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Relative Abundance and Size Composition of Red Sea Urchin, *Strongylocentrotus franciscanus*, Populations Along the Mendocino County Coast, 1991

by

Peter Kalvass
and
Ian Taniguchi

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ABSTRACT

Underwater surveys were conducted in the summer of 1991, as part of a three year survey, to determine density and size composition of red sea urchin, *Strongylocentrotus franciscanus*, populations along the Mendocino coast at three different depth zones. The study consisted of two parts: i) a broad scale survey, with 12 systematically chosen sites from Gualala to Mendocino and ii) a fine scale survey, with nine sites in the vicinity of Fort Bragg. The fine scale sites were selected to represent different habitat types and levels of commercial exploitation. The sites included the Point Cabrillo Marine Reserve (PCMR) as an unfished control and the Caspar Commercial Urchin Closure Area, established in 1989 to assess the effects of closure upon recovery of fished areas.

The broad scale mean density was 0.71 red urchin m^{-2} (SD 1.9), a decline from the 1.3 and 1.1 red urchin m^{-2} found during the 1988 and 1989 surveys, respectively. The 4.6-m depth zone yielded only 0.17 m^{-2}. No site in the broad scale survey had greater than 2.2 red urchin m^{-2}. Fine scale fished site mean density declined to 0.34 (SD 1.1) and the PCMR control site density increased to 7.0 m^{-2} (SD 6.2). Abundance was variable; however, as in past surveys the highest densities were generally found at the 10.7-m and 15.2-m depth zones.

The presence of a mode in the 15-35 mm size interval indicated a recent recruitment event. However, continued declines in legal-sized (>89 mm) red sea urchins survey-wide demonstrate the need for more effective fishery management.

1/ Marine Resources Administrative Report No. 93-1
2/ CDFG, 19160 S. Harbor Dr., Fort Bragg, CA 95437
3/ CDFG, 330 Golden Shore, Suite 50, Long Beach, CA 90802

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INTRODUCTION

The California Department of Fish and Game (Department) has studied the northern California sea urchin fishery since 1987. As part of these investigations and commencing in 1988, the Department initiated a multi-year survey of red sea urchin, *Strongylocentrotus franciscanus*, populations at various locations along the Mendocino and Sonoma county coasts. Red sea urchin densities and recruitment patterns were assessed by examining adult-juvenile aggregations and size frequency data collected along subtidal transects.

The main fishery area for this commercially important echinoid in northern California extends from approximately Fort Bragg, Mendocino county to Bodega Bay in Sonoma county (Figure 1). This area, except for occasional stretches of sandy beach, is characterized by an alternating series of small coves and headlands of exposed bedrock. Tidal areas are dominated by lush seasonal growths of large-bladed brown algae. In 1991, Bodega Bay was the primary northern California port with catches totaling 5.4 million pounds of red sea urchin.

Exponentially increasing catches in northern California between 1985 and 1988 triggered concern in both the Department and the sea urchin industry for the long-term sustainability of the red sea urchin fishery (Figure 2). This concern prompted legislation establishing a landing tax to partially fund investigations into sea urchin population characteristics. This report summarizes the results of the 1991 northern California sea urchin survey. Previous northern California sea urchin investigations are summarized in Department administrative reports (Kalvass et al 1991, Kalvass, Taniguchi and Buttolph 1990, and Kalvass 1989).

METHODS

The study was patterned after a two-phase approach used to study the red sea urchin in British Columbia, Canada (Sloan, Lauridsen and Harbo 1987). Both phases, the 'broad scale' and 'fine scale' surveys, were conducted during the same three week period beginning in late July. The 'broad scale' survey consisted of systematically sampling selected sites along the central portion of the fishery area in Mendocino county, though in 1991 the Sonoma county coast was not surveyed as in past years. During the broad scale survey, the Saunders Reef area was also examined as an area of special interest since it is one of the largest offshore reefs in northern California and a state-designated Area of Special Biological Significance. Fine scale survey sites were selected near Fort Bragg, within the Point Cabrillo Marine Reserve (PCMR), within the Caspar Urchin Closure Area, and at locations with a history of intensive commercial exploitation (Figure 3).

Broad Scale Survey

Divers from the Department and Humboldt State University surveyed 30-meter long transects from July 23 to August 14, 1991. Sea conditions were hazardous at times during the survey period, causing difficulty in obtaining vessel support. The Department patrol vessels *Bluefin* and *Broadbill* were utilized to access some sites. Remaining sites were accessed by small boat or eliminated from the survey when vessel support was unavailable. Forty-five transects were surveyed by divers during the broad scale phase at 12 sites from Robinson Reef, Mendocino county (site 9) (Figure 4) to Jack Peters Creek, Mendocino county (site 22) (Figure 5), including Saunders Reef (Table 1). In the survey design used in 1988 and 1989, 22 sites were systematically chosen at intervals of 2.7 nautical miles along the coast. Sites were located in subsequent surveys using Loran and photographic landmark descriptions of the original sites. However, no attempt was made to locate the path of a previous transect line. We eliminated the Sonoma coast sites (sites 1-8) in the 1991 survey in order to focus effort in the fine scale phase of the survey. The broad scale study area was divided at Point Arena, the prominent geographical feature of the area, into two zones, designated Point Arena South and Point Arena North (Figures 4 and 5). These zones represent distinct oceanographic and commercial urchin fishing areas. No site in this phase of the survey was exempt from commercial urchin harvest.

Fine Scale Surveys

The fine scale phase consisted of surveying 63 thirty-meter transects at nine sites. Sites and subsites (individual dive locations within a larger site, such as the PCMR) were selected during the first survey year to represent a variety of habitat types (i.e. headland and cove) with varying degrees of harvest pressure. In 1991 several new sites were added and one area (Laguna Pt) surveyed in 1989 was deleted. The Point Cabrillo Marine Reserve served as an unfished control. In May 1991, the PCMR was expanded to nearly twice its previous size to encompass approximately one mile of shoreline. Two new survey subsites were added to assess reef structures in the expanded portion of the PCMR. The Caspar Commercial Urchin Closure Area was selected to assess population recovery and interactions in a previously fished area. This area was closed to commercial sea urchin fishing in the spring of 1989.

The fine scale survey design allowed flexibility in transect placement to compare and contrast habitats, as well as the option of using permanent transects in selected locations within sites. During the 1991 survey, we placed three 'permanent' transects for use in future surveys. Two were placed in the Caspar Closure Area and one in the PCMR. Each was marked by 18.2 Kg concrete piers at 5 meter intervals. In 1988 and 1989, two fine scale surveys were completed during each year, one in spring and one in summer. In 1990, an abbreviated spring fine scale was completed, but due to budget constraints that year the summer fine scale and broad scale surveys were postponed to 1991. During the spring 1990 fine scale survey 31 transects were surveyed.

For both the broad and fine scale survey sites, transect starting points were randomly selected within potential urchin habitat (defined as less than 50% sand substrate). Transect lines, 30 m long x 2 m wide, were laid on an approximate north/south compass bearing, along depth contours at 4.6, 10.7 and 15.2 meters (+/- 1.5 m). Each transect was partitioned into six 5 m long sectors. Each sector was surveyed, with the aid of a movable 1 m long pvc pipe segment on either side of the line, and data was recorded separately for each adjacent 1 m x 5 m quadrat.

This was the most significant departure from previous surveys in which we surveyed 30 m x 1 m lines.

Most of the divers working the 1988 surveys also worked the 1989, 1990, and 1991 surveys. Divers counted all exposed red urchin in each quadrat. Crevices and algal turf were also searched for red urchin. The test diameter of the first 25 red urchin encountered by divers, beginning on opposite ends and working on opposite sides of the line, was measured to the nearest 5 mm. These urchin were removed from the substrate to check for cryptic canopied conspecifics. Red urchin smaller than 5 mm were considered too small to be consistently visible to the divers and were excluded from the survey. Red urchin exhibiting spine or test overlap, with one or more red urchin providing shelter for one or more smaller conspecific urchin were considered to be a canopy group (Sloan, Lauridsen and Harbo 1987). Red urchin of similar size merely aggregated or touching spines were not considered canopy groups. Canopy-grouped red urchin within the first 25 encountered were measured and categorized as sheltered or shelter-providing. Following completion of the measurement phase, each diver continued to count red urchin along the remainder of the transect line.

In 1991, we also sampled 239 one-half square meter plots placed approximately three meters off the left side of a selection of the regular transects, in part to assess the accuracy of our transect sampling method in determining the number of juvenile red sea urchin. Juvenile red sea urchin were defined in this study as red urchins with a test diameter <= 50 mm (Sloan, Lauridsen and Harbo 1987) and one-year-olds as red urchins with test diameters <= 30 mm. Pearse and Hines (1987) defined one-year-olds in a 1975 California cohort as being between 20 and 40 mm, with a major mode between 26 and 30 mm. Tegner and Barry (1989) defined young-of-the-year red sea urchin as having a test diameter <=35 mm. This definition was based on a growth study conducted at Pt Loma, California; however, they felt that growth was probably somewhat faster in southern California waters. Recent work by Ebert, Dixon and Schroeter (1992) suggests that on average, 15 mm size red urchin may grow to 30 mm in about a year, but that urchin smaller than 15 mm actually may grow more slowly.

A diver searched as many contiguous plots as time allowed. Small rocks were overturned and replaced, crevices were searched, and all red sea urchin found within a plot were counted, measured, removed and examined on the oral surface for clinging juveniles. Plots were characterized by substrate-type and by the presence of other organisms in the same manner as the regular 30 m transects.

Additional information collected on the surveys included; (i) percent of area covered by type of substrate (boulder-bedrock, cobble, or sand), (ii) percent of area covered by type of algae (canopy, subcanopy, turf, or encrusting), (iii) number of red urchin competitors including exposed purple sea urchin, *S. purpuratus*, and exposed red abalone, *Haliotis rufescens*, pinto abalone, *H. kamschatka* and flat abalone, *H. wallalensis*, and (iv) number of exposed sea stars by species or genus, including the sunflower star, *Pycnopodia helianthoides*, a sea urchin predator (Morris, Abbott and Haderlie 1980), and members of the genus *Pisaster*. Substrate and algae determinations were made at 10 meter intervals along the transect line.

RESULTS
Broad Scale Survey

Size Composition

The mean test diameter (MTD) of randomly-sampled red urchin at all broad scale locations was 77 mm (SD 36 mm), with the smallest urchin in the 5-10 mm interval and the largest in the 165-170 mm interval (Figure 6). This is a decrease in mean size from the two previous broad scale surveys. Mean test diameters in 1988 and 1989 were 92 mm and 90 mm (Figure 7). Some of this difference could be due to the reduced survey area in 1991. However, in 1991 there was a marked increase in the percent frequency of red urchin under 50 mm, particularly in comparison to 1989.

By Coastal Zone

South of Point Arena, the mean test diameter was 81 mm (SD 41 mm). The relatively high standard deviation indicates a rather wide size distribution. The Point Arena North distribution had a smaller MTD (75 mm) and appeared bimodal with modes at 30-35 mm and 90-95 mm (Figure 8). In 1988 and 1989, the most northerly sites (sites 19-22) had the lowest mean size and the lowest percentage of red urchin over 90 mm. The present commercial minimum size limit is 89 mm. Size frequency distributions between the two coastal zones were significantly different (Table 2).

By Depth Zone

Mean sizes were significantly different by depth (ANOVA, $p<0.0000$). The mean test diameter at the 4.6 m depth zone was 29 mm larger than at the 15.2 m depth, and 5 mm larger than the intermediate depth (Table 3). A reduction in size with depth was evident in 1991 as in all three survey years. Size classes above 100 mm were sparsely represented in the 15.2 m depth zone (Figure 9). Size frequency distributions between the 15.2 m depth and the two shallower depth zones were significantly different in pairwise comparisons (Table 4). The inverse relationship between depth and test diameter noted in past surveys was stronger in 1991 in the Point Arena North zone than the Point Arena South zone (Figure 10).

Recruitment

It is important to note that size frequency distributions are presented in terms of *percent* frequency. Relative frequency for given size classes may increase or decrease from zone to zone or survey to survey but does not account for changes in density. Size frequency data needs to be viewed in the context of density data to make accurate population or recruitment assessments.

Juveniles totaled 28.4% by number, and one-year-olds 16.1% from all sites combined, compared to 7.3% and 3.1%, respectively in 1989. When partially corrected for harvesting pressure by removing urchin greater than 90 mm from the analysis (Tegner and Dayton 1981), the values increased to 45.8% for all juveniles and 26.0% for one-year-olds, compared to 13.9% and 6.0%, respectively in 1989 (Table 5). The percentage of commercially legal individuals greater than 90 mm was 38.0%, with approximately even distribution between coastal zones.

Analysis by depth zone indicated higher frequencies of juveniles at the 10.7 m and 15.2 m depths than at the 4.6 m depth; this was also the case in 1989 and in 1988. Commercially sublegal individuals (5-90 mm) were also more abundant in the deeper depth zones (Table 5).

The coefficient of variation (CV) was calculated for red urchin at each broad scale site as an index of recruitment (Ebert and Russell 1988). Larger CV's can indicate a distribution with a wide range of sizes relative to the mean and so could be an indication of more frequent recruitment. A mean CV was calculated for combined sites and the deviation of each site from the mean was plotted. As in 1989, five of the sites north of Point Arena showed some positive deviation (Figure 11).

Canopy Grouping

The size frequency distribution of canopy-grouped red urchin displayed a characteristic bimodality with a mean of 55 mm. The distribution of non-canopied urchin was much less bimodal, with relatively fewer juveniles (Figure 12). The mean size of canopy-providers was 94 mm compared to 25 mm for sheltered conspecifics. Survey-wide, canopy-providers and sheltered conspecifics were present in a ratio of 1.00 to 1.27 (Figure 13).

A total of 46.2% of all juveniles were sheltered under canopy, compared to 45.6% in 1989. Sheltered juveniles comprised 13.1% of all measured urchin, but made up only 5.8% of the total in the Pt Arena South zone (Table 6). In 1988, a lower percentage of juveniles were sheltered (32.8%).

Density

The mean red urchin density for all sites combined was 0.71 per square meter (m^{-2}) (SD 1.9).

In 1989 the mean density for all sites was 1.1 m^{-2} (SD 2.4), and in 1988 the mean density was 1.3 m^{-2} (SD 2.0). The 1988 and 1989 mean densities were significantly different (ANOVA, $p<0.0000$). Individual site densities in 1991 ranged from a low of 0.0 red urchin m^{-2} at the Sail Rock site (site 11) to a high of 2.2 m^{-2} at the Van Damme Headland site (site 21). Unlike surveys in previous years, there were no 'high density sites' (Table 6). Red urchin densities were also significantly different between depths (ANOVA, $p<0.0000$). As in 1988 and 1989, the 4.6m depth zone density was markedly lower than densities in each of the deeper depths (Table 7).

Density by size-category for each of the depth zones confirms the suggestion from analysis of the size frequency data that the shallowest depth zone had the lowest numbers of red sea urchin in all size intervals, particularly in the smaller size categories (Figure 14).

Almost 65% of the 460, 1 m x 5 m quadrats examined in all areas contained no red urchin, a figure that was higher than in any previous survey (Figure 15). The distribution of red urchin counts is a classic negative binomial featuring a high variance to mean ratio (mean 3.6, var. 90.7) characteristic of contagiously distributed populations. This type of population distribution can hinder accurate assessment as both patch number and patch mean size decrease (Elliott 1977).

Habitat and Competitors

Boulder-bedrock was the dominant substrate at all sites regardless of depth, and accounted for over 90% of the identified substrate types. Unlike past years, algae, except for the turf category (foliose algae or articulated corallines less than 0.3 m above the substrate), was most abundant at the 10.7 m depth zone (Table 8).

Overall, red urchin densities were higher than those for purple urchin, red abalone, sunflower star, and all other macroinvertebrate categories enumerated in both coastal zones (Figure 16). As in 1989, red abalone mean transect counts exceeded those of red sea urchin at the 4.6 m depth zone. Red abalone was the dominant abalone, showing a definite inverse relationship between density and depth zone. The *Pisaster* sea star category was the most abundant of the emergent sea stars examined at the 10.7 and 15.2 m depths. Sunflower stars were more common at the 4.6 and 10.7 m depth zones than at 15.2 m. Red urchin were at least twice as abundant as the other macroinvertebrates at the 10.7 and 15.2 m depths. Purple sea urchin were less abundant than red abalone at the 4.6 and 10.7 m depth zones.

Van Damme Headland (site 21) at 10.7 m had the highest count of red urchin (196) as well as the highest count of purple urchin (200). Interestingly, this site and depth had the highest counts of red and purple urchin (285 and 208, respectively) in 1989 as well. Cavanaugh Gulch (site 18) at 10.7 m had the highest red abalone count (45), while Schooner Gulch (site 12) at 15.2 m had the highest *Pisaster* count (33) (Table 8).

Fine Scale Surveys

The fine scale survey yielded size frequency and density data from 63, 2 m x 30 m transects at nine sites between Fort Bragg and Mendocino in the Fort Bragg area (Figure 17). The Caspar Commercial Urchin Closure Area and Point Cabrillo Marine Reserve were intensively surveyed to assess red urchin in a variety of microhabitats including northern and southern wave and swell exposure, surge channel, and protected reef pool (Figure 18).

Size Composition

The mean red urchin test diameter at all sites sampled in the 1991 survey was 94 mm (SD 29 mm) with a range of 5-155 mm (Figure 19). Point Cabrillo Marine Reserve, Caspar Closure Area and combined fished site MTD's were 94 mm (SD 34 mm), 95 mm (SD 27 mm), and 91 mm (SD 27 mm), respectively (Figure 20). The PCMR MTD was unchanged from the summer 1989 survey. Size frequency distributions from all three areas showed an approximate bimodality, with the lower mode in the 15 to 40 mm range. This mode of smaller animals was not evident in the 1989 data, but is echoed in the 1991 broad scale data (Figure 6).

As in past surveys, stratification of size by depth was evident in the combined fished sites, as well as in the PCMR and the Caspar Closure Area, with a 6-17 mm mean size difference between urchin from the 4.6 and 15.2 m depths (Table 9). The 15.2 m depth zone yielded smaller urchin on average.

Recruitment

Juveniles (<= 50 mm test diameter) and one-year-olds (<=30 mm) totaled 11.7% and 7.6% of all red urchin sampled during the fine scale survey. These percentages are higher than the 1989 summer values of 9.4% and 3.4%. However, there are reduced red urchin densities in the fished sites compared to past years and as larger urchin are removed from these sites, those size classes remaining make up a relatively greater proportion of the size distribution. As in past surveys, PCMR subsites had higher juvenile frequencies than did harvested sites (15.4% versus 12.4%) (Table 9).

Conclusions regarding stratification of recruitment by depth zone are difficult to make due to limited data; but, the trend for fewer juveniles at shallower depths agrees with observations made from past surveys. The 15.2 m depth had the highest number of juvenile red urchin averaged over all survey sites. Often, this depth stratum has the lowest density of foliose algae, which could be a factor in either attracting new recruits, increasing survival of newly settled urchin or allowing divers to see them more easily.

Canopy Grouping

More juveniles were under canopy in the fine scale survey (69.9%) than were observed in the broad scale survey (46.2%). These canopied juveniles made up 8.2% of all measured urchin. More juveniles were under canopy in the PCMR (77.4%) compared to fished sites (65.2%) and the Caspar Closure Area (65.1%). In the 1989 fine scale survey, 66.2% of the juveniles were under canopy at fished sites. The canopy-provider to canopied urchin ratio from all sites combined was 1:1.06.

Density

In the fine scale survey, the fished sites yielded 0.34 (SD 1.1) red urchin m^{-2} while the PCMR site had 7.0 m^{-2} (SD 6.2) (Tables 10 and 11). Harvested-site mean densities ranged from 0.0 urchin m^{-2} at Noyo Bay to 1.1 at Beaver Pt. (Table 12). The Caspar Closure Area had an average density of 3.7 urchin m^{-2} (SD 5.2) (Table 13). These densities compare to 5.4 m^{-2} at PCMR, 2.3 at the Caspar Closure Area and 1.7 at fished sites in 1989.

Density varied significantly by depth (ANOVA, $p<0.0000$) at the Caspar Closure Area and the PCMR, but not at the combined fished sites ($p=0.593$) (Tables 10, 11 and 13). At PCMR and Caspar, the shallowest depth had the lowest density of red urchin (Figure 21).

The proportion of 1 m x 5 m quadrats within the PCMR with no red urchins was less than 15% and over 75% for combined fished sites, much higher than in previous surveys (Figure 22). Harvest-site densities were very low, particularly in comparison to densities in the smaller size intervals at the PCMR and the Caspar Closure Area. Densities of the 5-30 mm interval at the PCMR were about the same as the density for all size classes found in the broad scale survey in 1991 (0.71 m^{-2}) (Figure 23).

Habitat/Competitors

Boulder-bedrock substrate was prevalent at all sites (>= 53%) and at all depths during the fine scale survey. The highest densities of purple urchin were found at the 4.6 m depth zone at PCMR. The densities of red abalone were also highest here. As in past surveys, high red abalone densities were encountered at sites with either high or low urchin density. The high red urchin densities at PCMR and Caspar were accompanied by abundant encrusting and turf-type algaes (Table 14). PCMR had very low amounts of canopy and subcanopy-type algaes.

Saunders Reef

Transects at Saunders Reef, between broad scale sites 11 and 12, were surveyed at two depth zones (10.7 and 15.2 m). Mean density was 2.6 red urchin m^{-2} (SD 4.1) and MTD was 68 mm.

In 1989 mean density at Saunders Reef was 3.1 m^{-2}. A relatively high percentage of red urchin (34.6%) were under 50 mm TD. Saunders Reef consists of uplifted blocks of sand and siltstone bedrock forming alternating ridges and valleys. Many red urchin were found along linear cracks in the bedrock. The area was characterized by large numbers of purple urchin burrowed into the substrate, with many of the purple urchin canopied under red urchin.

Intensive Plots

Intensive 0.5 m^2 plots were sampled throughout the broad scale and fine scale survey range to assess the accuracy of juvenile urchin counts on the 30 m transects. Overall density was 2.3 red urchin m^{-2}, but only 1.4 m^{-2} outside the PCMR and the Caspar Urchin Closure Area. MTD within the plots was 79 mm, with 22.3% under 50 mm, and 83.7% of juveniles $\leq$ 50 mm were under canopy (Fig 24).

DISCUSSION

Broad Scale Survey

The 1991 broad scale survey data suggest a 1989 recruitment event, indicated by a mode in the 15-35 mm size interval (Figure 6). Apparently, the 1987 and 1988 cohorts were not well represented in the population in 1991 as evidenced by the relatively low densities in the 51-90 mm size interval and the clearly bimodal size distribution (Figure 7).

Juveniles comprised 28% of all red urchins measured during the broad scale survey. This is an increase compared to 1989 data (7.3%). However, a steady decline in density of animals greater than 90 mm accounts for part of this increase. A decline from 0.67 in 1988 to 0.51 in 1989 and finally to 0.27 m^{-2} in 1991, represents a 60% decline in abundance of legal sized animals in three years.

