Survey Results of Green Sea Urchin *(Strongylocentrotus droebachiensis)* Populations in Queen Charlotte Strait, British Columbia, November 1997 and March 1998

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SURVEY RESULTS OF GREEN SEA URCHIN (*Strongylocentrotus droebachiensis*) POPULATIONS IN QUEEN CHARLOTTE STRAIT, BRITISH COLUMBIA, NOVEMBER 1997 AND MARCH 1998

by

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Two surveys of green sea urchins (*Strongylocentrotus droebachiensis*) were undertaken jointly between Fisheries and Oceans Canada (DFO) and industry (West Coast Green Urchin Association - WCGUA) in Queen Charlotte Strait, British Columbia, the first from November 5-7, 1997, and the second from March 3-4, 1998. These surveys are part of a continuing series, where long-term objectives are to assess variability in green sea urchin populations, and to monitor impacts due to a commercial fishery. The surveys described here were performed before and after the commercial fishery, during one fishing season, and were undertaken at three sites, in areas open or closed to fishing. Surveys were conducted by SCUBA divers, using the transect-quadrat method. Data were collected on size and abundance of green sea urchins, gonad weight and quality, and on the depth, substrate and vegetation of each quadrat in the survey.

The total biomass of legal-sized green sea urchins in the site open to commercial fishing (Stephenson Islets) increased by 2.21 t (or 2.39 t, depending on the method of calculation), from 41.02 ± 7.72 t in November, 1997 to 43.23 (or 43.41) ± 9.53 t in March, 1998, likely as a result of net immigration and/or growth into the legal size category. The total biomass of green urchins removed over the course of the fishery at Stephenson Islets (November, 1997 to January, 1998) was 11.65 t, which is 28% of the estimated pre-fishery biomass of legal-sized green urchins at this location.

RÉSUMÉ

Waddell, B. J., R. I. Perry, and D. Kensall. 2003. Survey results of green sea urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British Columbia, November 1997 and March 1998. Can. Tech. Rep. Fish. Aquat. Sci. 2476: x + 68 p.

Pêches et Océans Canada (MPO) et l'industrie (West Coast Green Urchin Association - WCGUA) ont entrepris conjointement deux relevés sur les oursins verts (*Strongylocentrotus droebachiensis*) dans le détroit Reine-Charlotte, en Colombie-Britannique, le premier du 5 au 7 novembre 1997 et le deuxième, les 3 et 4 mars 1998. Ces relevés s'inscrivent dans une série dont les objectifs à long terme sont l'évaluation de la variabilité des populations d'oursins verts et la surveillance des impacts de la pêche commerciale. Les relevés décrits dans le présent article ont été effectués avant et après la campagne de pêche commerciale, pendant une saison de pêche, sur trois sites, dans des zones ouvertes ou fermées à la pêche. Les relevés ont été effectués par des plongeurs autonomes, à l'aide de la méthode des transects et des quadrats. Les données recueillies portaient sur la taille et l'abondance des oursins verts, le poids et la qualité de leurs gonades, ainsi que sur la profondeur, le substrat et le couvert végétal de chaque quadrat.

La biomasse totale des oursins verts de taille légale sur le site ouvert à la pêche commerciale (îlots Stephenson) a augmenté de 2,21 t (ou de 2,39 t, selon la méthode de calcul), passant de 41,02 ± 7,72 t en novembre 1997 à 43,23 (ou 43,41) ± 9,53 t en mars 1998, probablement à la suite d'une immigration nette et/ou de la croissance des spécimens qui sont passés dans la catégorie de taille légale. La biomasse totale des oursins verts capturés au cours de la pêche dans les îlots Stephenson (novembre 1997 à janvier 1998) s'établissait à 11,65 t, ce qui correspond à 28 % de l'estimation avant la pêche de la biomasse des oursins verts de taille légale à cet endroit.

INTRODUCTION

The commercial green sea urchin (*Strongylocentrotus droebachiensis*) fishery has existed in British Columbia since 1987. Hand-picking by divers is the only method allowed to harvest this species. It is currently managed using a minimum size limit of 55 mm test diameter (TD), by restricting areas and fishing seasons (usually from November until February or March), area quotas, and by an Individual Quota (IQ) system. Fishers are required, as a condition of licence, to complete harvest logbooks and submit them to Fisheries and Oceans Canada (DFO). The logbooks contain information on the dates and locations that green urchins were caught, divers' names, how long fishing was conducted each day (i.e., effort), and the total weight of urchins removed (i.e., catch). Up until 1996, these, along with sales slip data, have been the only sources of B.C. data available upon which DFO stock assessments and management decisions have been based. These data are of variable quality because of changes in fishing practices and the aggregating nature of green sea urchin distributions. The harvest logbooks also do not contain information on sublegal-sized urchins, size frequencies from the whole population, densities, roe quality and quantity, or habitat associations. Therefore, detailed surveys were conducted in October, 1995 and March, 1996 (Waddell *et al.* 1997), and in November, 1996 and February, 1997 (Waddell *et al.* 2002) to obtain this crucial information. By coordinating surveys that involved all parties with interests in the green sea urchin fishery, i.e., DFO, First Nations (first two years of surveys only) and the commercial industry, there has been improved confidence and acceptance of these data. This report presents the data collected from on-going cooperative surveys performed by DFO and industry (West Coast Green Urchin Association or WCGUA) in November, 1997 and March, 1998 in Pacific Fisheries Management Area (PFMA) 12 (Queen Charlotte Strait; Figs. 1a-c). An overview and interpretations of these and on-going surveys will be presented in a future paper.

The first survey occurred November 5 to 7, 1997, just prior to the opening of the commercial green sea urchin fishery (November 10, 1997). The survey included the Stephenson Islets, an area open to commercial harvest, and nearby Stubbs Island and the Plumper Islands, areas both closed to commercial fishing (Fig. 1a). During this fishing season, Area 12 (or PFMA 12), where the survey area is located, was closed on January 16, 1998, when the allowed quota for the area was reached. The second survey was performed following the closure (March 3 to 4, 1998), and was basically a repeat of the first survey, involving the same parties and sites.

The long-term objectives of these green sea urchin scientific surveys are to monitor population changes and to assess the impacts of the fishery on green sea urchin populations at a key fishery location. To do this, green sea urchin densities, size measurements, and subsamples for gonad quantity and quality were obtained, both in areas open and closed to commercial green sea urchin fishing (prior to the opening of and following the closure of the commercial fishery). The Stephenson Islets met the criterion for the survey site open to commercial fishing because it is located in PFMA 12, where the majority of the fishery occurs, and because fishers have historically found this site to have high densities of legal-sized green sea urchins. Stubbs Island and the Plumper Islands met the criterion for monitoring population changes due to environmental variations, and are located close to the Stephenson Islets. Stubbs Island and the

NW section of the Plumper Islands have been closed to commercial fishing (for research purposes) since the fall of 1995 (Fig. 1a).

METHODS

(a) DATA COLLECTION – FIELD AND LAB

During the first survey (November 5-7, 1997), ten transects were surveyed for green sea urchins in the Stephenson Islets (50°34.5' N, 126°49.5' W), at the north end of Johnstone Strait, near Telegraph Cove and Weynton Passage (Fig. 1b), four transects at nearby Stubbs Island (50°36.2' N, 126°49.2' W; Fig. 1c), and six transects in the Plumper Islands (50°34.6' N, 126°48.0' W; Fig. 1c). The vessels involved were the CFV '*Clo-oose*' and the CFV '*Top Gun*', both industry-owned.

The second survey basically repeated the first survey. It was performed from March 3 to 4, 1998, following the Area 12 closure on January 16, 1998. The two vessels involved in this survey, the CFV '*Clo-oose*' and the CFV '*Risky Business*', were both owned by industry fishers.

In both surveys, there were two dive teams (i.e., two boats), each with one industry and one DFO diver, one boat driver (industry), one dive tender (industry), and one DFO observer/recorder. The green urchin surveys were designed, organized and supervised by DFO, and costs were supported by both DFO and industry.

The same transects at Stephenson Islets were surveyed as in the two green urchin surveys from the previous fishing season (Waddell *et al.* 2002), except that Transect 3A was surveyed instead of Transect 3 (slightly different positions; Fig. 1b), and Transect 6A was surveyed in November, 1997 instead of Transect 6. One additional transect was surveyed at Stubbs Island in comparison to past surveys, and two additional transects in the Plumper Islands. The transects at Stubbs Island and the Plumper Islands were the same in both the November, 1997, and March, 1998, surveys.

Transect positions had been randomly selected during previous surveys (Waddell *et al.* 1997, 2002). The additional transects were also randomly selected and marked on a chart prior to arriving at the survey area. The transects ran perpendicular to the shoreline and/or depth contours, starting at 10.0 m (32.8 ft) below Chart Datum (CD) and continuing up to zero CD. The angles were adjusted slightly to run parallel with the direction of the current. A computer program called "TIDE1" (Micronautics Inc. 1994) was used to calculate the tide levels for every half-hour so that the depth to CD could be determined before each dive commenced. A weighted line was laid from shallow to deep to mark the transect, with a surface marker buoy indicating the deep end of the line. At the start of each transect, a compass bearing was taken by the divers from the marker buoy to the shallow end. Beginning at the deep end, the divers placed a 1 m^2 aluminum quadrat on the substrate and counted and measured the test diameter (TD) (using calipers) of all sea urchins within the quadrat. All urchins were removed from the quadrat as they

were being measured to avoid repeating measurements. An urchin was considered to be in a quadrat if one-half or more of its body was within the quadrat's boundaries. Sometimes green urchins were under rocks or in crevices, so all surfaces were explored in order to find all sea urchins. One diver did all of the measuring while the other diver recorded the data on waterproof paper. The depth, substrate and type of vegetation were also recorded for each quadrat, and then the quadrat frame was rolled over in the direction of the lead line (or the compass bearing, where lead line could not be used), and the procedure was repeated along the transect line.

The surface personnel recorded the position (using a GPS) for both the start and finish of the transects, as well as the divers' start and finish times for each transect (for use in calculating depth from CD), and the weather conditions.

Green sea urchins of various size classes (small, medium and large) were randomly collected along the transect lines during the surveys for later laboratory analyses of weight and size and to examine the quality of the roe. For both surveys, the green urchins were measured and dissected on the same day they were collected. For each urchin collected, the following data were recorded: test diameter; test height; total wet weight; drained weight; gutted weight (stomach and contents removed); gonad weight, colour and texture; and sex. Gonad colour was given a qualitative rating code of 0 (unknown (i.e., missing), or no gonad present), 1 (orange/yellow), 2 (yellow with other colours), or 3 (brown/red). Gonad texture was also given a qualitative rating code of 0 (unknown (i.e., missing), or no gonad present), 1 (firm), 2 (semi-firm), and 3 (flimsy).

(b) DATA ANALYSES

It was noted that the divers occasionally started surveying deeper than 10.0 m below CD. Since the area estimate for the Stephenson Islets is based on the 10 m isobath, and green urchins are usually sparse below 10 m below CD, the divers' data were truncated to 10 m (33 ft) for the overall density calculations, and for the density by substrate calculations. This should help mitigate an underestimate of the total biomass. The original (unadjusted) data were used for all other calculations presented in this report.

Test diameter frequency distributions were analyzed using the software "MIX3aa" (Macdonald 1994) to identify dominant size modes under the assumption that individual modes were normally distributed (see Macdonald and Pitcher (1979), and Macdonald and Green (1988), for details). In general, initial parameters (mean, and standard deviation) were assigned by examination of test diameter frequency data collected during the surveys at each site. The software "MIX3aa" was then used to estimate the proportions while keeping the mean and standard deviation parameters fixed. Next, estimates of mean, standard deviation, and proportion were calculated by varying the constraints on each until a reasonable fit to the data was established. This fit was determined by the goodness-of-fit chi-square statistical test and examination of the size frequency histogram with its fitted components. The software fit the means, proportions, and standard deviations of the size frequency distributions using the Quasi-Newton Algorithm technique (Macdonald and Green 1988). The test diameter frequency

distributions were analyzed for data obtained at Stephenson Islets, Stubbs Island, and Plumber Islands during both surveys.

In many of the analyses, the data have been separated into three different size classes: legal-sized (TD ≥ 55 mm); sublegal-mature (25 mm ≥ TD < 55 mm); and sublegal-immature (TD < 25 mm). The mature/immature size of 25 mm TD was approximated from the dissection roe quality and maturity data, in which 100% of green urchins < 25 mm were immature (no gonad present) compared with 6% of urchins ≥ 25 mm being immature.

Mean and total densities of green urchins for each transect within each of the three survey sites (Stephenson Islets, Stubbs Island, and Plumper Island) were calculated as described by Jamieson and Schwarz (1998). These surveys are characterized by the quadrats within a transect not being independent (e.g. if one quadrat has a high number of urchins, then adjacent quadrats are likely to have high numbers as well), transect lengths vary among the transects, and all urchins within each transect are counted. These features indicate a "complete cluster" sampling design with unequal-sized clusters (Jamieson and Schwarz 1998). The appropriate calculation for the mean density (of a particular size class of urchins) is:

$$\overline{D} = \frac{\sum_{i=1}^{n} U_i}{\sum_{i=1}^{n} L_i} \qquad (1)$$

and for the standard error of density is:

$$SE(\overline{D}) = \sqrt{\frac{1}{\overline{L}^2}\frac{1}{n}\frac{\sum (U_i - L_i\overline{D})^2}{n-1}} \qquad (2)$$

With n = the number of transects sampled in a particular site;
U_i = the total number of urchins of the appropriate size class in transect i, $i = 1,2,...,n$;
L_i = the total number of quadrats in transect i; and
$\overline{L}$ = $\frac{1}{n}\sum_{i=1}^{n} L_i$, the average area of the transects in the site.

Since the area of a quadrat was 1 m^2, L_i is also equal to the area of the transect.

In the results that follow, standard errors have not been calculated for the individual transects since the transect has been defined as the (cluster) sample unit, and therefore the (n-1) term in the denominator of the equation for the standard error goes to zero. In the calculation of urchin densities by depth range and substrate type, however, the quadrats have been considered as the sampling unit, and distributed among the various depth and substrate categories. This reduces (but does not entirely eliminate) the problem of non-independence among adjacent quadrats, and so standard errors about the mean densities for these classifications have been calculated using standard formulae (e.g. as found in Sokal and Rohlf (1981) and as implemented in the "EXCEL 2002" (Microsoft) statistical software package).

The depth ranges below CD used for the "densities by depth range" calculations were determined by taking the tide height above CD every minute (from the "Tides and Currents for Windows" program (Nautical Software Inc. 1995)), then averaging them over the whole dive time for each transect. Then this mean tide height above CD was subtracted from the depth gauge reading recorded for each quadrat to give the approximate adjusted depth below CD.

For substrate data, the three most abundant substrates in the quadrat were recorded, in order of prominence. The tables and figures in this report displaying the substrate data use three digit codes that represent the order of prominence and type of substrates observed. A similar recording method was used for vegetation types. However, the vegetation data were incomplete, making it difficult to interpret from the data sheets whether algae were absent or just not recorded. In addition, the divers had varying skill levels in identifying algae species, so the data are not considered reliable. Therefore, the vegetation data have not been presented in this report.

The statistical software package "EXCEL 2002" (Microsoft) was used to find the best (i.e. highest R^2) relationships between TD (mm) and the variables test height (mm), total wet weight (g), and gonad weight (g). These were calculated from dissection data for all sites combined, and for each of the three sites separately, for the November, 1997 and March, 1998 surveys, and were in the form of $variable = \alpha(TD)^{\beta}$.

The mean abundance of green urchins was converted to total biomass for all of the survey sites using the mean weight of an individual urchin (separated into three size classes), the mean densities, and the total area of each site. Rather than using a single mean weight to convert abundance to biomass (as in Waddell *et al.* 1997), we used the following method (as in Waddell *et al.* 2002). The measured green urchins were separated into three size classes: legal-sized (TD $\geq$ 55 mm); sublegal-mature (25 mm $\geq$ TD < 55 mm); and sublegal- immature (TD < 25 mm). Mean weights of urchins ($\overline{W}_j$) were determined by calculating the weight of each individual urchin measured in the field survey (using the TD-weight relationships derived from the laboratory measurements), then calculating the mean weight of urchins within each size class (j). Standard errors about the mean weights (SE($\overline{W}_j$)) within a size class were determined by calculating the standard deviation of the mean weight and dividing by the square root of the sample size. In order to resolve if the test diameter and the natural log of the total wet weight relationship could be used for all sites combined (in each survey) or if the relationship for each site had to be used separately, a test for homogeneity of the regression slopes was performed. This test was programmed in "EXCEL 2002" using equations from Zar (1984, p. 300).

The total biomass for a particular site was then calculated as

$$B = \sum_{j=1}^{3} \overline{D}_j (\overline{W}_j)(A) \qquad (3)$$

in which j subscripts the three size classes. The area (A) (from 0 to 10.0 m below CD) of each survey site was determined to be 485,200 m^2 for Stephenson Islets, 19,600 m^2 for Stubbs Island, and 223,600 m^2 for the Plumper Islands, based on a geographic information program called COMPUGRID (Geo-Spatial Systems Ltd. 1996).

The standard error of the total biomass for a particular site, which includes the uncertainties in the mean density and mean weight by size category, is:

$$(4) \qquad SE(B) = \left[\sum_{j=1}^{3} \left[\left(\left(\frac{SE(D)_j}{\overline{D}_j} \right)^2 + \left(\frac{SE(W)_j}{\overline{W}_j} \right)^2 \right)^{\frac{1}{2}} (B_j) \right]^2 \right]^{\frac{1}{2}},$$

with symbols as previously defined, and assuming that the area (A) (used within the calculation for B_j) is known without error. A further assumption is that the errors in mean density and mean weight, and among size classes, are independent and random.

In order to determine the impact of fishing on the stock of green sea urchins at Stephenson Islets (the roe fishery site), we calculated exploitation by the fishing industry using two methods.

First, the exploitation by fishing of green urchins at Stephenson Islets can be defined as:

$$(5) \qquad Expl = \frac{B_{fishing}}{B_{Nov}},$$

with standard error defined by:

$$(6) \qquad SE(Expl) = (Expl) \left[\left(\frac{SE(B_{fishing})}{B_{fishing}} \right)^2 + \left(\frac{SE(B_{Nov})}{B_{Nov}} \right)^2 \right]^{\frac{1}{2}},$$

in which $B_{fishing}$ is the biomass removed by fishing, with standard error $SE(B_{fishing})$; B_{Nov} is the pre-season biomass, with standard error $SE(B_{Nov})$, defined here as either the total biomass or the biomass of legal-sized urchins from the November, 1997 survey, and *Expl* is the exploitation of green urchins (with standard error *SE(Expl)*), defined as a proportion of the pre-fishery biomass (either total or legal-sized only). The biomass removed by the fishery ($B_{fishing}$) at Stephenson Islets was determined by examining dockside validation records and charts of fishing locations submitted with these records, and tabulating the total landings. The precise error of the dockside weight measurements for validation is unknown, but considered to be small, therefore $SE(B_{fishing})$ was set at 1% of $B_{fishing}$.

Second, exploitation of green urchins at Stephenson Islets by the fishery can also be expressed as an instantaneous rate (E). This requires knowledge of the green urchin population before and after the fishery. The full equation for the change in biomass (B) between the two surveys is:

$$(7)\ B_{Mar} = B_{Nov} + growth + recruitment + immigration - emigration - natural\ mortality - fishing\ .$$

In this equation, growth effects between the two surveys can be removed by dealing in numbers of urchins rather than the biomass, and so "B" becomes "N", and growth = 0. However, dealing in numbers of urchins also requires fishing removals to be converted from biomass to numbers.

We did this by dividing the biomass removed by fishing ($B_{fishing}$) by the mean weight of a legal-sized urchin in November ($\overline{W}_{Legal,Nov}$):

$$N_{fishing} = \frac{B_{fishng}}{W_{Legal,Nov}}. \quad (8)$$

Recruitment will be zero if dealing with the entire stock at Stephenson Islets, since with spawning in the spring, settlement of juvenile urchins most likely occurs in late summer or early fall (i.e., before the November survey). However, when dealing with legal-sized urchins, "recruitment" of sublegal-sized animals into the legal size class as a result of growth during the winter is possible (and likely). At present we cannot estimate the numbers of urchins which may have grown into the legal size class between the two surveys, but we assume this to be small relative to the numbers of urchins already of legal size, and so we set recruitment to be zero for both total and legal-sized populations. In the absence of any quantitative information on immigration and emigration of green sea urchins in and out of the Stephenson Islets site between these November, 1997 and March, 1998 surveys, we assume the net of these two terms to be zero.

These assumptions then leave an equation in the form:

$$N_{Mar} = N_{Nov} - N_{fishing} - N_M, \quad (9)$$

in which N is the number of urchins (total population or legal size), and N_M represents the numbers of urchins lost to natural mortality. The instantaneous total mortality (Z) of legal-sized urchins over the winter can then be calculated by:

$$N_{Mar} = N_{Nov}e^{-Zt} \equiv \frac{(\ln N_{Nov} - \ln N_{Mar})}{t} = Z, \quad (10)$$

in which t is time, defined here to be one fishing season. Assuming that commercial fishing occurred only within the depth range of the survey (0 to 10.0 m below CD), the instantaneous fishing mortality (F) is:

$$F = \frac{N_{fishing}Z}{\left[N_{Nov}\left(1-e^{-Zt}\right)\right]}. \quad (11)$$

The instantaneous exploitation rate (E) is then calculated as:

$$E = \frac{F}{Z} \quad (12)$$

and the instantaneous natural mortality rate (M) is

$$M = Z - F. \quad (13)$$

Note that EXCEL spreadsheets are used for many of these calculations, and that each result from a sequence of calculations is not rounded off. Therefore, any differences between calculations and values shown in the tables are due to rounding errors.

RESULTS

(a) NOVEMBER 5-7, 1997 SURVEY

Ten transect lines were surveyed in the Stephenson Islets (Fig. 1b), four transects were surveyed at Stubbs Island (Fig. 1c), and six transects in the Plumper Islands (Fig. 1c). The tidal current was strong throughout most of the survey.

Size: Over all the sites sampled during this survey, data were recorded for 501 quadrats and test diameters (TD's) were measured for all but 10 green urchins in Transect 13. Of the 950 TD's measured, 433 (45.6%) were of legal size, 478 (50.3%) were sublegal-mature, and 39 (4.1%) were sublegal-immature (Table 1, corrected for unknowns). Figure 2a shows the size frequency distribution for all the sites combined during the November, 1997 survey. When combining all the test diameters measured at all sites during the November, 1997 survey, two distinct modes best fit the distribution (X^2 =92.5; df = 35; p <0.0001), with test diameter means at 43 and 56 mm (Table 2). The proportions of these modes were 36% and 64%, respectively. Mean TD's and total wet weights for urchins from all sites combined were 62.4 mm and 104.1 g for legal-sized urchins, 44.2 mm and 43.4 g for sublegal-mature urchins, and 17.0 mm and 4.1 g for sublegal-immature urchins (Table 3).

Density: The mean total density during this survey (all sites combined) was 1.90 ± 0.34 urchins/m^2 (Table 4). The mean overall legal density was 0.85 ± 0.15 urchins/m^2, the mean overall sublegal-mature density was 0.94 ± 0.22 urchins/m^2, and the mean overall sublegal-immature density was 0.08 ± 0.02 urchins/m^2.

Depth: The sample mean densities of green sea urchins by depth range for all sites combined are shown in Table 5a and Fig. 3a. The highest overall mean density (3.81 ± 0.85 urchins/m^2) of all sizes of green sea urchins (for all sites combined) were observed in the 0.1 to 1.5 m (0.1 to 5.0 ft) below CD range. This range included the highest density of legal-sized green sea urchins (1.66 urchins/m^2), and the highest density of sublegal green sea urchins (2.06 urchins/m^2) for all sites combined. The total mean densities generally decreased continuously with each deeper depth interval.

Substrate: Table 6a and Fig. 4a show the mean densities of green sea urchins by substrate type for all sites combined. While substrate of creviced bedrock only was the most sampled substrate (184 quadrats), followed by smooth bedrock (138 quadrats), smooth bedrock with shell had the highest total density (8.50 urchins/m^2; 4 quadrats), followed by creviced bedrock with boulders and cobble (8.00 urchins/m^2; 2 quadrats).

(i) Stephenson Islets

Size: Data were recorded for 688 green sea urchins from 317 quadrats. Of all of the TD measurements, 281 (40.8%) were of legal size, while 383 (55.7%) were sublegal-mature and 24 (3.5%) were sublegal-immature (Table 1, corrected for unknowns). The size frequency distribution can be seen in Fig. 2b. The test diameter frequency analysis for the November, 1997

survey is presented in Table 2. Stephenson Islets showed the best fit (X^2 = 87.0; df = 35; p <0.0001) with two dominant size modes with means occurring at 39 and 53 mm test diameter. The proportion of the length frequency data occurring in the first mode was 23%, with 77% occurring in the second mode. Mean TD's and total wet weights for urchins from Stephenson Islets were 60.9 mm and 96.8 g for legal-sized urchins, 44.8 mm and 44.5 g for sublegal-mature urchins, and 14.3 mm and 2.9 g for sublegal-immature urchins (Table 3).

