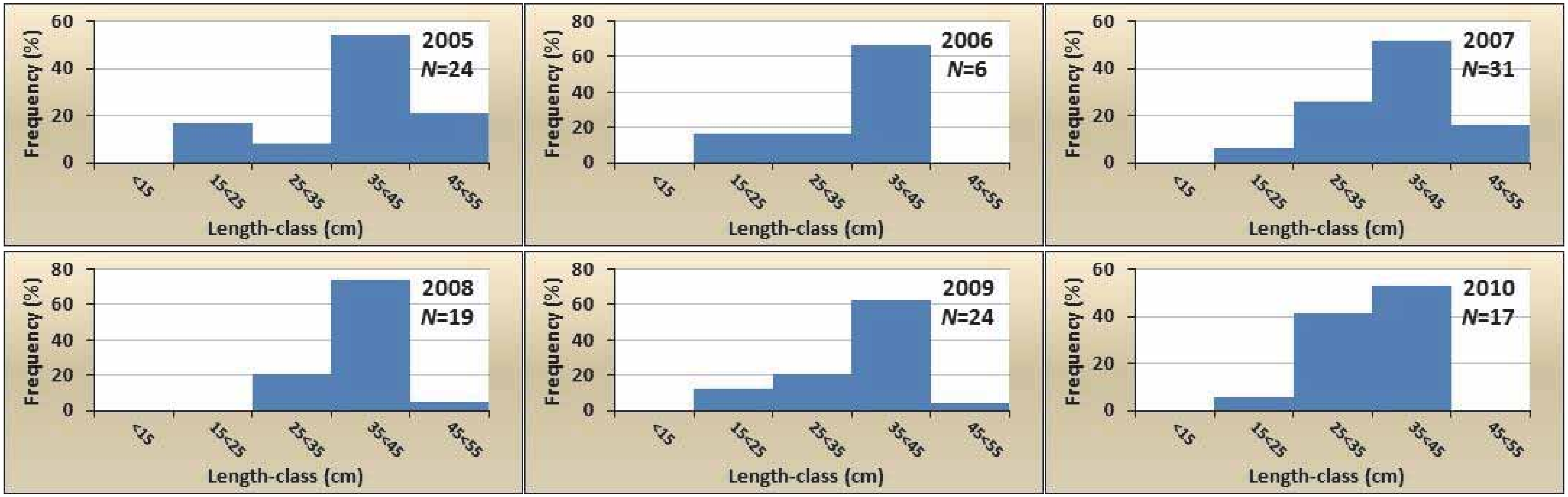
Appendix 19.E. Kelp Greenling length-class frequency histograms by year (expressed as percent of total N) at Brackett's Landing Shoreline Sanctuary Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.