In 1991, the 10.7 and 15.2 m depth zones yielded the highest densities of urchin for all size intervals combined, with the 10.7 m depth having the greatest density in all but one size interval (31-50 mm). The largest mode at 15.2 m was the 20-25 mm interval (Figure 9). The commercial fishery is concentrated in subtidal areas that we characterize as the mid-depth to deep depth zones (6.1 to 18.4 m).

Adult-juvenile canopy associations were similar to those observed in 1989, with just under 50% of the juveniles canopied under adult spine or test compared to 45.6% in 1989. The juveniles to adult ratio (1.27) in this association was slightly higher than observed in 1989 (1.01). Yet, this ratio is much lower than the ratio reported in southern California surveys where as many as 30 juveniles canopied per adult have been noted in these associations (Tegner and Barry 1989). Canopy-providers were also much larger than in northern California (80% of canopy-providers in southern California were between 90 and 129 mm). In 1991, 54.7% of canopy-providers were under 90 mm test diameter, compared to 49% in 1989. Interestingly, the largest canopy-provider mode was the 85-90 mm size interval (21.3%), just under legal size. It appears that the 89 mm (3.5 inch) minimum size limit performs an important function in protecting the remaining canopy-providers (Figure 13).

Fine Scale Survey

The bimodal size frequency distributions apparent at PCMR in 1988 and in the current survey year were not evident in 1989. This pattern was also evident in the broad scale survey data. PCMR was surveyed six times between spring 1988 and summer 1991 (Figure 25). The size frequency distributions from the first three sampling events (sampled within a 12 month period) show a similar pattern in the smaller size intervals. By the 1989 summer survey, the 20-30 mm mode had shifted to 40-45 mm. Eight months later, in spring 1990, it was in the 65-75 mm range. Sixteen months later, in summer 1991, the mode was lost in the greater than 90 mm group. Also, a new mode at 15-35 mm was apparent, having recruited in the 16 month interval since the previous survey.

PCMR densities remained fairly stable with 6.7 m^{-2} (SD 6.9) in the summer 1988 survey, 5.4 (SD 5.8) in summer 1989, and 7.0 (SD 6.2) in the summer 1991 survey. This stability would be expected in an unfished area subject only to natural mortality and low, relatively regular recruitment.

The Caspar Closure Area was closed in spring 1989. Prior to the closure, in summer 1988, there were 4.5 red urchin m^{-2} (SD 5.6). In the summer 1989 survey there were 2.3 m^{-2} (SD 3.2) and 3.7 (SD 5.2) in the summer 1991 survey. The increase in density in the two years between the post-closure surveys may represent a recovery due in combination to the recruitment event noted in 1991 and the closure to fishing. However, densities still do not approach the pre-closure level.

A shift of the 70-90 mm mode apparent in summer 1989 to 90-110 mm at Caspar in summer 1991 represents a 20 mm size increase in two years (Figure 26). Bernard and Miller (1973) developed a growth curve for red urchin at a location in British Columbia, Canada, which suggests a period of approximately 1.1 years to grow from 70 to 90 mm (approximately 2.8 years old at 70 mm and 3.9 years old at 90 mm). Tegner and Barry (1989) developed a growth curve for red urchin at Pt. Loma, California that suggests growth from 70 to 90 mm may take 1.3 years with a 90 mm red urchin being about 3.6 years old. Ebert and Russell (1992) studied two intertidal red sea urchin populations at San Nicolas Island, California. Using a tetracycline tagging method they developed a growth equation which estimates the age of a 70 mm red urchin to be about 5.5 years and a 90 mm urchin to be as old as 24 years. This comparatively slow growth rate may be due to the fact that Ebert and Russell worked with an intertidal rather than a subtidal urchin population.

The 1991 broad scale survey showed that 62.0% of the red urchin were sublegals (under 90mm TD), contrasted with 52.6% in 1989 and 46.5% in 1988. The increasing percentage of sublegals in northern California is much more an effect of fishing down larger size classes than increasing recruitment as shown by the actual decline in densities of sublegals in the surveys.

Ebert and Russell (1992) used recruitment rates to estimate total mortality (Z) in a stable urchin population where mortality is balanced by recruitment. This condition is probably approximated at the PCMR. Recruitment rates (the proportion of red urchin less than 30 mm test diameter) at PCMR were 0.096 in 1988, 0.039 in 1989 and 0.097 in 1991. The average annual recruitment was 0.077 for these three sampling years. These estimates of Z compare with 0.076 and 0.075 determined for red urchin populations at two locations at San Nicolas Island by Ebert and Russell (1992) using the same method for red urchin less than 35 mm. The annual mortality rate for PCMR with a Z=0.077 would be, $1 - e^{-Z}$, or 0.074. Bradbury (1989) estimated the mean recruitment rate in the Strait of Juan de Fuca to be 0.097.

Kenner (1992) found densities of purple urchin at Stillwater Cove in Carmel Bay, California, to range from 6.5 to 12.7 per 0.25 m^2 quadrat, much higher than for any individual sites in our study. Our highest densities, which were at PCMR, ranged from 4.8 m^{-2} at the 4.6 m depth zone to a low of 1.6 at the 10.7 m depth zone. Red abalone densities at PCMR varied from 0.98 m^{-2} at the 4.6 m depth zone to 0.13 at the 10.7 m depth zone. Red abalone densities at PCMR in 1986 were 1.21 m^{-2} (Parker, Haaker and Henderson 1988).

SUMMARY

1. A total of 108 transects, covering 6480 square meters, was completed during the summer 1991 fine scale and broad scale surveys. Also, 239 0.5 m^2 plots were sampled. An additional 31 transects were surveyed during the spring 1990 fine scale survey.

2. Red urchin mean density for the broad scale sites was 0.71 m^{-2} (SD 1.9). Summer fine scale survey density for all harvested sites was only 0.34 m^{-2} (SD 1.1) compared to the Point Cabrillo Marine Reserve (PCMR) red urchin density of 7.0 m^{-2} (SD 6.2).

3. Relative abundance was variable within and among sites in all surveys; however, as in past surveys highest urchin densities were generally found at the 10.7 m and 15.2 m depth zones. The 4.6 m depth zone yielded the lowest mean density (0.17 red urchin m^{-2}) in the broad scale survey. No site in the broad scale survey had more than 2.2 red urchin m^{-2}.

4. A significant development in the 1991 surveys was the appearance of a mode in the 15-35 mm size interval, probably consisting of red sea urchin from the 1989 cohort.

5. About 62% of the red urchins sampled in the broad scale areas were under the 89 mm (3.5 inch) minimum test diameter size limit in 1991, contrasted with 52.6% in 1989 and 46.5% in 1988. Declines in density of legal sized animals continued, dropping from 0.67 m^{-2} in the 1988 broad scale survey to 0.27 in 1991.

6. 46.2% of juvenile (<= 50 mm) red urchin measured in the broad scale survey were under canopy, and juveniles represented 28.4% of all measured urchin. Juveniles accounted for 11.7% of red urchin from all sites of the fine scale survey, compared to 15.4% from the PCMR, and 12.4% from combined fished sites.

7. Average annual recruitment at PCMR over the 1988 to 1991 period was estimated as 0.077, yielding an estimated annual mortality rate of 0.074.

8. Though red abalone densities were usually lower than those of red urchin, mean red abalone counts were more than double those of red sea urchin at the 4.6 m depth zone in the 1991 broad scale surveys. In 1989 mean red abalone counts were only slightly higher than red urchin (0.62 m^{-2} versus 0.54 m^{-2}).

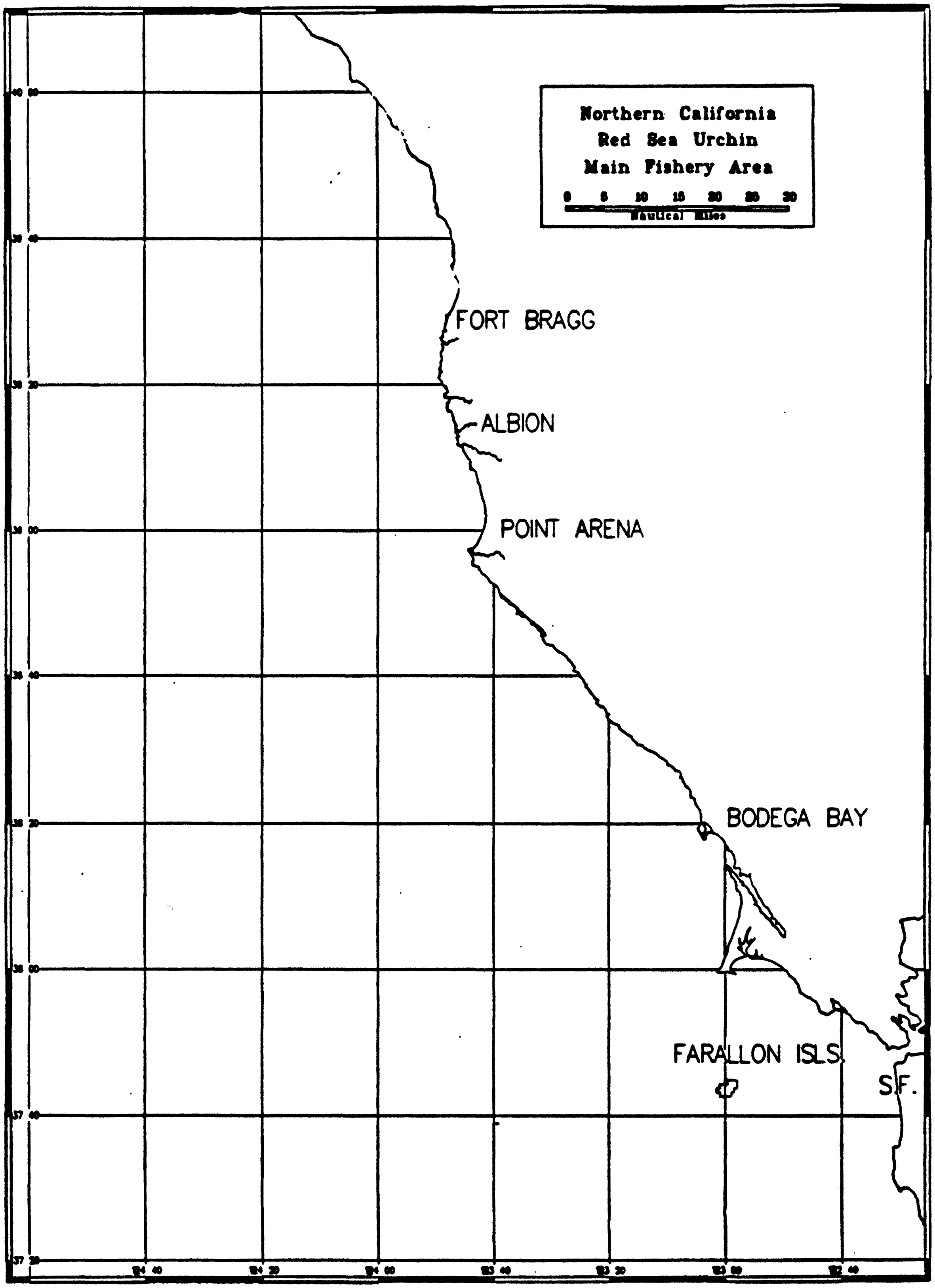

FIGURE 1. Northern California red sea urchin harvest area centered between Bodega Bay and Fort Bragg.

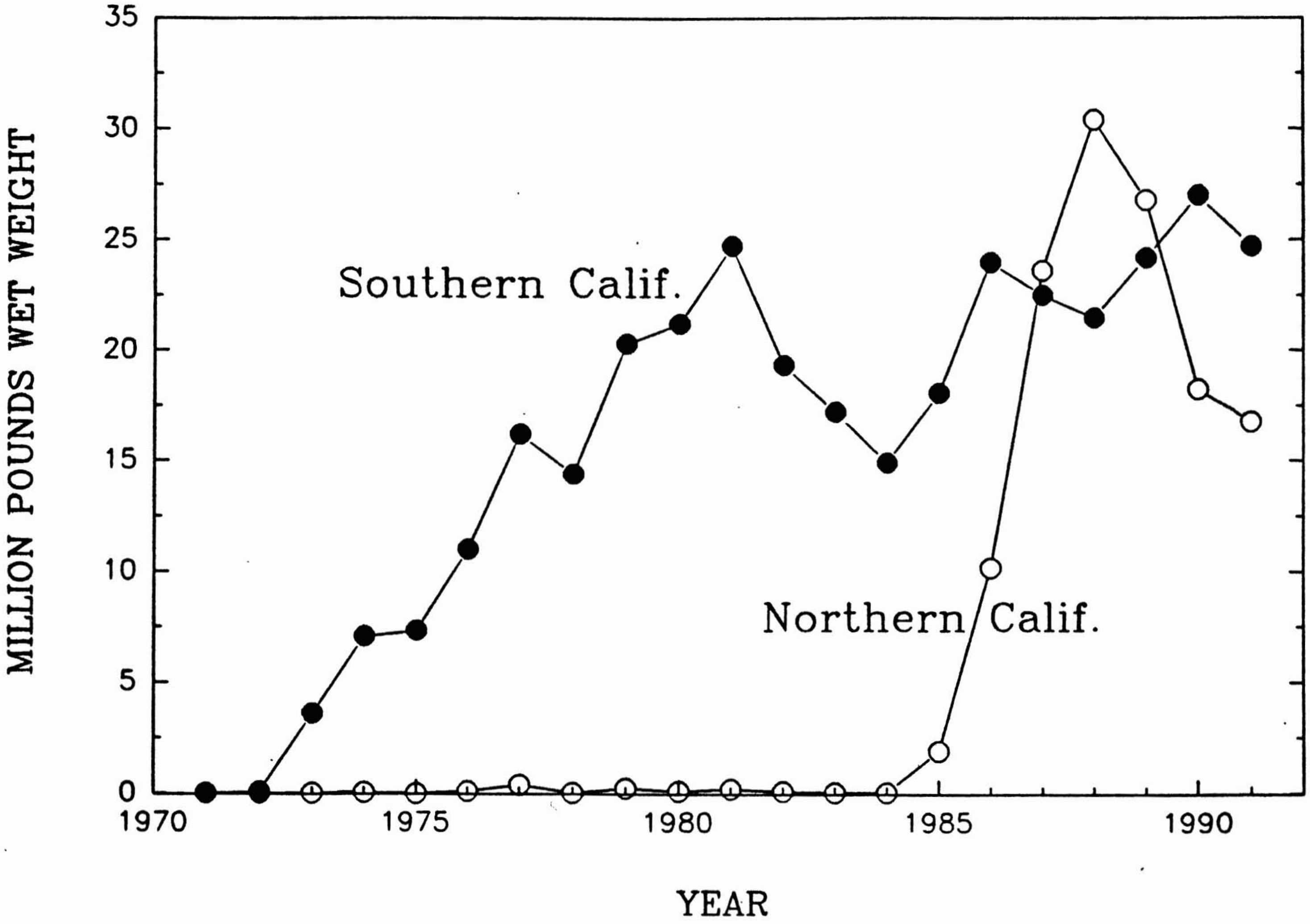

FIGURE 2. Commercial red sea urchin landings in northern and southern California from 1971 through 1991.

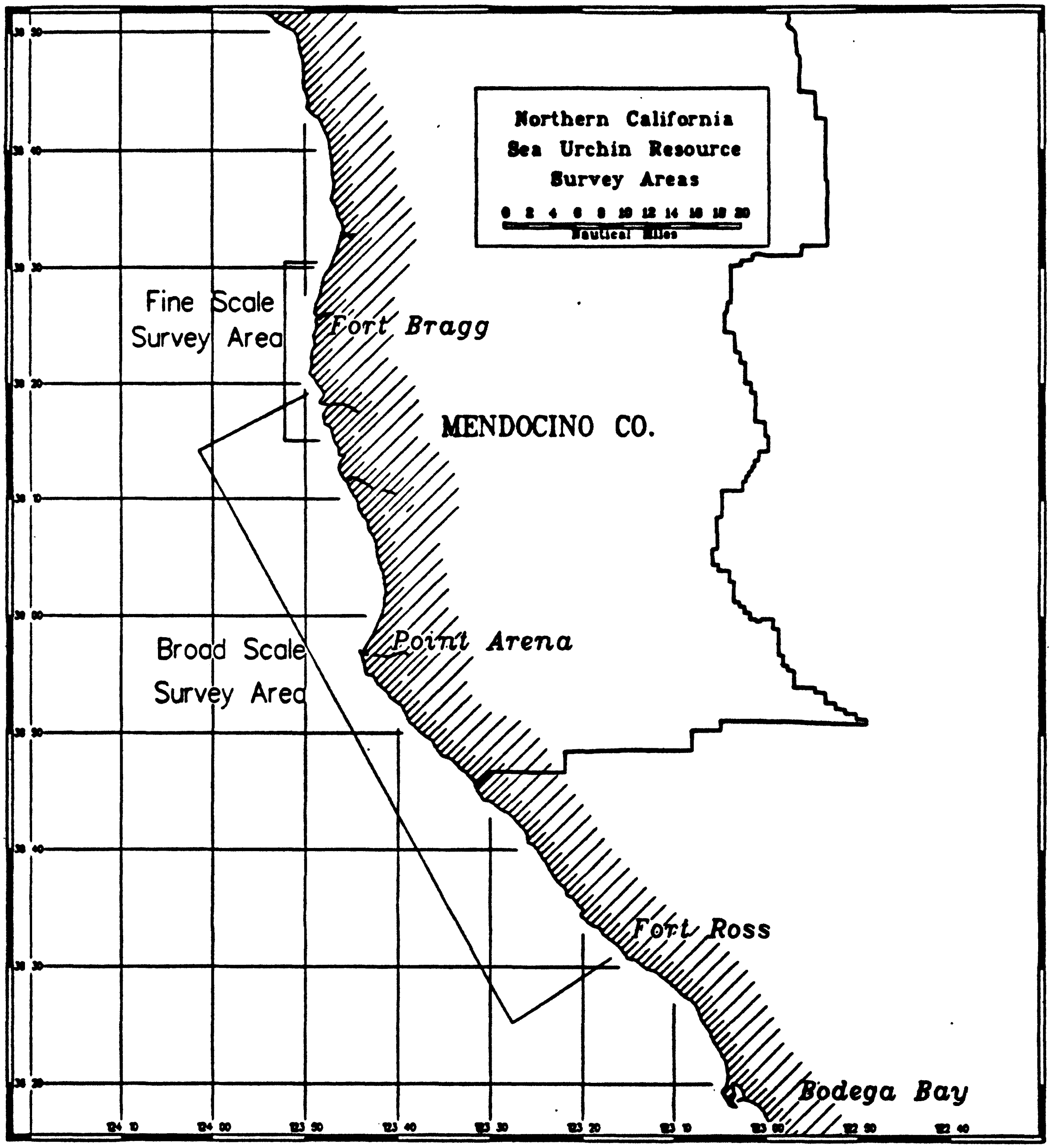

FIGURE 3. Northern California sea urchin resource survey areas showing fine scale (upper box) and broad scale areas.

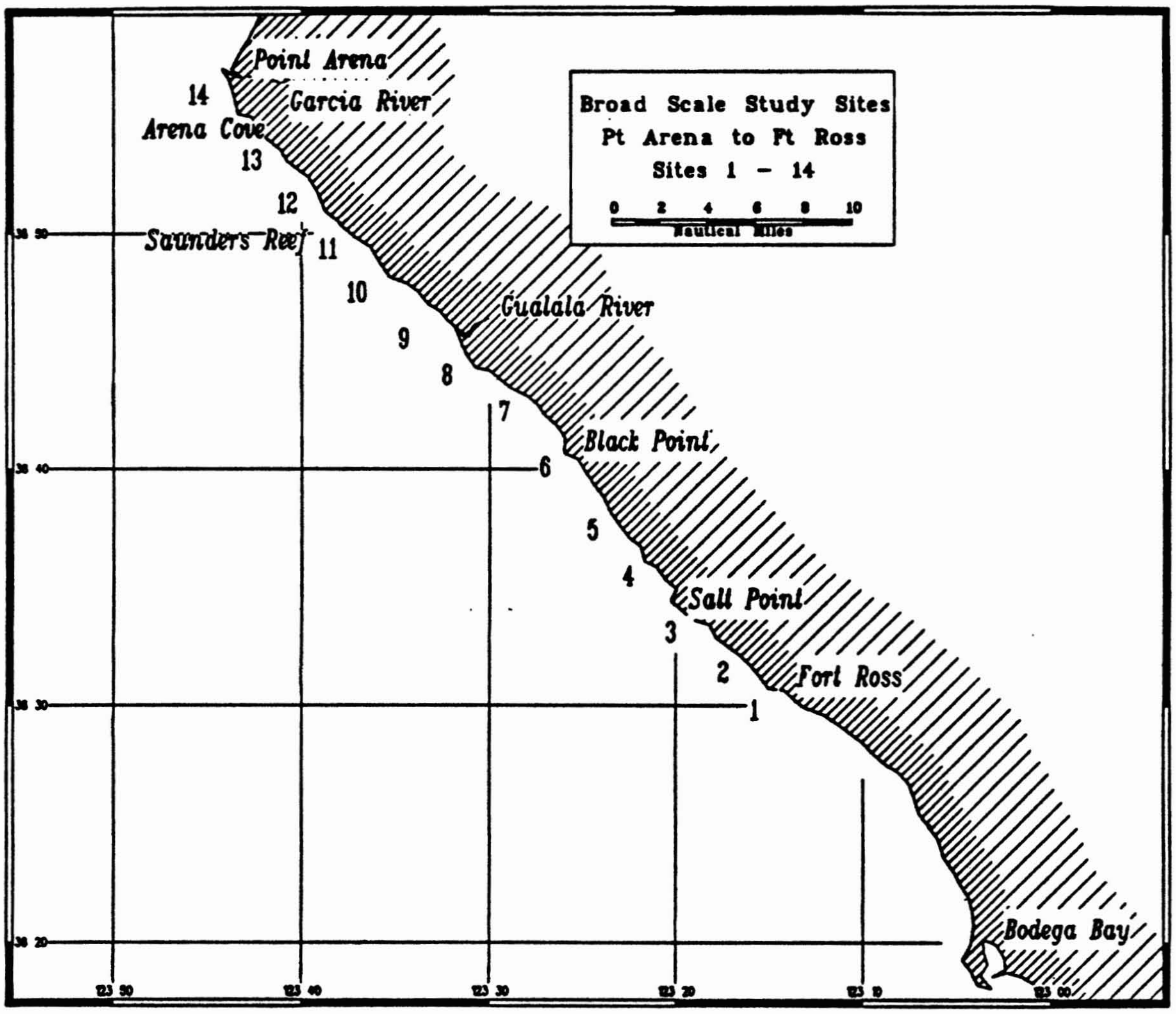

FIGURE 4. Broad scale study site locations in the Point Arena South coastal zone from the Gualala River to Point Arena, summer 1991.