Density: The mean overall density (all sizes combined) at Stephenson Islets was 2.17 ± 0.49 urchins/m^2, while the mean overall legal density was 0.87 ± 0.16 urchins/m^2, the mean overall sublegal-mature density was 1.19 ± 0.33 urchins/m^2, and the mean overall sublegal-immature density was 0.08 ± 0.03 urchins/m^2 (Table 4). The mean total densities per transect ranged from 0.70 urchins/m^2 in Transect 6A to 4.53 urchins/m^2 in Transect 13 (Table 4). The highest mean densities for legal-sized urchins occurred in Transect 14 (1.47 urchins/m^2), while the highest mean density of sublegal-mature urchins occurred in Transect 13 (3.12 urchins/m^2; Table 4). The highest mean density of sublegal-immature urchins occurred in Transect 5A (0.26 urchins/m^2; Table 4).

Depth: The mean total densities were highest (5.97 ± 1.40 urchins/m^2) between 0.1 to 1.5 m (0.1 to 5.0 ft) below CD, and generally became continuously lower with each deeper depth interval, down to 0.00 urchins/m^2 at 10.7 to 11.2 m (35.1 to 36.6 ft) below CD (Table 5b, Fig. 3b). The same general trend occurred for legal and sublegal urchins, with the highest mean densities of legal (2.32 urchins/m^2) and sublegal (3.50 urchins/m^2) urchins occurring between 0.1 to 1.5 m (0.1 to 5.0 ft) below CD (Table 5b).

Substrate: At Stephenson Islets, the most common substrate sampled was bedrock with crevices (108 quadrats), of which the mean total density was 3.61 urchins/m^2 (Table 6b, Fig. 4b). The highest mean total density (6.00 urchins/m^2) occurred on cobble with creviced bedrock (one quadrat). When the data were grouped by the main or primary substrate type, creviced bedrock had the highest total density (3.35 urchins/m^2 over 136 quadrats), whereas cobble had the lowest total density (0.89 urchins/m^2 over 19 quadrats).

(ii) Stubbs Island

Size: Data were recorded for green sea urchins from a total of 70 quadrats, on four transects. Of the total 179 green sea urchins measured, 121 (67.6%) were of legal size, 51 (28.5%) were sublegal-mature, and 7 (3.9%) were sublegal-immature (Table 1). When analyzing the size frequency distribution (Table 2 and Fig. 2c), the best fit occurred with two modes (X^2 = 31.2; df = 28; p = 0.3068), with the means at 32 and 62 mm TD, with proportions of 13% and 87%, respectively. Mean TD's and total wet weights for urchins from Stubbs Island were 65.9 mm and 120.2 g for legal-sized urchins, 45.7 mm and 47.1 g for sublegal-mature urchins, and 21.6 mm and 6.1 g for sublegal-immature urchins (Table 3).

Density: The mean overall (all transects combined) densities at Stubbs Island of legal, sublegal-mature, sublegal-immature, and total green sea urchins were 1.73 ± 0.54, 0.73 ± 0.19, 0.10 ± 0.05, and 2.56 ± 0.67 urchins/m^2, respectively (Table 4). The mean total densities ranged from

0.21 urchins/m^2 in Transect 18 to 3.43 urchins/m^2 in Transect 15 (Table 4). The highest mean legal (2.56 urchins/m^2) density occurred at Transect 17, the highest sublegal-immature (1.12 urchins/m^2) density occurred at Transect 16, and the highest mean sublegal-mature (0.29 urchins/m^2) density occurred at Transect 15 (Table 4).

Depth: The highest legal (4.88 urchins/m^2) and total (7.00 urchins/m^2) mean densities of green sea urchins for all sites during this survey, occurred at Stubbs Island between 4.8 and 6.1 m (15.1 and 20.0 ft) below CD (Table 5c and Fig. 3c). The highest density of sublegal (2.13 urchins/m^2) green urchins at Stubbs Island occurred between 4.8 and 6.1 m (15.1 and 20.0 ft) below CD. There were no urchins of any size in the Stubbs Island quadrats above CD.

Substrate: The most frequently sampled substrate was creviced bedrock (42 quadrats; Table 6c). This main substrate had a total overall density of 2.15 urchins/m^2 (Table 6c, Fig. 4c). High total mean densities occurred on substrates of smooth bedrock with shell (8.50 urchins/m^2; 4 quadrats), and on creviced bedrock with boulders and cobble (8.00 urchins/m^2; 2 quadrats; Table 6).

(iii) Plumper Islands

Size: Data were recorded for 83 green sea urchins, from 114 quadrats on six transects in the Plumper Islands. Of the total test measurements, 30 (36.1%) were of legal size, 45 (54.2%) were sublegal-mature, and 8 (9.6%) were sublegal-immature (Table 1). The size frequency distribution for the Plumper Islands fits two modes ($X^2 = 38.1$; df = 29; p = 0.1191), with mean test diameters occurring at 27 and 50 mm (Table 2, Fig. 2d). The proportions were 24% and 76% in the first and second mode, respectively. Mean TD's and total wet weights for urchins from the Plumper Islands were 62.7 mm and 106.8 g for legal-sized urchins, 38.4 mm and 31.3 g for sublegal-mature urchins, and 20.9 mm and 5.8 g for sublegal-immature urchins (Table 3).

Density: The mean overall densities of legal, sublegal-mature, sublegal-immature, and total green sea urchins at the Plumper Islands were 0.26 ± 0.09, 0.39 ± 0.14, 0.07 ± 0.03, and 0.73 ± 0.17 urchins/m^2, respectively (Table 4). The mean total densities ranged from 0.00 urchins/m^2 in Transect 19, to 1.29 and 1.17 urchins/m^2 in Transects 21 and 23, respectively (Table 4). The highest mean density for legal-sized urchins occurred in Transect 21 (0.71 urchins/m^2), while the highest mean densities of sublegal-mature urchins occurred in Transect 23 (1.06 urchins/m^2), and the highest mean density of sublegal-immature urchins (0.14 and 0.15 urchins/m^2) occurred in Transects 21 and 22, respectively.

Depth: The mean total density was highest (1.90 urchins/m^2; 20 quadrats) in the 3.0 to 4.8 m (10.1 to 15.0 ft) below CD depth range (Table 5d, Fig. 3d). The highest mean density of legal-sized green urchins (0.80 urchins/m^2) and sublegal urchins (1.10 urchins/m^2) occurred in the 3.0 to 4.8 m (10.1 to 15.0 ft) below CD depth range (Table 5d). Like Stubbs Island, there were no urchins of any size in the Plumper Islands quadrats above CD.

Substrate: The highest mean total density (6.00 urchins/m^2) of green urchins occurred on a substrate of creviced bedrock with boulders (1 quadrat only; Table 6d and Fig. 4d). The highest

sublegal density (6.00 urchins/m^2) also occurred on this substrate. The highest legal density (1.00 urchins/m^2) occurred on a substrate of smooth bedrock with sand (8 quadrats). The primary substrate with the highest total density of green urchins (1.03 ± 0.35 urchins/m^2) was smooth bedrock (Table 6d).

(iv) Dissection Data

There were a total of 101 green sea urchins of various sizes, from random locations and depths that were measured, weighed and sampled for roe quantity and quality during this survey (Table 7). All mean measurements (i.e., mean test height, mean test diameter, mean total wet weight, mean drained weight, mean gutted weight, and mean gonad weight) taken of the randomly selected legal-sized urchins were highest for Stubbs Island, intermediate at the Plumper Islands, and lowest at the Stephenson Islets (except test heights, which were intermediate for Stephenson Islets and lowest at the Plumper Islands; Table 7). This reflects the same results (TD only) found in the field survey data (Table 3).

The best (i.e., highest R^2) power relationships were calculated between TD (mm) and test heights (mm) (Figs. 5 and 6), TD (mm) and total wet weight (g) (Figs. 7 and 8), and TD (mm) and gonad weight (g) (Figs. 9 and 10), for all sites combined and for each of the three sites separately (see figures for equations).

A test for homogeneity showed no significant difference between the slopes of the regression lines for the relationship between test diameter (mm) and the natural log transformation (to approximate normality) of the total wet weight for each of the three sites separately (F value = 0.91 with df = 2, 98 and $p > 0.05$). This allowed the allometric equation ($W=\alpha TD^{\beta}$) to be used for all sites in the November, 1997 survey when calculating the total wet weight (g) from the TD (mm).

Amongst the legal-sized green urchins, those from Stephenson Islets had the best quality roe (i.e., colour = 1 (orange/yellow) and texture = 1 (firm)), with 51.6% having the highest quality, followed by the Plumper Islands with 50.0% and Stubbs Island with 33.3% (Table 8). Amongst the sublegal urchins, those from the Plumper Islands (50.0%) had the best quality roe, followed by Stephenson Islets (39.4%) and Stubbs Island (18.2%). The Plumper Islands had the highest (24.4%) legal-sized overall roe recovery rate (total gonad weight (all grades) divided by total drained weight of all urchins collected), followed by the Stephenson Islets (21.3%) and the Plumper Islands (21.1%; Table 8).

(iv) Biomass Estimates

Stephenson Islets is estimated to have an area of 485,200 m^2 between 0.0 and 10.0 m (0.0 and 32.8 ft) below CD. By extrapolation of the total mean density (2.17 ± 0.49 urchins/m^2; Table 4), there were approximately 1,053,052 ± 238,380 green sea urchins of all sizes in November, 1997, at Stephenson Islets (Table 9). (Note that EXCEL spreadsheets are used to make these calculations and that each sequential calculation is not rounded off. Therefore, any differences between calculations and values shown in the tables are due to rounding errors). Of

these, 423,976 (40.3%) were of legal size, and 613,770 (58.3%) were of sublegal size (577,036 mature-sized and 36,734 immature). As described in the Methods section, the weight of each individual urchin measured in the field survey was calculated using the TD-weight relationships derived from the laboratory measurements, and then the mean weight was calculated for each of the three size classes. Using the TD-weight relationship for all sites combined (Fig. 7), the mean weight per legal-sized green sea urchin from Stephenson Islets was determined to be 96.8 g (Table 3). (Note that the mean individual weight for legal-sized urchin from the Stephenson Islets was calculated to be 86.9 g in November, 1996 and 82.5 g in February, 1997 (Waddell *et al.* 2002)). Using the same TD-weight relationship, the mean weight per sublegal-mature-sized green urchin was determined to be 44.5 g, and the mean weight per immature-sized green urchin was 2.9 g (Table 3). The total biomass of legal-sized, sublegal-mature and immature green sea urchins at Stephenson Islets in November, 1997 was 41.02, 25.65 and 0.11 t, respectively, for an overall total biomass of 66.78 ± 10.56 t (Table 9).

Stubbs Island is estimated to have an area of 19,600 m^2 between 0.0 and 10.0 m (0.0 and 32.8 ft) below CD. By extrapolation from the mean densities (Table 4), there were approximately 50,120 ± 13,208 green sea urchins of all sizes (33,880 legal-sized, 14,280 sublegal-mature-sized, and 1,960 immature-sized) at Stubbs Island in November, 1997 (Table 9). The mean weight for individual legal-sized, sublegal-mature, and sublegal-immature urchins at Stubbs Island was 120.2, 47.1, and 6.1 g (Table 3). The total biomass of legal-sized, sublegal-mature, and immature green sea urchins at Stubbs Island in November, 1997 was 4.07, 0.67 and 0.01 t, respectively, for an overall total biomass of 4.76 ± 1.28 t (Table 9).

The survey site in the Plumper Islands has an area of approximately 223,600 m^2 between 0.0 and 10.0 m (0.0 and 32.8 ft) below CD. By extrapolating the mean densities (Table 4), there was a total abundance of approximately 162,796 ± 37,657 green sea urchins (58,842 legal-sized, 88,263 sublegal-mature-sized, and 15,691 immature) at the Plumper Islands in November, 1997 (Table 9). The mean weight of legal, sublegal-mature and sublegal-immature green urchins in the Plumper Islands in November, 1997 was 106.8, 31.3, and 5.8 g (Table 3). Ignoring the green urchins of unknown size, the biomass of legal-sized, sublegal-mature, and immature green sea urchins at the Plumber Islands in November, 1997 was 6.29, 2.77 and 0.10 t, respectively, for an overall total biomass of 9.14 ± 2.43 t (Table 9).

(b) MARCH 3-4, 1998

The same transect lines were surveyed in March, 1998 as in November, 1997 (ten in the Stephenson Islets (Fig. 1b), four at Stubbs Island, and six in the Plumper Islands (Fig. 1c)), except that Transect 6 was surveyed instead of Transect 6A (different angles and Transect 6A did not go any shallower than 18 ft below CD). The tidal current was strong throughout most of the survey.

Size: There were 1,364 test diameter measurements recorded for green sea urchins (Table 1) from a total of 487 quadrats during the whole survey. It was found that 427 (31.3%) of the green urchins were of legal size, 865 (63.4%) were sublegal-mature, and 72 (5.3%) were sublegal-

immature (Table 1, corrected for unknowns). The size frequency distribution for all sites combined is presented in Fig. 11a. When analyzing the combined data for all of the test diameter measurements taken during the entire survey, two dominant size modes fit the data best (X^2 = 63.9; df = 36; p = 0.0028) with test diameter means of 33 and 52 mm (Table 2). The proportions for these modes were 26% and 74%, respectively. Mean TD's and total wet weights for urchins from all sites combined were 61.3 mm and 98.2 g for legal-sized urchins, 43.6 mm and 42.0 g for sublegal-mature urchins, and 17.8 mm and 4.3 g for sublegal-immature urchins (Table 10a).

Density: The mean total density (all sizes combined) for all sites combined during this survey was 2.80 ± 0.52 urchins/m^2 (Table 11). The mean overall legal, sublegal-mature, and sublegal-immature densities for March, 1998 were 0.87 ± 0.19, 1.77 ± 0.38, and 0.15 ± 0.06 urchins/m^2, respectively (Table 11).

Depth: The sample mean densities of green sea urchins by depth range for all sites combined are shown in Table 12a and Fig. 12a. The highest overall mean total density (6.17 ± 1.10 urchins/m^2) of green sea urchins (for all sites combined) were found in the 1.5 to 3.0 m (5.1 to 10.0 ft) range, below CD. The highest density of sublegal green sea urchins (4.37 urchins/m^2) occurred in this same range, whereas the highest densities of legal urchins occurred both in this depth range (1.80 urchins/m^2) and between 0.1 to 1.5 m (0.1 to 5.0 ft) below CD (2.00 urchins/m^2; Table 12a).

Substrate: Table 13a and Fig. 13a show the mean densities of green sea urchins by substrate type for all sites combined. There was a high occurrence (122 quadrats) where the substrate type was not recorded (labelled "unknown"). The highest total densities occurred on substrates of creviced bedrock with gravel (19.00 urchins/m^2; 1 quadrat only), and boulders with gravel (10.00 urchins/m^2; 1 quadrat only; Table 13a). Smooth bedrock was the most sampled substrate (181 quadrats) and was the main substrate with the highest overall total density (3.28 urchins/m^2).

(i) Stephenson Islets

Size: There were 303 quadrats surveyed, and 1,063 test measurements recorded for green sea urchins in the Stephenson Islets, of which 27.1% were of legal size, 66.8% were sublegal-mature, and 6.1% were sublegal-immature (Table 1, corrected for unknowns). Fig. 11b shows the size frequency distribution. Stephenson Islets showed two dominant size modes (X^2 = 46.3; df = 35; p = 0.0950) where mean test diameters occurred at 41 mm (55%) and 53 mm (45%; Table 2). Mean TD's and total wet weights for urchins from the Stephenson Islets were 60.4 mm and 94.1 g for legal-sized urchins, 43.9 mm and 42.7 g for sublegal-mature urchins, and 17.8 mm and 4.3 g for sublegal-immature urchins (Table 10a).

Density: The mean overall density (all sizes combined) at the Stephenson Islets was 3.50 ± 0.66 urchins/m^2 (Table 11). The mean overall legal, sublegal-mature and sublegal-immature densities were 0.95 ± 0.21, 2.34 ± 0.52, and 0.21 ± 0.10 urchins/m^2, respectively. The mean total densities per transect ranged from 1.00 urchins/m^2 in Transect 5A to 8.17 urchins/m^2 in Transect 3A (Table 11). Legal densities ranged from 0.22 urchins/m^2 in Transect 14 to 1.76 urchins/m^2 in Transect 13. Densities of sublegal-mature urchins ranged from 0.45 urchins/m^2 in Transect 6 to

6.67 urchins/m^2 in Transect 3A. No sublegal-immature urchins occurred in Transects 6 and 9, while the highest density occurred in Transect 14 (0.76 urchins/m^2).

Depth: The highest mean total (7.09 urchins/m^2) and sublegal (5.64 urchins/m^2) densities occurred between 1.5 and 3.0 m (5.1 and 10.0 ft) below CD, and the highest mean legal density (1.72 urchins/m^2) occurred between 0.1 and 1.5 m (0.1 and 5.0 ft) below CD (Table 12b and Fig. 12b). The general trend was that the densities continuously decreased both above and below these depth ranges.

Substrate: The green urchin densities for the Stephenson Islets by substrate type are presented in Table 13b and Fig. 13b). Unfortunately, the substrate was not recorded for 79 of the quadrats (labelled "unknown"). The highest mean total (19.00 urchins/m^2), legal (6.00 urchins/m^2) and sublegal (13.00 urchins/m^2) densities were observed on creviced bedrock with gravel, but there was only one quadrat with this substrate type (Table 13b). There were also high mean total, legal and sublegal densities (10.00, 3.00, and 7.00 urchins/m^2, respectively) on substrate consisting of boulders with gravel, but again, there was only one quadrat observed with this substrate type.

(ii) Stubbs Island

Size: There were 66 quadrats surveyed at Stubbs Island and 55 green sea urchin TD's measured. Legal, sublegal-mature and sublegal-immature-sized green urchins represented 49.1%, 49.1%, and 1.8%, respectively, of the sample (Table 1, corrected for unknowns). Figure 11c shows the size frequency distribution. The test diameter frequency distribution for Stubbs Island showed the best fit with three dominant size modes ($X^2 = 33.5$; df = 24; p = 0.0939; Table 2). The mean test diameters for the modes with their proportions were 27 mm (9%), 46 mm (33%), and 63 mm (58%). Mean TD's and total wet weights for urchins from the Stephenson Islets were 66.3 mm and 121.5 g for legal-sized urchins, 44.4 mm and 43.7 g for sublegal-mature urchins, and 20.0 mm and 5.0 g for sublegal-immature urchins (Table 10a).

Density: The mean overall total density for Stubbs Island was 0.83 ± 0.25 urchins/m^2 (Table 11). The overall legal, sublegal-mature, and sublegal-immature densities were 0.39 ± 0.16, 0.39 ± 0.17, and 0.02 ± 0.01 urchins/m^2, respectively. The mean total and sublegal-mature densities were highest (1.36 and 1.09 urchins/m^2, respectively) in Transect 17, while the highest legal and sublegal-immature densities were highest (0.79 and 0.05 urchins/m^2, respectively) in Transect 15. All densities were lowest in Transect 16 (although there were also no sublegal-immature urchins in Transects 15, 16 and 17; Table 11).

Depth: The highest mean total (1.70 urchins/m^2) and legal (1.10 urchins/m^2) densities of green sea urchins occurred between 9.1 to 10.7 m (30.1 to 35.0 ft) below CD (Table 12c, Fig. 12c). The second most highest sublegal density (0.60 urchins/m^2) also occurred at this depth range, superceded by the 6.1 to 7.6 m (20.1 to 25.0 ft) below CD depth range (0.62 urchins/m^2; Table 12c). No urchins occurred between 7.6 and 9.1 m (25.1 to 30.0 ft).

Substrate: There were only 29 quadrats where substrate type was recorded (Table 13c and Fig. 13c), and there was very little variety of substrate noted. The highest mean total, legal, and sublegal densities (3.43, 2.14 and 1.29 urchins/m^2) occurred on creviced bedrock (Table 13c).

(iii) Plumper Islands

Size: There were 118 quadrats surveyed and 246 green urchin TD measurements recorded in the Plumper Islands. Of these urchins, 113 (45.9%) were of legal size, 127 (51.6%) were sublegal-mature, and 6 (2.4%) were sublegal-immature (Table 1). Figure 11d presents the size frequency distribution. Analyses of the test diameter frequency data showed the best fit ($X^2 = 44.7$; df = 32; p = 0.0677) resulted with two dominant size modes, at 46 mm (72%) and 61 mm (28%; Table 2). Mean TD's and total wet weights for urchins from the Stephenson Islets were 62.4 mm and 103.1 g for legal-sized urchins, 42.0 mm and 38.1 g for sublegal-mature urchins, and 17.7 mm and 4.2 g for sublegal-immature urchins (Table 10a).

Density: The mean overall total density for the Plumper Islands was 2.09 ± 1.03 urchins/m^2 (Table 11). The overall legal, sublegal-mature, and sublegal-immature densities were 0.96 ± 0.58, 1.08 ± 0.46, and 0.05 ± 0.02 urchins/m^2, respectively. The highest mean total, legal and sublegal-mature densities (5.03, 2.62, and 2.38 urchins/m^2) occurred in Transect 20, while the highest mean sublegal-immature density (0.13 urchins/m^2) occurred in Transect 23. No green urchins occurred in Transect 19 (16 quadrats).

Depth: The highest mean densities of green urchins for all size categories occurred between 1.5 and 3.0 m (5.1 and 10.0 ft) below CD (7.75, 3.75, and 4.00 urchins/m^2 for total, legal, and sublegal urchins, respectively; 12 quadrats; Table 12d and Fig. 12d).

Substrate: The highest mean total (4.44 urchins/m^2), legal (2.29 urchins/m^2) and sublegal (2.15 urchins/m^2) densities of green urchins were observed on a substrate of smooth bedrock (34 quadrats; Table 13d, Fig. 13d).

(iv) Dissection Data

There were 137 green urchins collected from all of the transects and dissected during this survey (Table 14). There were no sublegal-immature–sized urchins collected for dissection. Legal-sized green urchins randomly collected from the Plumper Islands and observed in the lab had the largest mean test diameter, and heaviest mean total wet weight and mean drained weight, whereas legal-sized green urchins collected from Stubbs Island had the largest mean test height and the heaviest mean gutted weight and mean gonad weight (Table 14). However, the field measurements showed that legal-sized green urchins had the largest mean diameters at Stubbs Island, followed by the Plumper Islands, and then Stephenson Islets (Table 10a).

The best (i.e., highest R^2) power relationships were calculated between TD (mm) and test heights (mm) (Figs. 14 and 15), TD (mm) and total wet weight (g) (Figs. 16 and 17), and TD (mm) and gonad weight (g) (Figs. 18 and 19), for all sites combined, and for each of the three sites separately (see figures for equations).

A test for homogeneity showed that there was no significant difference between the slopes of the regression lines for the relationship between test diameter (mm) and the natural log of the total wet weight for the three sites separately ($F = 0.53$ with $df = 2, 134$ and $p > 0.05$). This allowed the allometric equation ($W=\alpha TD^{\beta}$) to be used for all sites in the March, 1998 survey when calculating the total wet weight (g) from the TD (mm).

The best quality roe (i.e., colour=1 (orange/yellow) and texture=1 (firm)) was observed at Stubbs Island, with 30.0% of the legal-sized and 20.0% of the sublegal-sized green urchins having the highest quality (Table 8). This is in comparison to 14.3% of the legal urchins at the Plumper Islands and 10.0% of the legal urchins at Stephenson Islets having the highest roe quality. The mean roe recovery rates (total gonad weight (all grades) divided by total drained weight of all urchins collected) for legal-sized urchins ranged from 34.9% at Stubbs Island to 26.0% at the Plumper Islands (Table 8).

(v) Biomass Estimates

By extrapolating the total mean density (3.50 urchins/m^2; Table 11) over the area of Stephenson Islets, it was calculated that there were approximately 1,699,001 ± 321,483 green sea urchins of all sizes on March 4, 1998 (Table 15a). Of these, approximately 459,579 (27.1%) were of legal size, 1,135,336 (66.8%) were of sublegal-mature size, and 104,086 (6.1%) were of an immature size. The mean weight per legal-sized green sea urchin at Stephenson Islets in March, 1998 was determined to be 94.1 g (Table 10a). This was calculated by applying the TD-total wet weight relationship (Fig. 17a) from the dissection data for all urchins collected at Stephenson Islets in March, 1998 and then applying it to all test diameter measurements recorded in the field. Then the mean weights were calculated for each of the three size classes. Using the same TD-weight relationship, the mean weight per sublegal-mature-sized and immature-sized green urchin was 42.7 and 4.3 g, respectively (Table 10a). The biomass of legal-sized, sublegal-mature-sized, and immature-sized green sea urchins at Stephenson Islets in March, 1998 was 43.23, 48.53, and 0.45 t, respectively, for a total biomass (not including "unknowns") of 92.21 t ± 14.33 t (Table 15a).

On March 4, 1998, there were approximately 16,333 ± 4,984 green sea urchins in total (7,721 legal-sized, 7,721 sublegal-mature, and 297 of an immature size) at Stubbs Island (Table 15a). Based on the TD-total wet weight relationship calculated for Stubbs Island in March, 1998 (Fig. 17b), the mean weight per legal-sized green urchin was 121.5 g (Table 10a). The mean weight per sublegal-mature and sublegal-immature green urchin was 43.7 g and 5.0 g, respectively (Table 10a). The total biomass was calculated as 1.28 t ± 0.40 t, of which 0.94, 0.34, and 0.001 t were comprised of legal, sublegal-mature and sublegal-immature urchins, respectively (Table 15a).