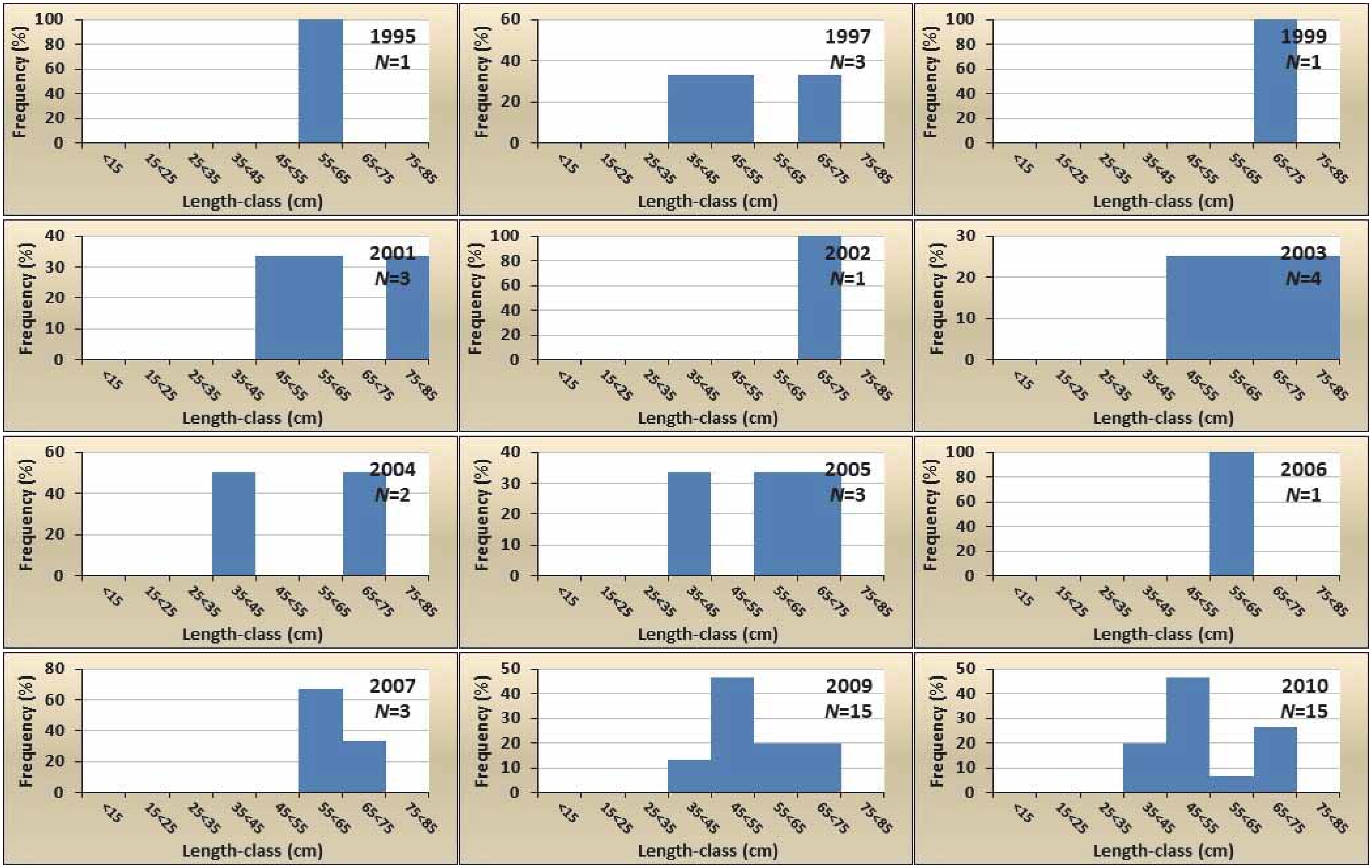

2005
N=3
2006
N=1
2007
N=3
2008
N=4
2009
N=5
2010
N=5
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
55<65

Appendix 19.F. Kelp Greenling length-class frequency histograms by year (expressed as percent of total N) at Port Blakely. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.




2005
N=24
2006
N=6
2007
N=31
2008
N=19
2009
N=24
2010
N=17
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55

Appendix 20.A. Cabezon length-class frequency histograms by year (expressed as percent of total N) at Blake Island Artificial Reef. No surveys were conducted in 1998. No Cabezon were observed in 1996, 2000, or 08. Note that y-axis scales may differ in this appendix.