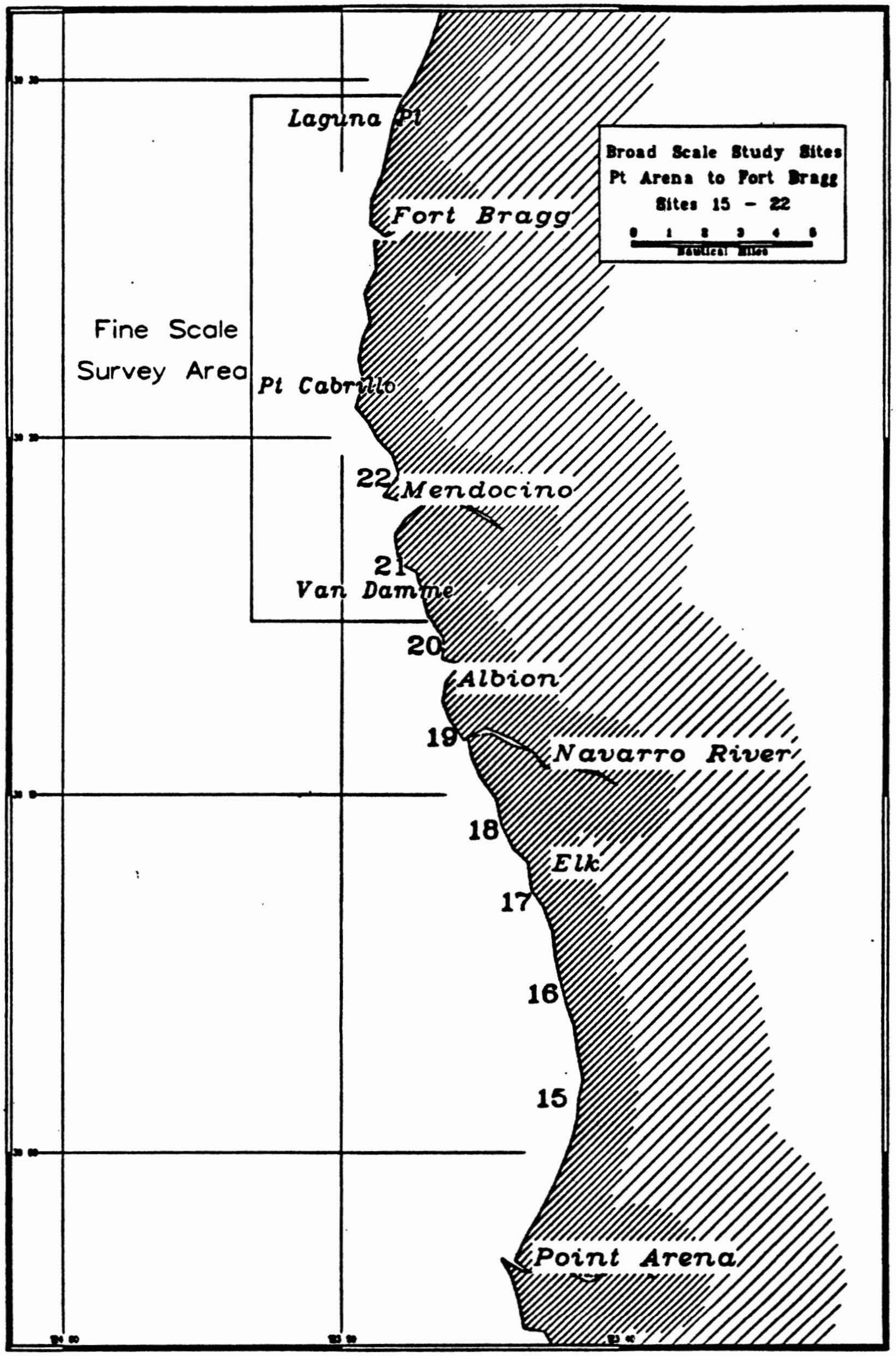

FIGURE 5. Broad scale study site locations in the Point Arena North coastal zone from Point Arena to Mendocino, summer 1991.

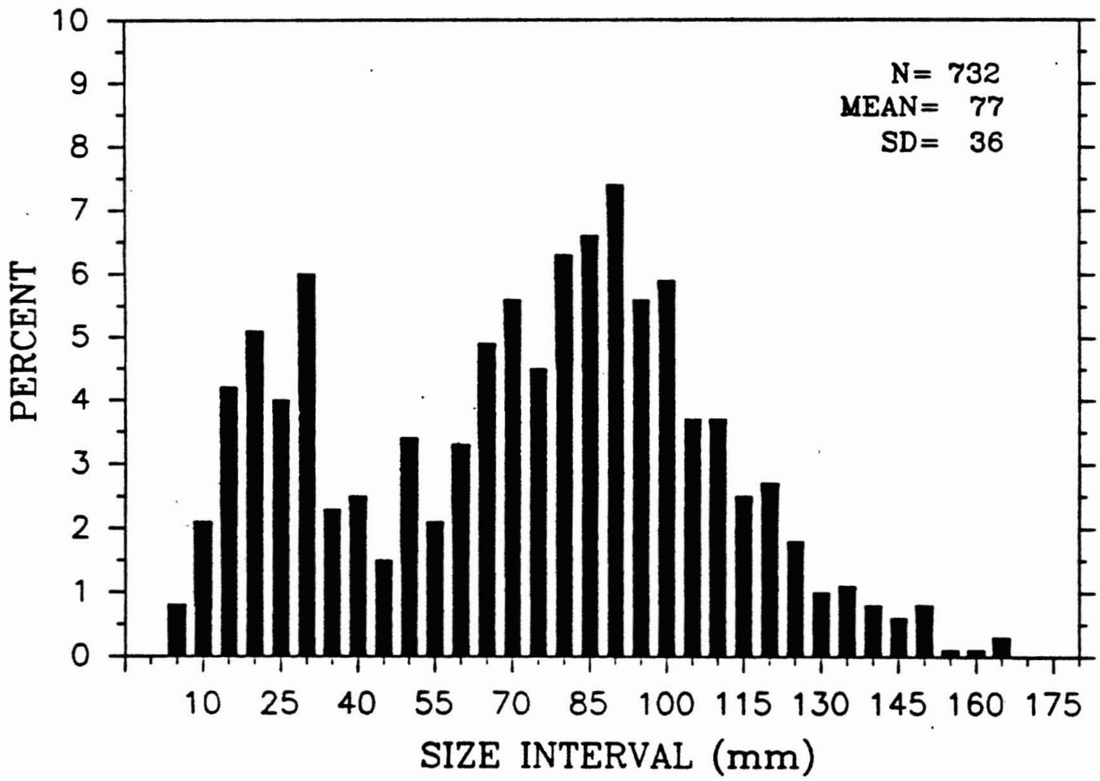

FIGURE 6. Frequency distribution of red sea urchin test diameters from all broad scale survey sites, summer 1991.

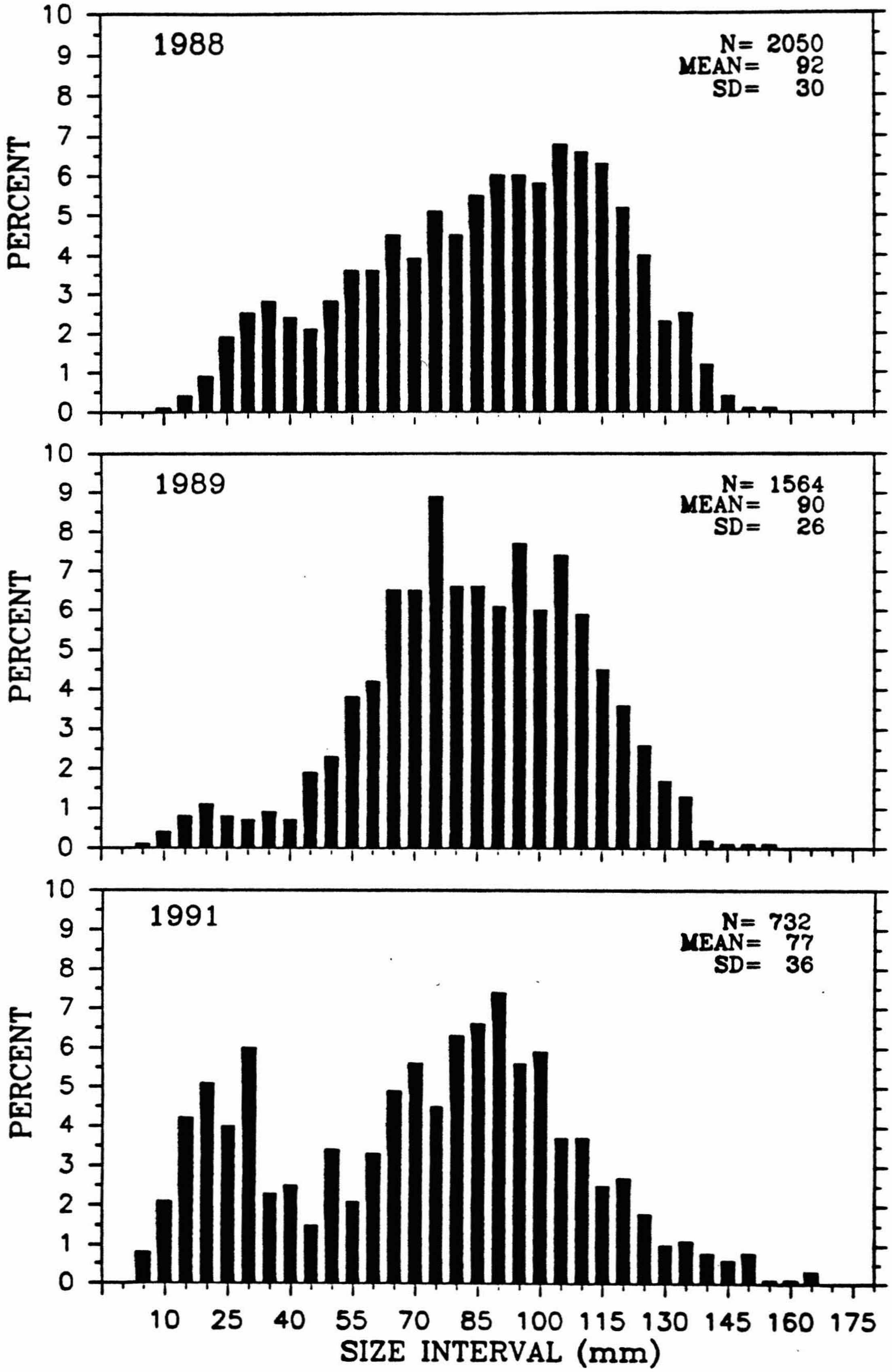

FIGURE 7. Frequency distribution of red sea urchin test diameters from the 1988, 1989 and 1991 broad scale surveys.

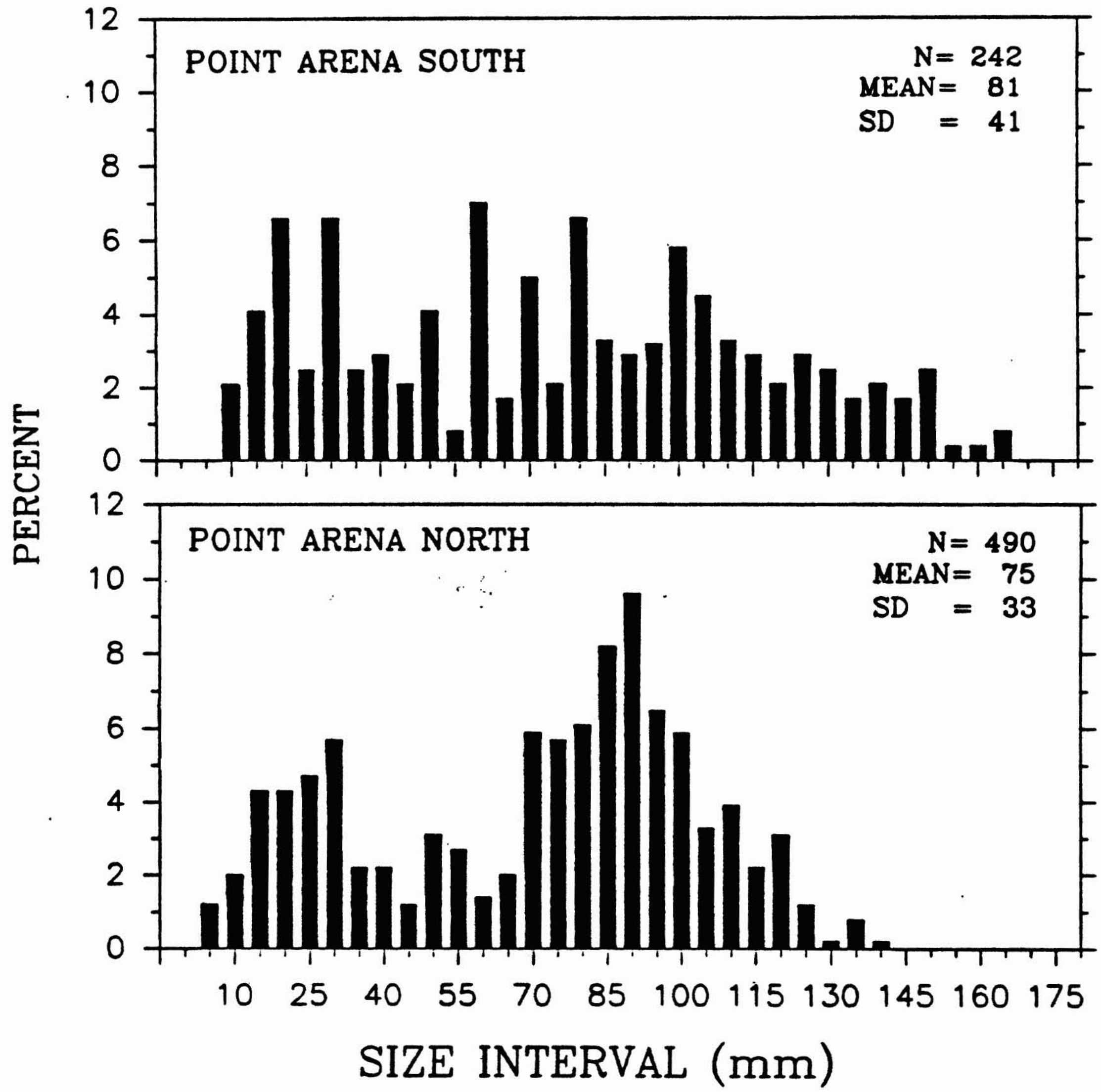

FIGURE 8. Frequency distribution of red sea urchin test diameters by coastal zone from all broad scale survey sites, summer 1991.

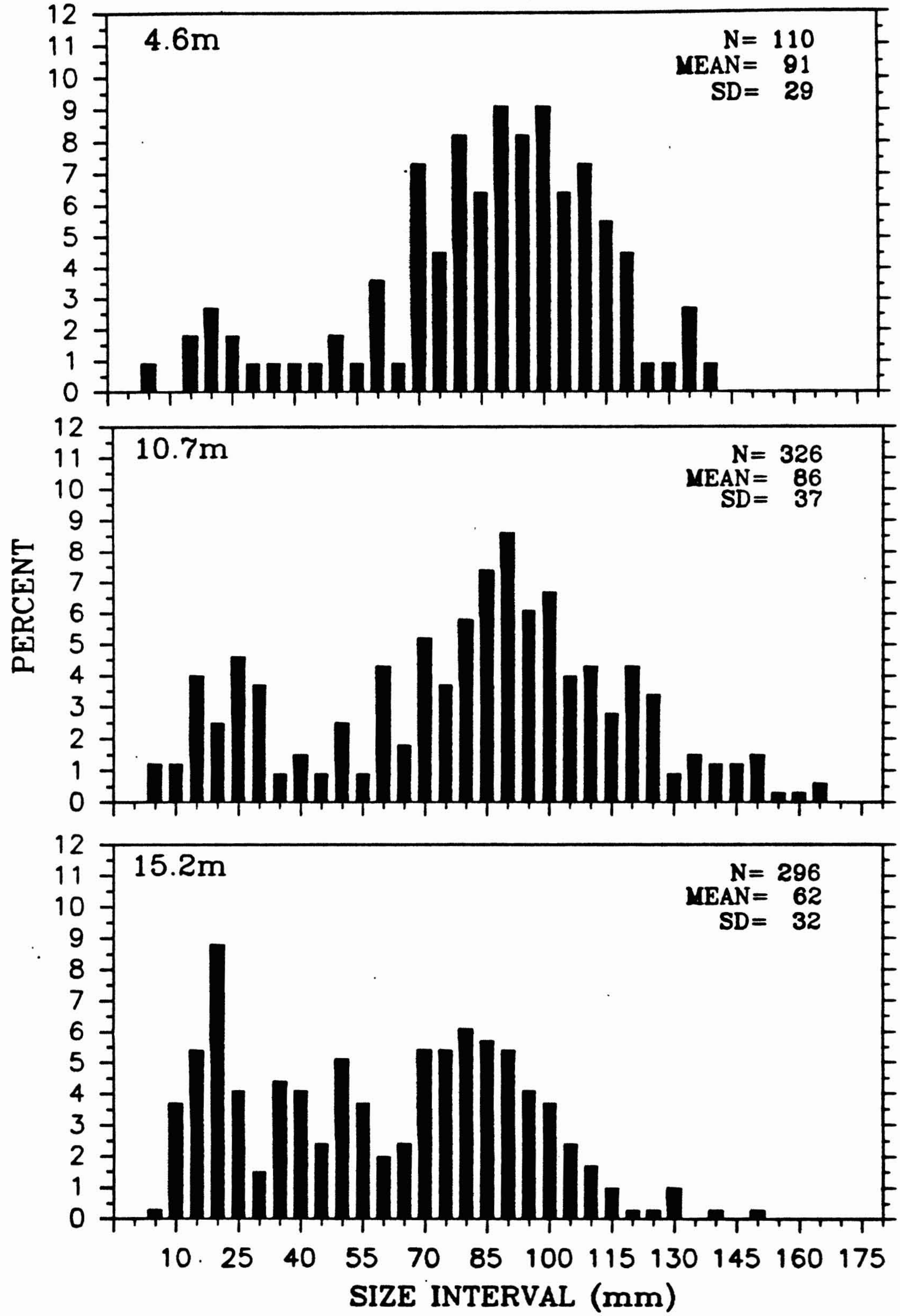

FIGURE 9. Frequency distribution of red sea urchin test diameters by depth zone from all broad scale survey sites, summer 1991.

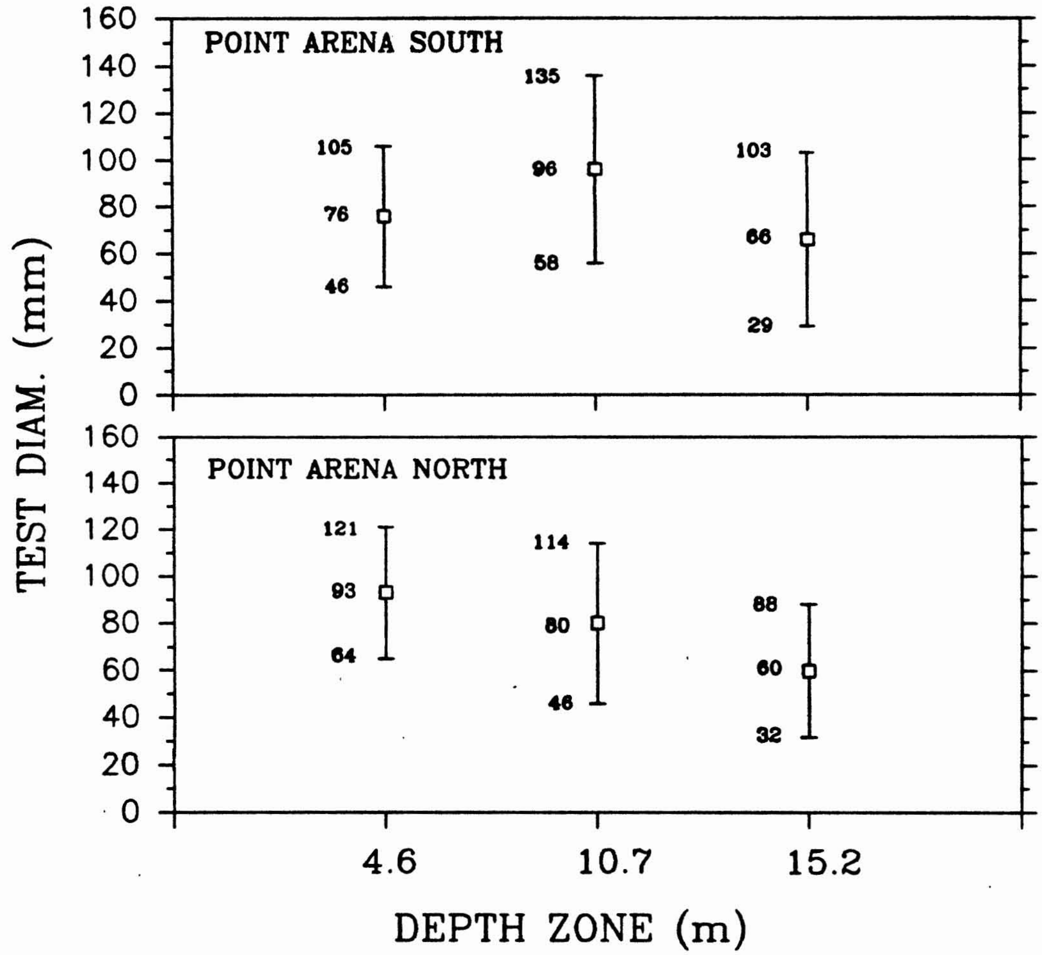

FIGURE 10. Mean and SD of red sea urchin test diameters by depth zone and coastal zone from the 1991 broad scale survey.