At the Plumper Islands survey site on March 4, 1998, there were approximately 468,044 ± 229,932 green sea urchins (214,125 legal-sized, 240,654 sublegal-mature, and 11,369 immature; Table 15a). Based on the TD versus total wet weight relationship calculated for the Plumper Islands in March, 1998 (Fig. 17c), the mean weight per legal-sized, sublegal-mature-sized and immature green urchin was 103.1, 38.1, and 4.2 g (Table 10a). The total biomass was

31.29 t ± 13.87 t, of which 22.08 t was legal-sized, 9.16 t was of sublegal-mature size, and 0.05 t was immature green urchins (Table 15a).

(c) THE FISHERY

During 1997/98 fishing season, the areas open to fishing included Areas 11, 12, 13, 17, 18, 19, 20 and 28. The fishing season for all areas occurred from November 10, 1997 until March 15, 1998. However, in Area 12, the area where the study area is located, fishing began on November 15, 1997 and continued until January 16, 1998, when it was closed because the area quota had been reached. Fig. 20 shows the monthly removals of legal-sized green urchins harvested from the Stephenson Islets in the 1997/98 fishing season. The total biomass of urchins removed from the Stephenson Islets by commercial harvest (as recorded in the harvest logbook records), $B_{fishing}$, was 11.65 t, or approximately 120,300 legal-sized green urchins. The total effort required to harvest these urchins from Stephenson Islets over the season was 117.5 hr of diver time. There were also 364 kg of green sea urchins commercially fished by accident at Stubbs Island during the 1997/98 fishing season due to misunderstandings of the research closure boundaries.

(d) PRE- AND POST-FISHERY COMPARISONS

(i) Changes in Biomass over the Fishing Season

The total biomass of legal-sized green urchins at the Stephenson Islets site increased by 2.21 t between November, 1997 and March, 1998, using the biomass estimates from the TD-weight relationships calculated from the November, 1997 and March, 1998 surveys (Tables 9 and 15a). This is within the uncertainty of the biomass estimates and represents no net change between surveys. Alternatively, if we assume that there is no growth of individual urchins between surveys, (as described previously), and use the November, 1997, relationship of TD versus total wet weight to calculate the biomass of green urchins present in March, 1998, the increase in biomass between November and March is slightly greater (2.39 t), although still within the uncertainties of the estimates. Using this November 1997 relationship (Fig. 7), the mean weight per legal, sublegal-mature and sublegal-immature green urchin was 94.5, 42.8, and 4.3 g, respectively (Table 10b). Consequently, the total legal, sublegal-mature, and sublegal-immature biomass at Stephenson Islets in March, 1998 was 43.41, 48.54, and 0.44 t, respectively, for an overall total biomass of 92.39 ± 14.33 t (Table 15b). This is within one standard error of the March, 1998 biomass using the March TD-weight relationship, and is caused by there being no significant differences in the mean weights of any of the three size categories between November, 1997 and March, 1998. If we add the biomass removed by the fishery to the March, 1998 biomass, then the actual difference in legal biomass between November and March was a net gain of 13.86 t (or 14.04 t using the November, 1997 TD-weight relationship).

At Stephenson Islets, the biomass of sublegal-mature and sublegal-immature green urchins also increased over the duration of the fishing season, by 22.88 t (almost doubled) and 0.34 t (quadrupled), respectively. As a result, the overall biomass at Stephenson Islets increased by 25.43 t, or 37.08 t if the urchins removed by the fishery are included. In contrast, the biomass

of legal, sublegal-mature, and sublegal-immature urchins at Stubbs Island decreased by 3.13, 0.33, and 0.009 t, respectively, for an overall total decrease in biomass of 3.48 t, which is similar to the previous fishing season (Waddell *et al.* 2002). The difference in the legal-sized biomass at Stubbs Island between November, 1997 and March, 1998 was marginally within two standard errors of the means. Like the Stephenson Islets, there was an overall increase in biomass in the Plumper Islands of 22.15 t between November, 1997 and March, 1998. However, there is a very high uncertainty about the mean estimate for March, 1998 (in particular), such that the mean biomass estimates from the two surveys are within two standard errors. The biomass of legal-sized and sublegal-mature urchins increased by 15.79 and 6.39 t, respectively, while the biomass of sublegal-immature urchins decreased by 0.05 t.

(ii) Mortality Calculations

- The exploitation of green sea urchins from Stephenson Islets during the fishing season (which was between November 15, 1997 and January 16, 1998 in Area 12, or 2 months), as calculated using equations 5 and 6, is 0.28 ± 0.05. Instantaneous mortality rates between the two surveys (where t equals one "fishing season"[1]) cannot be calculated for Stephenson Islets nor the Plumper Islands because the biomass in March was greater than in November.

For **Stubbs Island**: Difference in numbers of legal-sized urchins estimated from surveys:
33,880 ± 10,511 – 7,721 ± 3,042 = 26,159 ± 10,942 urchins
Instantaneous total mortality (of legal size) [2]: Z = 1.48 ± 0.74

DISCUSSION

The population percentage of legal-sized urchins was highest at Stubbs Island in both November, 1997 and March, 1998, lowest in the Plumper Islands in November, 1997 and lowest at Stephenson Islets in March, 1998. The population percentage of sublegal-mature green urchins was highest at Stephenson Islets, intermediate at Stubbs Island, and lowest at the Plumper Islands for both surveys. The population percentage of legal-sized urchins decreased between November, 1997 and March, 1998 at Stephenson Islets (33.6%) and Stubbs Island (27.4%), but increased at the Plumper Islands by 27.1%. The opposite occurred for the population percentage of sublegal-mature green urchins, where it increased between the two surveys at Stephenson Islets by 19.9% and by 72.3% at Stubbs Island, but decreased by 4.8% at the Plumper Islands. In

[1] Note that this report calculates Z differently than in Waddell *et al.* (1997), where t equalled a fraction of the year (e.g. 3 months of fishing out of 12, or 0.25). We believe that the current calculation (where t equals one fishing season) more accurately represents instantaneous total mortality because mortality due to fishing is by far the largest cause of mortality, and it only occurs during one period of the year.

[2] Instantaneous mortality rates were calculated from $\frac{N_{Feb}}{N_{Nov}} = e^{-zt}$ (eqn. 10`), with fractional uncertainty $\frac{\delta q}{q}$ calculated as $\frac{\delta q}{q} = SQRT\left[\left(\frac{\delta N_{Nov}}{N_{Nov}}\right)^2 + \left(\frac{\delta N_{Feb}}{N_{Feb}}\right)^2\right]$. Actual uncertainty was then calculated as $Z * \left(\frac{\delta q}{q}\right)$.

addition, Stubbs Island had the highest mean overall total, legal, and sublegal densities in November, 1997 (except for the sublegal-matures, which had the highest density in the Stephenson Islets) and the lowest of all of these densities in March, 1998. In contrast, the Plumper Islands had the lowest densities for all size classes in November, 1997, and then had the highest density of legal urchins (Stephenson Islets was very close) and the second highest densities for all other size classes in March, 1998. It is interesting to note that the legal, sublegal and total densities all increased between November, 1997 and March, 1998 at Stephenson Islets and the Plumper Islands (except the sublegal-immature urchins decreased slightly at the Plumper Islands), but decreased at Stubbs Island. The total density increase at Stephenson Islets is mainly due to increases in the sublegal-mature (from 1.19 to 2.34 urchins/m^2) and sublegal-immature (from 0.08 to 0.21 urchins/m^2) green urchin densities, while the total density increase at the Plumper Islands is due mainly to increases in the legal (from 0.26 to 0.96 urchins/m^2) and sublegal-mature (from 0.39 to 1.08 urchins/m^2) green urchin densities. At Stubbs Island, the decrease in total density is mainly due to a large decrease in legal density (from 1.73 to 0.39 urchins/m^2).

The changes in size frequencies between November and March are difficult to analyze. Test size is not a reliable index of age, especially for older individuals due to their discontinuous growth, which fluctuates with the availability and species of vegetation (Himmelman *et al.* 1983, Larson *et al.* 1980, Vadas 1997, Vadas *et al.* 2002). The size frequency distributions of green urchins best fit two distinct frequency modes at all sites for both surveys, except for Stubbs Island, which fit three modes in March, 1998. At Stephenson Islets, the first mode increased from 39 mm in November to 41 mm in March, and the proportion increased from 23% to 55%, while the second mode stayed at 53 mm between the two surveys, but the proportion decreased. The urchins that made up part of the second mode in the first survey likely grew to legal size and were harvested between the two surveys, thus decreasing their proportion in the second survey. Growth of smaller urchins and immigration likely contributed to the urchins at Stephenson Islets in the first mode of the second survey. It is difficult to interpret what occurred at Stubbs Island and the Plumper Islands. There likely were not enough data for the model to analyze the size frequency distributions properly.

From field survey results, it appears that the largest green urchins (largest TD's and weights) in all size categories occurred at Stubbs Island in both November, 1997 and March, 1998. Stubbs Island has been closed to commercial fishing since the fall of 1995, and prior to that, has been considered locally as a "reserve", thus allowing the urchins to remain and grow (except for the small amount that was harvested by accident). The smallest legal-sized urchins occurred in the Stephenson Islets during both surveys. The Stephenson Islets have always been open to fishing since the commercial fishery started, and is considered a major commercial fishery location, so larger urchins are more likely to be removed. The mean TD's for legal urchins in the Stephenson Islets decreased slightly from 60.9 mm in November, 1997 to 60.4 mm in March, 1998. Again, this is to be expected since urchins in the Stephenson Islets are being removed from the population through fishing, and larger urchins would most likely be harvested before urchins closer to the size limit, thus lowering the mean size. There was also a slight decrease in legal-sized mean TD for the Plumper Islands between November, 1997 (62.7 mm) and March, 1998 (62.4 mm). In contrast, legal-sized green urchins increased slightly in TD from

65.9 mm in November, 1997 to 66.3 mm in March, 1998 at Stubbs Island, where fishing did not occur.

In November, 1997 the mean total densities of green urchins were generally highest at all sites in the shallower depths (from 0.1 to 6.1 m (0.1 to 20.0 ft) below CD, or 0.1 to 7.6 m (0.1 to 25.0 ft) below CD at Stubbs Island), probably to feed on algae, especially kelp, and lowest in deeper depths. Himmelman (1986) also reported green urchin abundance generally decreased at greater depth. In March, 1998, the urchins appeared to be more spread out over the whole depth range sampled. The highest densities still occurred in shallower waters at Stephenson Islets and the Plumper Islands (0.0 to 3.0 m (0.0 to 10.0 ft) below CD), but at Stubbs Island the densities were highest in the deeper section of the depth range sampled (9.1 to 11.7 m (30.1 to 38.4 ft) below CD).

The main substrate type where green urchins occurred in highest densities seems to vary slightly between smooth and creviced bedrock at the three sites during both the November, 1997 and March, 1998 surveys. In November, 1997, the highest total density by main substrate type occurred on creviced bedrock in the Stephenson Islets, and on smooth bedrock at Stubbs Island and the Plumper Islands. In March, 1998, the highest total density by main substrate occurred on smooth bedrock in the Stephenson Islets, and the Plumper Islands, and on creviced bedrock at Stubbs Island. It should be noted that the number of quadrats of each of the substrate types sampled varied at each of the sites between the two surveys. Therefore, part of these differences in substrate preference results may be due to the fact that different divers were involved in the two surveys, and they may have used different criteria for determining between the substrate types, especially between the smooth and creviced bedrock. Also, there were two dive teams for each survey, so again the dive teams may have used different criteria, even though the teams are given guidelines for determining between the substrates. Additionally, as mentioned previously, the transect lines are never repeated exactly between surveys.

The highest quality roe in legal-sized green sea urchins was observed in samples collected from the Stephenson Islets in November, 1997, and from Stubbs Island in March, 1998. However, the percentage of legal-sized green sea urchins with high quality roe decreased at all sites between the November, 1997 (range of 33.3 to 51.6%) and March, 1998 surveys (range of 10.0 to 30.0%). The roe texture was flimsy (i.e., low quality) for many of the green urchins in March, 1998, as they were getting close to spawning, therefore bringing the overall roe quality lower for all urchins collected in March, 1998, no matter which site. Between the two surveys, the proportion of legal-sized urchins with the poorest texture (i.e., flimsy) increased at all sites, from 0.03 to 0.27 at Stephenson Islets, from 0.11 to 0.20 at Stubbs Island, and from 0.00 to 0.14 at the Plumper Islands (Tables 7 and 14). The highest roe recovery rate for legal urchins occurred in the Plumper Group (24.4%) in November, 1997 and at Stubbs Island (34.9%) in March, 1998. The roe recovery rate increased at all sites between November, 1997, and March, 1998 for both legal and sublegal green sea urchins, as expected (with the exception of sublegal urchins at Stubbs Island, but there was only a sample size of ten) as the gonads should be increasing in size and maturing until they spawn in late February/early March. The urchins likely did not spawn before the March, 1998 survey (for that season).

The exploitation of legal-sized green urchins at Stephenson Islets was calculated as 0.28 ± 0.05, similar to results from the previous year (Waddell *et al.* 2002). The instantaneous total mortality rate for legal-sized urchins at Stubbs Island was estimated as 1.48 ± 0.74. This is similar to results from the previous year (Waddell *et al.* 2002) and represents the natural mortality rate since fishing mortality is assumed to be zero. The instantaneous mortality rates at Stephenson Islets and the Plumper Islands could not be calculated as the biomass in the March, 1998 survey was the same as or higher than that estimated during the November, 1997 survey. However, these calculations of instantaneous rates assumed no net immigration or emigration, nor growth into the legal size category, during the fishing season. Deviations from these assumptions may decrease the mortality due to fishing and allow for natural mortality. In fact, the size frequency results suggest growth into the legal-sized category. Obviously, natural mortality will dominate during the remaining eight months of the year when the commercial fishing season is closed. This also shows that there was likely a great deal of migration into the Stephenson Islets area from other areas between November, 1997 and March, 1998. Anecdotal observations from fishers during the commercial fishing season report that green sea urchins will be absent at a location in one week, and then will appear in great numbers in the following week. The fishers believe they are moving up from deep waters, and that they will remain in areas where food (fleshy algae) is present.

The other factor potentially causing differences between the two surveys are sampling problems. First, it was noted that occasionally the divers started deeper than 10.0 m below CD. Since the area estimate for Stephenson Islets was based on the 10 m isobath, and green urchins are usually sparse at depths below this, the divers' data were truncated to 10 m (33 ft) to calculate the density so that the sampling occurred within the area estimate (however, the original data were for the size frequency analyses). Keeping these data probably would have underestimated the densities (and therefore the biomass estimates). Second, the divers occasionally neglected to note empty quadrats. This was evident when the recorded depths between quadrats had a difference of more than 4 ft. "Empty quadrats" were approximately added in, thus reducing the overestimate of density and biomass. Thirdly, due to various reasons (poor weather conditions, strong tidal currents, divers running out of air or having other difficulties, etc.), the divers did not survey the full length of several of the transects in both of the surveys. Since the divers always started at the deep end of the transect and worked their way to the shallow end, the shallower depths were not sampled sufficiently. The density by depth analyses (Tables 5a-d and 12a-d) show that densities were generally higher in the shallower depths, especially in the November, 1997 survey. Therefore, density and biomass estimates may be underestimated, especially for the November, 1997 survey. There was no method available to compensate for the lack of these data.

SUMMARY

(a) NOVEMBER, 1997 SURVEY:

The mean densities for all sites combined were 0.85/m^2 for legal-sized green sea urchins (45.1%), 0.94/m^2 for sublegal-mature urchins (49.8%), 0.08/m^2 for sublegal-immature urchins

(4.1%), and 1.90/m^2 for all sizes combined in November, 1997. A total of 101 green urchins from all locations were dissected. The mean TD and individual weights for legal-sized urchins from all sites combined were 62.4 mm and 104.1 g, respectively. The mean roe recovery rates for legal-sized green urchins were 21.3% for Stephenson Islets, 21.1% for Stubbs Island, and 24.4% for the Plumper Islands. The best quality roe occurred at the Plumper Islands, with 50.0% of the legal-sized urchins having the highest grade of colour and texture. The estimated biomass of legal-sized (≥ 55 mm TD) green urchins at Stephenson Islets, Stubbs Island, and the Plumper Islands in November, 1997 was 41.02, 4.07, and 6.29 t, respectively.

(b) MARCH, 1998 SURVEY:

The mean densities for all sites combined were 0.87/m^2 for legal-sized green sea urchins (31.2%), 1.77/m^2 for sublegal-mature urchins (63.2%), 0.15/m^2 for sublegal-immature urchins (5.3%), and 2.80/m^2 for all sizes combined in March, 1998. A total of 137 green urchins from all sites were dissected. The mean TD and individual weight for legal-sized urchins from all sites combined were 61.3 mm and 98.2 g, respectively (or 61.3 mm and 98.7 g using the TD versus total wet weight relationship from the November, 1997 survey). The mean roe recovery rates for legal-sized urchins were 28.5% for Stephenson Islets, 34.9% for Stubbs Island, and 26.0% for the Plumper Islands. The best quality roe occurred at Stubbs Island, with 30.0% of the legal-sized urchins having the highest grade of colour and texture. The estimated biomass of legal-sized (≥ 55 mm TD) green urchins at Stephenson Islets, Stubbs Island and the Plumper Islands in March, 1998 was 43.23, 0.94, and 22.08 t, respectively (or 43.41, 0.94 and 22.19 t using the November, 1997 TD-weight relationship on March, 1998 field data).

(c) COMPARISON BETWEEN SURVEYS:

The percentage of legal-sized urchins decreased between the November, 1997 and March, 1998 surveys at Stephenson Islets (13.7%) and Stubbs Island (18.5%), but increased at the Plumper Islands (9.8%). Conversely, the percentage of sublegal-sized urchins increased between the two surveys at Stephenson Islets and Stubbs Island, and decreased at the Plumper Islands. Additionally, the mean densities of all size categories increased between the two surveys at the Stephenson Islets, and at the Plumper Islands (except for sublegal-immatures which decreased), but decreased for all size categories at Stubbs Island. The total biomass of legal-sized green urchins in the Stephenson Islets changed from 41.02 ± 7.72 t in November, 1997 to 43.23 ± 9.53 t in March, 1998 (or if using the Nov. TD-weight relationship, 43.41 ± 9.53 t), a net increase of 2.21 t (or 2.39 t). Considering the commercial fishery removed 11.65 t of legal-sized green urchins, the total biomass of legal green urchins actually increased by 13.86 t (or 14.04 t) between the two surveys. The exploitation at Stephenson Islets was 0.28 ± 0.05. The instantaneous total mortality of legal-sized urchins at Stubbs Island was calculated to be 1.48 ± 0.74. The instantaneous mortality could not be calculated for the Stephenson Islets or the Plumper Islands because the biomass in March was greater than in November. This leads us to believe that either growth occurred, there was a net gain from emigration and immigration, or both occurred.

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Table 1. Numbers and percentages of green sea urchins of legal size, sublegal-mature size, sublegal-immature size, unknown size (i.e., counted only), and all sizes (total) for all sites, measured during the November, 1997 and March, 1998 surveys. Note that the numbers in the brackets indicate calculations where the unknowns have been proportioned into legal and sublegal values using the ratios from measured data, then added to the original legal and sublegal values, and a zero value assigned to the unknowns. (Legal ≥ 55 mm test diameter (TD), Sublegal-mature = 25 mm ≥ TD < 55 mm TD, Sublegal-immature = < 25 mm, Unknown = size unknown, Total Number = total number of green sea urchins measured).

Site	Survey Date		Number of Legal	Number of Sublegal-mature	Number of Sublegal-immature	Number of Unknown	Total Number
All Sites Combined	Nov. 1997	Number	428 (433)	473 (478)	39 (39)	10 (0)	950
		Percent	45.1% (45.6%)	49.8% (50.3%)	4.1% (4.1%)	1.1% (0%)	
	Mar. 1998	Number	426 (427)	862 (865)	72 (72)	4 (0)	1,364
		Percent	31.2% (31.3%)	63.2% (63.4%)	5.3% (5.3%)	0.3% (0%)	
Stephenson Islets	Nov. 1997	Number	277 (281)	377 (383)	24 (24)	10 (0)	688
		Percent	40.3% (40.8%)	54.8% (55.7%)	3.5% (3.5%)	1.5% (0%)	
	Mar. 1998	Number	287 (288)	709 (710)	65 (65)	2 (0)	1,063
		Percent	27.0% (27.1%)	66.7% (66.8%)	6.1% (6.1%)	0.2% (0%)	
Stubbs Island	Nov. 1997	Number	121	51	7	0	179
		Percent	67.6%	28.5%	3.9%	0.0%	
	Mar. 1998	Number	26 (27)	26 (27)	1 (1)	2 (0)	55
		Percent	47.3% (49.1%)	47.3% (49.1%)	1.8% (1.8%)	3.6% (0%)	
Plumper Islands	Nov. 1997	Number	30	45	8	0	83
		Percent	36.1%	54.2%	9.6%	0.0%	
	Mar. 1998	Number	113	127	6	0	246
		Percent	45.9%	51.6%	2.4%	0.0%	

Table 2. Green sea urchin test diameter frequency distribution analysis for the November, 1997 and March, 1998 surveys. Results were obtained using the analysis software "Mix 3aa" (Macdonald 1994). (Sigma = standard deviation, X^2 = chi-square goodness of fit value, DF = degrees of freedom, P-value = the p-value of the chi-square test).

Site	Survey	Frequency Mode	Mode Mean (mm)	Sigma (mm)	Proportion Of Population	X^2	DF	P-value
All Sites Combined	Nov. 1997	1	43	15.9	0.36	92.5	35	<0.0001
		2	56	9.1	0.64			
	Mar. 1998	1	33	11.4	0.26	63.9	36	0.0028
		2	52	9.1	0.74			
Stephenson Islets	Nov. 1997	1	39	16.4	0.23	87.0	35	<0.0001
		2	53	8.4	0.77			
	Mar. 1998	1	41	14.0	0.55	46.3	35	0.0950
		2	53	6.3	0.45			
Stubbs Island	Nov. 1997	1	32	9.5	0.13	31.2	28	0.3068
		2	62	9.3	0.87			
	Mar. 1998	1	27	6.7	0.09	33.5	24	0.0939
		2	46	4.1	0.33			
		3	63	8.7	0.58			
Plumper Islands	Nov. 1997	1	27	4.2	0.24	38.1	29	0.1191
		2	50	14.5	0.76			
	Mar. 1998	1	46	12.7	0.72	44.7	32	0.0677
		2	61	4.9	0.28			

Table 3. Means and standard errors (SE) of test diameters (TD) (using November, 1997 field survey data) and weight (using TD-total wet weight relationships from November, 1997 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites during the November, 1997 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	430	62.4	0.3	104.1	1.4
	Sublegal-Mature	482	44.2	0.4	43.4	0.8
	Sublegal-Immature	39	17.0	1.0	4.1	0.4
Stephenson Islets	Legal	277	60.9	0.3	96.8	1.4
	Sublegal-Mature	381	44.8	0.4	44.5	0.8
	Sublegal-Immature	24	14.3	1.3	2.9	0.5
Stubbs Island	Legal	122	65.9	0.6	120.2	3.1
	Sublegal-Mature	51	45.7	1.1	47.1	2.6
	Sublegal-Immature	7	21.6	0.7	6.1	0.5
Plumper Islands	Legal	31	62.7	1.5	106.8	7.1
	Sublegal-Mature	50	38.4	1.3	31.3	2.7
	Sublegal-Immature	8	20.9	1.2	5.8	0.7

Table 4. Sample mean densities (urchins/m^2) by transect and overall standard errors for legal, sublegal-mature, sublegal-immature, and unknown-sized green sea urchins, and all sizes combined (total) in the November, 1997 survey. (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = size unknown. Stephenson Islets = Transects 3A to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transects 19 to 24).

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3A	20	1.20	1.70	0.15	0.00	3.05
5A	27	0.37	0.63	0.26	0.00	1.26
6A	66	0.36	0.33	0.00	0.00	0.70
7	29	1.00	0.69	0.21	0.00	1.90
8	27	0.85	0.85	0.00	0.00	1.70
9	23	1.39	0.87	0.04	0.00	2.30
10A	25	0.92	1.08	0.08	0.00	2.08
11B	17	0.41	0.47	0.00	0.00	0.88
13	34	0.97	3.12	0.15	0.29	4.53
14	49	1.47	2.04	0.00	0.00	3.51
Stephenson Islets Totals	317	0.87 ± 0.16	1.19 ± 0.33	0.08 ± 0.03	0.03 ± 0.03	2.17 ± 0.49
15	14	2.36	0.79	0.29	0.00	3.43
16	17	1.29	1.12	0.12	0.00	2.53
17	25	2.56	0.80	0.04	0.00	3.40
18	14	0.14	0.07	0.00	0.00	0.21
Stubbs Island Totals	70	1.73 ± 0.54	0.73 ± 0.19	0.10 ± 0.05	0.00	2.56 ± 0.67
19	14	0.00	0.00	0.00	0.00	0.00
20	29	0.38	0.41	0.03	0.00	0.83
21	14	0.71	0.43	0.14	0.00	1.29
22	26	0.31	0.27	0.15	0.00	0.73
23	18	0.06	1.06	0.06	0.00	1.17
24	13	0.00	0.08	0.00	0.00	0.08
Plumper Islands Totals	114	0.26 ± 0.09	0.39 ± 0.14	0.07 ± 0.03	0.00	0.73 ± 0.17
OVERALL TOTAL	501	0.85 ± 0.15	0.94 ± 0.22	0.08 ± 0.02	0.02 ± 0.02	1.90 ± 0.34

Table 5a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total, with standard errors) by depth range (feet and meters) below Chart Datum from all survey sites combined in the November, 1997 survey.