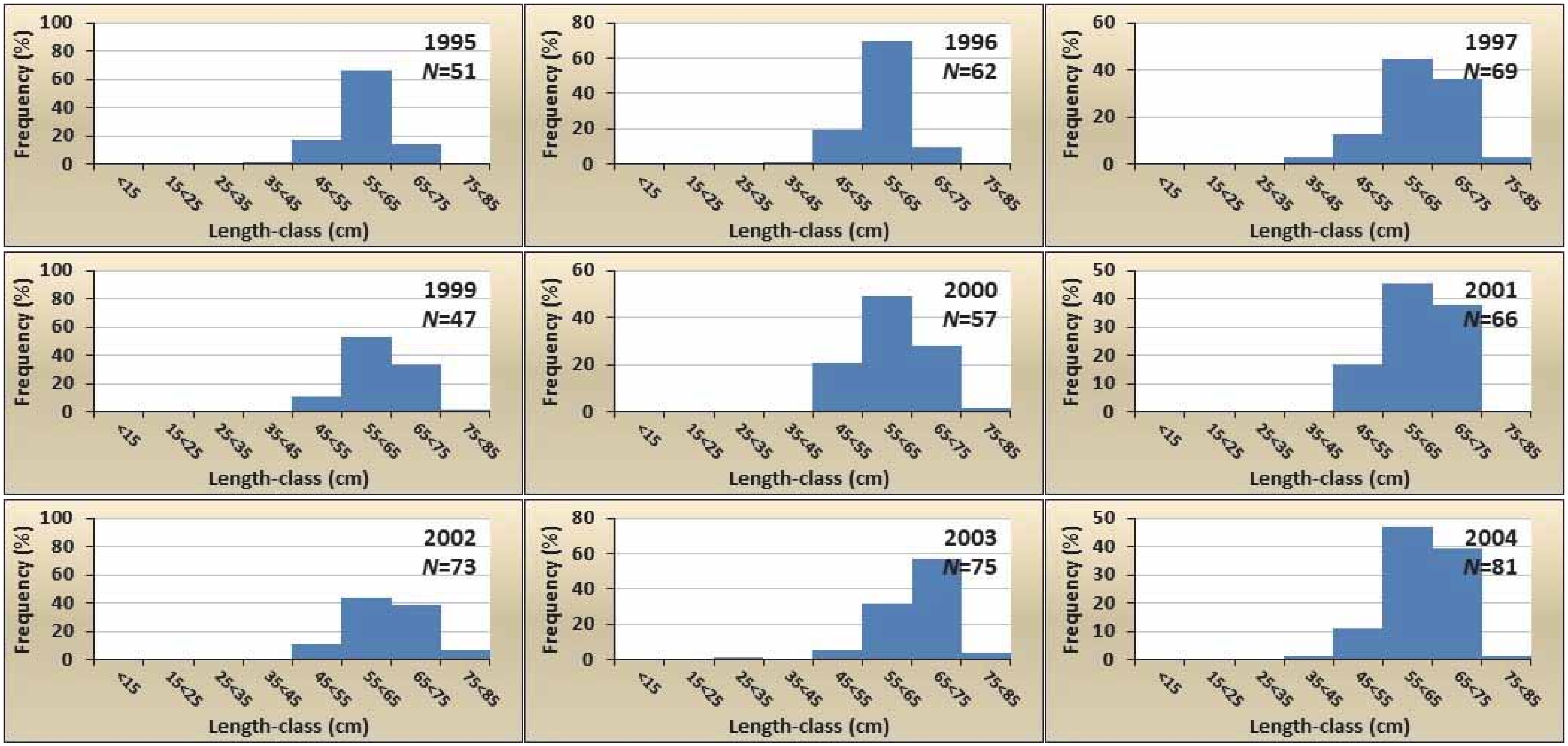


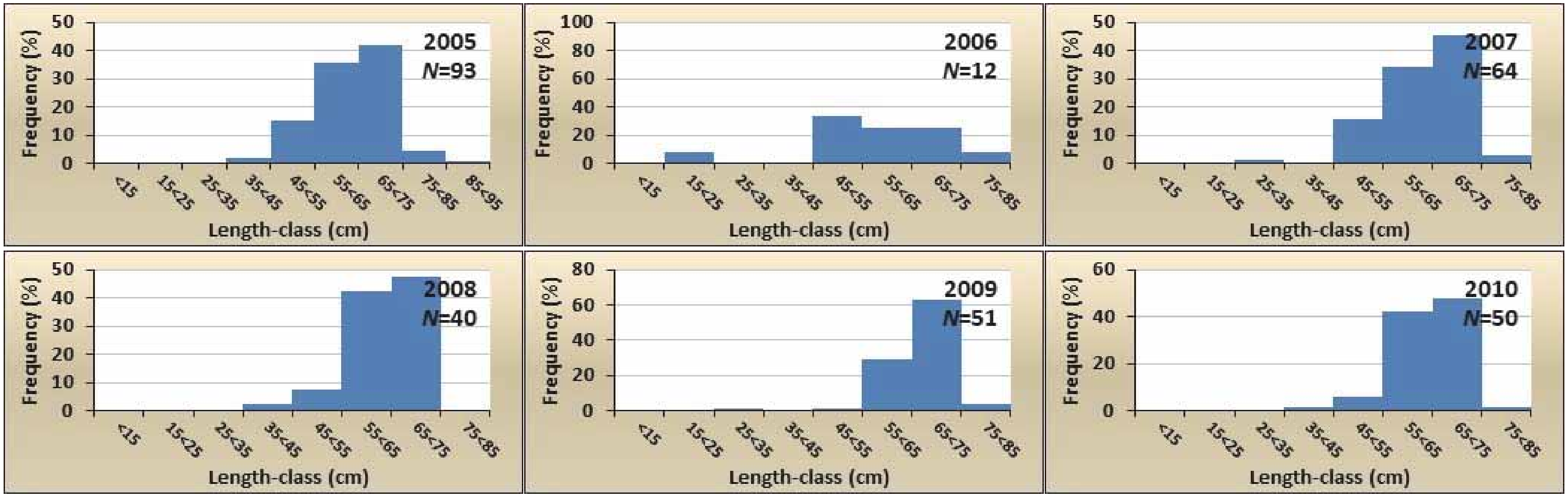
Appendix 20.B. The total number of Cabezon observed at Orchard Rocks Conservation Area in any year did not exceed five, thus they are not depicted here.

Appendix 20.C. The total number of Cabezon observed at Point Glover in any year did not exceed six, thus they are not depicted here.

Appendix 20.D. The total number of Cabezon observed at Keystone jetty in any year did not exceed two, thus they are not depicted here.

Appendix 20.E. Cabezon length-class frequency histograms by year (expressed as percent of total N) at Bracket's Landing Shoreline Conservation Area. No surveys were conducted in 1998. Note that y-axis scales may differ in this appendix.




2005
N=93
2006
N=12
2007
N=64
2008
N=40
2009
N=51
2010
N=50
Frequency (%)
Length-class (cm)
<15
15<25
25<35
35<45
45<55
55<65
65<75
75<85
85<95

Appendix 20.F. The total number of Cabezon observed at Port Blakely in any year did not exceed five, thus they are not depicted here.