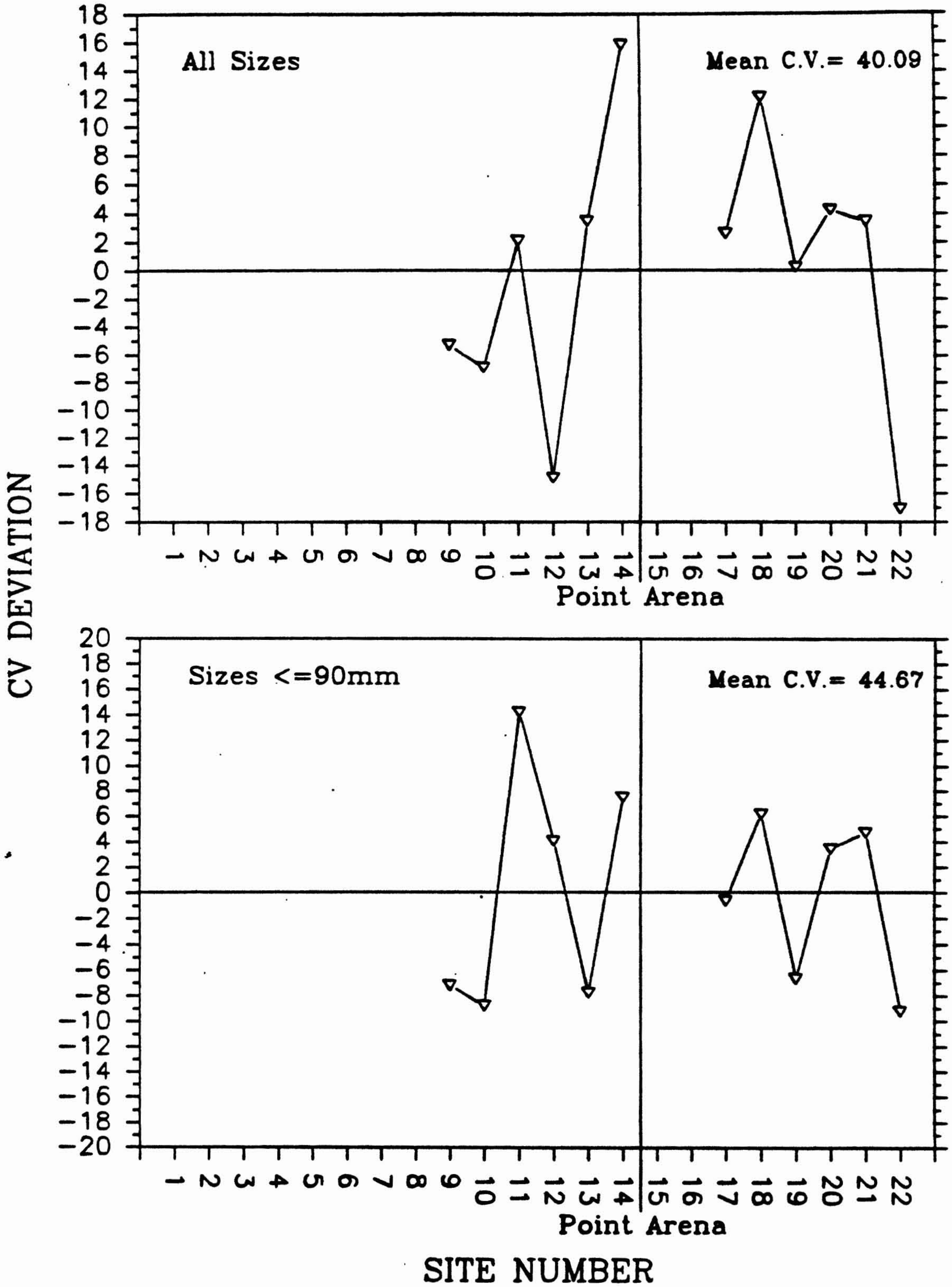

FIGURE 11. Deviations from the mean coefficient of variation (CV) for red sea urchin test diameters by site for all sizes and for urchins less than 90mm, broad scale survey.

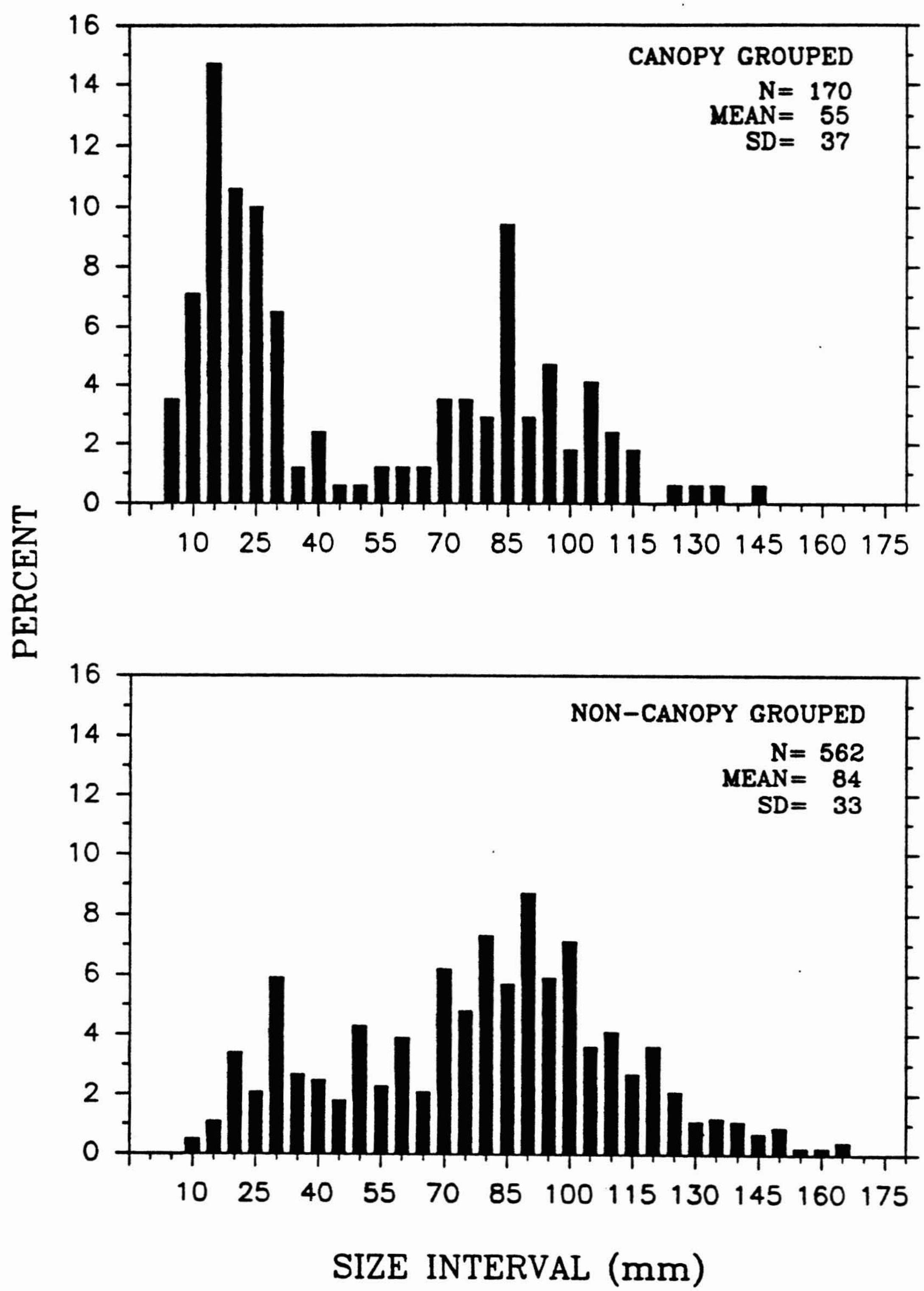

FIGURE 12. Frequency distribution of red sea urchin test diameters for canopy grouped and non-canopy grouped urchin from all broad scale sites.

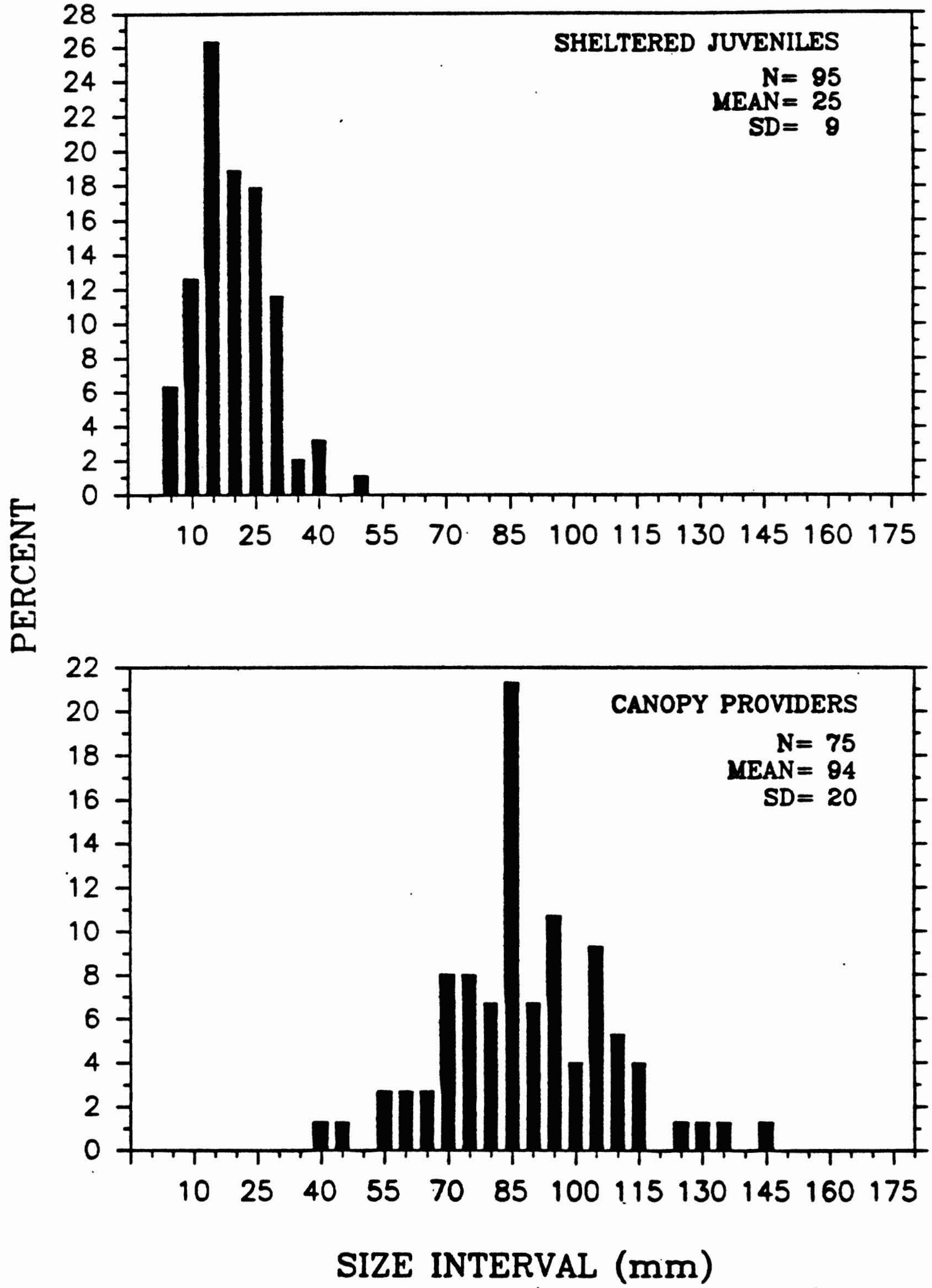

FIGURE 13. Frequency distribution of red sea urchin test diameters for sheltered juveniles and canopy providers from all broad scale sites.

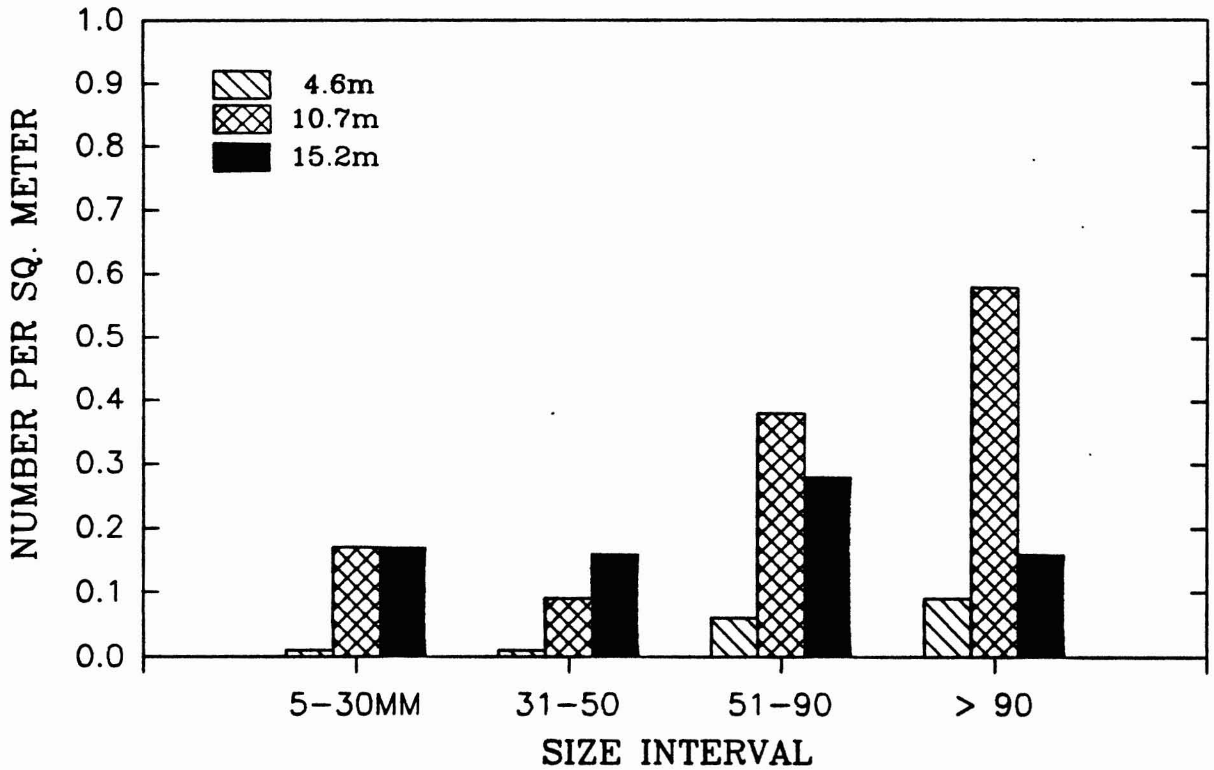

FIGURE 14. Red sea urchin densities by size category and depth zone, broad scale survey, 1991.

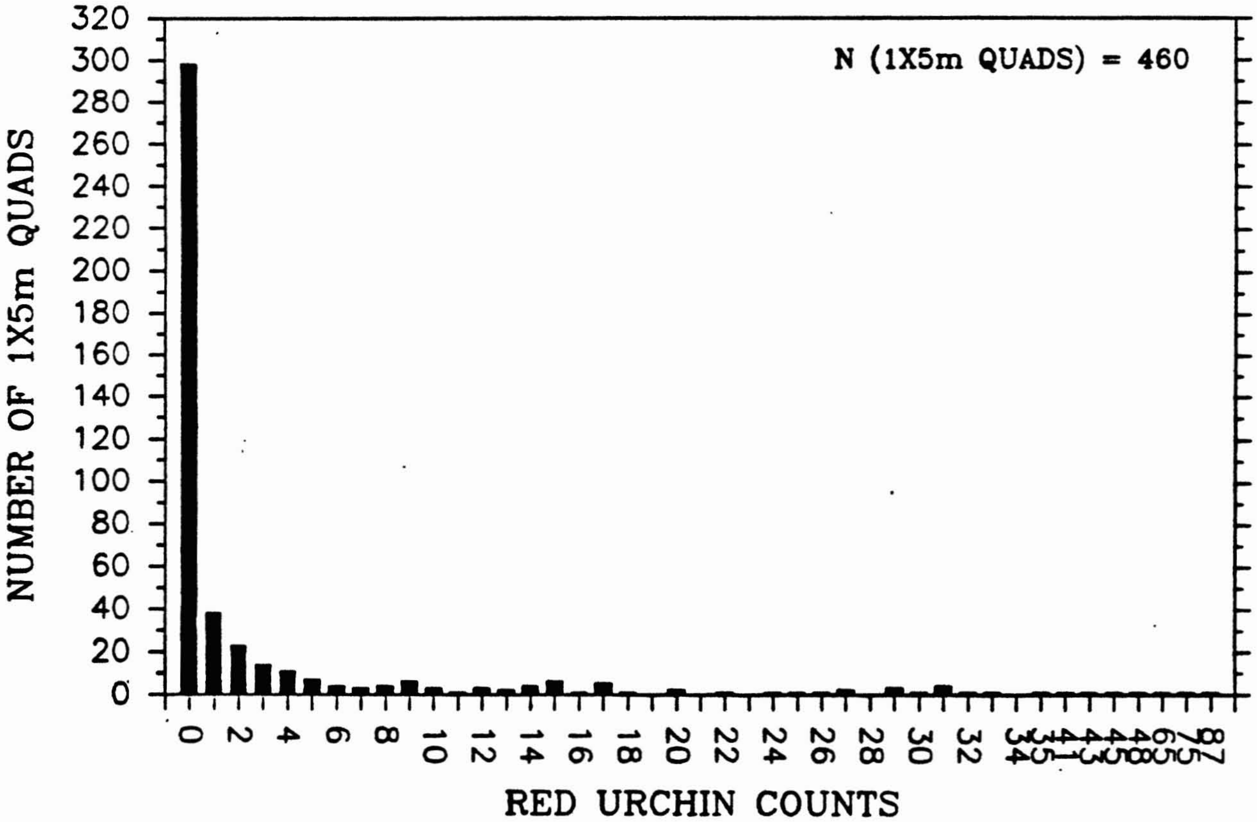

FIGURE 15. Frequency distribution of red sea urchin counts by transect quadrat for all broad scale survey sites.

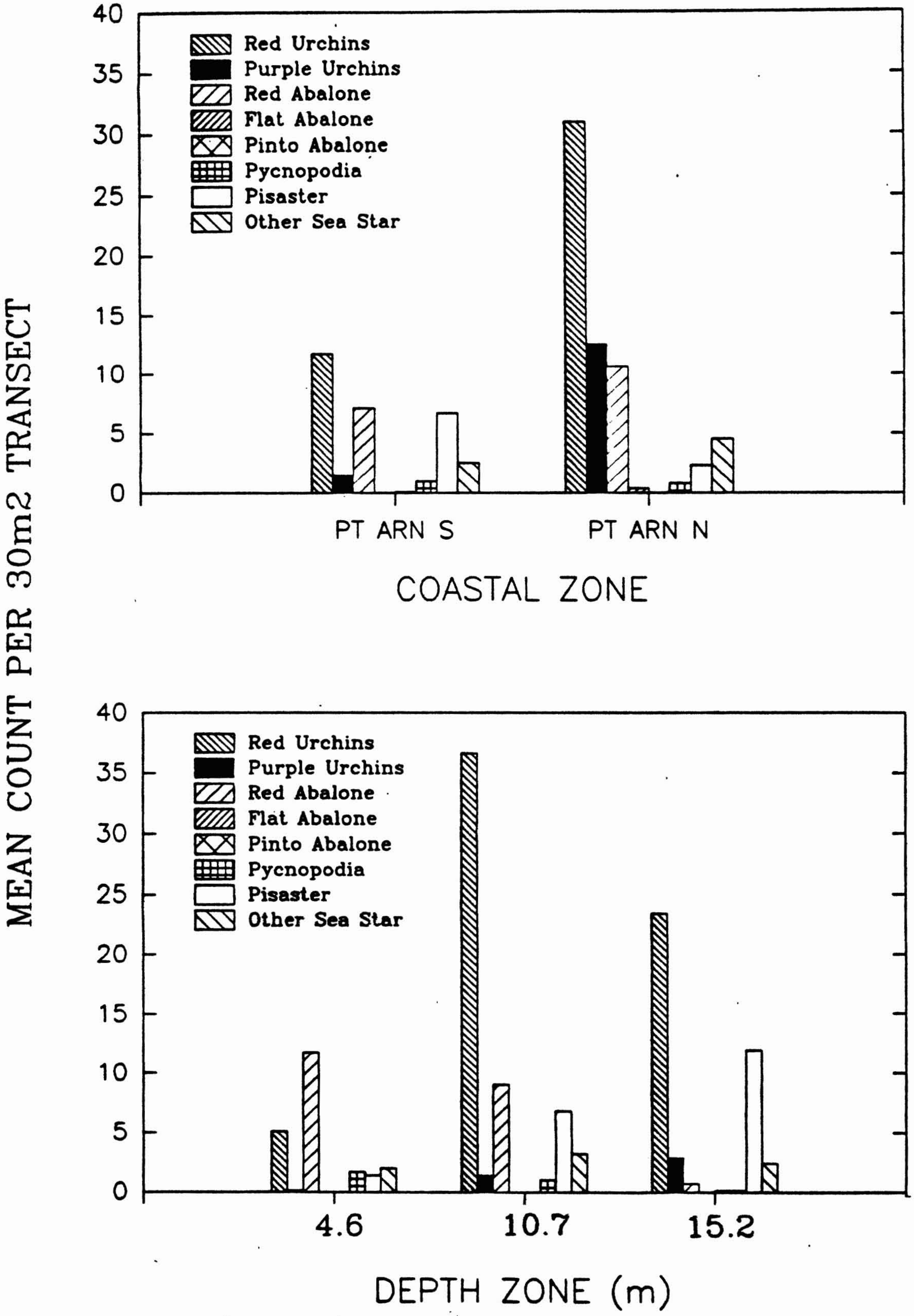

FIGURE 16. Comparison of invertebrate densities by coastal zone and depth zone from the 1991 broad scale survey.

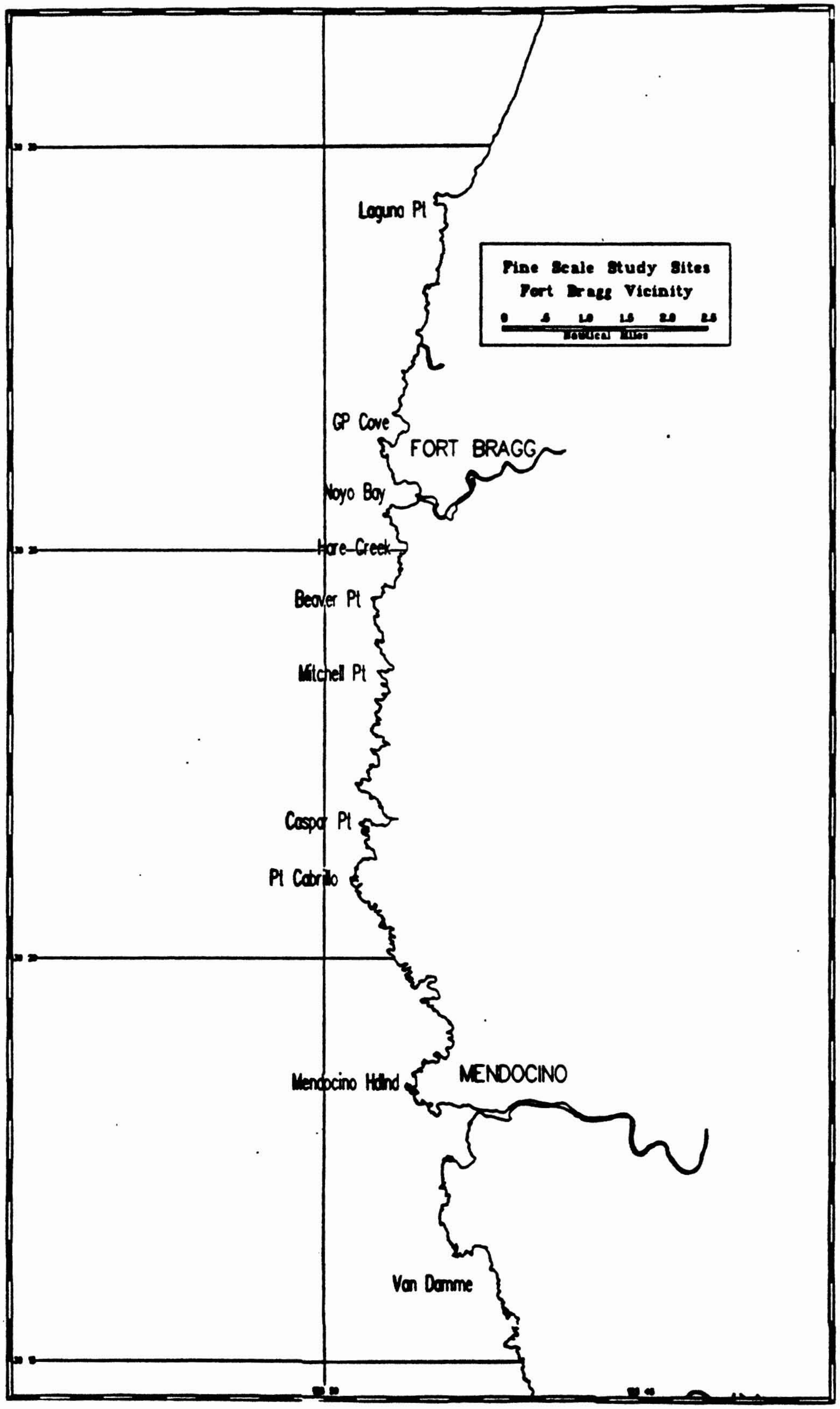

FIGURE 17. Individual fine scale study sites from Laguna Point to Van Damme Bay.