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-1.1 to 0.0	-0.3 to 0.0	12	0.25	0.17	0.42	0.83 ± 0.46
0.1 to 5.0	0.1 to 1.5	62	1.66	2.06	0.08	3.81 ± 0.85
5.1 to 10.0	1.5 to 3.0	53	1.23	2.00	0.00	3.23 ± 0.52
10.1 to 15.0	3.0 to 4.8	82	1.04	1.34	0.00	2.38 ± 0.30
15.1 to 20.0	4.8 to 6.1	89	1.02	1.02	0.00	2.04 ± 0.32
20.1 to 25.0	6.1 to 7.6	89	0.56	0.38	0.00	0.94 ± 0.20
25.1 to 30.0	7.6 to 9.1	58	0.26	0.34	0.00	0.60 ± 0.20
30.1 to 35.0	9.1 to 10.7	54	0.30	0.39	0.00	0.69 ± 0.14
35.1 to 36.6	10.7 to 11.2	2	0.00	0.00	0.00	0.00 ± 0.00

Table 5b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total, with standard errors) by depth range (feet and meters) below Chart Datum in the Stephenson Islets in the November, 1997 survey.

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-1.1 to 0.0	-0.3 to 0.0	7	0.43	0.29	0.71	1.43 ± 0.72
0.1 to 5.0	0.1 to 1.5	34	2.32	3.50	0.15	5.97 ± 1.40
5.1 to 10.0	1.5 to 3.0	29	1.31	2.62	0.00	3.93 ± 0.76
10.1 to 15.0	3.0 to 4.8	53	1.17	1.51	0.00	2.68 ± 0.37
15.1 to 20.0	4.8 to 6.1	64	0.81	1.02	0.00	1.83 ± 0.29
20.1 to 25.0	6.1 to 7.6	67	0.45	0.46	0.00	0.91 ± 0.20
25.1 to 30.0	7.6 to 9.1	31	0.19	0.45	0.00	0.65 ± 0.24
30.1 to 35.0	9.1 to 10.7	30	0.23	0.47	0.00	0.70 ± 0.20
35.1 to 36.6	10.7 to 11.2	2	0.00	0.00	0.00	0.00 ± 0.00

Table 5c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total, with standard errors) by depth range (feet and meters) below Chart Datum at Stubbs Island in the November, 1997 survey.

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-0.5 to 0.0	-0.2 to 0.0	3	0.00	0.00	0.00	0.00
0.1 to 5.0	0.1 to 1.5	17	1.41	0.47	0.00	1.88 ± 0.72
5.1 to 10.0	1.5 to 3.0	12	1.92	1.58	0.00	3.50 ± 1.07
10.1 to 15.0	3.0 to 4.8	9	0.78	0.89	0.00	1.67 ± 0.96
15.1 to 20.0	4.8 to 6.1	8	4.88	2.13	0.00	7.00 ± 1.86
20.1 to 25.0	6.1 to 7.6	8	2.38	0.25	0.00	2.63 ± 1.29
25.1 to 30.0	7.6 to 9.1	6	1.17	0.50	0.00	1.67 ± 1.48
30.1 to 33.8	9.1 to 10.3	7	0.29	0.14	0.00	0.43 ± 0.30

Table 5d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total, with standard errors) by depth range (feet and meters) below Chart Datum in the Plumper Islands in the November, 1997 survey.

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-0.7 to 0.0	-0.2 to 0.0	2	0.00	0.00	0.00	0.00
0.1 to 5.0	0.1 to 1.5	11	0.00	0.09	0.00	0.09 ± 0.09
5.1 to 10.0	1.5 to 3.0	12	0.33	0.92	0.00	1.25 ± 0.69
10.1 to 15.0	3.0 to 4.8	20	0.80	1.10	0.00	1.90 ± 0.56
15.1 to 20.0	4.8 to 6.1	17	0.00	0.53	0.00	0.53 ± 0.27
20.1 to 25.0	6.1 to 7.6	14	0.07	0.07	0.00	0.14 ± 0.10
25.1 to 30.0	7.6 to 9.1	21	0.10	0.14	0.00	0.24 ± 0.10
30.1 to 34.4	9.1 to 10.5	17	0.41	0.35	0.00	0.76 ± 0.24

Table 6a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 1997 survey (all sites combined). (Legal ≥ 55 mm test diameter (TD), Sublegal < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = mean density for all urchins within the dominant substrate type and the standard error).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
?	Unknown	19	0.00	0.00	0.53	0.53	0.53 ± 0.36
100	Bedrock (smooth)	138	0.66	0.59	0.00	1.25	
120	Bedrock (smooth)/bedrock (creviced)	29	1.00	0.90	0.00	1.90	
134	Bedrock (smooth)/boulders/ cobble	1	0.00	0.00	0.00	0.00	
140	Bedrock (smooth)/cobble	1	0.00	0.00	0.00	0.00	1.53 ± 0.18
145	Bedrock (smooth)/cobble/ gravel	14	1.43	0.50	0.00	1.93	
170	Bedrock (smooth)/sand	8	1.00	0.13	0.00	1.13	
180	Bedrock (smooth)/shell	4	7.00	1.50	0.00	8.50	
200	Bedrock (crevices)	184	1.03	1.64	0.00	2.67	
230	Bedrock (crevices)/boulders	5	0.40	2.00	0.00	2.40	
234	Bedrock (crevices)/boulders/ cobble	2	4.00	4.00	0.00	8.00	
238	Bedrock (crevices)/boulders/ shell	2	0.50	0.00	0.00	0.50	2.63 ± 0.29
240	Bedrock (crevices)/cobble	23	1.30	1.00	0.00	2.30	
270	Bedrock (crevices)/sand	2	1.00	2.50	0.00	3.50	
280	Bedrock (crevices)/shell	9	0.56	1.22	0.00	1.78	
310	Boulders/bedrock (smooth)	2	1.50	1.00	0.00	2.50	
340	Boulders/cobble	16	0.31	0.44	0.00	0.75	
341	Boulders/cobble/bedrock (smooth)	1	0.00	0.00	0.00	0.00	1.04 ± 0.26
370	Boulders/sand	5	0.00	1.60	0.00	1.60	
400	Cobble	1	0.00	0.00	0.00	0.00	
410	Cobble/bedrock (smooth)	17	0.29	0.35	0.00	0.65	
420	Cobble/bedrock (creviced)	1	0.00	6.00	0.00	6.00	0.79 ± 0.29
430	Cobble/boulders	1	0.00	2.00	0.00	2.00	
439	Cobble/boulders/mud	2	0.00	0.00	0.00	0.00	
490	Cobble/mud	2	0.00	0.00	0.00	0.00	
571	Gravel/sand/bedrock (smooth)	1	0.00	0.00	0.00	0.00	0.00
700	Sand	2	0.00	0.00	0.00	0.00	
710	Sand/bedrock (smooth)	6	0.17	0.00	0.00	0.17	0.11 ± 0.11
730	Sand/boulders	1	0.00	0.00	0.00	0.00	
800	Shell	1	0.00	0.00	0.00	0.00	0.00
870	Shell/sand	1	0.00	0.00	0.00	0.00	

Table 6b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 1997 survey (Stephenson Islets only). (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = mean density for all urchins within the dominant substrate type and standard error).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
?	Unknown	4	0.00	0.00	2.50	2.50	2.50 ± 1.44
100	Bedrock (smooth)	95	0.51	0.55	0.00	1.05	1.30 ± 0.16
120	Bedrock (smooth)/bedrock (creviced)	29	1.00	0.90	0.00	1.90	
134	Bedrock (smooth)/boulders/ cobble	1	0.00	0.00	0.00	0.00	
140	Bedrock (smooth)/cobble	1	0.00	0.00	0.00	0.00	
145	Bedrock (smooth)/cobble/ gravel	14	1.43	0.50	0.00	1.93	
200	Bedrock (crevices)	108	1.24	2.37	0.00	3.61	3.35 ± 0.44
230	Bedrock (crevices)/boulders	4	0.50	1.00	0.00	1.50	
240	Bedrock (crevices)/cobble	22	1.36	1.05	0.00	2.41	
270	Bedrock (crevices)/sand	2	1.00	2.50	0.00	3.50	
310	Boulders/bedrock (smooth)	2	1.50	1.00	0.00	2.50	1.28 ± 0.32
340	Boulders/cobble	11	0.36	0.55	0.00	0.91	
341	Boulders/cobble/bedrock (smooth)	1	0.00	0.00	0.00	0.00	
370	Boulders/sand	4	0.00	2.00	0.00	2.00	
400	Cobble	1	0.00	0.00	0.00	0.00	0.89 ± 0.35
410	Cobble/bedrock (smooth)	17	0.29	0.35	0.00	0.65	
420	Cobble/bedrock (creviced)	1	0.00	6.00	0.00	6.00	

Table 6c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 1997 survey (Stubbs Island only). (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = mean density for all urchins within the dominant substrate type and standard error).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
?	Unknown	4	0.00	0.00	0.00	0.00	0.00
100	Bedrock (smooth)	16	2.06	0.81	0.00	2.88	4.00 ± 0.99
180	Bedrock (smooth)/shell	4	7.00	1.50	0.00	8.50	
200	Bedrock (crevices)	42	1.21	0.74	0.00	1.95	2.15 ± 0.50
234	Bedrock (crevices)/ boulders/cobble	2	4.00	4.00	0.00	8.00	
238	Bedrock (crevices)/ boulders/ shell	2	0.50	0.00	0.00	0.50	

Table 6d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 1997 survey (Plumper Islands only). (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = mean density for all urchins within the dominant substrate type and standard error).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
?	Unknown	11	0.00	0.00	0.00	0.00	0.00
100	Bedrock (smooth)	27	0.37	0.63	0.00	1.00	1.03 ± 0.35
170	Bedrock (smooth)/sand	8	1.00	0.13	0.00	1.13	
200	Bedrock (crevices)	34	0.15	0.44	0.00	0.59	0.93 ± 0.23
230	Bedrock (crevices)/ boulders	1	0.00	6.00	0.00	6.00	
240	Bedrock (crevices)/cobble	1	0.00	0.00	0.00	0.00	
280	Bedrock (crevices)/shell	9	0.56	1.22	0.00	1.78	
340	Boulders/cobble	5	0.20	0.20	0.00	0.40	0.33 ± 0.21
370	Boulders/sand	1	0.00	0.00	0.00	0.00	
430	Cobble/boulders	1	0.00	2.00	0.00	2.00	0.40 ± 0.40
439	Cobble/boulders/mud	2	0.00	0.00	0.00	0.00	
490	Cobble/mud	2	0.00	0.00	0.00	0.00	
571	Gravel/sand/ bedrock (smooth)	1	0.00	0.00	0.00	0.00	0.00
700	Sand	2	0.00	0.00	0.00	0.00	0.11 ± 0.11
710	Sand/bedrock (smooth)	6	0.17	0.00	0.00	0.17	
730	Sand/boulders	1	0.00	0.00	0.00	0.00	
800	Shell	1	0.00	0.00	0.00	0.00	0.00
870	Shell/sand	1	0.00	0.00	0.00	0.00	

Table 7. Summary results of gonad sampling during the November, 1997 survey, by site. (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, SE = Standard error, Gutted Weight = stomach and contents removed; Gonad Colour: 0=unknown or not present, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or not present, 1=firm, 2=semi-firm, 3=flimsy).

Summary Information			Site								
			Stephenson Islets			Stubbs Island			Plumper Islands		
			Legal	Sublegal - mature	Sublegal – immature	Legal	Sublegal - mature	Sublegal – immature	Legal	Sublegal – mature	Sublegal – immature
Sample Size			31	32	3	9	10	1	6	9	0
Mean Test Height (mm) ± SE			28.58 (± 0.63)	18.88 (± 0.77)	9.33 (± 0.88)	31.67 (± 1.32)	18.00 (± 1.54)	11.00	27.83 (± 1.80)	18.33 (± 1.68)	0
Mean Test Diameter (mm) ± SE			61.19 (± 0.77)	42.31 (± 1.45)	22.33 (± 0.88)	67.22 (± 2.37)	43.80 (± 3.24)	24.00	61.33 (± 3.75)	40.11 (± 2.92)	0
Mean Total Wet Weight (g) ± SE			96.00 (± 3.72)	37.67 (± 3.07)	7.07 (± 1.02)	136.38 (± 13.79)	41.99 (± 6.81)	8.50	103.50 (± 19.24)	34.79 (± 6.49)	0
Mean Drained Weight (g) ± SE			76.27 (± 2.64)	31.24 (± 2.44)	6.67 (± 0.82)	99.18 (± 8.88)	36.65 (± 5.75)	7.70	77.13 (± 11.95)	27.47 (± 4.55)	0
Mean Gutted Weight (g) ± SE			61.84 (± 2.37)	24.71 (± 2.00)	4.93 (± 0.39)	78.47 (± 6.92)	30.27 (± 4.87)	6.10	62.53 (± 8.63)	21.02 (± 3.71)	0
Sex (%)	Male		45	25	0	56	50	0	50	0	0
	Female		55	72	0	44	50	0	50	89	0
	Unknown		0	3	100	0	0	100	0	11	0
Gonad	Mean Weight (g) ± SE		16.26 (± 1.11)	4.93 (± 0.74)	0	20.90 (± 2.68)	8.35 (± 1.89)	0.70	18.82 (± 3.30)	3.77 (± 1.04)	0
	Colour Proportion	0	0	0	1	0	0	0	0	0.11	0
		1	0.61	0.75	0	0.67	0.50	0	0.67	0.78	0
		2	0.23	0.19	0	0.22	0.40	1	0.33	0.11	0
		3	0.16	0.06	0	0.11	0.10	0	0	0	0
	Texture Proportion	0	0	0	1	0	0	0	0	0.11	0
		1	0.61	0.44	0	0.44	0.40	0	0.50	0.44	0
		2	0.35	0.47	0	0.44	0.50	1	0.50	0.44	0
		3	0.03	0.09	0	0.11	0.10	0	0	0	0

Table 8. Comparisons of percentage of highest roe quality (roe with best colour and texture) and mean roe recovery rates (total gonad weight divided by total drained weight) between the November, 1997 and March, 1998 surveys at Stephenson Islets, Stubbs Island and Plumper Islands. (Sample size = total number of urchins with roe).

Site	Sample Size		Highest Quality Roe		Mean Roe Recovery Rates	
	Legal	Sublegal	Legal	Sublegal	Legal	Sublegal
Stephenson Islets						
November 1997	31	33	51.6%	39.4%	21.3%	15.8%
March 1998	30	47	10.0%	8.5%	28.5%	21.2%
Stubbs Island						
November 1997	9	11	33.3%	18.2%	21.1%	22.5%
March 1998	10	10	30.0%	20.0%	34.9%	20.5%
Plumper Islands						
November 1997	6	8	50.0%	50.0%	24.4%	15.0%
March 1998	14	14	14.3%	7.1%	26.0%	15.4%

Table 9. Calculated total abundance (number) and biomass (tonnes) of green sea urchins, by site, in November, 1997, by size category (excluding unknowns). (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = size unknown).

Size Category	Stephenson Islets	Stubbs Island	Plumper Islands
Number of Legal-sized	423,976 ± 79,729	33,880 ± 10,511	58,842 ± 20,588
Number of Sublegal-mature	577,036 ± 161,883	14,280 ± 3,718	88,263 ± 30,407
Number of Sublegal-immature	36,734 ± 15,496	1,960 ± 1,075	15,691 ± 6,340
Number of Unknown	15,306 ± 15,352	0	0
Number of all sizes	1,053,052 ± 238,380	50,120 ± 13,208	162,796 ± 37,657
Biomass of Legal-size (t)	41.02 ± 7.72	4.07 ± 1.27	6.29 ± 2.23
Biomass of Sublegal-mature (t)	25.65 ± 7.21	0.67 ± 0.18	2.77 ± 0.97
Biomass of Sublegal-immature (t)	0.11 ± 0.05	0.01 ± 0.01	0.10 ± 0.04
Total Biomass (t) (excluding 'unknowns')	66.78 ± 10.56	4.76 ± 1.28	9.14 ± 2.43

Table 10a. Means and standard errors (SE) of test diameter (TD) (using March, 1998 field survey data) and weight (using TD-total wet weight relationships from March, 1998 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites during the March, 1998 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	430	61.3	0.3	98.2	1.2
	Sublegal-Mature	874	43.6	0.3	42.0	0.6
	Sublegal-Immature	72	17.8	0.6	4.3	0.3
Stephenson Islets	Legal	287	60.4	0.3	94.1	1.2
	Sublegal-Mature	710	43.9	0.3	42.7	0.7
	Sublegal-Immature	65	17.8	0.7	4.3	0.3
Stubbs Island	Legal	27	66.3	1.3	121.5	6.9
	Sublegal-Mature	26	44.4	1.5	43.7	3.2
	Sublegal-Immature	1	20.0	-	5.0	-
Plumper Islands	Legal	116	62.4	0.5	103.1	2.4
	Sublegal-Mature	138	42.0	0.6	38.1	1.4
	Sublegal-Immature	6	17.7	2.2	4.2	1.2

Table 10b. Means and standard errors (SE) of test diameter (TD) (using March, 1998 field survey data) and weight (using TD-total wet weight relationships from November, 1997 lab measurements and applying to March, 1998 field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites during the March, 1998 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	430	61.3	0.3	98.7	1.2
	Sublegal-Mature	874	43.6	0.3	42.0	0.6
	Sublegal-Immature	72	17.8	0.6	4.3	0.3
Stephenson Islets	Legal	287	60.4	0.3	94.5	1.3
	Sublegal-Mature	710	43.9	0.3	42.8	0.7
	Sublegal-Immature	65	17.8	0.7	4.3	0.3
Stubbs Island	Legal	27	66.3	1.3	122.2	7.0
	Sublegal-Mature	26	44.4	1.5	43.7	3.2
	Sublegal-Immature	1	20.0	-	4.9	-
Plumper Islands	Legal	116	62.4	0.5	103.6	2.5
	Sublegal-Mature	138	42.0	0.6	38.0	1.4
	Sublegal-Immature	6	17.7	2.2	4.2	1.2

Table 11. Sample mean densities (urchins/m^2) by transect and overall standard errors for legal, sublegal-mature, sublegal-immature, and unknown-sized green sea urchins, and all sizes combined (total) in the March, 1998 survey. (Legal = ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = size unknown. Stephenson Islets = Transects 3A to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transects 19 to 24).

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3A	24	1.42	6.67	0.08	0.00	8.17
5A	24	0.29	0.92	0.08	0.00	1.00
6	20	1.00	0.45	0.00	0.00	1.35
7	47	0.94	2.57	0.06	0.04	3.62
8	17	1.41	0.82	0.12	0.00	2.35
9	15	0.47	1.27	0.00	0.00	1.73
10A	25	0.88	1.44	0.08	0.00	2.40
11A	31	0.71	2.19	0.19	0.00	3.10
13	54	1.76	3.65	0.24	0.00	5.65
14	46	0.22	1.37	0.76	0.00	2.35
Stephenson Islets Totals	303	0.95 ± 0.21	2.34 ± 0.52	0.21 ± 0.10	0.01 ± 0.01	3.50 ± 0.66
15	19	0.79	0.42	0.05	0.00	1.26
16	15	0.13	0.07	0.00	0.00	0.20
17	11	0.27	1.09	0.00	0.00	1.36
18	21	0.29	0.24	0.00	0.10	0.62
Stubbs Island Totals	66	0.39 ± 0.16	0.39 ± 0.17	0.02 ± 0.01	0.04 ± 0.03	0.83 ± 0.25
19	16	0.00	0.00	0.00	0.00	0.00
20	34	2.62	2.38	0.03	0.00	5.03
21	14	0.21	0.50	0.00	0.00	0.71
22	27	0.63	1.00	0.11	0.00	1.74
23	16	0.25	0.38	0.13	0.00	0.75
24	11	0.00	0.55	0.00	0.00	0.64
Plumper Islands Totals	118	0.96 ± 0.58	1.08 ± 0.46	0.05 ± 0.02	0.00	2.09 ± 1.03
OVERALL TOTAL	487	0.87 ± 0.19	1.77 ± 0.38	0.15 ± 0.06	0.01 ± 0.01	2.80 ± 0.52

Table 12a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total, with standard errors) by depth range (feet and meters) below Chart Datum from all survey sites combined in the March, 1998 survey. (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-2.3 to 0.0	-0.7 to 0.0	12	0.42	0.58	0.00	1.00 ± 0.44
0.1 to 5.0	0.1 to 1.5	35	2.00	1.83	0.00	3.83 ± 1.24
5.1 to 10.0	1.5 to 3.0	54	1.80	4.37	0.00	6.17 ± 1.10
10.1 to 15.0	3.0 to 4.8	60	0.70	1.57	0.00	2.27 ± 0.38
15.1 to 20.0	4.8 to 6.1	90	0.67	2.20	0.02	2.89 ± 0.36
20.1 to 25.0	6.1 to 7.6	62	0.45	0.97	0.03	1.45 ± 0.26
25.1 to 30.0	7.6 to 9.1	97	0.90	2.20	0.00	3.09 ± 0.37
30.1 to 35.0	9.1 to 10.7	70	0.41	0.83	0.00	1.24 ± 0.27
35.1 to 38.4	10.7 to 11.7	7	1.14	0.43	0.00	1.57 ± 0.61

Table 12b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total, with standard errors) by depth range (feet and meters) below Chart Datum in the Stephenson Islets in the March, 1998 survey. (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-2.3 to 0.0	-0.7 to 0.0	8	0.63	0.75	0.00	1.38 ± 0.63
0.1 to 5.0	0.1 to 1.5	18	1.72	1.78	0.00	3.50 ± 0.87
5.1 to 10.0	1.5 to 3.0	33	1.45	5.64	0.00	7.09 ± 1.21
10.1 to 15.0	3.0 to 4.8	29	1.03	2.48	0.00	3.52 ± 0.61
15.1 to 20.0	4.8 to 6.1	61	0.90	3.07	0.00	3.97 ± 0.46
20.1 to 25.0	6.1 to 7.6	33	0.67	1.52	0.06	2.24 ± 0.40
25.1 to 30.0	7.6 to 9.1	72	1.14	2.68	0.00	3.82 ± 0.46
30.1 to 35.0	9.1 to 10.7	45	0.22	0.98	0.00	1.20 ± 0.25
35.1 to 37.6	10.7 to 11.5	4	1.00	0.50	0.00	1.50 ± 0.96

Table 12c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total, with standard errors) by depth range (feet and meters) below Chart Datum at Stubbs Island in the March, 1998 survey. (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
0.4 to 5.0	0.1 to 1.5	6	0.17	0.00	0.00	0.17 ± 0.17
5.1 to 10.0	1.5 to 3.0	9	0.44	0.22	0.00	0.67 ± 0.37
10.1 to 15.0	3.0 to 4.8	6	0.17	0.33	0.00	0.50 ± 0.34
15.1 to 20.0	4.8 to 6.1	15	0.20	0.53	0.13	0.87 ± 0.32
20.1 to 25.0	6.1 to 7.6	13	0.31	0.62	0.00	0.92 ± 0.47
25.1 to 30.0	7.6 to 9.1	5	0.00	0.00	0.00	0.00
30.1 to 35.0	9.1 to 10.7	10	1.10	0.60	0.00	1.70 ± 1.48
35.1 to 38.4	10.7 to 11.7	2	1.00	0.50	0.00	1.50 ± 1.50

Table 12d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total, with standard errors) by depth range (feet and meters) below Chart Datum in the Plumper Islands in the March, 1998 survey. (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-0.6 to 0.0	-0.2 to 0.0	4	0.00	0.25	0.00	0.25 ± 0.25
0.1 to 5.0	0.1 to 1.5	11	3.45	2.91	0.00	6.36 ± 3.61
5.1 to 10.0	1.5 to 3.0	12	3.75	4.00	0.00	7.75 ± 3.50
10.1 to 15.0	3.0 to 4.8	25	0.44	0.80	0.00	1.24 ± 0.46
15.1 to 20.0	4.8 to 6.1	14	0.14	0.21	0.00	0.36 ± 0.17
20.1 to 25.0	6.1 to 7.6	16	0.13	0.13	0.00	0.25 ± 0.14
25.1 to 30.0	7.6 to 9.1	20	0.25	1.00	0.00	1.25 ± 0.40
30.1 to 35.0	9.1 to 10.7	15	0.53	0.53	0.00	1.07 ± 0.42
35.1 to 36.4	10.7 to 11.9	1	2.00	0.00	0.00	2.00 ± 0.00