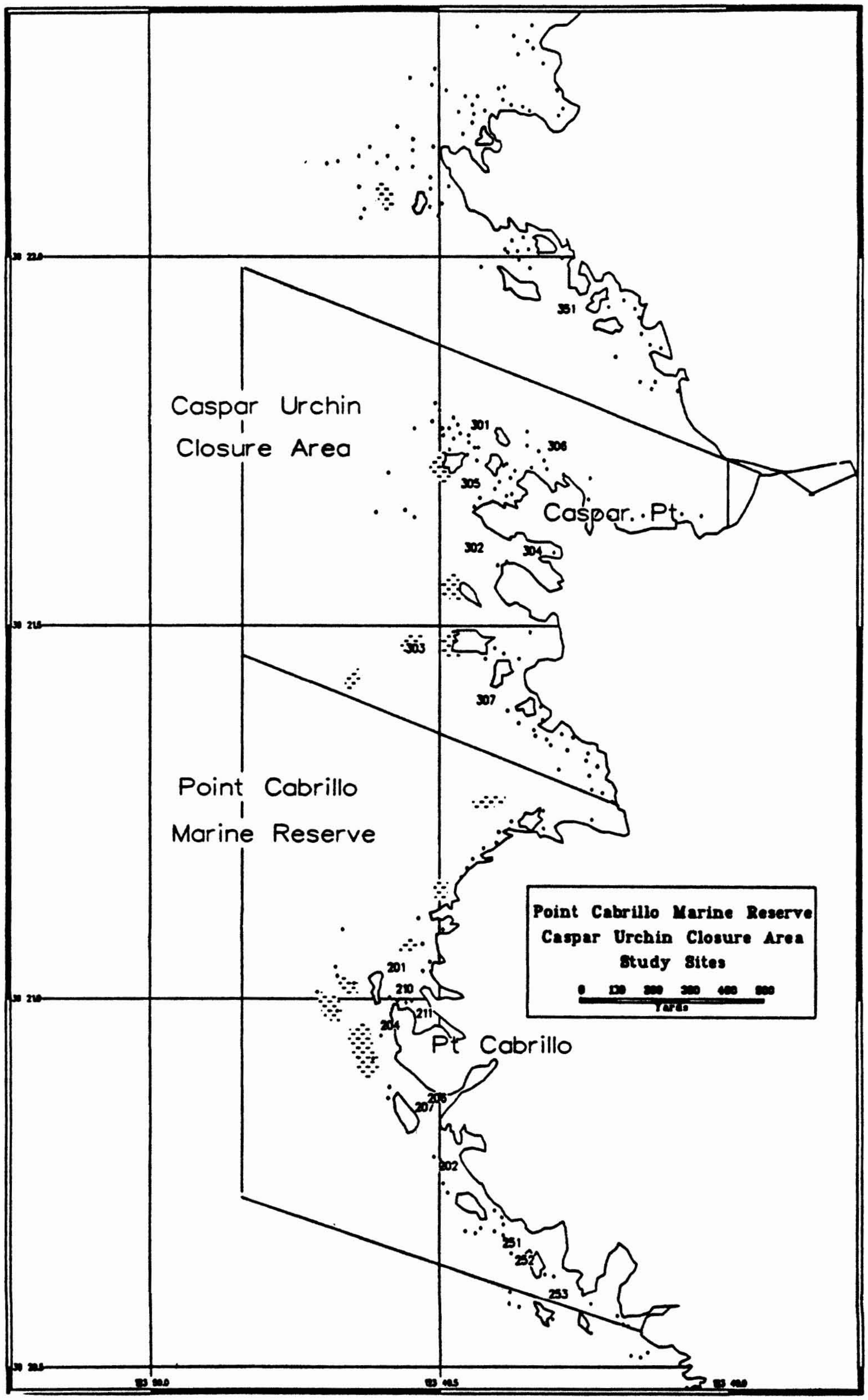

FIGURE 18. Point Cabrillo Marine Reserve and Caspar closure area fine scale study subsites showing approximate transect locations, 1991.

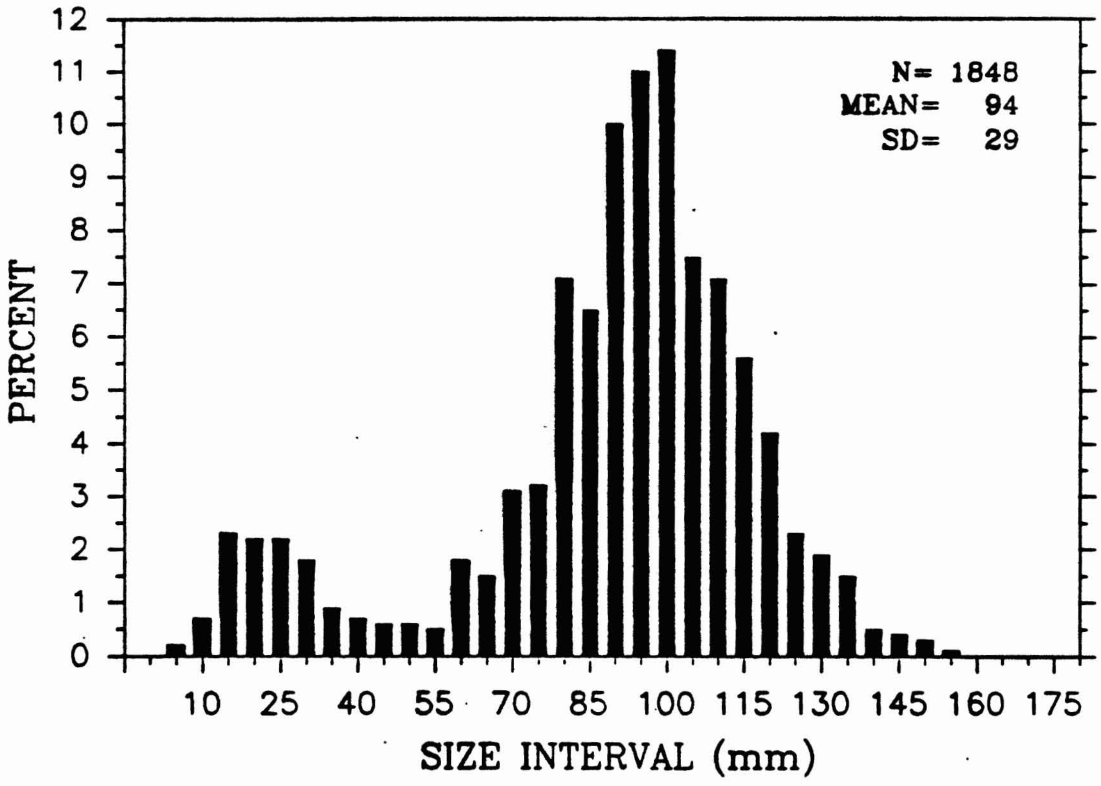

FIGURE 19. Frequency distribution of red sea urchin test diameters from all fine scale sites, summer 1991.

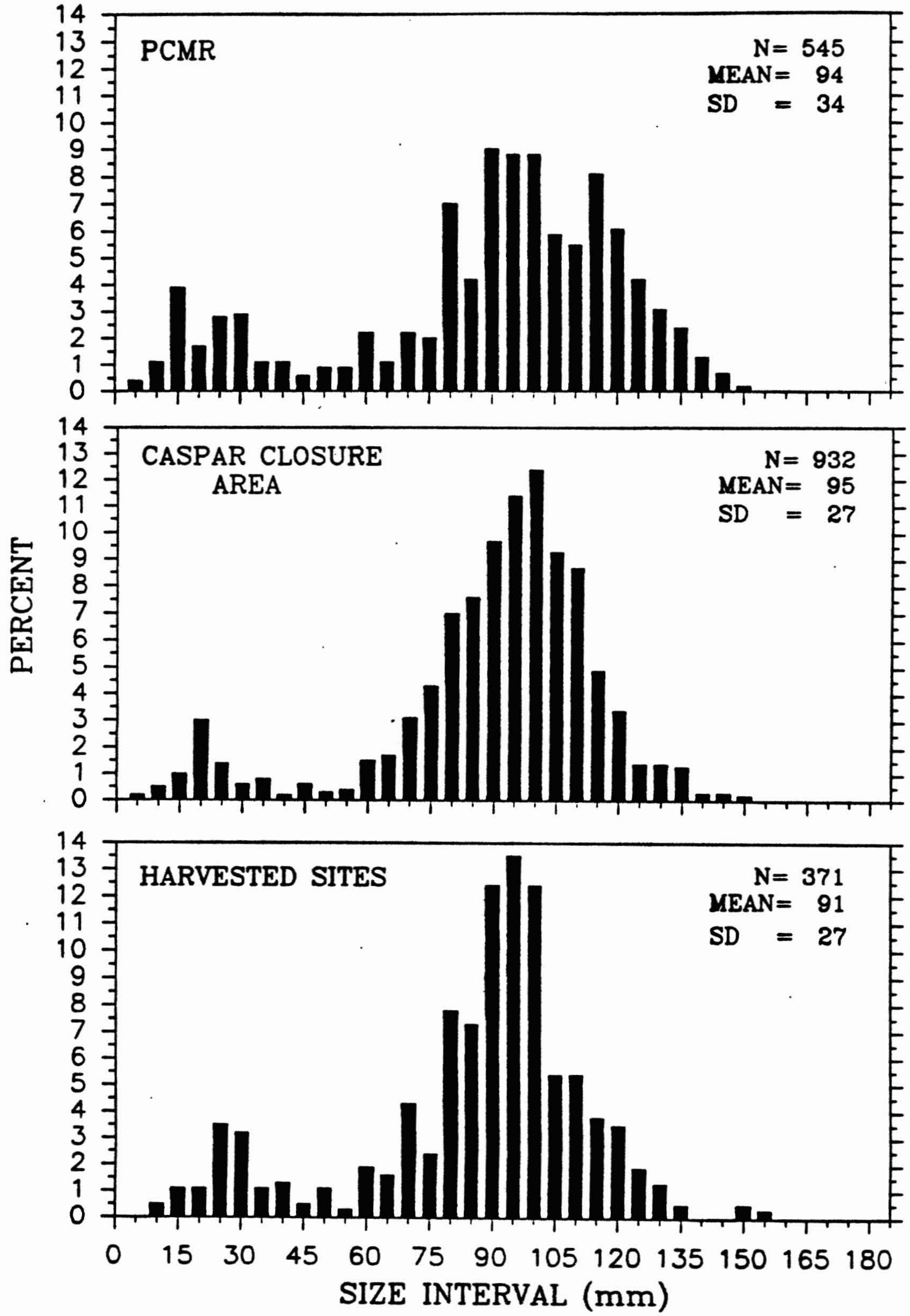

FIGURE 20. Frequency distribution of red sea urchin test diameters from Point Cabrillo Marine Reserve, Caspar Closure Area, and combined harvested sites, fine scale survey, summer 1991.

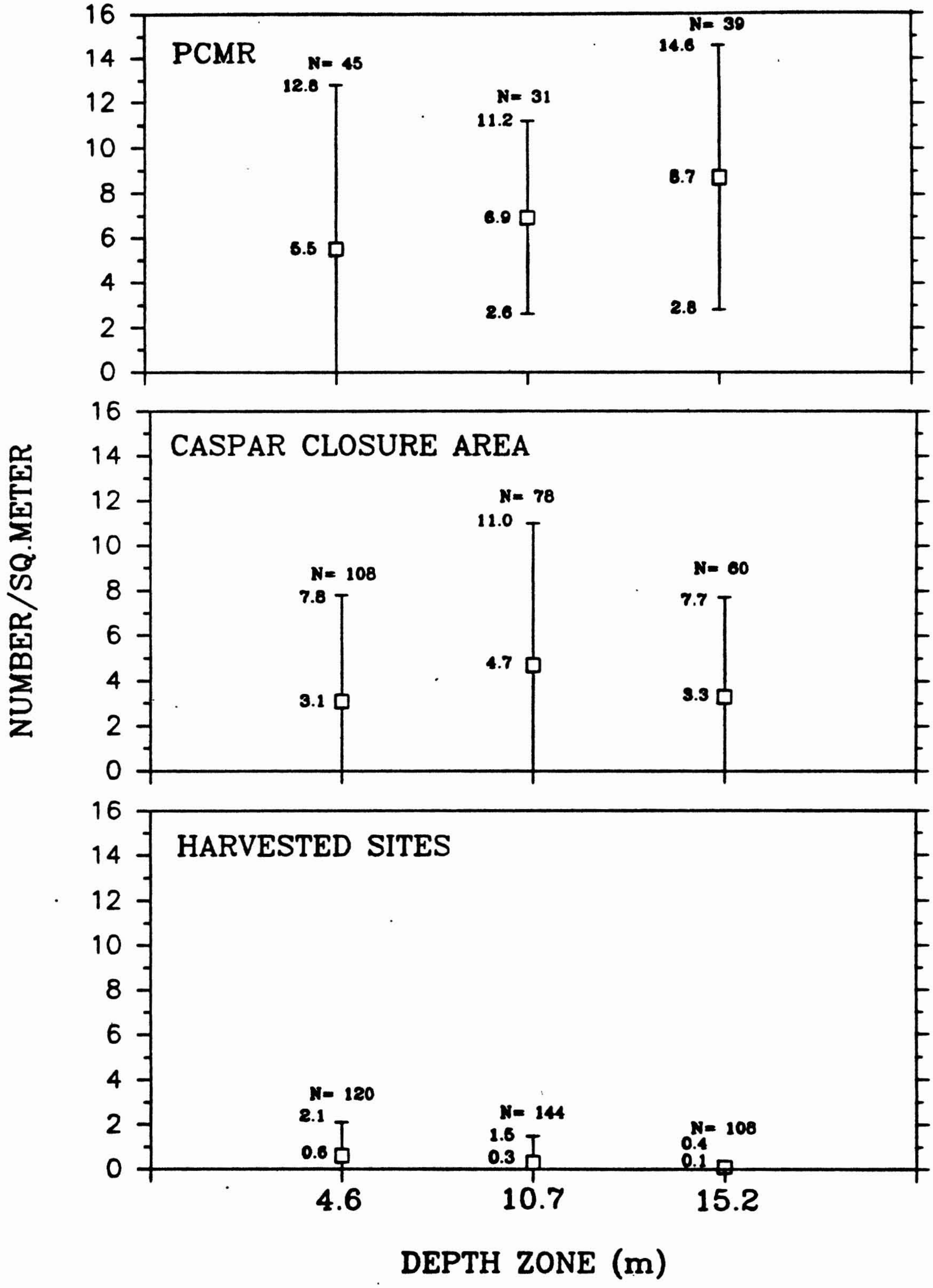

FIGURE 21. Mean and SD of red sea urchin densities (number per square meter) by depth zone from Point Cabrillo Marine Reserve, Caspar Closure Area and combined harvested sites, fine scale survey, summer 1991.

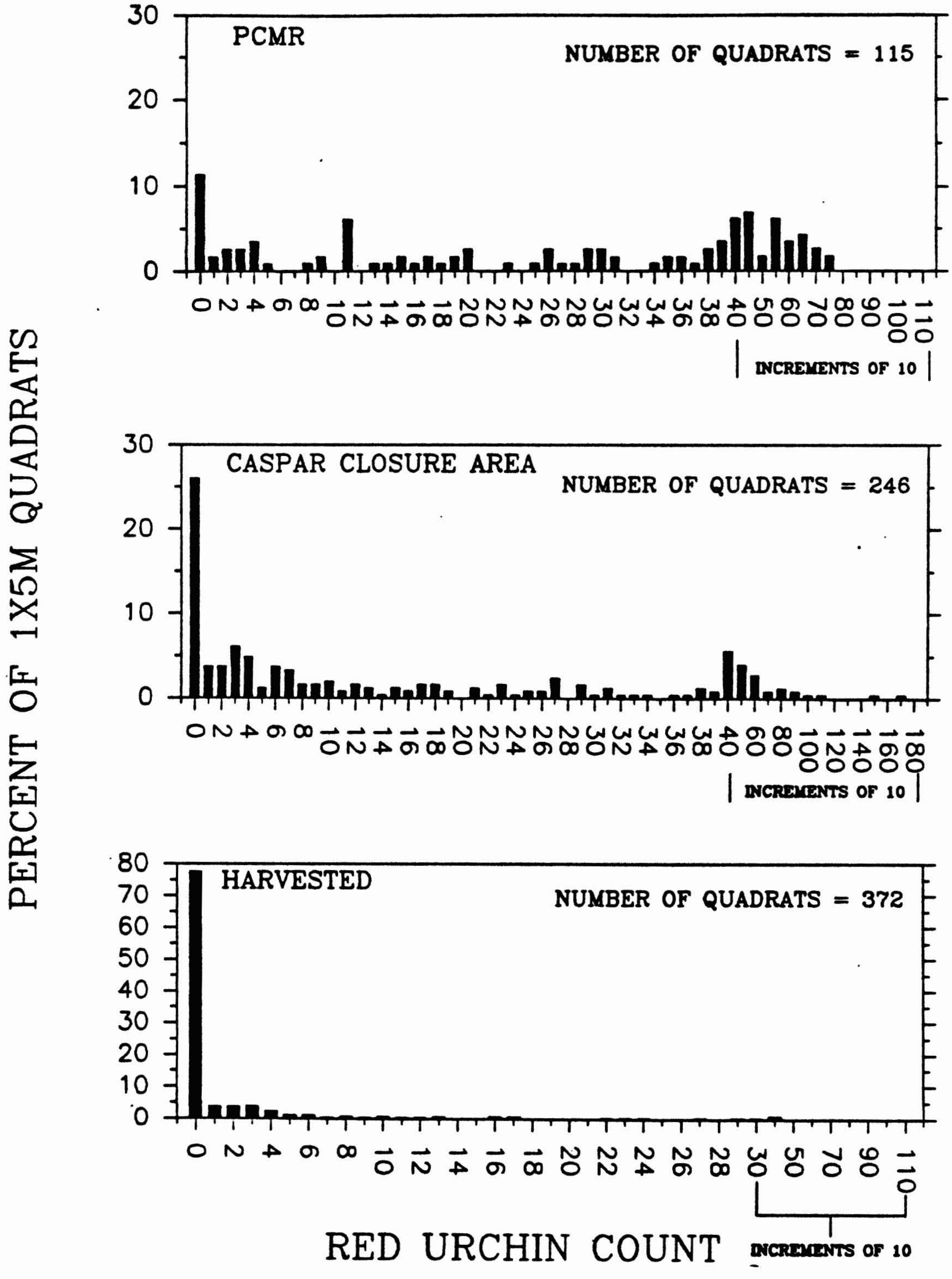

FIGURE 22. Frequency distribution of red sea urchin counts for Point Cabrillo Marine Reserve transect quadrats, Caspar Closure Area transect quadrats, and combined harvested site transect quadrats, fine scale survey, summer 1991.

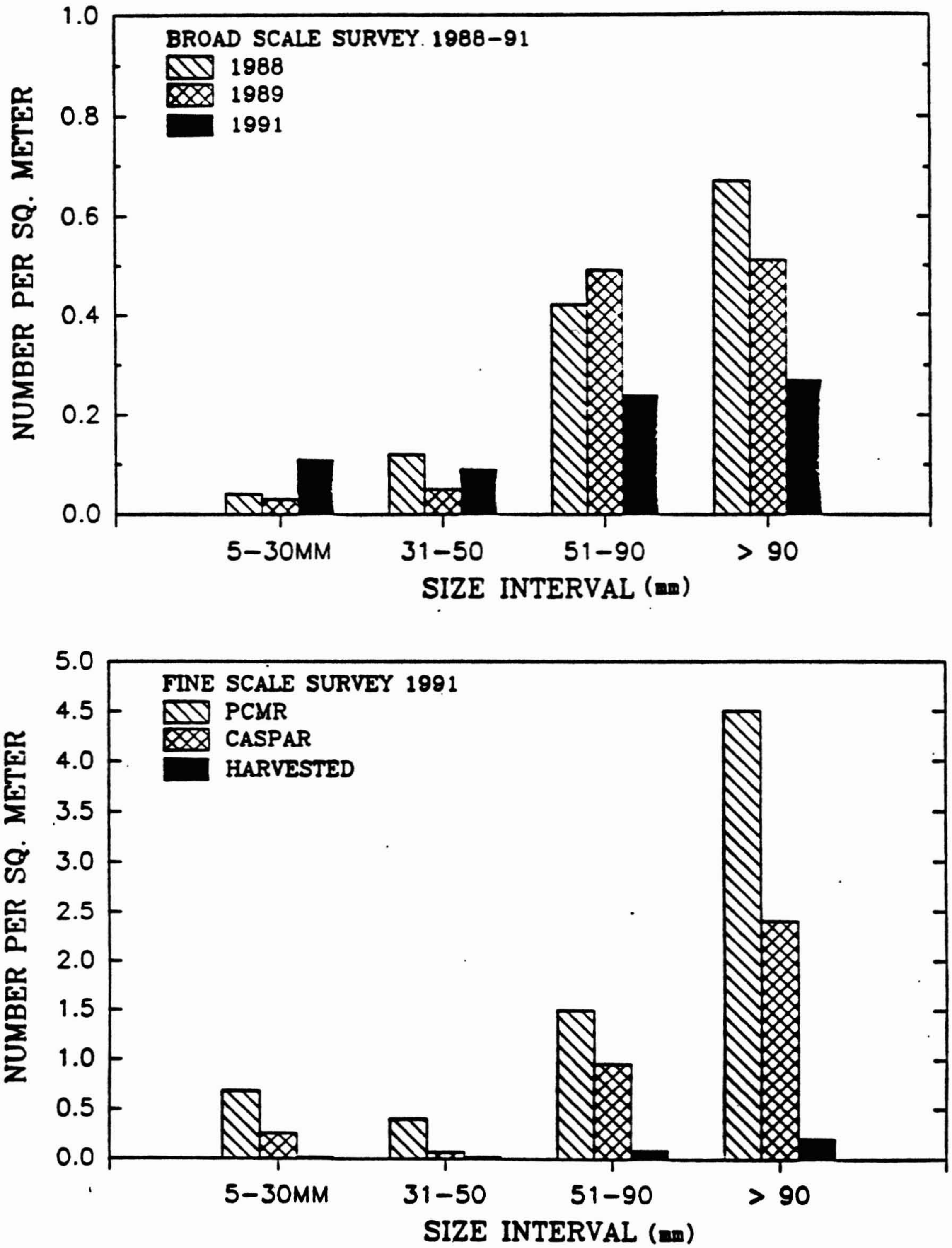

FIGURE 23. Red sea urchin densities by size category for each broad scale survey, 1988 to 1991, and red sea urchin densities by size category for Point Cabrillo Marine Reserve, Caspar closure area and combined fished sites, fine scale survey, summer 1991.