Table 13a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the March, 1998 survey (all sites combined). (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = density for all urchins within the dominant substrate type and the standard error).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density by Main Substrate
?	Unknown	122	0.99	1.84	0.02	2.84	2.84 ± 0.35
100	Bedrock (smooth)	144	1.08	2.61	0.00	3.69	
130	Bedrock (smooth)/boulders	2	0.00	0.50	0.00	0.50	
138	Bedrock (smooth)/boulders shell	1	0.00	1.00	0.00	1.00	
140	Bedrock (smooth)/cobble	7	0.43	1.14	0.00	1.57	
148	Bedrock (smooth)/cobble/ shell	2	0.00	1.00	0.00	1.00	3.28 ± 0.43
158	Bedrock (smooth)/gravel/shell	1	0.00	1.00	0.00	1.00	
180	Bedrock (smooth)/shell	20	0.95	1.20	0.00	2.15	
183	Bedrock (smooth)/shell/ boulders	2	0.00	0.00	0.00	0.00	
184	Bedrock (smooth)/shell/cobble	1	0.00	0.00	0.00	0.00	
190	Bedrock (smooth)/mud	1	0.00	3.00	0.00	3.00	
200	Bedrock (crevices)	92	0.82	1.50	0.02	2.34	
230	Bedrock (crevices)/boulders	1	1.00	0.00	0.00	1.00	
248	Bedrock (crevices)/cobble/ shell	9	0.89	1.44	0.00	2.33	
250	Bedrock (crevices)/gravel	1	6.00	13.00	0.00	19.00	2.52 ± 0.34
254	Bedrock (crevices)/gravel/ cobble	1	2.00	6.00	0.00	8.00	
280	Bedrock (crevices)/shell	3	0.67	2.00	0.00	2.67	
291	Bedrock (crevices)/mud/ bedrock (smooth)	1	0.00	0.00	0.00	0.00	
300	Boulders	16	0.31	0.94	0.00	1.25	
310	Boulders/bedrock (smooth)	2	0.00	1.00	0.00	1.00	
340	Boulders/cobble	11	1.18	1.27	0.00	2.45	
345	Boulders/cobble/gravel	1	0.00	5.00	0.00	5.00	1.84 ± 0.40
348	Boulders/cobble/shell	9	0.11	1.00	0.00	1.11	
349	Boulders/cobble/mud	1	0.00	1.00	0.00	1.00	
350	Boulders/gravel	1	3.00	7.00	0.00	10.00	
358	Boulders/gravel/shell	3	0.33	1.67	0.00	2.00	

(Table continued next page)

Table 13a (cont'd)

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density by Main Substrate
400	Cobble	1	0.00	0.00	0.00	0.00	
430	Cobble/boulders	6	1.17	1.50	0.00	2.67	
435	Cobble/boulders/gravel	1	0.00	1.00	0.00	1.00	
438	Cobble/boulders/shell	1	0.00	2.00	0.00	2.00	
450	Cobble/gravel	5	0.00	3.80	0.00	3.80	2.43 ± 0.44
458	Cobble/gravel/shell	6	0.00	2.17	0.00	2.17	
480	Cobble/shell	1	0.00	0.00	0.00	0.00	
500	Gravel	3	0.67	0.67	0.00	1.33	
510	Gravel/bedrock (smooth)	2	0.50	2.00	0.00	2.50	2.86 ± 0.86
580	Gravel/shell	2	0.50	5.00	0.00	5.50	
810	Mud/creviced bedrock	1	0.00	0.00	0.00	0.00	
813	Mud/creviced bedrock/ boulders	1	0.00	0.00	0.00	0.00	0.00
814	Mud/creviced bedrock/cobble	2	0.00	0.00	0.00	0.00	

Table 13b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the March, 1998 survey (Stephenson Islets only). (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = density for all urchins within the dominant substrate type and the standard error).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density by Main Substrate
?	Unknown	79	1.46	2.77	0.00	4.23	4.23 ± 0.47
100	Bedrock (smooth)	88	0.82	3.30	0.00	4.11	
130	Bedrock (smooth)/boulders	2	0.00	0.50	0.00	0.50	
138	Bedrock (smooth)/boulders/ shell	1	0.00	1.00	0.00	1.00	
140	Bedrock (smooth)/cobble	7	0.43	1.14	0.00	1.57	3.67 ± 0.44
148	Bedrock (smooth)/cobble/shell	1	0.00	1.00	0.00	1.00	
158	Bedrock (smooth)/gravel/shell	1	0.00	1.00	0.00	1.00	
180	Bedrock (smooth)/shell	5	1.00	2.20	0.00	3.20	
183	Bedrock (smooth)shell/ boulders	2	0.00	0.00	0.00	0.00	
190	Bedrock (smooth)/mud	1	0.00	3.00	0.00	3.00	
200	Bedrock (crevices)	47	0.94	2.13	0.04	3.11	
230	Bedrock (crevices)/boulders	1	1.00	0.00	0.00	1.00	
248	Bedrock (crevices)/cobble/ shell	9	0.89	1.44	0.00	2.33	
250	Bedrock (crevices)/gravel	1	6.00	13.00	0.00	19.00	3.22 ± 0.49
254	Bedrock (crevices)/gravel/ cobble	1	2.00	6.00	0.00	8.00	
280	Bedrock (crevices)/shell	3	0.67	2.00	0.00	2.67	
291	Bedrock (crevices)/mud/ bedrock (smooth)	1	0.00	0.00	0.00	0.00	
340	Boulders/cobble	11	1.18	1.27	0.00	2.45	
345	Boulders/cobble/gravel	1	0.00	5.00	0.00	5.00	
348	Boulders/cobble/shell	8	0.13	1.13	0.00	1.25	2.36 ± 0.64
349	Boulders/cobble/mud	1	0.00	1.00	0.00	1.00	
350	Boulders/gravel	1	3.00	7.00	0.00	10.00	
358	Boulders/gravel/shell	3	0.33	1.67	0.00	2.00	
400	Cobble	1	0.00	0.00	0.00	0.00	
430	Cobble/boulders	6	1.17	1.50	0.00	2.67	
435	Cobble/boulders/gravel	1	0.00	1.00	0.00	1.00	
438	Cobble/boulders/shell	1	0.00	2.00	0.00	2.00	2.43 ± 0.44
450	Cobble/gravel	5	0.00	3.80	0.00	3.80	
458	Cobble/gravel/shell	6	0.00	2.17	0.00	2.17	
480	Cobble/shell	1	0.00	0.00	0.00	0.00	
500	Gravel	3	0.67	0.67	0.00	1.33	
510	Gravel/bedrock (smooth)	2	0.50	2.00	0.00	2.50	2.86 ± 0.86
580	Gravel/shell	2	0.50	5.00	0.00	5.50	

Table 13c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the March, 1998 survey (Stubbs Island only). (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = density for all urchins within the dominant substrate type and the standard error).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density by Main Substrate
?	Unknown	37	0.16	0.14	0.05	0.35	0.35 ± 0.12
100	Bedrock (smooth)	22	0.23	0.59	0.00	0.82	0.82 ± 0.31
200	Bedrock (crevices)	7	2.14	1.29	0.00	3.43	3.43 ± 2.01

Table 13d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the March, 1998 survey (Plumper Islands only). (Legal = ≥ 55 mm test diameter (TD), Sublegal = < 55 mm TD, Unknown = size unknown; Total Density by Main Substrate = density for all urchins within the dominant substrate type and the standard error).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density by Main Substrate
?	Unknown	6	0.00	0.00	0.00	0.00	0.00
100	Bedrock (smooth)	34	2.29	2.15	0.00	4.44	3.51 ± 1.20
148	Bedrock (smooth)/cobble/shell	1	0.00	1.00	0.00	1.00	
180	Bedrock (smooth)/shell	15	0.93	0.87	0.00	1.80	
184	Bedrock (smooth)/shell/cobble	1	0.00	0.00	0.00	0.00	
200	Bedrock (crevices)	38	0.42	0.76	0.00	1.18	1.18 ± 0.26
300	Boulders	16	0.31	0.94	0.00	1.25	1.16 ± 0.37
310	Boulders/bedrock (smooth)	2	0.00	1.00	0.00	1.00	
348	Boulders/cobble/shell	1	0.00	0.00	0.00	0.00	
810	Shell/bedrock (smooth)	1	0.00	0.00	0.00	0.00	0.00
813	Shell/bedrock smooth)/ boulders	1	0.00	0.00	0.00	0.00	
814	Shell/bedrock (smooth)/cobble	2	0.00	0.00	0.00	0.00	

Table 14. Summary results of gonad sampling during the March, 1998 survey, by site. (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD <55 mm, Sublegal-immature < 25 mm TD, SE = Standard error, Gutted Weight = stomach and contents removed; Gonad Colour: 0=unknown or not present, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or not present, 1=firm, 2=semi-firm, 3=flimsy).

Summary Information			Site								
			Stephenson Islets			Stubbs Island			Plumper Islands		
			Legal	Sublegal – mature	Sublegal – immature	Legal	Sublegal – mature	Sublegal – immature	Legal	Sublegal – mature	Sublegal – immature
Sample Size			30	52	0	10	11	0	14	20	0
Mean Test Height (mm)± SE			29.63 (± 0.48)	19.40 (± 0.54)	0.00	29.70 (± 0.60)	19.73 (± 1.10)	0.00	28.14 (± 1.02)	17.55 (± 0.74)	0.00
Mean Test Diameter (mm) ± SE			61.27 (± 0.92)	41.23 (± 1.11)	0.00	61.10 (± 1.46)	40.91 (± 2.01)	0.00	62.14 (± 1.91)	38.65 (± 1.48)	0.00
Mean Total Wet Weight (g) ± SE			99.06 (± 4.31)	36.08 (± 2.29)	0.00	93.89 (± 5.28)	32.89 (± 3.63)	0.00	102.52 (± 10.38)	29.07 (± 3.30)	0.00
Mean Drained Weight (g) ± SE			77.93 (± 3.70)	30.10 (± 1.88)	0.00	69.94 (± 6.95)	29.45 (± 3.47)	0.00	85.65 (± 7.00)	24.12 (± 2.75)	0.00
Mean Gutted Weight (g) ± SE			66.86 (± 3.40)	24.89 (± 1.69)	0.00	68.10 (± 5.10)	23.65 (± 2.92)	0.00	66.99 (± 5.31)	19.08 (± 2.40)	0.00
Sex (%)	Male		43	37	0	20	55	0	57	20	0
	Female		57	54	0	80	36	0	43	50	0
	Unknown		0	10	0	0	9	0	0	30	0
Gonad	Mean Weight (g) ± SE		22.23 (± 1.99)	6.14 (± 0.77)	0	24.38 (± 3.47)	5.85 (± 1.26)	0	22.31 (± 2.57)	3.10 (± 0.87)	0.00
	Colour Proportion	0	0	0.10	0	0	0.09	0	0	0.30	0
		1	0.50	0.38	0	0.70	0.36	0	0.43	0.35	0
		2	0.20	0.37	0	0.10	0.36	0	0.14	0.15	0
		3	0.30	0.15	0	0.20	0.18	0	0.43	0.20	0
	Texture Proportion	0	0	0.10	0	0	0.09	0	0	0.30	0
		1	0.13	0.10	0	0.30	0.18	0	0.14	0.05	0
		2	0.60	0.40	0	0.50	0.55	0	0.71	0.35	0
		3	0.27	0.40	0	0.20	0.18	0	0.14	0.30	0

Table 15a. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site, in March, 1998, by size category (excluding biomass of unknowns). (Biomass estimates were calculated using TD-weight relationships determined from March, 1998 lab measurements for each of the three sites separately, and applied to the field survey TD measurements. Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = size unknown).

Size Category	Stephenson Islets	Stubbs Island	Plumper Islands
Number of Legal-sized	459,579 ± 101,237	7,721 ± 3,042	214,125 ± 128,735
Number of Sublegal-mature	1,135,336 ± 249,984	7,721 ± 3,322	240,654 ± 103,744
Number of Sublegal-immature	104,086 ± 46,128	297 ± 284	11,369 ± 5,113
Number of Unknown	3,203 ± 3,035	594 ± 543	0
Number of all sizes	1,699,001 ± 321,483	16,333 ± 4,984	468,044 ± 229,932
Biomass of Legal-size (t)	43.23 ± 9.53	0.94 ± 0.37	22.08 ± 13.29
Biomass of Sublegal-mature (t)	48.53 ± 10.70	0.34 ± 0.15	9.16 ± 3.96
Biomass of Sublegal-immature (t)	0.45 ± 0.20	0.001 ± 0.000	0.05 ± 0.03
Total Biomass (t) (excluding 'unknowns')	92.21 ± 14.33	1.28 ± 0.40	31.29 ± 13.87

Table 15b. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site, in March, 1998, by size category (excluding biomass of unknowns). (Biomass estimates were calculated using TD-weight relationships determined from November, 1997 lab measurements for each of the three sites separately, and applied to the March, 1998 field survey TD measurements. Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Size Category	Stephenson Islets	Stubbs Island	Plumper Islands
Biomass of Legal-size (t)	43.41 ± 9.57	0.94 ± 0.37	22.19 ± 13.35
Biomass of Sublegal-mature (t)	48.54 ± 10.70	0.34 ± 0.15	9.16 ± 3.96
Biomass of Sublegal-immature (t)	0.44 ± 0.20	0.001 ± 0.000	0.05 ± 0.03
Total Biomass (t) (excluding 'unknowns')	92.39 ± 14.36	1.28 ± 0.40	31.39 ± 13.93

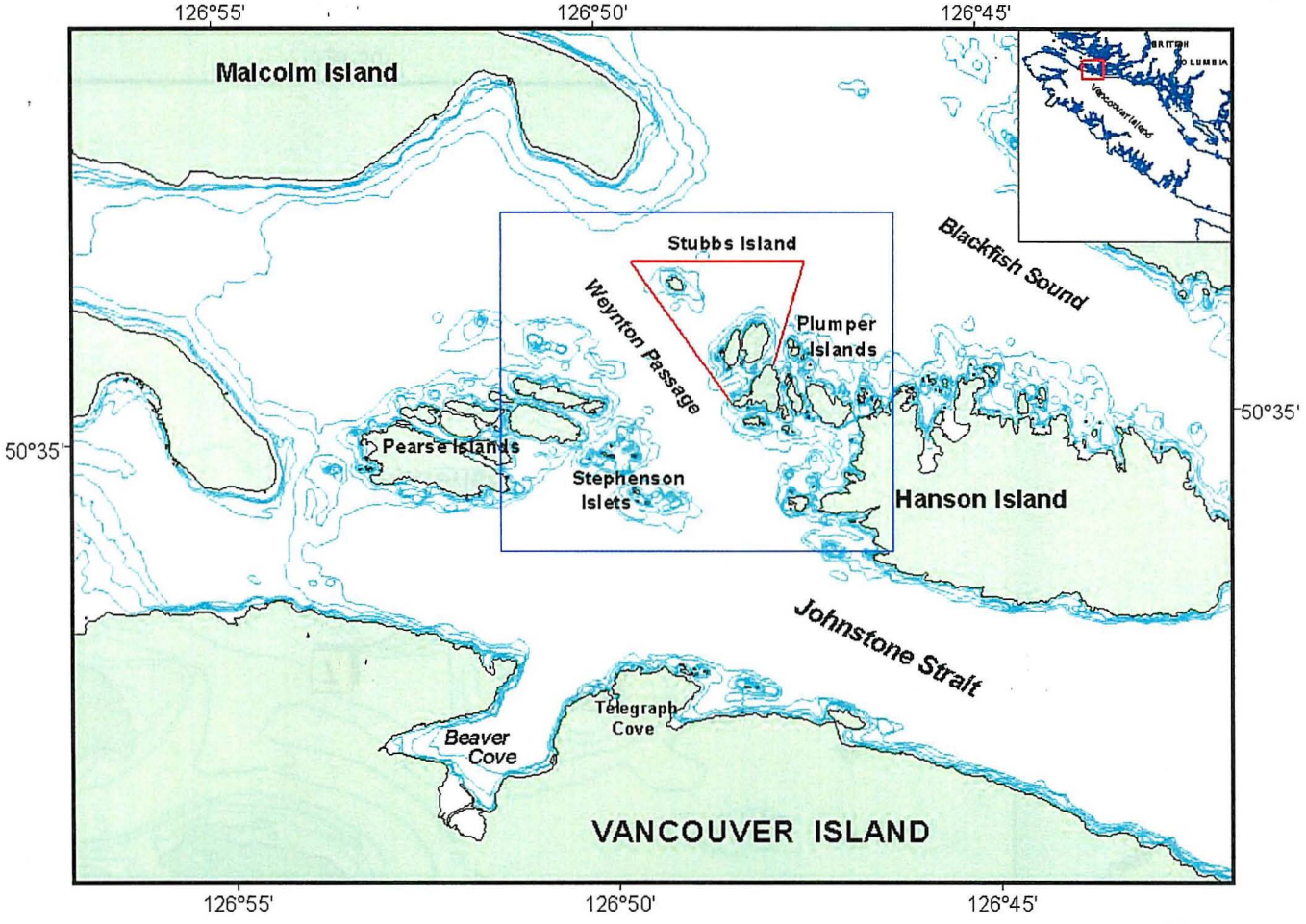

Fig. 1a. Site locations for the November, 1997 and March, 1998 green urchin surveys (Stephenson Islets, Stubbs Island and the Plumper Islands). The red border represents the boundaries of the research closure area. No commercial fishing may occur within these boundaries.

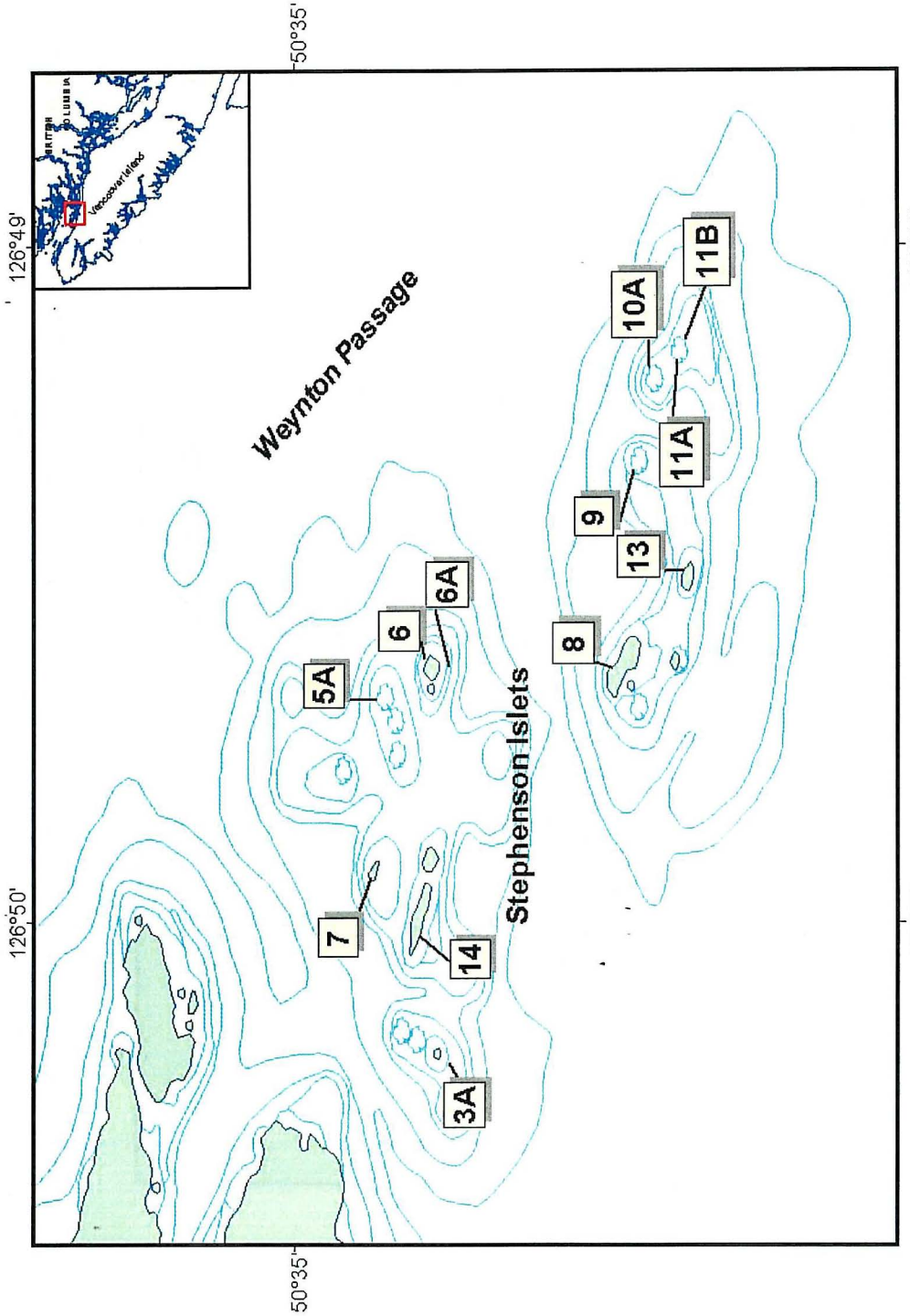

Fig. 1b. Transect locations (black lines) for the November, 1997 and March, 1998 green sea urchin surveys, Stephenson Islets.

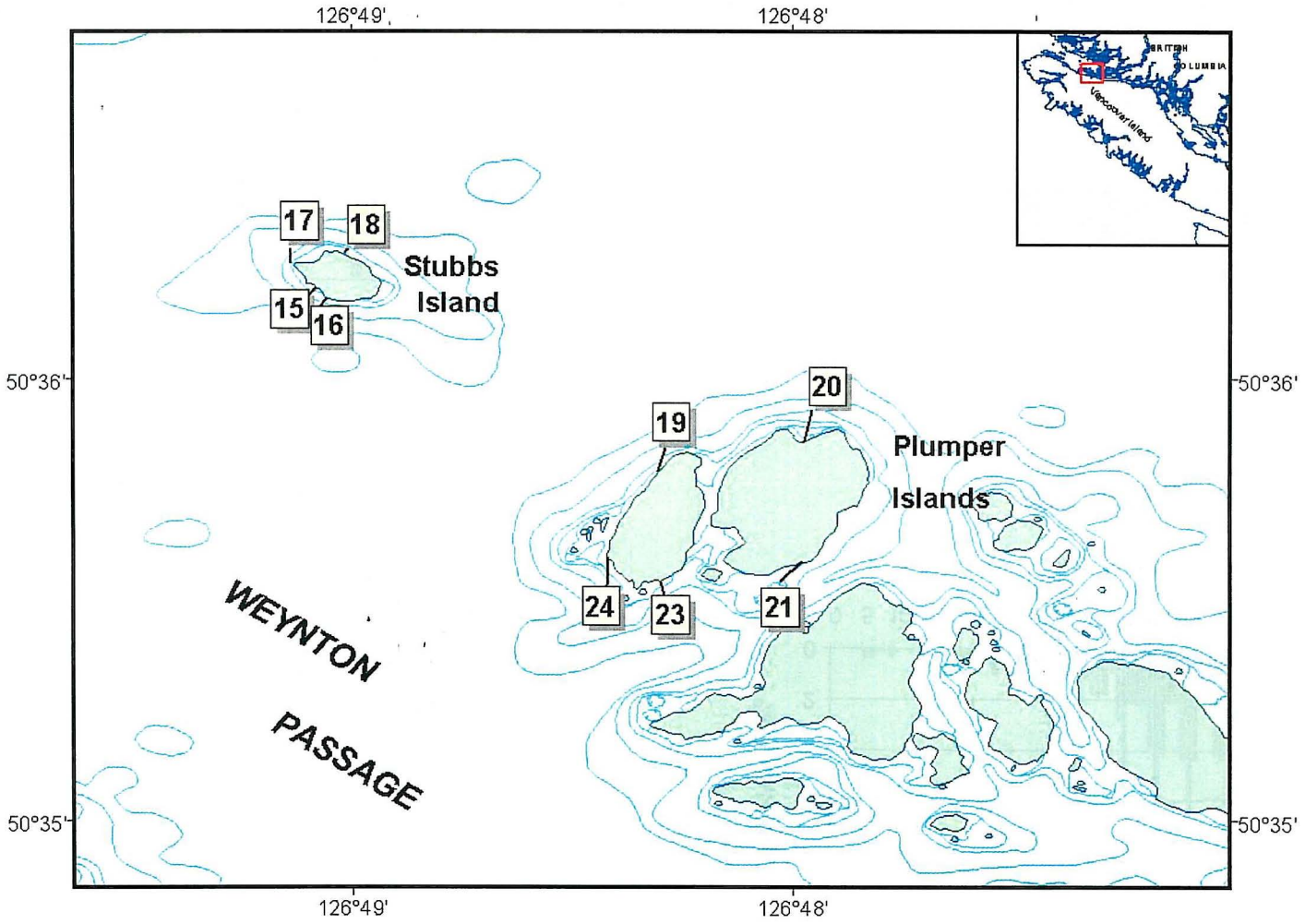

Fig. 1c. Transect locations (black lines) for the November, 1997 and March, 1998 green sea urchin surveys, Stubbs Island and the Plumper Islands.

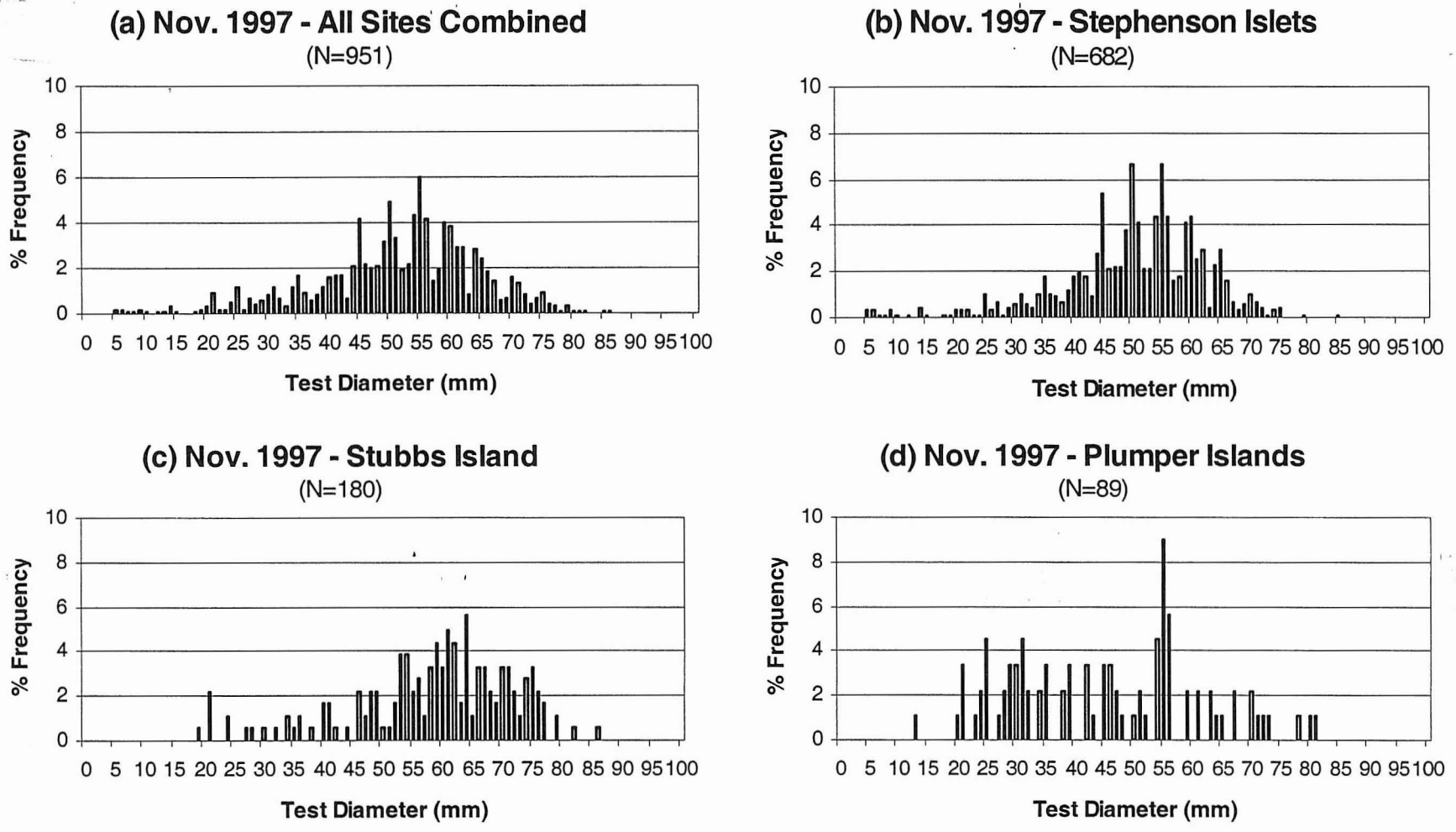

Fig. 2. Size (test diameter in millimeters) distribution of green sea urchins collected in November, 1997 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the size limit is 55 mm.

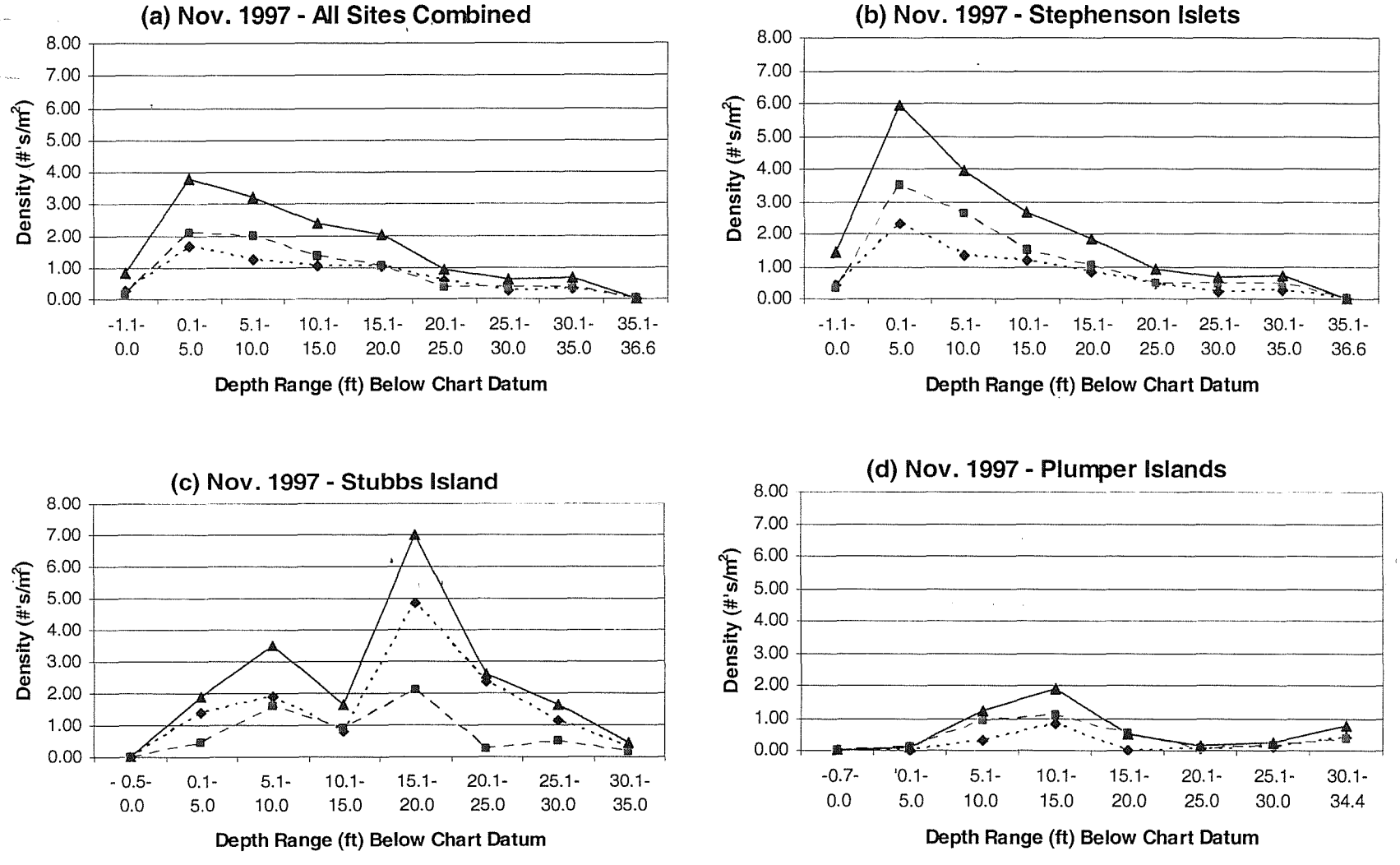

Fig. 3. November, 1997 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. (Totals include urchins of unknown size (not presented separately)).

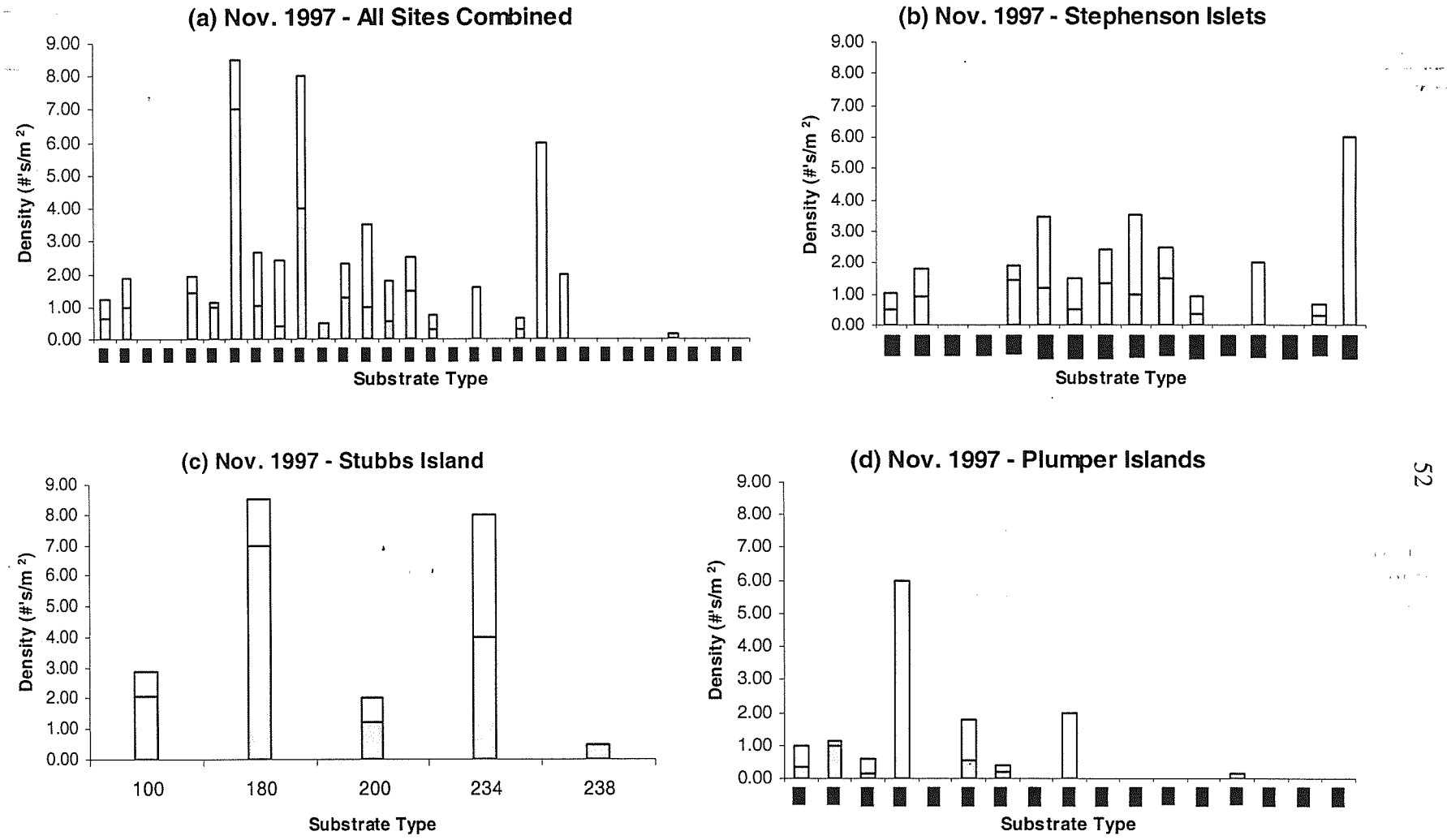

Fig. 4. November, 1997 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal (white), and unknown size (black) by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 6a-d for the keys to the substrate codes. Unidentified substrates not displayed.

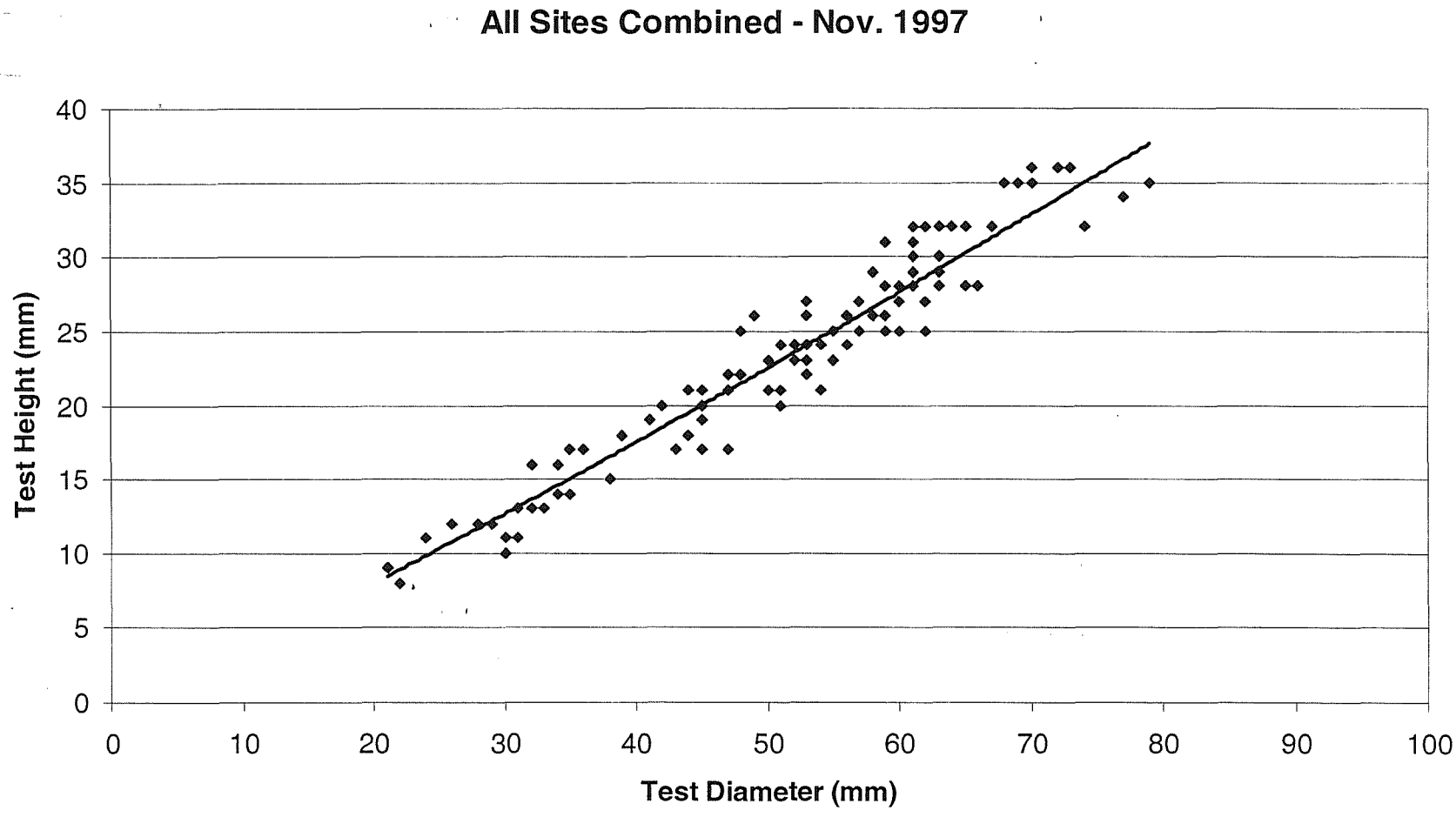

Fig. 5. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in November, 1997, all sites combined: TEST HEIGHT (mm) = $0.2738(TD^{1.1269})$, $R^2 = 0.9405$, n=102.

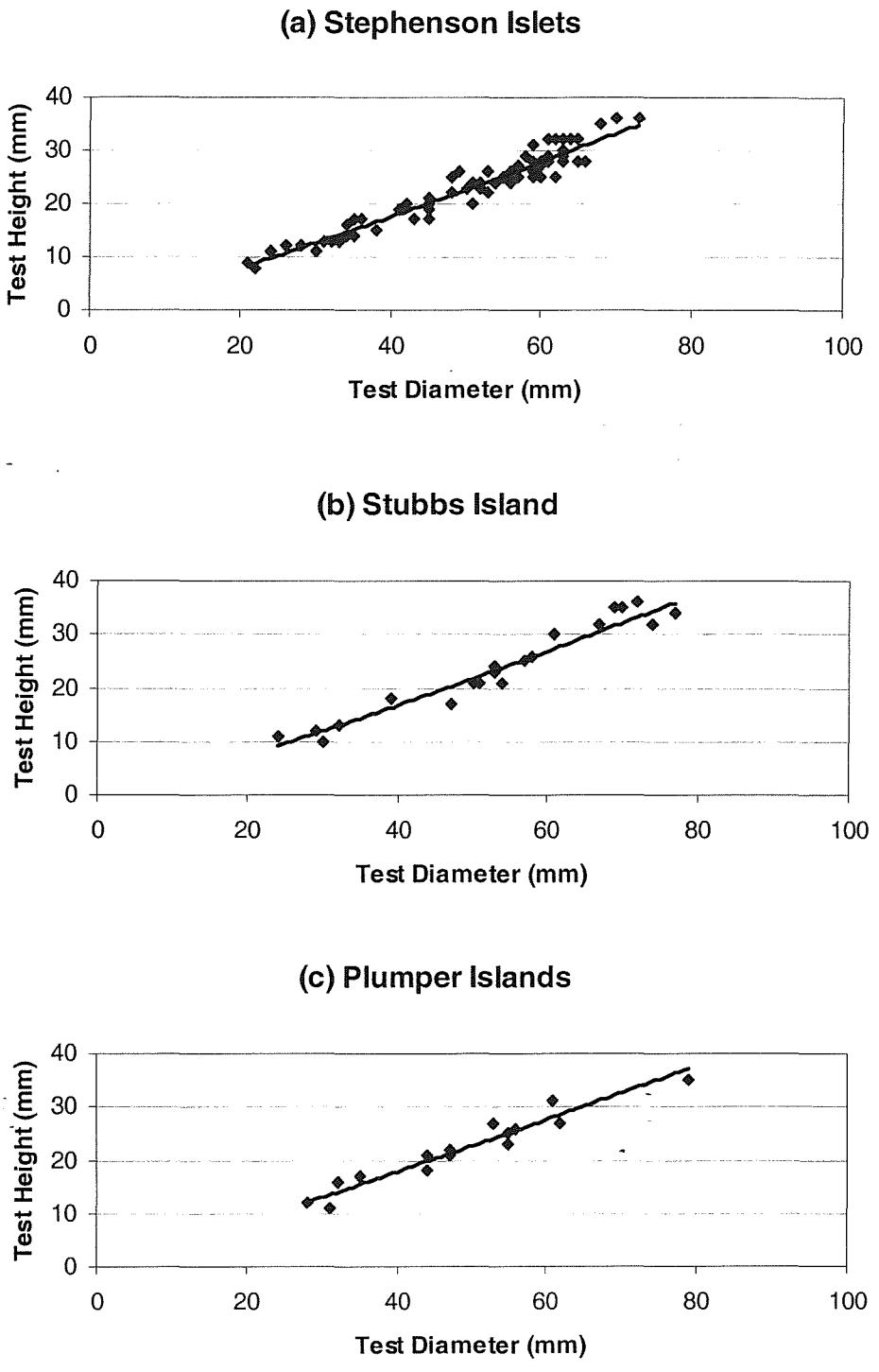

Fig. 6. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in November, 1997 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = $0.2698(TD^{1.1324})$, $R^2 = 0.9458$, n=67);
(b) Stubbs Island (TEST HEIGHT (mm) = $0.2345(TD^{1.1583})$, $R^2 = 0.9467$, n=20);
(c) Plumper Islands (TEST HEIGHT (mm) = $0.3393(TD^{1.0744})$, $R^2 = 0.9192$, n=15).

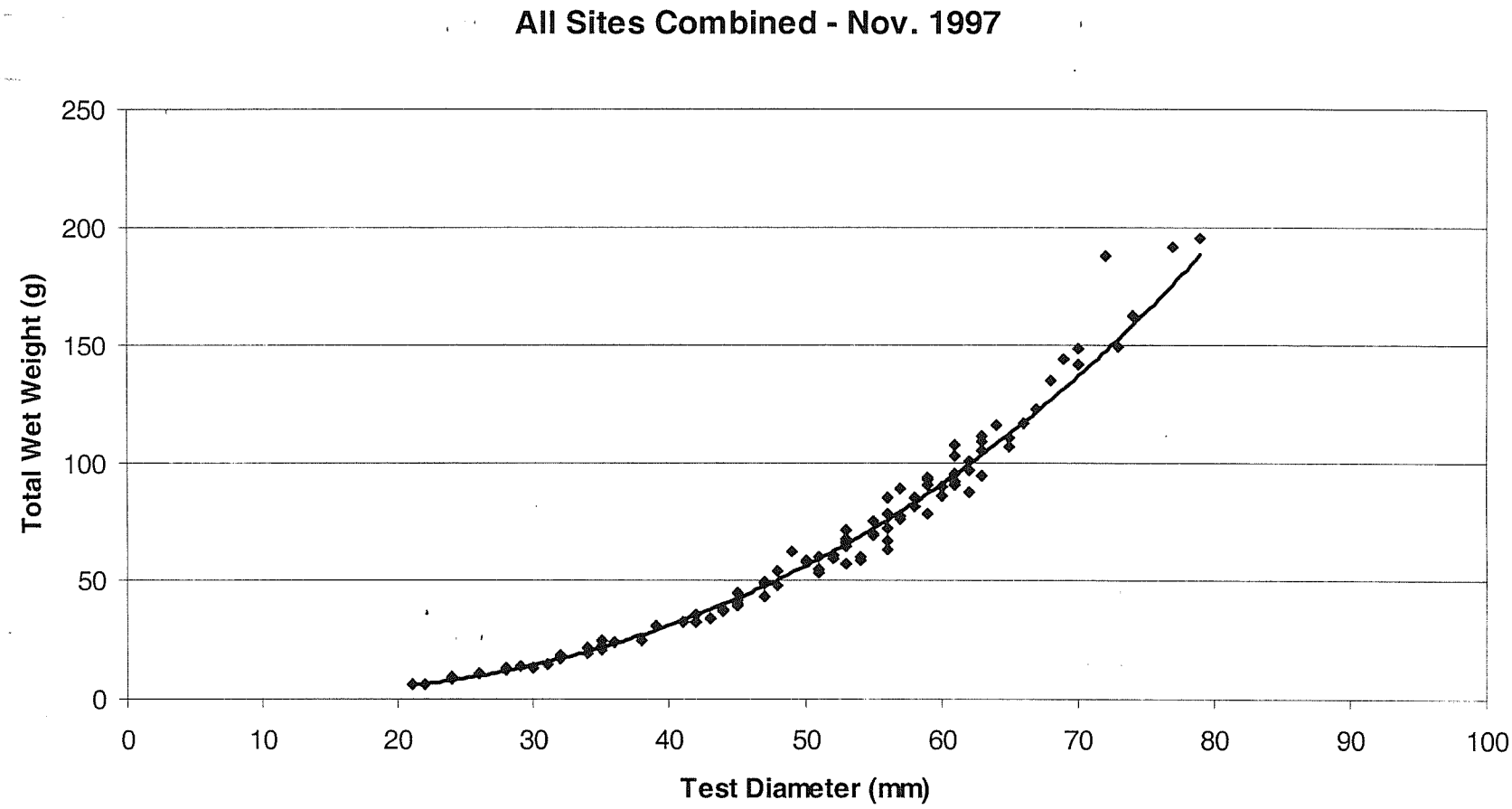

Fig. 7. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in November, 1997, calculated from all sites combined. TOTAL WET WEIGHT (g) = $0.0017(TD^{2.6608})$, $R^2 = 0.9909$, n=101.