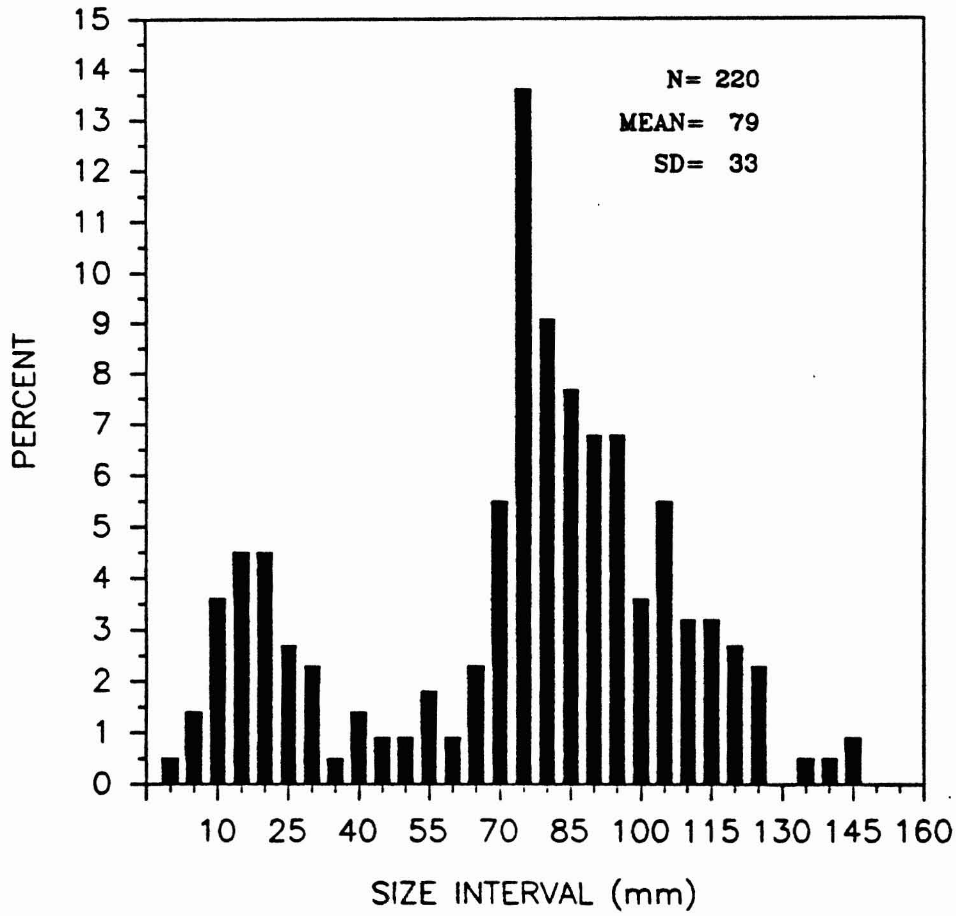

FIGURE 24. Frequency distribution of red sea urchin test diameters from intensive plots, summer 1991.

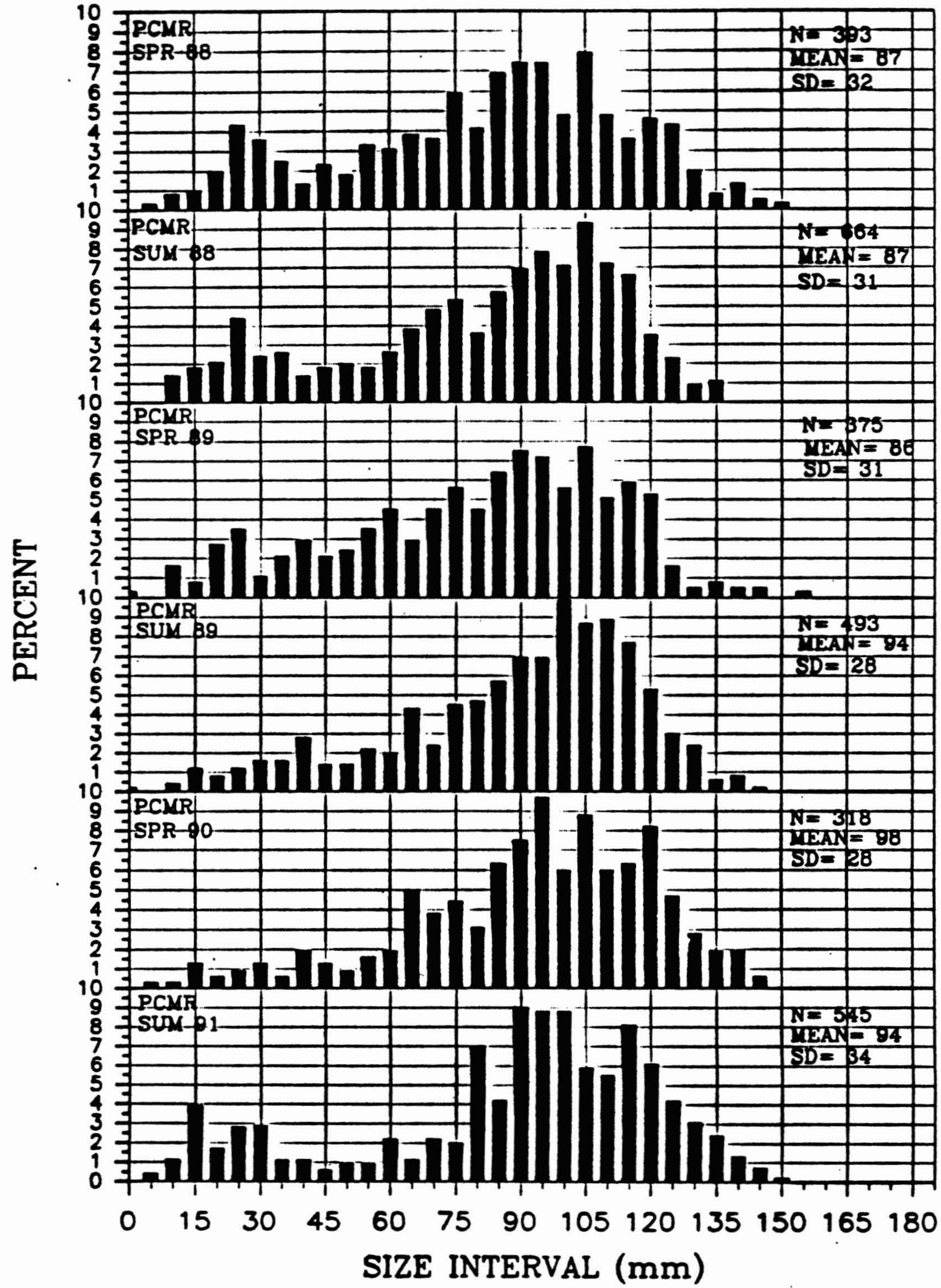

FIGURE 25. Frequency distribution of red sea urchin test diameters for PCMR from fine scale surveys from spring 1988 to summer 1991.

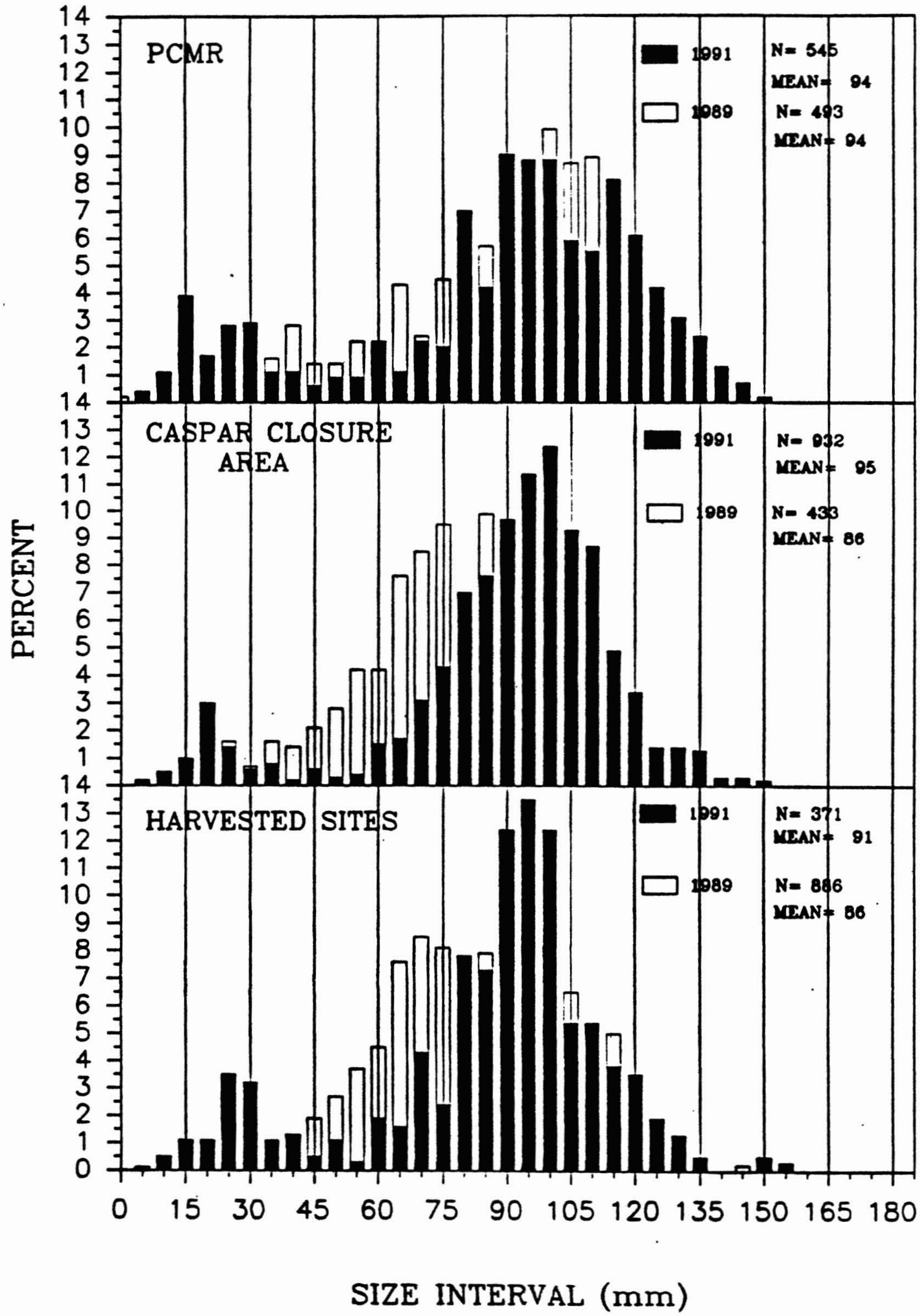

FIGURE 26. Frequency distribution of red sea urchin test diameters for PCMR, Caspar closure area and fished sites for 1989 and 1991 summer fine scale surveys.

TABLE 1. Broad Scale Survey Site Descriptions and Locations, Summer 1991.

Site Number	Description	Depth Zones Surveyed (m)	Approximate Location (Lat./Lon.)	Date
9	Robinson Reef	4.6,10.7,15.2	38.45.55 N x 123.32.40 W	07/23/91
10	Haven's Neck		38.48.30 N x 123.36.50 W	07/23/91
11	Sail Rock		38.49.55 N x 123.38.30 W	08/01/91
12	Schooner Gulch		38.51.45 N x 123.40.00 W	07/31/91
13	High Bluff		38.53.40 N x 123.41.55 W	07/31/91
14	Sea Lion Rocks		38.56.10 N x 123.44.50 W	07/31/91
15	Irish Gulch	*NOT SURVEYED*		
16	Bridgeport Landing	*NOT SURVEYED*		
17	Elk Rock		39.06.30 N x 123.43.30 W	08/03/91
18	Cavanaugh Gulch		39.08.55 N x 123.45.00 W	08/03/91
19	Navarro Pt.		39.11.75 N x 123.46.50 W	08/02/91
20	Albion Pt.		39.14.10 N x 123.47.00 W	08/14/91
21	Van Damme Hdlnd.		39.16.30 N x 123.48.05 W	08/14/91
22	Jack Peters Creek		39.19.10 N x 123.48.50 W	08/06/91

TABLE 2. **Pairwise Kolmogorov-Smirnov Tests of Observed Red Sea Urchin Size Frequency Distributions by Coastal Zone, Broad Scale Survey, Summer 1991.**

Kolmogorov-Smirnov Test			
Coastal Zone	*N*	*Deviation from Mean at Max*	
Point Arena South (Gualala North)	220	-1.264	KS Statistic 0.055863
Point Arena North (Navarro North & South)	512	0.829	D = 0.121839 KSasymp. = 1.51140 Prob > KSa = 0.0207
Total	732		

TABLE 3. Analysis of Variance of Red Sea Urchin Test Diameters by Depth Zone, Broad Scale Survey, Summer 1991.

ANOVA					
Source of Variation	DF	SS	MS	F	Prob.
Depth Zone	2	109211	54605.70	47.98	0.0000
Residual	729	829606	1138.01		
Total	731	938817			

TEST DIAMETER (mm)			
Depth Zone (m)	Mean	SD	N
4.6	91	29	110
10.7	86	37	326
15.2	62	32	296
Total	92	30	732

TABLE 4. Pairwise Kolmogorov-Smirnov Tests of Observed Red Sea Urchin Size Frequency Distributions by Depth Zone, Broad Scale Survey, Summer 1991.

Kolmogorov-Smirnov Test			
Depth Zone (m)	N	Deviation from Mean at Max	
4.6	110	-0.932	KS Statistic 0.051596
10.7	326	0.541	D = 0.118795 KSasymp. = 1.07736 Prob > KSa = 0.1961
	436		

Kolmogorov-Smirnov Test			
Depth Zone (m)	N	Deviation from Mean at Max	
4.6	110	-2.961	KS Statistic 0.172126
15.2	296	1.805	D = 0.387285 KSasymp. = 3.46825 Prob > KSa = 0.0001
	406		

Kolmogorov-Smirnov Test			
Depth Zone (m)	N	Deviation from Mean at Max	
10.7	326	-2.480	KS Statistic 0.144149
15.2	296	2.603	D = 0.288634 KSasymp. = 3.59506 Prob > KSa = 0.0001
	622		

TABLE 5. Comparison of Red Sea Urchin Size Categories by Coastal Zone and Depth Zone, Broad Scale Survey, Summer 1991.

		Red Urchin				Red Urchin <=90mm		
			Size Category				Size Category	
Coastal Zone	Site Nos.	N	% 0-30mm	0-50mm	0-90mm	N	% 0-30mm	0-50mm
Point Arena South	9 - 14	242	15.3	29.3	59.9	145	25.5	49.0
Point Arena North	17 - 22	490	16.5	28.0	63.1	309	26.2	44.3
TOTAL	9 - 22	732	16.1	28.4	62.0	454	26.0	45.8

	Red Urchin				Red Urchin <=90mm		
		Size Category				Size Category	
Depth Zone (m)	N	% 0-30mm	0-50mm	0-90mm	N	% 0-30mm	0-50mm
4.6	110	7.3	10.9	44.6	49	16.3	24.5
10.7	326	13.5	20.6	52.2	170	25.9	39.4
15.2	296	22.3	43.6	79.4	235	28.1	54.9
TOTAL	732	16.1	28.4	62.0	454	26.0	45.8

TABLE 6. Comparison of Red Sea Urchin Raw Counts, Mean Sizes, and Canopy and Non-Canopy Grouped Red Urchins by Site and Coastal Zone, Broad Scale Survey, Summer 1991.

Coastal Zone	Site No.	No. 30x1m Transects *	Urchin Count	Mean Cnt per sq.m	No. Urc Measurd	Mean Size (mm)	% Juvenile+	% Canopy Juvenile	CANOPIED No. Urch Measurd	CANOPIED Mean Size (mm)	CANOPIED Juv Urch Measured	CANOPIED Juv Mean Size (mm)	NON-CANOPIED No. Urch Measurd	NON-CANOPIED Mean Size (mm)	NON-CANOPIED Juv Urch Measured	NON-CANOPIED Juv Mean Size (mm)
Pt Arena South	9	6	41	0.2	39	102	10.3	2.6	3	93	1	40	36	103	3	27
	10	8	24	0.1	23	101	13.0	0.0	0	-	0	-	23	101	3	40
	11	5	10	0.0	10	91	20.0	10.0	2	60	1	20	8	98	1	35
	12	5	31	0.2	27	130	3.7	3.7	2	93	1	30	25	133	0	-
	13	6	61	0.3	61	63	36.1	0.0	0	-	0	-	61	63	22	34
	14	8	284	1.2	82	61	47.6	13.4	16	48	11	22	66	64	28	32
Subtotal		38	451	0.4	242	81	29.3	5.8	23	61	14	24	219	83	57	33
Pt Arena North	17	6	335	1.9	145	73	28.3	18.6	53	59	27	27	92	81	14	38
	18	6	147	0.9	82	63	43.9	15.9	19	44	13	24	63	69	23	34
	19	6	43	0.2	43	83	16.3	14.0	10	48	6	27	33	94	1	25
	20	6	250	1.4	124	73	29.0	19.4	42	55	24	24	82	83	12	41
	21	6	391	2.2	52	73	28.9	21.2	19	56	11	25	33	83	4	34
	22	9	29	0.1	44	105	4.6	2.3	2	45	1	20	42	108	1	35
Subtotal		39	1195	1.0	490	75	28.0	16.7	145	54	82	25	345	84	55	36
TOTALS	12	77	1646	0.7	732	77	28.4	13.1	168	55	96	25	564	84	112	35

* Some transects were not completed

\+ Juveniles are red urchins with test diameter <= 50mm

TABLE 7. Analysis of Variance of Log Transformed Red Sea Urchin Densities by Depth Zone, Broad Scale Survey, Summer 1991.

ANOVA (log transformed densities)					
Source of Variation	*DF(1x5m quads)*	*SS*	*MS*	*F*	*Prob.*
Depth Zone	2	10.08	5.04	16.84	0.0000
Residual	457	136.71	0.30		
Total	459	146.79			

DENSITY (untransformed no./sq.meter)			
Depth Zone	*Mean*	*SD*	*N (1x5m quads)*
4.6	0.17	0.65	154
10.7	1.22	2.71	144
15.2	0.78	1.71	162
Total	0.71	1.91	460

TABLE 8. Substrate and Algae Mean Percent Area and Selected Invertebrate Counts by Site and Depth Zone, Broad Scale Survey, Summer 1991.

SITE	DEPTH ZONE	NUMBER TRANS	|-SUBSTRATE-| (% area) bldr	cbl	snd	|-----ALGAE-----| (% area) cpy	scpy	trf	encr	|---INVERTEBRATES(count/30m2 transect)---| |--URCHIN--| red	purple	|---ABALONE---| red	flat	pint	|--SEA STARS--| pyc	pis	other
9	4.6	1	100	0	0	0	25	30	80	0.0	0.0	9.0	0.0	0.0	1.0	0.0	5.0
	10.7	1	98	2	0	0	0	16	83	11.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0
	15.2	1	100	0	0	0	20	20	60	9.5	0.0	0.0	0.0	0.0	0.0	22.0	1.0
10	4.6	1	50	50	0	0	0	100	0	0.0	0.0	21.0	0.0	0.0	1.0	1.0	2.0
	10.7	1	98	2	0	0	0	16	83	4.5	0.0	2.0	0.0	0.0	1.0	2.0	2.0
	15.2	1	100	0	0	0	20	20	60	3.8	0.0	0.0	0.0	0.0	0.0	7.0	0.5
11	4.6	1	100	0	0	0	0	92	0	0.5	0.0	7.0	0.0	0.0	1.0	1.0	2.0
	10.7	1	98	2	0	0	0	16	83	1.5	0.0	11.0	0.0	0.0	0.0	9.0	0.0
	15.2	1	100	0	0	0	20	20	60	2.0	0.0	2.0	0.0	0.0	0.0	2.0	1.0
12	4.6	1	94	3	3	0	0	60	8	0.0	0.0	0.0	0.0	0.0	0.0	6.0	2.0
	10.7	1	98	2	0	0	0	16	83	1.0		0.0	0.0	0.0	--	--	--
	15.2	1	100	0	0	0	20	20	60	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0
13	4.6	1	76	24	0	0	35	65	27	0.0	0.0	16.0	0.0	0.0	4.0	2.0	2.0
	10.7	1	98	2	0	0	0	16	83	17.0	2.0	16.0	0.0	0.0	2.0	12.0	1.0
	15.2	1	100	0	0	0	20	20	60	13.5	0.0	2.0	0.0	0.0	1.0	3.0	13.0
14	4.6	2	100	0	0	0	5	90	10	2.5	0.5	14.5	0.0	0.0	2.5	0.0	0.5
	10.7	1	98	2	0	0	0	16	83	15.5	5.0	25.0	0.0	0.0	1.0	1.0	3.0
	15.2	1	100	0	0	0	20	20	60	126.5	20.0	1.0	0.0	1.0	0.0	9.0	1.0
17	4.6	1	100	0	0	20	30	60	100	37.0	0.0	16.0	0.0	0.0	2.0	3.0	8.0
	10.7	1	98	2	0	0	0	16	83	110.5	2.0	0.0	1.0	0.0	3.0	3.0	10.0
	15.2	1	100	0	0	0	20	20	60	20.0	5.0	0.0	2.0	0.0	0.0	7.0	9.0
18	4.6	1	100	0	0	0	45	30	45	11.3	0.0	3.0	0.0	0.0	1.5	0.0	3.5
	10.7	1	98	2	0	0	0	16	83	3.0	0.0	45.0	0.0	0.0	0.0	1.0	2.0
	15.2	1	100	0	0	0	20	20	60	62.0	4.0	0.0	1.0	0.0	0.0	3.0	17.0
19	4.6	1	82	0	18	15	75	30	50	6.5	2.0	11.0	1.0	0.0	2.0	1.0	2.0
	10.7	1	98	2	0	0	0	16	83	2.0	0.0	4.0	0.0	0.0	0.0	0.0	1.0
	15.2	1	100	0	0	0	20	20	60	13.0	1.0	0.0	0.0	0.0	1.0	13.0	10.0
20	4.6	1	100	0	0	0	16	57	33	6.5	0.0	0.0	0.0	0.0	1.0	2.0	13.0
	10.7	1	98	2	0	0	0	16	83	56.5	0.0	7.0	0.0	0.0	0.0	3.0	8.0
	15.2	1	100	0	0	0	20	20	60	62.0	36.0	0.0	0.0	0.0	0.0	0.0	1.0
21	4.6	1	100	0	0	0	2	100	0	0.0	0.0	2.0	0.0	0.0	2.0	3.0	2.0
	10.7	1	98	2	0	0	0	16	83	195.5	200.0	20.0	3.0	0.0	0.0	4.0	0.0
	15.2	1	100	0	0	0	20	20	60	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0
22	4.6	1	53	8	39	15	40	45	30	1.0	0.0	15.0	0.0	0.0	3.0	0.0	3.0
	10.7	1	98	2	0	0	0	16	83	7.7	0.0	35.5	0.0	0.0	0.5	0.0	0.5
	15.2	1	100	0	0	0	20	20	60	0.5	0.0	3.0	0.0	0.0	0.0	1.0	0.0

-- Some transects were not completed, counts extrapolated to 30m.

TABLE 9. **Test Diameter and Percentage of Red Urchin Juveniles by Study Site and Depth Zone, Fine Scale Survey, Summer 1991.**

		Size(mm)		One Year Old <= 30 mm		Juvenile* <= 50 mm	
Site	*N*	*Mean*	*Range*	*%*	*n*	*%*	*n*
All Sites	1848	94	5-155	7.6	141	11.7	216
Depth (m)							
4.6	754	100	5-150	3.6	27	5.3	40
10.7	594	91	5-150	7.7	46	12.0	71
15.2	500	87	5-155	13.6	68	21.0	105
Point Cabrillo Reserve	545	94	5-150	9.7	53	15.4	84
4.6	173	97	5-135	6.4	11	10.4	18
10.7	156	94	10-145	10.1	9	8.3	13
15.2	216	91	5-150	15.3	33	24.5	53
Caspar Closure Area	932	95	5-150	3.0	65	9.2	86
4.6	377	101	10-150	3.2	12	4.2	16
10.7	313	95	5-150	7.0	20	9.8	28
15.2	242	84	5-145	12.2	33	15.6	42
Harvested Sites	371	91	10-155	6.2	23	12.4	46
4.6	204	100	10-150	2.0	4	3.1	6
10.7	125	78	10-150	13.6	17	24.0	30
15.2	42	85	20-155	4.0	2	20.0	10
Individual Harvested Sites							
Mill Cove	38	98	30-155				
Noyo Bay	3	105	80-110				
Hare Creek	31	112	65-130				
Beaver Pt	53	98	10-125				
Mitchell Pt	0	-	-				
N Casp Bay	40	88	25-120				
Pt Cab So	125	84	10-135				
Mendo Hdlnd	81	88	15-150				

* Juvenile category includes one year olds

TABLE 10. Analysis of Variance of Log Transformed Red Sea Urchin Densities, by Depth Zone from Combined Harvested Sites, Fine Scale Survey, Summer 1991.

ANOVA (log transformed densities)					
Source of Variation	DF(1x5m quads)	SS	MS	F	Prob.
Depth Zone	2	2.96	1.48	9.58	0.0000
Residual	369	57.00	0.15		
Total	371	59.97			

DENSITY (untransformed number/sq.m)			
Depth Zone (m)	Mean	SD	N (1x5m quads)
4.6	0.62	1.5	120
10.7	0.29	1.2	144
15.2	0.09	0.3	108
Total	0.34	1.1	372

TABLE 11. **Analysis of Variance of Log Transformed Red Sea Urchin Densities, by Depth Zone from Point Cabrillo Marine Reserve, Fine Scale Survey, Summer 1991.**

ANOVA (log transformed densities)					
Source of Variation	*DF(1x5m quads)*	*SS*	*MS*	*F*	*Prob.*
Depth Zone	2	16.30	8.15	10.16	0.0000
Residual	112	89.79	0.80		
Total	114	106.08			

DENSITY (untransformed number/sq.m)			
Depth Zone (m)	*Mean*	*SD*	*N (1x5m quads)*
4.6	5.5	7.3	45
10.7	6.9	4.3	31
15.2	8.7	5.9	39
Total	7.0	6.2	115

TABLE 12. Analysis of Variance of Log Transformed Red Sea Urchin Densities, by Site, Fine Scale Survey, Summer 1991.

ANOVA (log transformed densities)					
Source of Variation	DF(1x5m quads)	SS	MS	F	Prob.
Site	9	258.16	28.68	53.85	0.0000
Residual	723	385.09	0.53		
Total	732	643.25			

DENSITY (untransformed number/sq.m)			
Site	Mean	SD	N (1x5m quads)
1-Mill Cove	0.2	0.4	48
2-Noyo Bay	0.0	0.1	36
3-Hare Creek	0.1	0.3	48
4-Beaver Pt	1.1	2.2	36
5-Mitchell Pt	0.0	0.0	24
6-N Caspar	0.2	0.4	48
7-Caspar Closure Area	3.7	5.2	246
8-PCMR	7.0	6.2	115
9-Pt Cabrillo South	0.4	1.5	96
10-Mendocino Hdlnd	0.6	1.3	36

Scheffe Test for Sites with Significant Differences (log transformed)				
Group one		Group Two	Mean Diff.	Prob.(alpha=0.005)
7	Caspar Closure Area	1	0.96	0.0000
7		2	1.05	0.0000
7		3	0.98	0.0000
7		4	0.65	0.0032
7		5	1.06	0.0000
7		6	0.94	0.0000
7		9	0.87	0.0000
7		10	0.75	0.0002
8	PCMR	1	1.59	0.0000
8		2	1.68	0.0000
8		3	1.60	0.0000
8		4	1.28	0.0000
8		5	1.69	0.0000
8		6	1.57	0.0000
8		7	0.63	0.0000
8		9	1.50	0.0000
8		10	1.38	0.0000

TABLE 13. **Analysis of Variance of Log Transformed Red Sea Urchin Densities, by Depth Zone from Caspar Closure Area Fine Scale Survey, Summer 1991.**

ANOVA (log transformed densities)					
Source of Variation	*DF(1x5m quads)*	*SS*	*MS*	*F*	*Prob.*
Depth Zone	2	0.96	0.48	0.52	0.593
Residual	243	223.15	0.92		
Total	245	224.11			

DENSITY (untransformed number/sq.m)			
Depth Zone (m)	*Mean*	*SD*	*N (1x5m quads)*
4.6	3.1	4.7	108
10.7	4.7	6.3	78
15.2	3.3	4.4	60
Total	3.7	5.2	246

TABLE 14. Substrate and Algae Mean Percent Area and Selected Invertebrate Counts by Site and Depth Zone, Fine Scale Survey, Summer 1991.

SITE*	DEP ZONE	NUMBR TRANS	SUBSTRATE (% area) bldr	cbl	snd	ALGAE (% area) cpy	scpy	trf	encr	INVERTEBRATES(count/30m2 transect)** URCHIN red	URCHIN purple	ABALONE red	ABALONE flat	ABALONE pint	SEA STARS pycn	SEA STARS pis	SEA STARS other
1	4.6	4	97	4	0	0	18	32	45	163.8	145.4	29.3	0.0	0.0	1.7	2.1	5.1
	10.7	3	67	18	16	0	0	0	100	207.1	49.4	3.9	0.0	0.0	4.8	3.5	16.8
	15.2	4	89	11	0	0	0	0	70	261.6	72.6	20.5	0.0	1.1	1.1	1.8	21.5
2	4.6	9	89	11	0	8	32	65	31	94.4	9.9	8.3	0.3	0.0	1.4	1.9	19.2
	10.7	3	67	18	16	0	0	0	100	141.2	9.7	10.1	0.0	0.4	2.3	2.3	23.2
	15.2	4	89	11	0	0	0	0	70	100.3	3.2	3.6	0.0	0.0	0.4	3.2	2.0
3	4.6	1	100	0	0	0	3	96	7	8.0	1.0	3.0	0.0	0.0	0.0	0.0	4.0
	10.7	3	67	18	16	0	0	0	100	7.5	0.0	8.0	0.0	0.0	1.0	0.0	2.0
	15.2	4	89	11	0	0	0	0	70	2.8	0.0	0.0	0.0	0.0	0.0	1.0	0.0
4	4.6	1	100	0	0	0	20	53	40	95.5	6.0	13.0	0.0	0.0	0.0	1.0	39.0
	10.7	3	67	18	16	0	0	0	100	0.5	0.0	5.0	0.0	0.0	2.0	2.0	6.0
	15.2	4	89	11	0	0	0	0	70	0.0	0.0	2.0	0.0	0.0	0.0	1.0	1.0
5	4.6	2	68	5	27	0	30	45	12	7.5	6.5	6.0	0.0	0.0	2.0	1.0	6.0
	10.7	3	67	18	16	0	0	0	100	0.0	0.0	11.5	0.0	0.0	0.5	56.0	0.5
	15.2	4	89	11	0	0	0	0	70	--	--	--	--	--	--	--	--
6	4.6	1	73	7	20	0	60	60	0	0.0	1.0	35.0	0.0	0.0	2.0	0.0	1.0
	10.7	3	67	18	16	0	0	0	100	1.5	0.0	7.0	0.0	0.0	2.0	0.0	1.0
	15.2	4	89	11	0	0	0	0	70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	4.6	1	75	0	25	0	60	0	80	1.5	0.0	9.0	2.0	0.0	4.0	1.0	2.0
	10.7	3	67	18	16	0	0	0	100	1.5	0.0	22.5	0.5	0.0	1.0	2.5	6.0
	15.2	4	89	11	0	0	0	0	70	13.5	0.0	2.0	0.0	0.0	1.0	1.0	1.0
8	4.6	3	53	47	0	34	41	34	18	8.5	1.0	19.0	0.0	0.0	2.0	0.3	21.7
	10.7	3	67	18	16	0	0	0	100	38.5	13.0	9.0	0.0	0.5	0.5	1.5	41.5
	15.2	4	89	11	0	0	0	0	70	1.3	0.0	22.0	0.3	0.0	0.0	1.0	39.0
9	4.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	10.7	3	67	18	16	0	0	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0
	15.2	4	89	11	0	0	0	0	70	--	--	--	--	--	--	--	--
10	4.6	1	100	0	0	0	30	60	50	39.5	43.0	2.0	0.0	0.0	1.0	3.0	7.0
	10.7	3	67	18	16	0	0	0	100	15.0	2.0	21.0	2.0	0.0	0.0	1.0	12.0
	15.2	4	89	11	0	0	0	0	70	1.5	57.0	9.0	2.0	0.0	0.0	1.0	0.0

*1=PCMR,2=S.Caspar,3=N.Caspar,4=Beaver Pt.,5=Hare Crk.,6=Noyo,7=GP Mill,8=S.PCMR,9=Mitchell Pt, 10=Mendocino

** Some transects were not completed, extrapolated to 30m

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APPENDIX A

TRANSECT DATA FROM BROAD SCALE SURVEY SITES, SUMMER 1991

Explanation of Transect Data Display Format:

1. Red Urchin Counts by Transect

2. Solitary Red Urchin Size Frequency Data by Transect

3. Canopy Grouped Red Urchin Size Data by Transect

These three data bases are linked by the transect code.

APPENDIX A:1991 BROAD SCALE SURVEY RED URCHIN COUNTS BY TRANSECT

TRANSECT			SITE	DEP	QUADRATS*												
CODE	DATE	LOCATION	NO.	M	Q1A	Q2A	Q3A	Q4A	Q5A	Q6A	Q1B	Q2B	Q3B	Q4B	Q5B	Q6B	TOTAL
800	072391	ROBINSON REEF	9	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
801	072391	ROBINSON REEF	9	10.7	0	0	0	0	0	0	3	10	0	0	9	0	22
802	072391	ROBINSON REEF	9	15.2	0	1	9	0	0	0	1	0	0	4	4	0	19
803	072391	HAVENS NECK	10	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
804	072391	HAVENS NECK	10	10.7	0	0	0	5	1	0	0	0	3	0	0	0	9
805	072391	HAVENS NECK	10	15.2	0	0	2	0	0	4	0	0	1	0	0	0	7
806	072391	HAVENS NECK	10	15.2	0	0	0	0	1	5	0	0	2	0	0	0	8
807	080191	SAIL ROCK	11	4.6	0	0	0	0	0	1	0	0	0	0	0	0	1
808	080191	SAIL ROCK	11	10.7	0	0	0	0	0	0	1	0	2	0	0	0	3
809	080191	SAIL ROCK	11	15.2	0	0	1	0	1	0	999	999	999	999	999	999	2
810	073191	SCHOONER GULCH	12	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
811	073191	SCHOONER GULCH	12	10.7	4	2	2	2	6	15	999	999	999	999	999	999	31
812	073191	SCHOONER GULCH	12	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0
813	073191	HIGH BLUFF	13	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
814	073191	HIGH BLUFF	13	10.7	0	2	2	3	7	9	4	0	4	0	2	1	34
815	073191	HIGH BLUFF	13	15.2	1	1	2	2	3	2	2	1	12	0	0	1	27
816	073191	SEA LION ROCKS	14	4.6	0	0	1	0	0	0	0	0	0	0	0	0	1
817	073191	SEA LION ROCKS	14	4.6	0	0	0	0	2	0	0	3	1	0	3	0	9
818	073191	SEA LION ROCKS	14	10.7	4	1	0	0	1	0	6	0	9	0	0	0	21
819	073191	SEA LION ROCKS	14	15.2	0	5	17	15	29	17	35	13	15	30	48	29	253
820	080391	ELK ROCK	17	4.6	31	10	0	0	1	1	1	3	0	0	12	15	74
821	080391	ELK ROCK	17	10.7	43	27	3	0	1	9	75	20	22	1	3	17	221
822	080391	ELK ROCK	17	15.2	7	3	1	1	0	0	8	0	20	0	0	0	40
823	080391	CAVANAH GULCH	18	4.6	0	0	0	5	1	0	0	0	0	11	999	999	17
824	080391	CAVANAH GULCH	18	10.7	0	0	0	0	0	0	3	0	2	1	0	0	6
825	080391	CAVANAH GULCH	18	15.2	6	8	2	1	24	0	17	8	45	5	4	4	124
826	080291	NAVARRO PT.	19	4.6	4	0	5	1	0	1	0	2	0	0	0	0	13
827	080291	NAVARRO PT.	19	10.7	0	0	0	0	0	4	0	0	0	0	0	0	4
828	080291	NAVARRO PT.	19	15.2	0	0	0	0	0	5	3	2	0	1	0	15	26
829	081491	ALBION PT.	20	4.6	0	0	1	3	0	0	0	2	6	1	0	0	13
830	081491	ALBION PT.	20	10.7	0	0	0	13	18	31	0	0	0	10	14	27	113
831	081491	ALBION PT.	20	15.2	16	0	2	14	14	8	0	7	1	12	41	9	124
832	081491	VAN DAMME HEAD	21	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
833	081491	VAN DAMME HEAD	21	10.7	31	14	26	33	32	87	1	31	17	25	29	65	391
834	081491	VAN DAMME HEAD	21	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0
835	080891	JACK PETERS	22	4.6	0	0	0	0	0	0	0	0	0	1	0	1	2
836	080891	JACK PETERS	22	10.7	3	0	15	0	0	1	999	999	999	999	999	999	19
837	080891	JACK PETERS	22	10.7	2	0	0	0	0	0	2	0	0	0	0	0	4
838	080891	JACK PETERS	22	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0
839	080891	JACK PETERS	22	15.2	0	0	2	0	0	0	0	0	0	0	0	0	2

* 999 = NOT SURVEYED

1991 BROAD SCALE SOLITARY RED URCHIN SIZE(MM) FREQUENCY DATA BY TRANSECT CODE

CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ
801	65	2	811	130	1	818	120	1	822	90	3	829	105	2
801	70	1	811	135	1	818	140	1	822	95	2	830	40	1
801	85	3	811	145	2	819	15	1	822	100	2	830	45	1
801	90	1	811	150	4	819	20	2	822	105	1	830	85	1
801	125	2	811	155	4	819	25	6	823	80	1	830	90	1
801	130	5	811	165	1	819.	30	3	823	90	3	830	95	8
801	135	1	811	170	2	819	35	8	823	95	2	830	100	4
801	140	2	814	15	1	819	40	2	823	100	2	830	105	4
801	145	1	814	20	1	819	45	1	823	105	2	830	110	3
801	160	1	814	25	2	819	50	2	823	110	2	830	115	3
802	20	1	814	30	2	819	55	2	823	115	3	830	125	2
802	25	1	814	35	2	819	60	1	823	120	1	831	25	1
802	35	1	814	40	1	819	65	1	823	125	1	831	35	4
802	55	1	814	45	1	819	70	1	824	75	1	831	45	2
802	75	1	814	50	1	819	75	2	824	80	1	831	50	1
802	85	1	814	55	4	819	90	3	824	85	1	831	55	4
802	90	1	814	60	1	819	105	1	824	95	3	831	60	4
802	95	2	814	65	8	819	110	1	825	15	1	831	70	1
802	110	2	814	70	1	820	25	1	825	20	1	831	75	1
802	115	3	814	75	2	820	30	2	825	25	2	831	85	3
802	120	1	814	85	1	820	35	1	825	30	3	831	90	5
802	125	1	814	95	1	820	40	1	825	35	8	831	95	8
802	145	1	814	105	1	820	50	1	825	40	6	831	105	2
804	75	1	814	120	1	820	55	1	825	45	2	833	30	1
804	85	1	814	125	1	820	65	2	825	55	2	833	35	3
804	110	3	815	20	1	820	75	2	825	60	3	833	65	1
804	115	1	815	25	2	820	80	1	825	65	1	833	70	1
804	120	1	815	35	2	820	85	3	825	75	3	833	75	3
804	145	1	815	40	2	820	90	-4	825	80	3	833	80	3
805	45	1	815	45	3	820	95	6	825	90	1	833	85	5
805	50	1	815	50	1	820	100	4	825	100	3	833	90	2
805	85	1	815	55	1	820	105	3	825	105	1	833	95	5
805	105	1	815	65	3	820	110	3	826	55	1	833	100	4
805	135	2	815	75	1	820	115	2	826	80	1	833	105	3
805	155	1	815	80	2	820	120	3	826	100	1	833	115	2
806	25	1	815	85	3	820	125	2	826	105	2	835	105	1
806	55	1	815	95	1	820	130	1	826	110	2	835	120	1
806	85	1	815	100	3	820	140	1	826	115	1	836	35	1
806	105	1	815	105	2	821	45	1	826	125	2	836	80	1
806	110	2	816	100	1	821	55	2	826	135	1	836	85	3
806	120	1	817	25	1	821	60	2	826	140	1	836	95	2
806	135	1	817	45	1	821	65	2	826	145	1	836	100	3
807	140	1	817	65	2	821	70	1	827	75	1	836	105	3
808	95	1	817	70	1	821	75	4	827	105	1	836	110	1
809	35	1	817	75	1	821	80	2	827	125	2	836	115	5
809	80	1	817	80	1	821	90	5	828	25	1	836	120	4
809	85	1	817	85	2	821	95	1	828	55	1	836	125	6
809	105	1	818	25	1	821	100	2	828	60	1	836	130	4
809	115	1	818	65	1	822	30	1	828	70	8	836	140	1
809	130	1	818	75	3	822	35	2	828	75	1	837	95	2
811	85	1	818	80	1	822	40	2	828	80	3	837	100	1
811	90	1	818	85	1	822	45	1	828	85	3	837	105	1
811	95	1	818	90	2	822	50	1	828	95	2	839	70	1
811	100	2	818	95	1	822	55	8	828	105	1	839	85	1
811	105	2	818	100	1	822	70	1	829	75	5			
811	115	1	818	105	4	822	75	2	829	80	2			
811	120	1	818	110	1	822	80	3	829	85	3			
811	125	1	818	115	1	822	85	2	829	95	1			

BROAD SCALE CANOPIED RED URCHIN SIZE (MM) DATA BY TRANSECT CODE

CODE	CNPY*	SIZE
801	101	135
801	101	105
801	201	40
808	101	100
808	201	20
811	101	155
811	201	30
814	101	110
814	201	55
818	101	110
818	201	20
819	101	120
819	201	15
819	102	100
819	202	15
819	103	115
819	203	35
819	203	15
819	203	20
819	104	75
819	204	25
819	204	35
819	204	20
819	204	20
819	204	25
820	101	115
820	101	85
820	201	10
820	201	25
820	102	95
820	102	100
820	202	20
820	103	115
820	103	120
820	203	20
821	101	80
821	101	80
821	201	35
821	102	65
821	202	20
821	103	90
821	203	35
821	104	90
821	104	90
821	204	25
821	105	80

CODE	CNPY*	SIZE
821	105	105
821	205	35
821	205	30
821	205	10
821	205	10
821	106	85
821	106	45
821	206	25
821	206	20
821	107	80
821	207	25
821	108	85
821	208	30
821	109	90
821	209	25
821	110	95
821	210	20
821	210	30
822	101	100
822	201	25
822	102	90
822	202	45
822	103	100
822	203	30
822	104	90
822	204	25
822	105	85
822	205	40
822	106	80
822	206	35
822	107	80
822	207	30
825	101	90
825	201	15
825	201	45
825	201	25
825	201	20
825	102	95
825	202	20
825	103	110
825	203	25
825	104	80
825	204	30
825	105	80
825	205	20
825	205	25

CODE	CNPY*	SIZE
825	205	15
825	205	20
825	106	80
825	206	30
825	206	15
828	101	85
828	201	35
828	102	85
828	202	25
828	103	75
828	103	75
828	203	25
828	203	25
828	203	25
828	203	25
830	101	90
830	201	35
830	102	105
830	102	75
830	202	35
830	202	20
830	103	85
830	203	30
830	104	110
830	204	25
830	204	30
830	105	70
830	105	85
830	205	15
830	205	15
830	205	20
830	106	90
830	206	10
830	107	115
830	107	130
830	207	15
830	108	110
830	108	140
830	208	45
830	208	30
831	101	100
831	201	10
831	102	110
831	202	30
831	202	20
831	103	75

CODE	CNPY*	SIZE
831	203	35
831	203	30
831	104	50
831	204	20
831	105	75
831	205	15
831	106	60
831	206	15
831	107	80
831	207	20
831	207	15
833	101	80
833	201	20
833	201	10
833	102	90
833	202	30
833	202	30
833	103	100
833	103	120
833	203	20
833	203	30
833	104	90
833	204	20
833	204	30
833	105	90
833	205	20
833	106	110
833	206	30
833	107	100
833	207	35
836	101	70
836	201	20

* First digit: 1= canopy provider, 2=canopied urchin
Second, third digits: canopy group within transect

APPENDIX B

TRANSECT DATA FROM FINE SCALE SURVEY SITES, SUMMER 1991

Explanation of Transect Data Display Format:

1. Red urchin counts by transect

2. Solitary red urchin size (mm) frequency data by transect

3. Canopy grouped red urchin size data by transect

These three data bases are linked by the transect code.