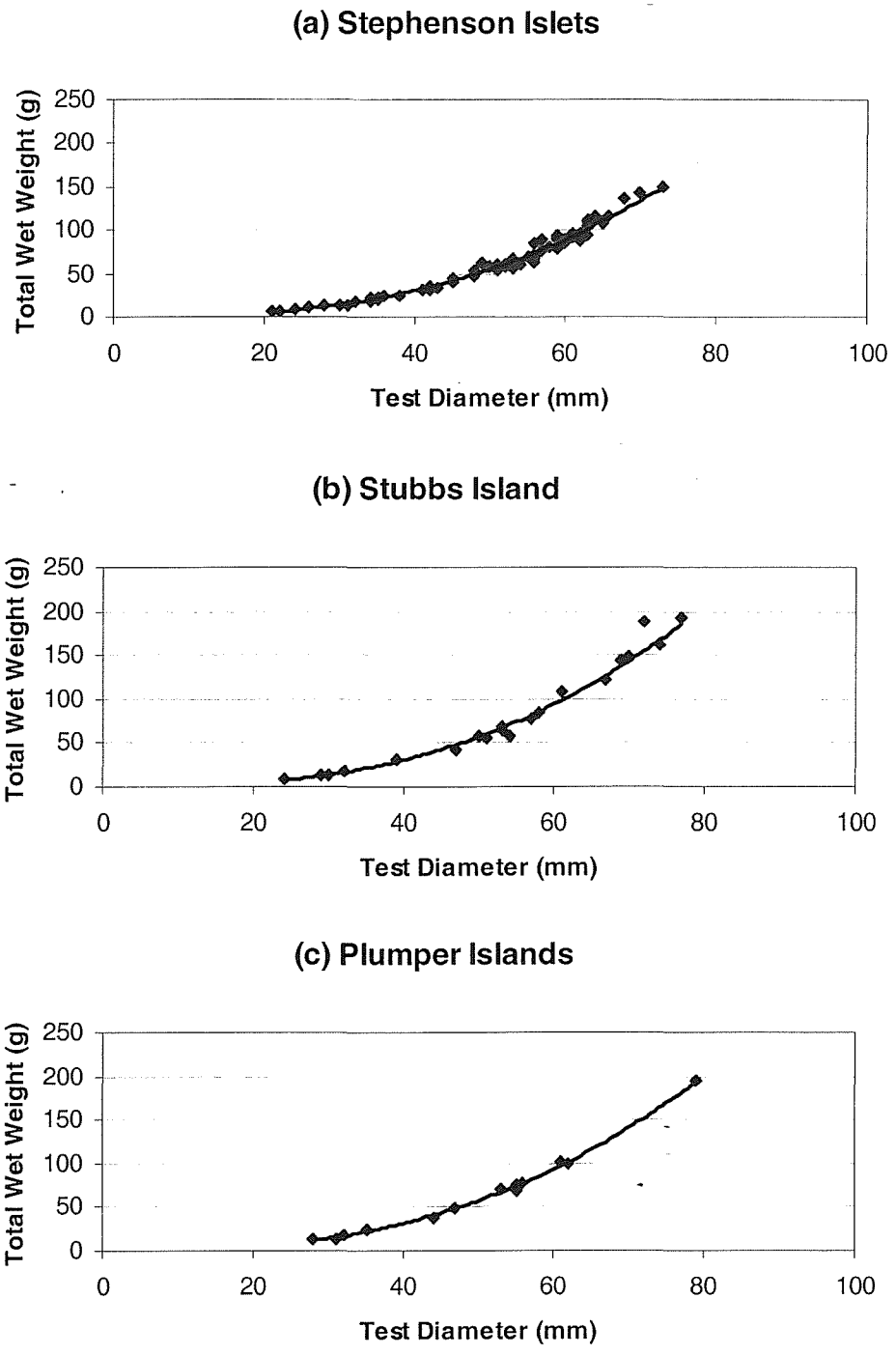

Fig. 8. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in November, 1997 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = $0.0019(TD^{2.6320})$, R^2=0.9914, n=66);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = $0.0013(TD^{2.7300})$, R^2=0.9913, n=20);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = $0.0017(TD^{2.6599})$, R^2=0.9930, n=15).

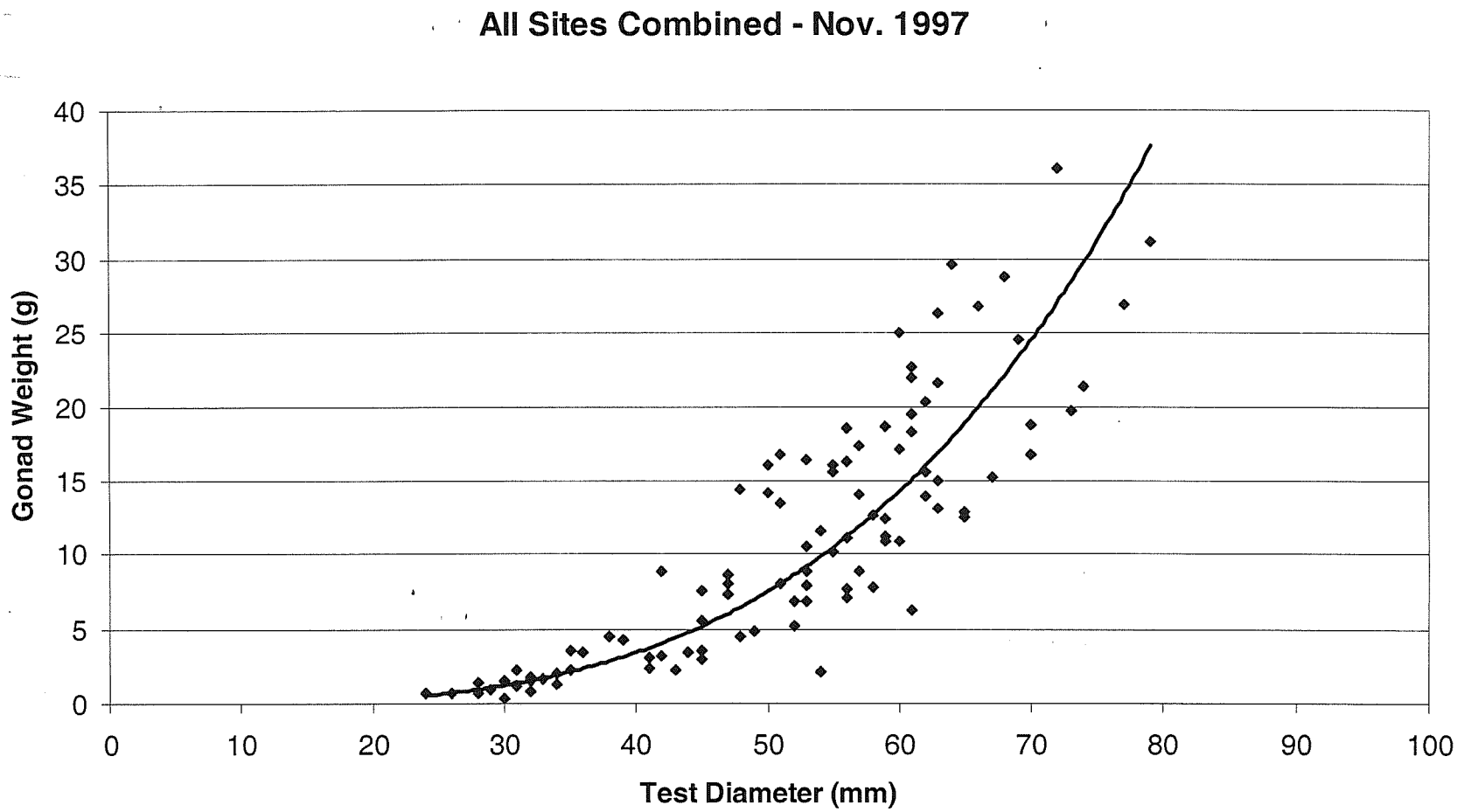

Fig. 9. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in November, 1997, calculated from all sites combined: GONAD WEIGHT (g) = $8 \times 10^{-6}(TD^{3.5299})$; $R^2 = 0.8409$, n = 98.

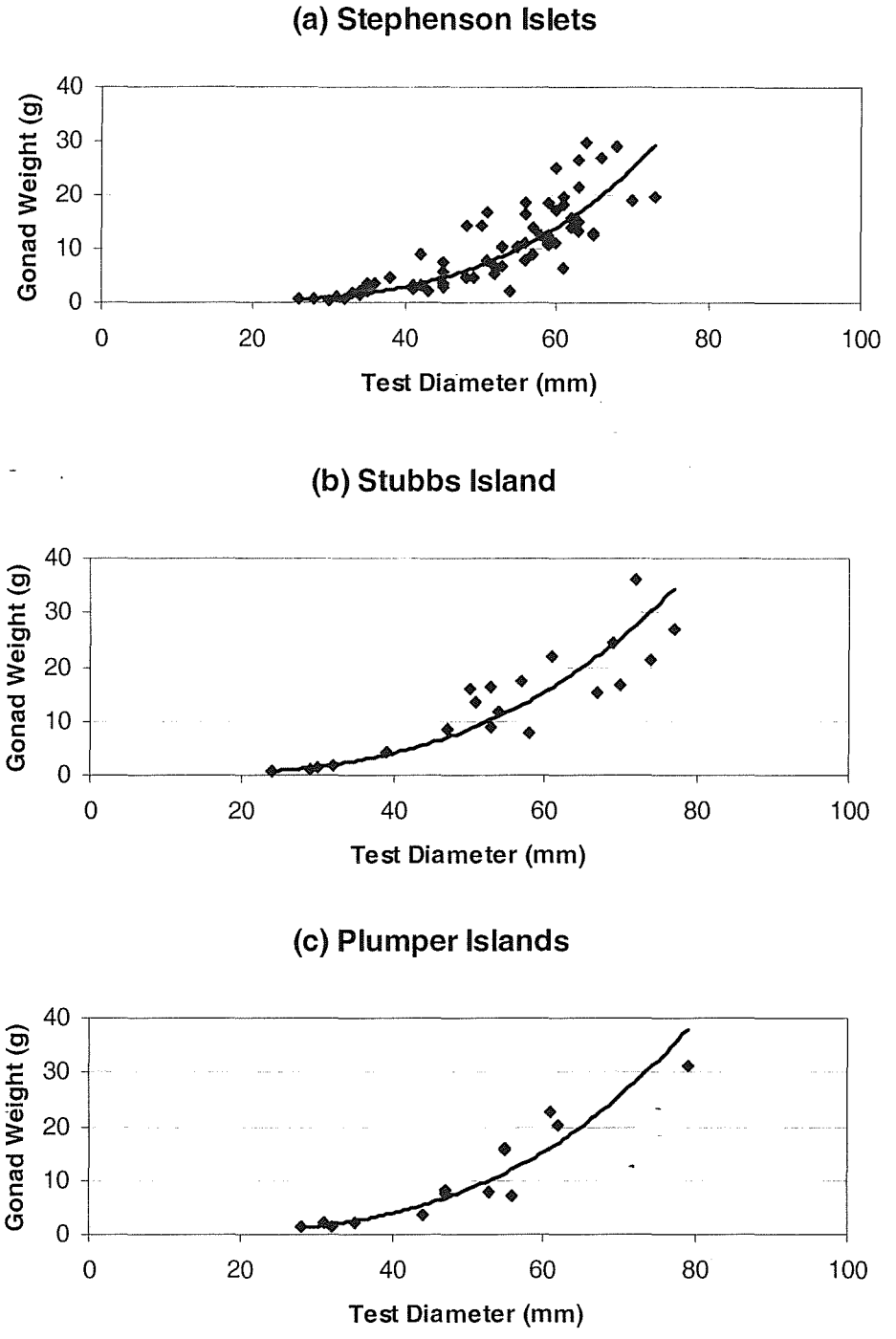

Fig. 10. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in November, 1997 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 3 x 10^{-6} ($TD^{3.7707}$), R^2 = 0.8124, n=64);
(b) Stubbs Island (GONAD WEIGHT (g) = 3 x 10^{-5} ($TD^{3.2382}$), R^2 = 0.9178, n=20);
(c) Plumper Islands (GONAD WEIGHT (g) = 2 x 10^{-5} ($TD^{3.3181}$), R^2 = 0.9185, n=14).

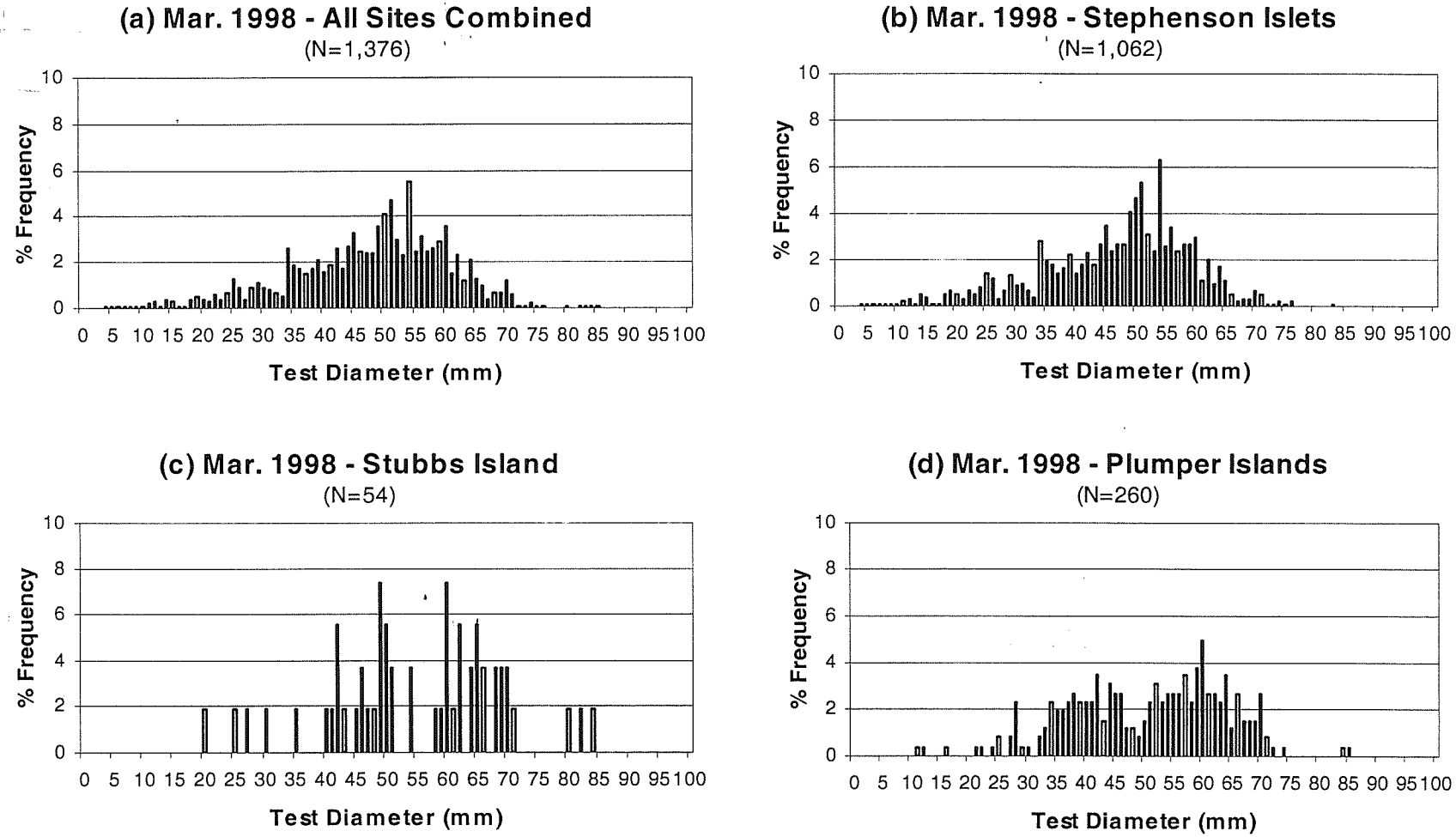

Fig. 11. Size (test diameter in millimeters) distributions of green sea urchins collected in March, 1998 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the legal size limit is 55 mm.

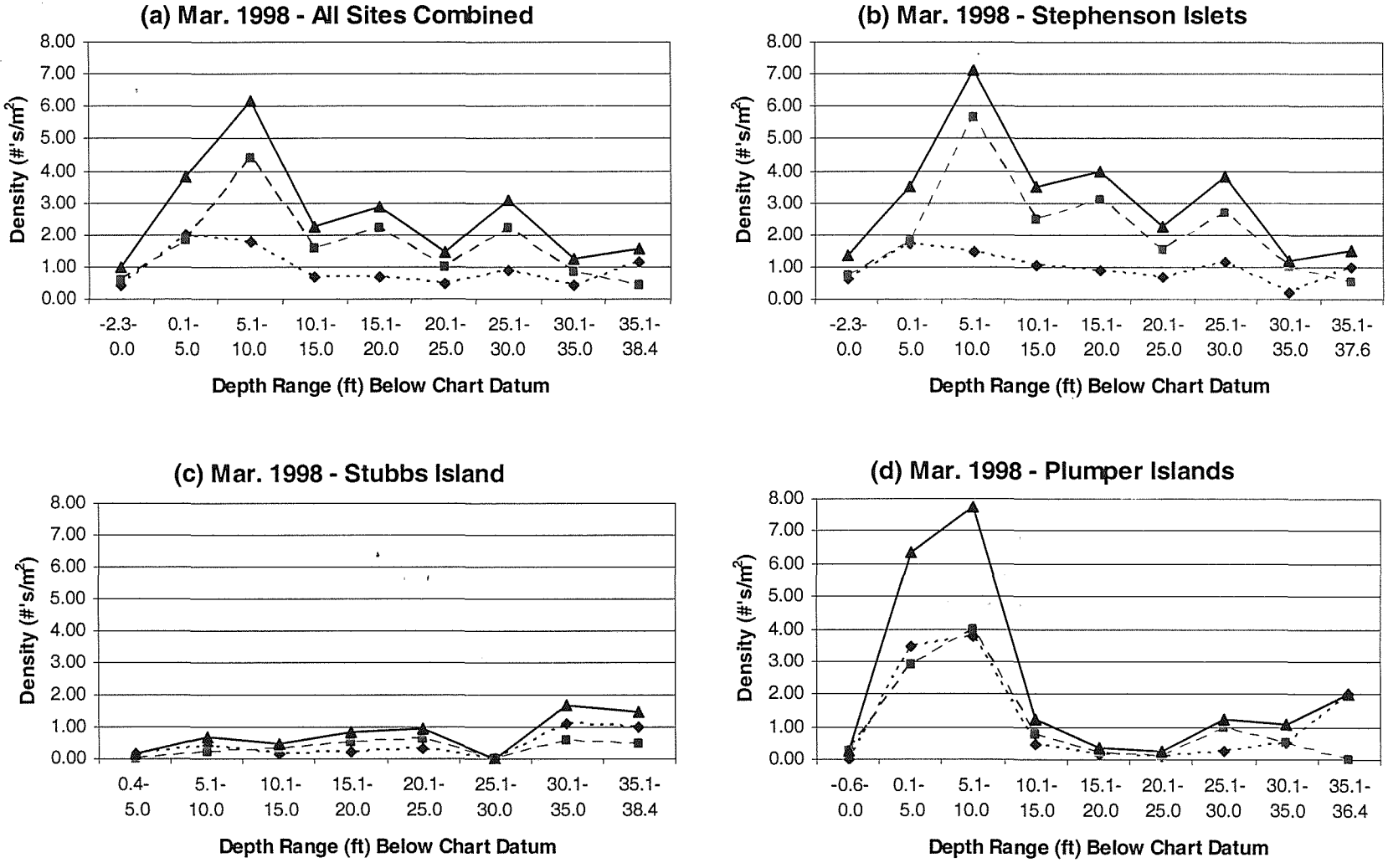

Fig. 12. March, 1998 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds) and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. (Totals include urchins of unknown size (not presented separately)).

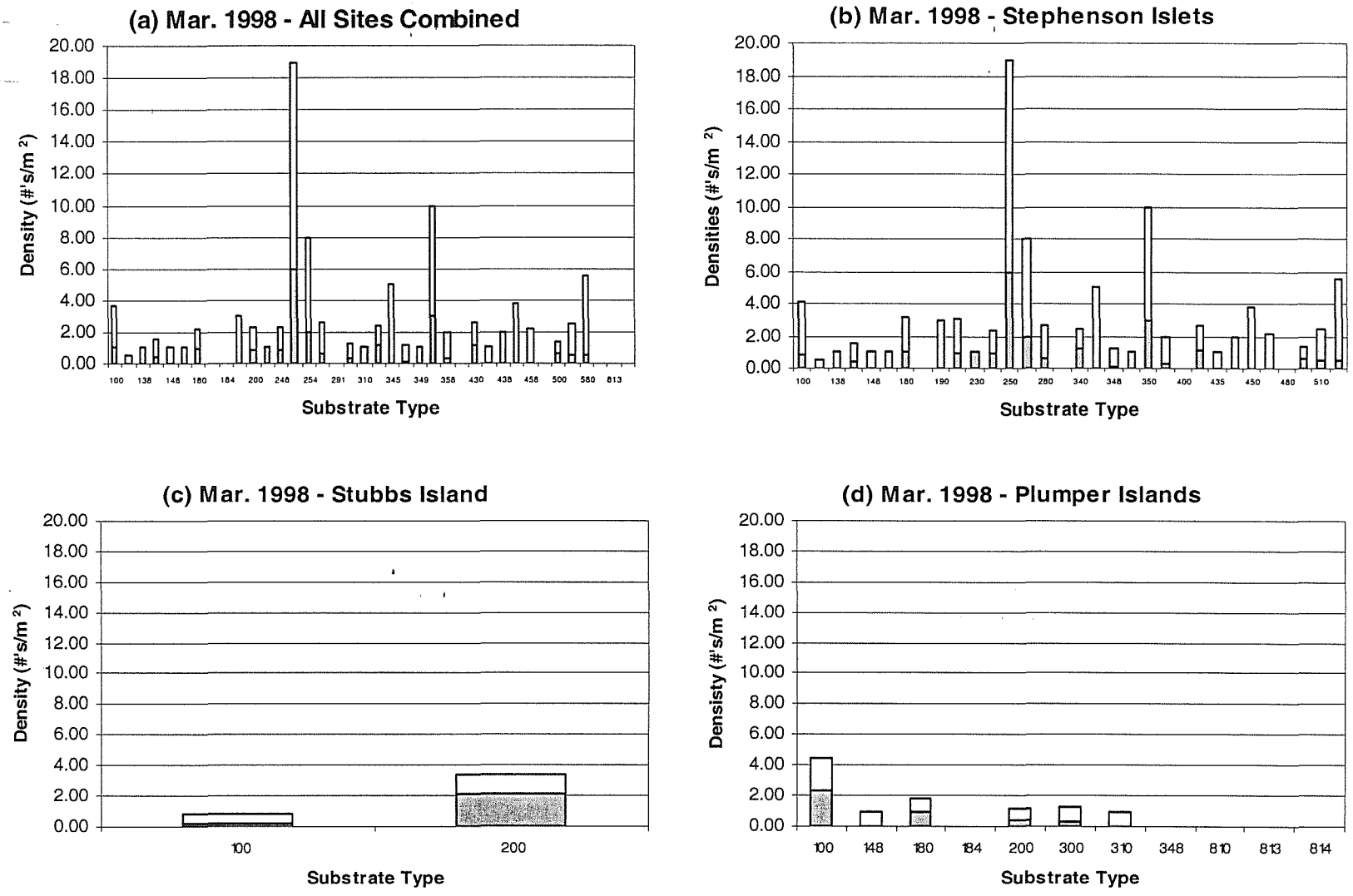

Fig. 13. March, 1998 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal (white), and unknown size (black) by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 13a-d for the keys to the substrate codes. Unidentified substrates not displayed.

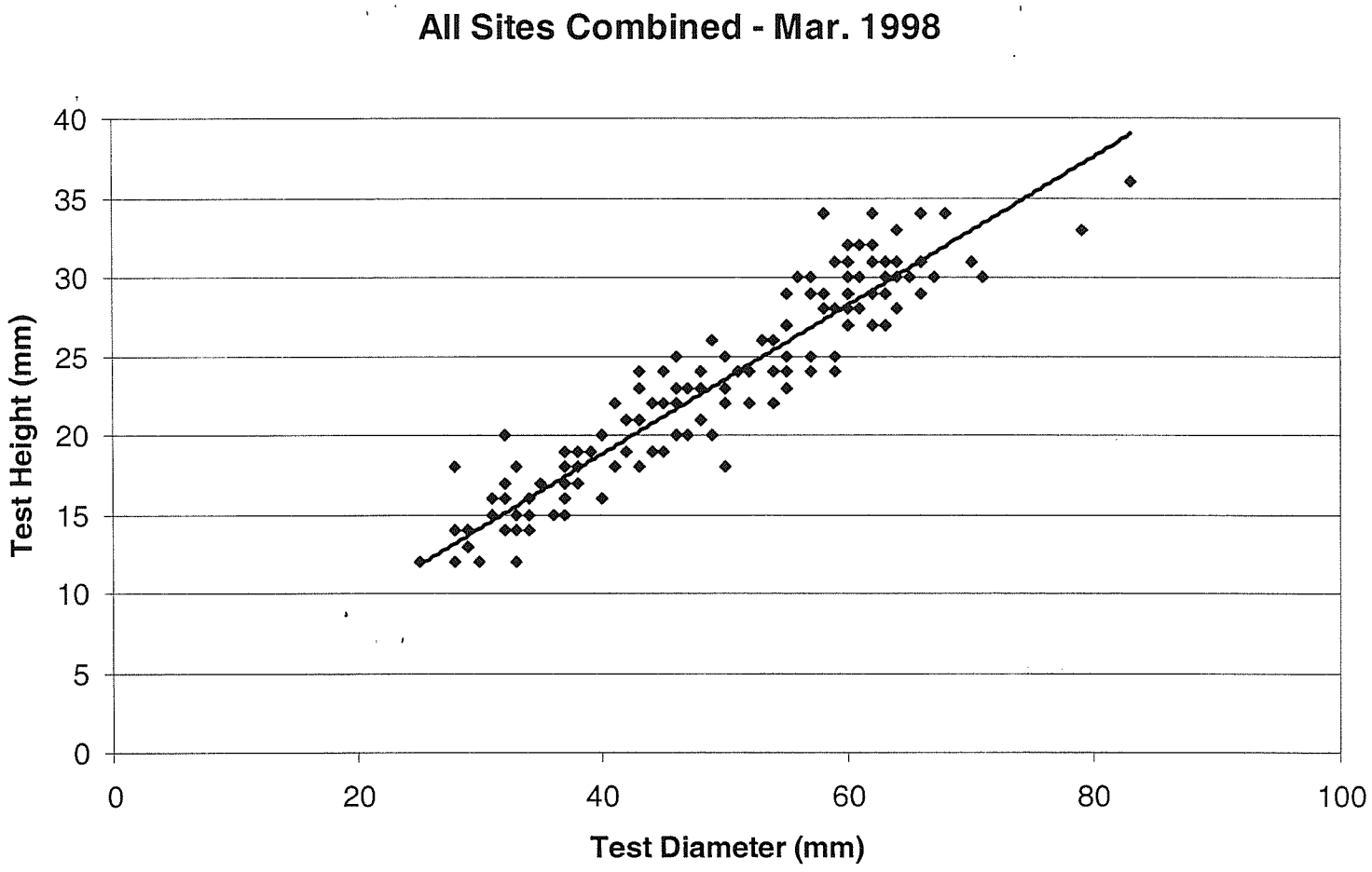

Fig. 14. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in March, 1998, all sites combined: TEST HEIGHT (mm) = 0.4718 ($TD^{0.9992}$), $R^2 = 0.8833$, n = 137.