APPENDIX B:1991 FINE SCALE SURVEY RED URCHIN COUNTS BY TRANSECT

TRANSECT			SITE	DEP	QUADRATS*												
CODE	DATE	LOCATION	NO.	M	Q1A	Q2A	Q3A	Q4A	Q5A	Q6A	Q1B	Q2B	Q3B	Q4B	Q5B	Q6B	TOTAL
900	081291	PCMR NORTH	211	4.6	0	0	38	29	81	0	11	0	23	31	8	0	221
901	081291	PCMR NORTH	210	10.7	999	25	55	65	42	4	46	53	999	999	999	999	290
902	081291	PCMR NORTH	201	15.2	26	37	45	36	38	16	30	31	20	59	20	20	378
903	072591	PCMR REEF POOL	204	4.6	0	9	35	89	15	9	11	11	11	999	999	999	190
904	072591	PCMR REEF POOL	204	10.7	26	11	11	41	4	39	64	2	2	48	50	75	373
905	072591	PCMR REEF POOL	204	15.2	999	999	74	17	34	76	65	81	82	999	999	999	429
906	072591	PCMR INNERSURGE	206	4.6	5	13	29	50	101	104	72	27	98	94	98	117	808
907	072591	PCMR OUTERSURGE	207	15.2	114	84	4	83	105	74	73	67	999	999	999	999	604
908	080791	PCMR SOUTH	202	4.6	2	3	1	0	0	0	0	0	3	1	0	0	10
909	080791	PCMR SOUTH	202	10.7	17	26	28	18	42	50	39	38	30	3	42	74	407
910	080791	PCMR SOUTH	202	15.2	15	19	11	4	19	35	36	39	29	30	39	14	290
911	081291	PCMR OLD S BOUN	252	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
912	081291	PCMR OLD S BOUN	252	4.6	0	0	0	0	10	0	0	0	0	0	6	4	20
913	081291	PCMR OLD S BOUN	251	10.7	22	3	42	3	0	3	48	2	5	3	0	3	134
914	081291	PCMR OLD S BOUN	251	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0
915	072991	PCMR NEW SOUTH	253	4.6	2	0	0	17	11	1	0	0	0	0	0	0	31
916	072991	PCMR NEW SOUTH	253	10.7	4	0	0	0	0	0	16	0	0	0	0	0	20
917	072991	PCMR NEW SOUTH	253	15.2	0	2	0	0	0	0	0	0	0	0	0	0	2
918	072991	PCMR NEW SOUTH	253	15.2	0	0	0	0	0	6	0	0	0	0	0	0	6
919	072991	GP MILL COVE	650	10.7	0	0	0	0	1	0	0	0	0	1	0	0	2
920	072991	GP MILL COVE	650	10.7	0	0	0	2	0	1	0	0	0	1	0	0	4
921	072991	GP MILL COVE	650	4.6	3	0	0	0	0	0	0	0	0	0	0	0	3
922	072991	GP MILL COVE	650	15.2	0	0	8	3	0	0	7	6	3	0	0	0	27
923	072891	NOYO BAY	601	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0
924	072891	NOYO BAY	601	10.7	0	0	2	0	0	0	0	0	1	0	0	0	3
925	072891	NOYO BAY	601	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0
926	072891	HARE CREEK	501	4.6	2	0	2	0	4	8	0	0	0	1	0	5	22
927	072891	HARE CREEK	501	10.7	0	0	0	0	0	0	0	0	0	0	0	0	0
928	072891	HARE CREEK	501	10.7	0	0	0	0	0	0	0	0	0	0	0	0	0
929	072891	HARE CREEK	501	4.6	0	6	0	0	0	0	0	2	0	0	0	0	8
930	081591	BEAVER PT	401	4.6	3	13	46	23	24	5	3	27	29	3	13	2	191
931	081591	BEAVER PT	401	10.7	0	0	0	0	0	0	0	1	0	0	0	0	1
932	081591	BEAVER PT	401	15.2	0	0	0	0	0	0	0	0	0	0	0	0	0
933	081591	MITCHELL PT.	402	10.7	0	0	0	0	0	0	0	0	0	0	0	0	0
934	081591	MITCHEL PT.	402	10.7	0	0	0	0	0	0	0	0	0	0	0	0	0
935	072791	NORTH CASPAR	301	4.6	0	2	0	0	0	0	0	1	2	0	9	2	16
936	072791	NORTH CASPAR	301	10.7	10	0	0	0	4	0	0	1	0	0	0	0	15
937	072791	NORTH CASPAR	301	15.2	0	3	0	0	0	3	0	0	0	0	0	0	6
938	072791	NORTH CASPAR	301	15.2	0	0	0	0	0	4	0	0	0	0	0	1	5
939	073091	MENDO PIPE LINE	105	4.6	16	0	17	2	1	0	33	1	4	0	1	4	79
940	073091	MENDO PIPE LINE	105	10.7	0	0	0	3	12	4	2	0	4	5	0	0	30
941	073091	MENDO PIPE LINE	105	15.2	0	0	0	0	0	3	0	0	0	0	0	0	3
942	081391	CASPAR N.W.	301	4.6	3	17	0	18	15	18	36	6	10	10	0	21	154
943	081391	CASPAR N.W.	301	10.7	31	0	0	3	40	33	72	0	0	1	7	63	250
944	081391	CASPAR N.W.	301	15.2	51	6	23	4	16	6	22	0	0	0	12	3	143
945	080891	CASPAR WEST	302	4.6	68	17	5	0	31	4	14	9	0	2	10	4	164

APPENDIX B:1991 FINE SCALE SURVEY RED URCHIN COUNTS BY TRANSECT (CONT.)

TRANSECT CODE	DATE	LOCATION	SITE NO.	DEP M	QUADRATS* Q1A	Q2A	Q3A	Q4A	Q5A	Q6A	Q1B	Q2B	Q3B	Q4B	Q5B	Q6B	TOTAL
946	080891	CASPAR WEST	302	10.7	0	31	54	37	56	13	27	29	36	6	28	1	318
947	080891	CASPAR WEST	302	15.2	0	3	0	53	53	55	0	0	0	118	60	42	384
948	080791	CASPAR REEF	303	4.6	3	0	4	1	0	0	3	1	4	1	0	0	17
949	080791	CASPAR REEF	303	4.6	0	0	0	2	9	0	0	0	0	0	0	4	15
950	080791	CASPAR REEF	303	10.7	68	29	45	95	45	3	999	999	999	999	999	999	285
951	080791	CASPAR REEF	303	15.2	17	16	26	27	15	3	40	21	46	41	43	27	322
952	081591	CASPAR NEWHOUSE	304	4.6	4	25	0	9	27	2	3	38	0	78	7	0	193
953	081591	CASPAR NEWHOUSE	304	4.6	23	34	15	43	81	171	44	8	40	19	25	68	571
954	080891	CASPAR POOL	305	4.6	27	8	27	18	62	18	4	13	1	4	9	28	219
955	080591	CASPAR POOL	305	10.7	21	0	11	101	83	89	39	3	30	89	152	86	646
956	080591	CASPAR POOL	305	10.7	1	0	0	0	0	0	0	3	0	63	60	42	169
957	072791	CASPAR STEAMER	306	4.6	0	4	8	7	0	0	0	60	40	0	0	0	118
958	072791	CASPAR STEAMER	306	10.7	0	2	5	3	2	12	2	0	0	0	0	0	26
959	072791	CASPAR STEAMER	306	15.2	7	13	11	1	2	2	39	12	6	7	8	0	108
960	080891	CASPAR RESERVE	307	4.6	4	6	23	29	32	29	6	10	19	23	24	43	248
961	080891	CASPAR RESERVE	307	10.7	2	0	17	64	0	3	4	6	12	0	0	3	111
962	080891	CASPAR RESERVE	307	15.2	7	7	1	3	8	0	7	0	5	10	0	0	48
963	080191	SAUNDERS REEF S	803	10.7	0	3	0	12	0	2	5	14	9	999	999	999	45
964	080191	SAUNDERS REEF S	803	10.7	0	1	0	0	8	13	3	8	0	0	0	0	33
965	080191	SAUNDERS REEF S	803	15.2	1	0	0	27	0	0	9	0	0	10	0	0	47
966	080191	SAUNDERS REEF N	807	10.7	12	21	0	0	49	79	41	34	57	64	80	30	467
967	080191	SAUNDERS REEF N	807	15.2	28	27	5	8	1	16	28	42	0	0	0	0	155

*999 = NOT SURVEYED

1991 FINE SCALE SOLITARY RED URCHIN SIZE (MM) FREQUENCY DATA BY TRANSECT CODE

CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ
900	45	1	903	110	3	907	65	2	913	105	1	929	70	1
900	70	1	903	115	4	907	70	2	913	125	1	929	80	1
900	75	1	903	120	6	907	75	1	915	75	1	929	95	1
900	85	5	903	125	4	907	85	4	915	80	1	929	100	2
900	90	1	903	130	4	907	90	1	915	90	1	929	105	2
900	95	2	903	135	1	907	95	2	915	95	5	929	120	1
900	100	5	904	25	1	907	100	4	915	100	3	930	70	1
900	105	5	904	35	1	907	105	2	915	105	6	930	75	2
900	110	8	904	55	3	907	110	4	915	115	2	930	80	1
900	115	5	904	60	1	907	115	2	915	120	1	930	85	4
900	120	3	904	65	3	907	120	5	915	125	1	930	90	5
900	125	4	904	75	5	907	125	4	915	130	3	930	95	8
900	130	2	904	85	2	907	135	5	915	140	1	930	100	12
901	55	1	904	90	1	907	140	3	916	65	2	930	105	7
901	65	1	904	95	1	907	145	2	916	75	3	930	110	4
901	75	1	904	100	1	907	150	2	916	85	4	930	115	2
901	85	6	904	105	1	907	155	1	916	90	2	930	120	2
901	90	2	904	115	2	908	95	1	916	95	3	930	125	2
901	95	9	904	120	3	908	100	2	916	100	4	930	130	1
901	100	4	904	125	3	908	115	2	916	105	2	935	65	2
901	105	8	904	130	5	908	130	1	917	65	1	935	75	3
901	110	1	904	135	5	908	135	1	917	115	1	935	80	1
901	115	2	904	140	2	908	140	1	919	55	1	935	85	3
901	120	2	904	145	2	909	60	1	919	65	1	935	95	2
901	125	4	904	150	1	909	65	2	919	85	1	935	105	2
901	135	1	905	25	2	909	70	1	919	105	1	935	120	2
901	145	1	905	30	1	909	75	3	919	75	1	935	125	1
901	150	1	905	35	1	909	80	2	919	155	1	936	70	1
902	35	1	905	45	1	909	85	8	920	90	1	936	75	1
902	40	1	905	70	1	909	90	4	920	100	1	936	80	2
902	50	2	905	80	2	909	95	11	920	120	1	936	95	3
902	60	2	905	85	1	909	100	3	920	130	1	936	100	1
902	65	1	905	90	1	909	105	8	921	105	1	936	105	3
902	80	2	905	95	1	909	110	4	921	125	1	936	110	2
902	85	1	905	100	2	909	120	1	921	140	1	936	125	1
902	90	3	905	105	2	910	80	1	922	35	3	937	80	1
902	95	4	905	110	3	910	90	2	922	45	1	937	110	1
902	100	6	905	115	2	910	95	2	922	75	2	938	45	1
902	105	2	905	120	9	910	100	2	922	80	1	938	60	1
902	110	2	905	125	5	910	105	3	922	90	1	938	75	2
902	115	1	905	135	1	910	115	1	922	95	3	938	110	1
902	120	5	905	140	4	910	120	4	922	100	2	939	65	1
902	125	2	905	145	1	910	135	1	922	105	4	939	70	1
902	130	3	906	55	1	912	85	1	922	115	4	939	75	1
902	135	2	906	85	1	912	90	4	922	120	2	939	85	4
903	30	1	906	90	1	912	95	2	922	125	1	939	90	3
903	35	1	906	95	5	912	100	1	922	160	1	939	95	7
903	45	1	906	100	4	912	105	3	924	85	1	939	100	7
903	60	1	906	105	8	912	110	3	924	115	2	939	105	11
903	65	3	906	110	1	912	115	2	926	80	1	939	110	4
903	70	1	906	115	7	913	35	2	926	100	4	939	115	5
903	75	1	906	120	2	913	50	1	926	105	2	939	120	2
903	80	4	906	125	3	913	55	1	926	110	2	939	125	1
903	85	5	906	130	1	913	70	1	926	115	2	939	155	1
903	90	4	907	30	1	913	85	3	926	120	2	940	30	1
903	95	4	907	35	1	913	90	2	926	125	4	940	35	2
903	100	5	907	45	1	913	95	6	926	130	1	940	40	2
903	105	4	907	80	1	913	100	3	926	135	5	940	45	2

1991 FINE SCALE SOLITARY RED URCHIN SIZE (MM) FREQUENCY DATA BY TRANSECT CODE (CONT.)

CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ	CODE	SIZE	FREQ
940	55	2	945	120	2	950	115	2	955	75	1	959	85	1
940	85	4	945	125	2	950	120	2	955	80	2	959	100	4
940	90	2	945	130	1	950	135	1	955	85	4	959	105	4
940	100	2	945	135	1	951	20	1	955	90	6	959	110	5
940	110	1	945	140	1	951	25	2	955	95	8	959	115	2
941	50	1	946	30	1	951	30	1	955	100	6	959	120	2
942	40	1	946	40	1	951	40	1	955	105	7	959	125	1
942	70	1	946	45	1	951	50	2	955	110	2	959	130	2
942	75	1	946	50	1	951	60	3	955	115	2	959	135	2
942	80	3	946	65	2	951	70	1	955	120	1	959	140	1
942	85	4	946	80	1	951	80	3	955	125	4	959	145	1
942	90	6	946	85	2	951	85	2	955	135	1	959	150	2
942	95	4	946	90	2	951	90	5	955	140	2	960	70	2
942	100	5	946	95	3	951	95	1	955	145	1	960	80	1
942	105	5	946	100	3	951	100	2	956	80	3	960	85	3
942	110	3	946	105	1	951	105	1	956	85	3	960	90	1
942	115	2	946	110	3	951	115	1	956	90	4	960	95	6
942	120	3	946	115	10	951	120	1	956	95	3	960	100	10
942	125	1	946	120	4	952	65	4	956	100	5	960	105	5
942	135	1	946	125	3	952	80	3	956	105	4	960	110	9
943	40	1	946	130	2	952	85	3	956	110	4	960	115	5
943	70	2	946	140	1	952	100	6	956	120	1	960	120	3
943	75	3	947	20	1	952	105	10	956	125	1	960	125	3
943	80	2	947	25	1	952	110	9	957	75	2	961	45	1
943	85	4	947	65	3	952	115	5	957	80	1	961	55	1
943	90	3	947	70	2	952	120	2	957	95	1	961	85	5
943	95	8	947	75	10	952	130	1	957	100	5	961	90	2
943	100	2	947	80	5	952	140	1	957	105	4	961	95	7
943	105	9	947	85	3	953	70	1	957	110	4	961	100	3
943	110	5	947	90	2	953	75	1	957	115	7	961	105	13
943	115	6	947	95	4	953	85	6	957	120	6	961	115	7
943	125	1	947	100	7	953	90	7	957	125	4	961	120	2
944	15	1	947	105	1	953	95	5	957	130	2	961	125	2
944	25	1	947	110	6	953	100	5	957	135	2	962	50	1
944	30	1	947	115	2	953	105	8	957	140	3	962	60	1
944	40	1	948	70	1	953	110	3	957	145	1	962	65	1
944	55	2	948	75	1	953	115	2	957	150	1	962	70	2
944	65	3	948	80	2	953	120	4	958	75	2	962	75	1
944	70	1	948	100	4	953	125	1	958	80	1	962	80	1
944	75	2	948	105	2	953	130	2	958	85	1	962	85	1
944	80	3	948	110	2	953	135	4	958	90	1	962	90	4
944	85	4	948	115	1	953	140	1	958	95	2	962	95	2
944	90	10	948	120	2	954	30	1	958	100	1	962	100	6
944	95	4	948	125	2	954	35	1	958	105	6	962	105	5
944	100	5	949	80	1	954	65	3	958	110	3	962	110	7
944	105	1	949	85	6	954	75	1	958	115	4	962	115	1
944	110	3	949	100	6	954	80	2	958	120	2	962	120	1
944	120	4	949	105	2	954	85	5	958	130	1	963	20	1
944	125	2	950	25	1	954	90	4	958	135	1	963	25	1
944	130	1	950	65	2	954	95	8	958	140	1	963	30	3
945	50	1	950	70	2	954	100	4	958	155	1	963	35	1
945	80	1	950	75	3	954	105	6	959	25	1	963	40	1
945	85	1	950	80	2	954	110	2	959	35	2	963	55	2
945	95	6	950	85	4	954	115	5	959	40	1	963	65	2
945	100	7	950	95	4	954	120	2	959	50	1	963	75	3
945	105	7	950	100	3	954	125	4	959	80	3	963	80	5
945	110	8	950	105	9	954	140	1	959	85	3	963	85	6
945	115	10	950	110	3	954	155	1	959	90	2	963	90	2

1991 FINE SCALE SOLITARY RED URCHIN SIZE (MM) FREQUENCY DATA BY TRANSECT CODE (CONT.)

CODE	SIZE	FREQ	CODE	SIZE	FREQ
963	95	2	967	40	2
963	105	1	967	65	2
964	25	1	967	70	2
964	30	1	967	75	3
964	35	2	967	80	4
964	45	2	967	85	6
964	55	1	967	90	1
964	65	1	967	105	1
964	95	2			
964	100	2			
964	105	2			
964	110	2			
964	115	5			
964	120	2			
964	125	1			
964	130	1			
965	25	2			
965	30	2			
965	35	2			
965	40	4			
965	45	2			
965	50	1			
965	55	3			
965	60	1			
965	70	2			
965	75	2			
965	80	2			
965	85	4			
965	90	3			
965	95	2			
965	100	1			
965	105	1			
965	110	1			
965	125	1			
966	25	1			
966	30	1			
966	35	1			
966	40	1			
966	45	1			
966	60	1			
966	65	3			
966	75	2			
966	80	2			
966	85	4			
966	90	4			
966	95	5			
966	105	5			
966	110	1			
966	115	1			
966	120	1			
966	125	1			
966	130	1			
966	135	1			
967	20	2			
967	25	3			
967	30	3			

1991 FINE SCALE CANOPY GROUPED RED URCHIN SIZE (MM) DATA BY TRANSECT CODE

CODE	CNPY*	SIZE	CODE	CNPY*	SIZE	CODE	CNPY*	SIZE	CODE	CNPY*	SIZE	CODE	CNPY*	SIZE
800	101	85	806	102	105	810	113	130	840	102	100	851	201	20
800	201	25	806	202	20	810	213	15	840	202	80	851	201	25
800	102	100	806	103	85	810	213	20	840	103	130	851	102	80
800	202	35	806	203	20	810	213	25	840	203	25	851	202	25
800	103	100	806	104	100	810	114	85	840	104	80	852	101	105
800	203	35	806	204	20	810	214	25	840	204	30	852	201	35
801	101	120	806	105	115	812	101	100	841	101	70	852	102	100
801	201	20	806	105	115	812	201	30	841	201	25	852	202	25
801	102	85	806	105	125	812	102	100	842	101	80	852	103	95
801	202	20	806	105	120	812	202	30	842	201	20	852	203	30
801	103	100	806	205	45	813	101	105	842	102	85	854	101	80
801	203	25	806	105	85	813	201	30	842	202	30	854	201	25
801	104	120	806	106	95	813	102	80	842	202	25	855	101	120
801	204	15	806	206	30	813	102	100	842	103	105	855	201	15
802	101	120	806	206	35	813	202	20	842	103	115	855	201	10
802	201	10	807	101	145	813	103	85	842	203	20	855	102	110
802	102	130	807	101	105	813	103	85	843	101	100	855	202	20
802	202	40	807	201	25	813	203	30	843	201	15	859	101	110
802	103	140	807	201	35	813	104	100	843	102	70	859	201	20
802	203	30	807	102	125	813	104	85	843	102	85	859	102	105
802	203	20	807	202	35	813	204	30	843	202	35	859	202	25
802	104	100	808	101	100	813	204	25	844	101	85	859	202	30
802	204	20	808	201	15	813	105	80	844	201	25	859	103	120
802	105	130	809	101	80	813	205	30	844	102	105	859	203	25
802	205	40	809	101	110	813	205	35	844	202	25	859	104	75
802	205	40	809	201	20	813	106	100	845	101	115	859	204	20
802	106	105	809	102	80	813	106	85	845	201	25	859	105	80
802	206	35	809	202	20	813	206	15	846	101	115	859	105	85
802	107	110	810	101	100	813	206	35	846	201	40	859	205	25
802	207	45	810	201	35	813	206	25	846	102	85	859	106	100
803	101	100	810	102	140	813	107	85	846	102	115	859	206	25
803	101	110	810	202	30	813	207	20	846	202	30	859	107	80
803	201	30	810	103	105	813	108	85	846	202	20	859	207	25
803	102	125	810	203	30	813	108	80	846	103	105	859	207	25
803	202	30	810	104	110	813	208	35	846	103	115	860	101	100
803	202	10	810	204	25	813	109	85	846	203	35	860	201	15
804	101	80	810	105	140	813	209	30	846	104	85	860	102	85
804	201	30	810	205	30	813	209	20	846	204	20	860	202	20
804	102	100	810	205	20	813	110	80	847	101	100	860	103	85
804	202	40	810	106	130	813	210	30	847	201	25	860	203	15
804	202	20	810	206	20	813	210	35	847	102	80	861	101	110
804	103	130	810	206	35	815	101	100	847	202	25	861	101	80
804	203	35	810	206	20	815	201	35	850	101	130	861	201	30
804	203	35	810	206	15	815	102	85	850	201	80	861	102	115
805	101	130	810	107	105	815	202	20	850	102	105	861	202	20
805	201	40	810	207	15	818	101	120	850	102	80	861	103	100
805	102	85	810	108	110	818	201	40	850	202	35	861	203	30
805	202	30	810	208	20	830	101	85	850	202	30	862	101	80
805	103	85	810	208	15	830	201	15	850	202	30	862	201	25
805	203	30	810	208	20	838	101	80	850	103	100	862	102	85
805	104	85	810	109	85	838	201	30	850	203	30	862	202	10
805	204	35	810	209	20	838	201	45	850	104	80	862	103	110
805	105	125	810	110	100	839	101	85	850	104	85	862	203	30
805	205	30	810	210	30	839	101	100	850	204	30	862	104	80
805	106	130	810	111	85	839	101	110	850	204	35	862	204	35
805	206	80	810	211	30	839	201	40	850	105	110	862	105	85
806	101	110	810	112	85	840	101	110	850	205	30	862	205	25
806	201	30	810	212	30	840	201	30	851	101	110	862	106	80

1991 FINE SCALE CANOPY GROUPED RED URCHIN SIZE (MM) DATA BY TRANSECT CODE

CODE	CNPY*	SIZE	CODE	CNPY*	SIZE
962	106	125	967	102	80
962	206	20	967	202	35
962	107	115	967	103	100
962	207	25	967	103	110
963	101	80	967	203	15
963	201	15	967	203	25
963	102	80	967	203	25
963	202	20	967	104	90
963	103	75	967	204	20
963	103	80	967	204	30
963	203	25	967	204	15
963	203	25	967	204	20
963	104	80	967	204	20
963	204	25	967	105	95
963	105	65	967	205	20
963	105	80	967	205	10
963	205	15	967	106	80
964	101	110	967	206	25
964	201	20	967	107	80
964	102	100	967	207	45
964	102	95			
964	202	30			
964	103	90			
964	103	110			
964	203	25			
965	101	80			
965	201	30			
965	102	80			
965	202	25			
965	103	85			
965	203	35			
965	203	35			
965	104	55			
965	204	30			
966	101	105			
966	101	110			
966	201	35			
966	201	25			
966	102	80			
966	102	105			
966	202	40			
966	103	80			
966	103	100			
966	203	30			
966	104	100			
966	104	80			
966	104	55			
966	204	30			
966	105	85			
966	105	85			
966	205	25			
966	106	80			
966	106	100			
966	206	25			
966	206	25			
966	206	15			
967	101	105			
967	201	15			

* First digit: 1 = canopy provider, 2 = canopied urchin
Second, third digits: canopy group within transect