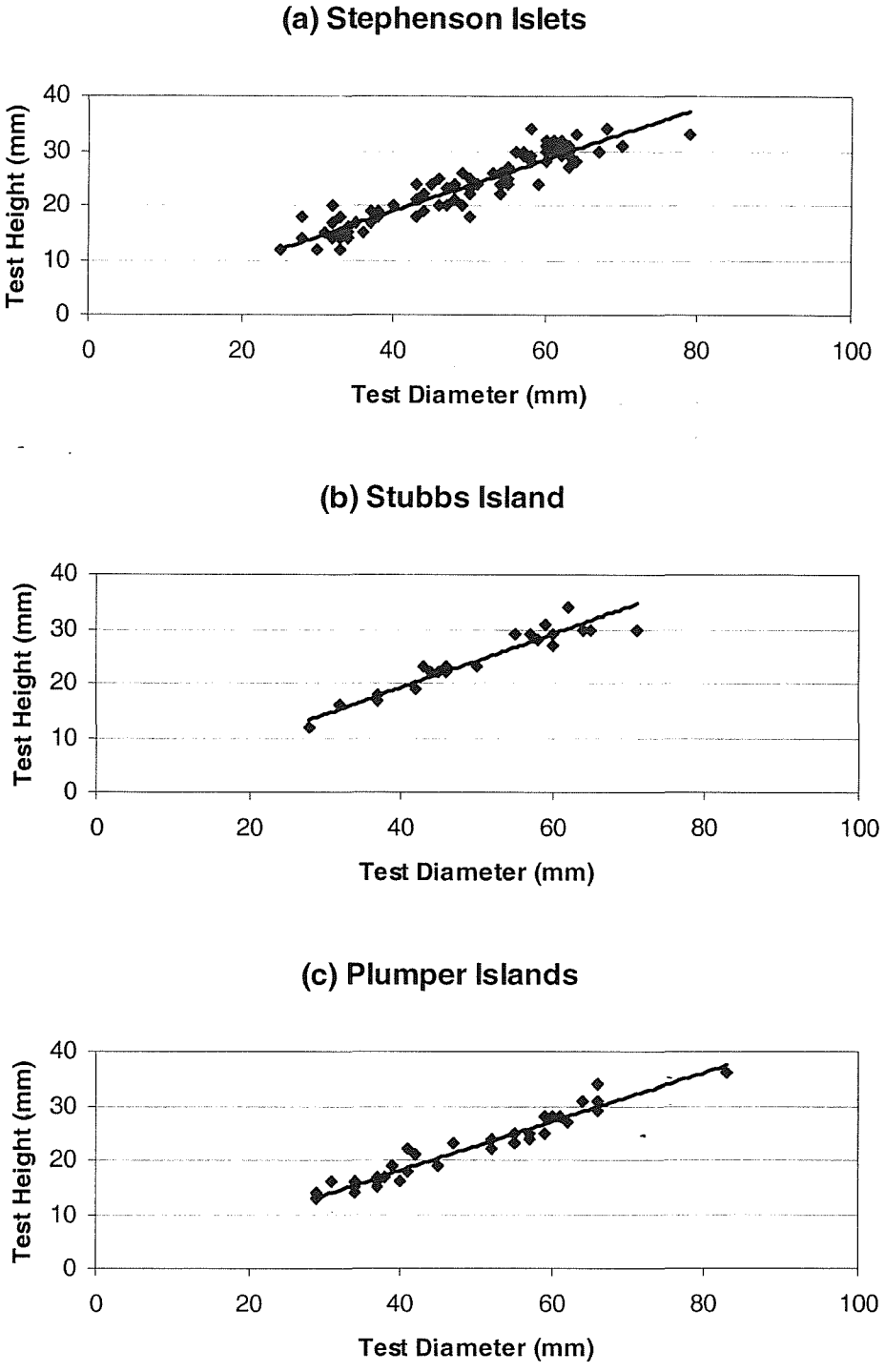

Fig. 15. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in March, 1998 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = 0.4995 ($TD^{0.9868}$), R^2=0.8578, n=82);
(b) Stubbs Island (TEST HEIGHT (mm) = 0.4365 ($TD^{1.0260}$), R^2=0.9315, n=21);
(c) Plumper Islands (TEST HEIGHT (mm) = 0.4567 ($TD^{0.9975}$), R^2=0.9351, n=34).

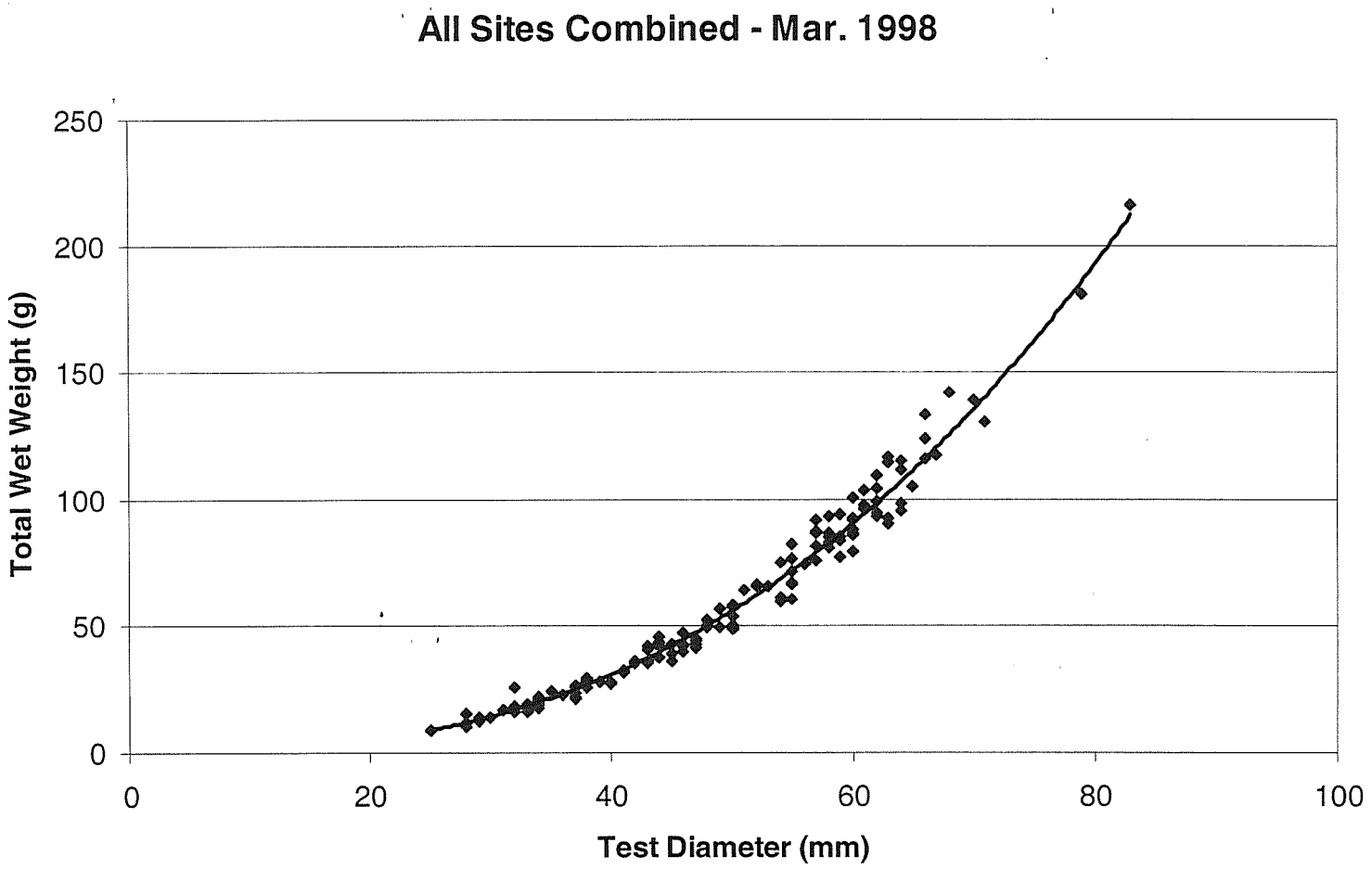

Fig. 16. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in March, 1998, calculated from all sites combined: TOTAL WET WEIGHT (g) = 0.0018 ($TD^{2.6459}$), $R^2 = 0.9841$, n=137.

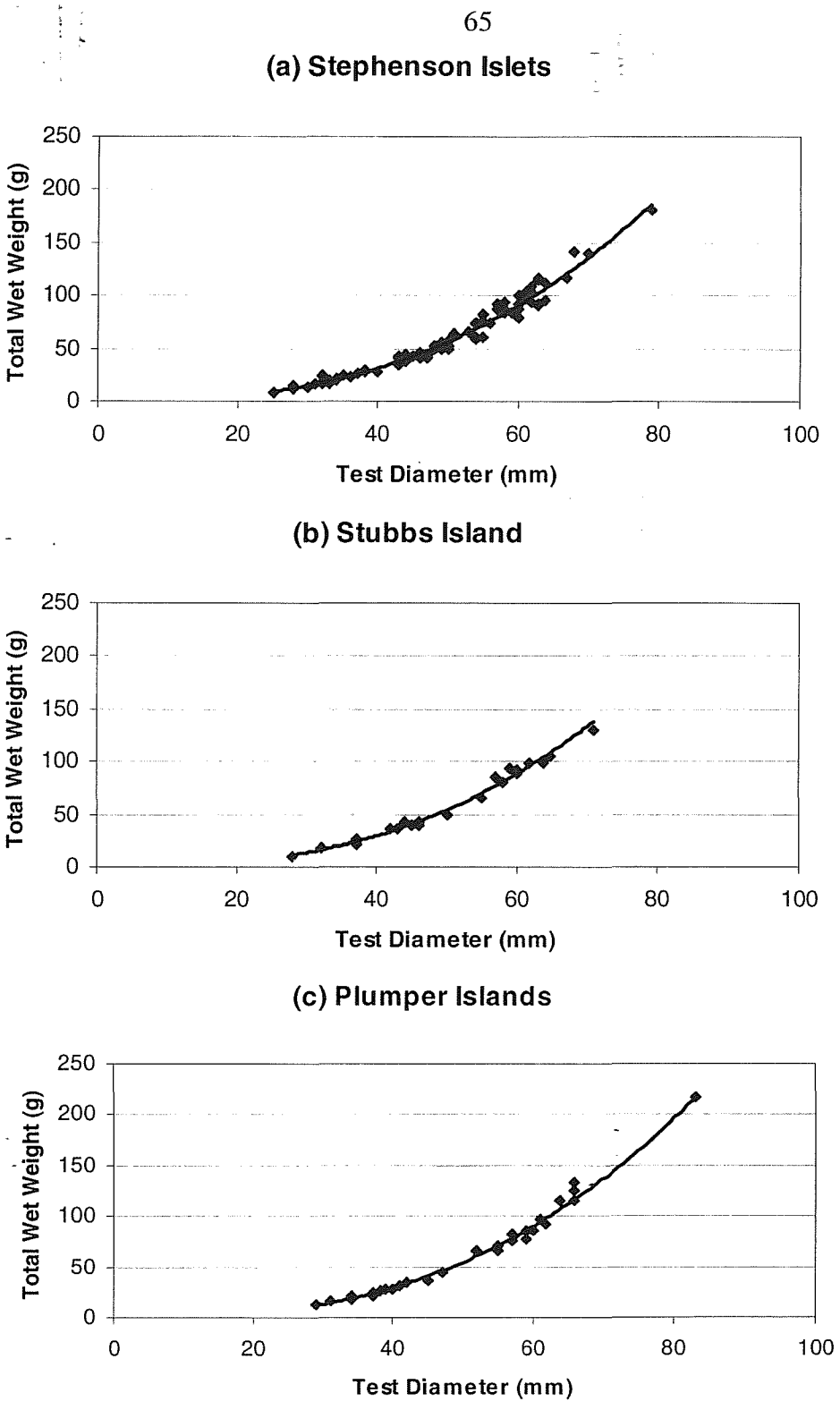

Fig. 17. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in March, 1998 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = 0.0021 ($TD^{2.6109}$), R^2=0.9809, n=82);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = 0.0015 ($TD^{2.6813}$), R^2=0.9876, n=21);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = 0.0014 ($TD^{2.7100}$), R^2=0.9922, n=34).

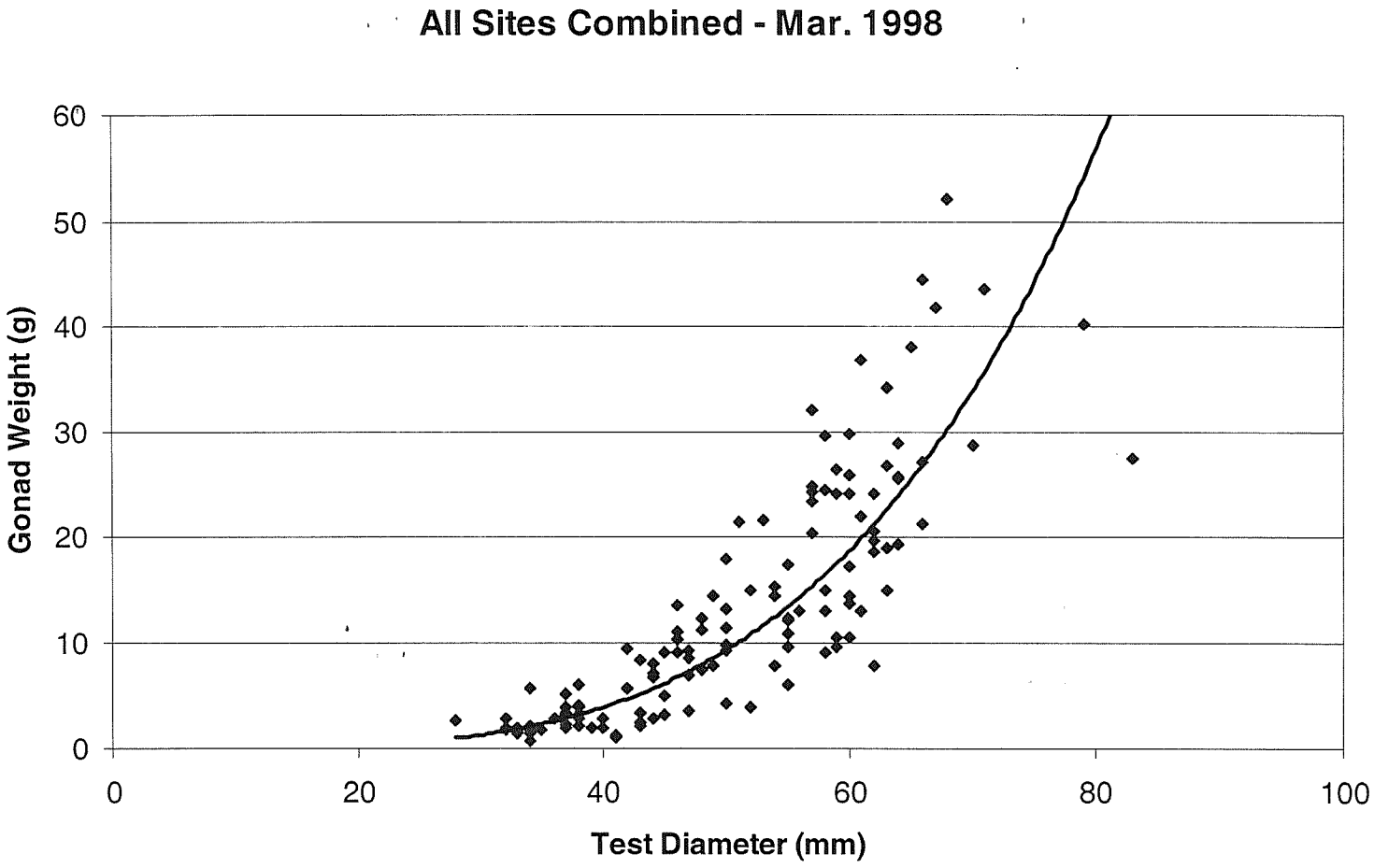

Fig. 18. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in March, 1998, calculated from all sites combined: GONAD WEIGHT = 3×10^{-6} ($TD^{3.8637}$), R^2=0.7837, n=125.

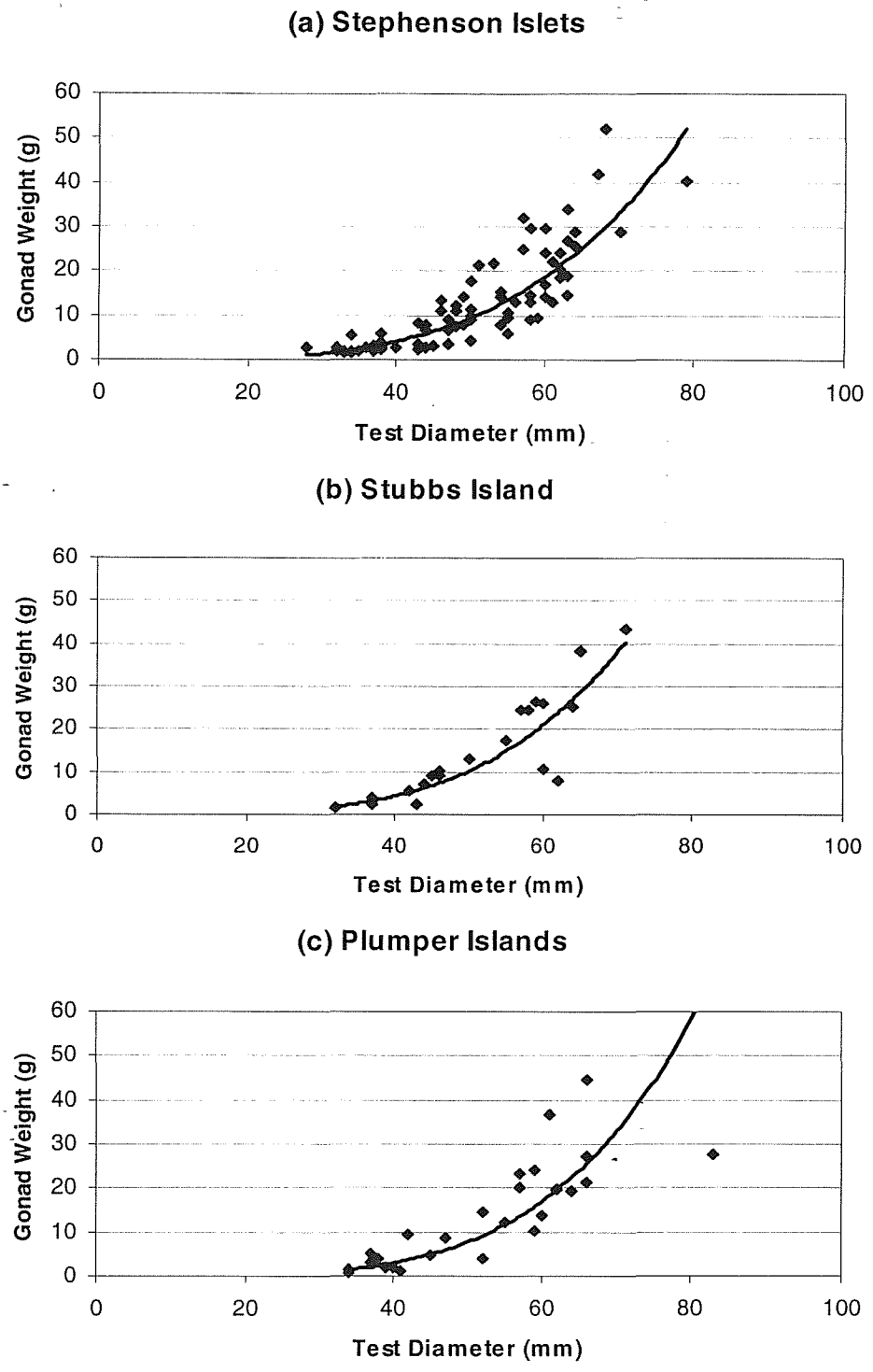

Fig. 19. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in March, 1998 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 5 x 10^{-6}(TD$^{3.7176}$), R^2=0.8069, n=77);
(b) Stubbs Island (GONAD WEIGHT (g) = 2 x 10^{-6}(TD$^{3.9148}$), R^2=0.7983, n=20);
(c) Plumper Islands (GONAD WEIGHT (g) = 4 x 10^{-7}(TD$^{4.2845}$), R^2=0.7661, n=28).

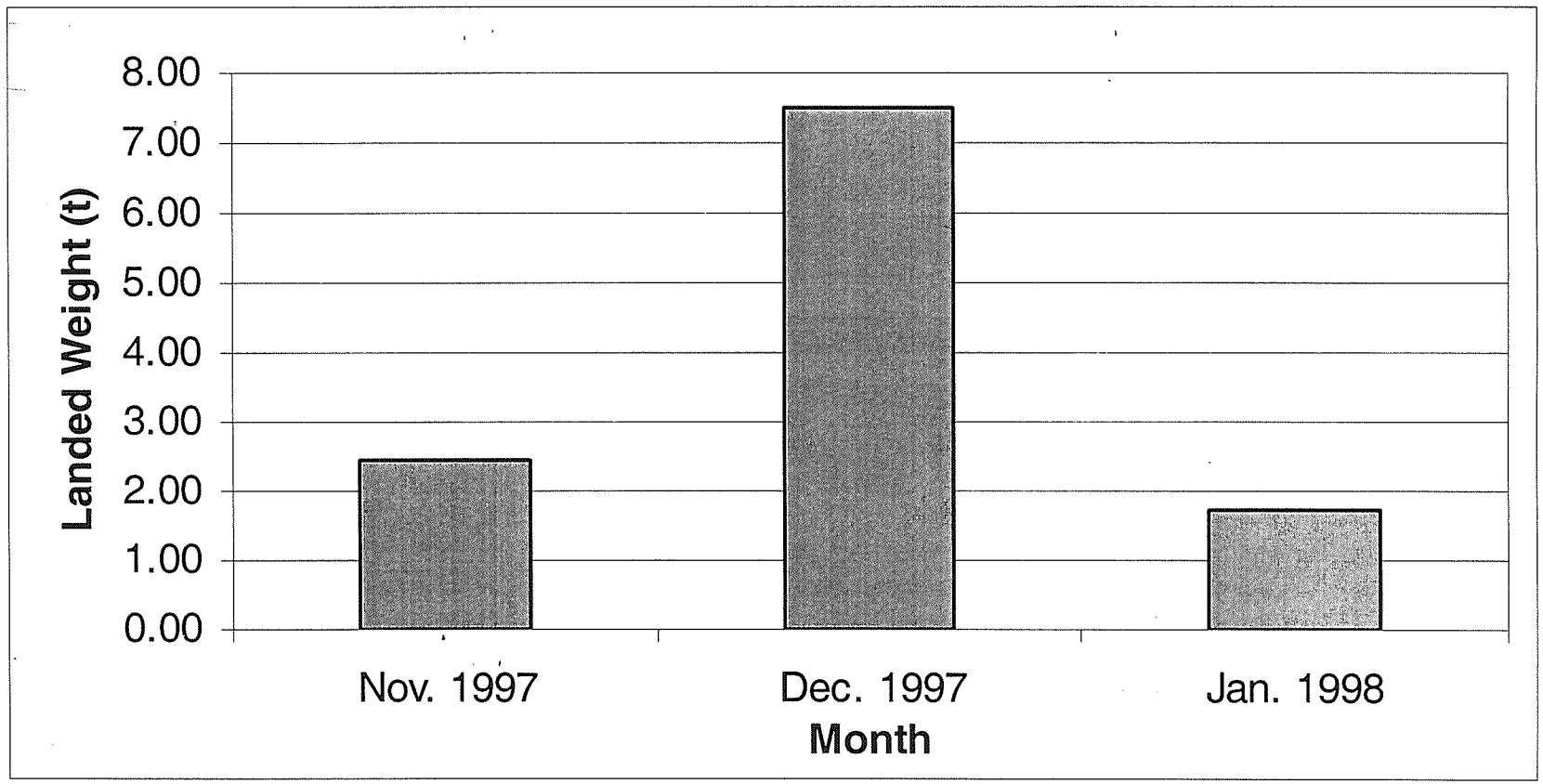

Fig. 20. Landed weight (in tonnes) of green sea urchins removed from the Stephenson Islets, by month, over the 1997/98 fishing season. Note that fishing occurred in Area 12 from November 15, 1997 to January 16, 1998.