Survey Results of Green Sea Urchin *(Strongylocentrotus droebachiensis)* Populations in Queen Charlotte Strait, British Columbia, November, 1996 and February, 1997

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Nanaimo, British Columbia
V9R 5K6

2002

Canadian Technical Report of Fisheries and Aquatic Sciences 2419

Fisheries and Oceans Canada | Pêches et Océans Canada

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Canadian Technical Report of Fisheries and Aquatic Sciences

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SURVEY RESULTS OF GREEN SEA URCHIN (*Strongylocentrotus droebachiensis*) POPULATIONS IN QUEEN CHARLOTTE STRAIT, BRITISH COLUMBIA, NOVEMBER, 1996 AND FEBRUARY, 1997

by

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Cat. No. Fs 97-6/2419E ISSN 0706-6457

Correct citation for this publication:

Waddell, B.J., C.M. Crossley, D.P. Tzotzos, R.I. Perry, and D. Kensall. 2002. Survey results of green sea urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British Columbia, November, 1996 and February, 1997. Can. Tech. Rep. Fish. Aquat. Sci. 2419: 65 p.

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ABSTRACT

Waddell, B.J., C.M. Crossley, D.P. Tzotzos, R.I. Perry, and D. Kensall. 2002. Survey results of green sea urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British Columbia, November, 1996 and February, 1997. Can. Tech. Rep. Fish. Aquat. Sci. 2419: 65 p.

Two surveys of green sea urchins (*Strongylocentrotus droebachiensis*) were undertaken jointly between Fisheries and Oceans Canada (DFO), the Kwakiutl Territorial Fisheries Commission (KTFC), and industry (West Coast Green Urchin Association - WCGUA) in Queen Charlotte Strait, British Columbia, the first from November 3-4, 1996, and the second from February 18-20, 1997. The main objectives of the surveys were to assess variability in green sea urchin populations due to environmental differences, and to monitor impacts due to a commercial fishery. Surveys were performed immediately before and after the commercial fishery, 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) decreased by 10.64 to 11.13 t (depending on the method of calculation), from 40.43 ± 8.34 t in November, 1996 to 29.79 to 29.30 ± 5.11 t in February, 1997. The total biomass of green urchins removed over the course of the fishery (November, 1996 to February, 1997) was 9.56 t, resulting in an exploitation of legal-sized green urchins at Stephenson Islets of 0.24. Assuming no net growth over the fishing season, and not considering emigration and immigration, the instantaneous total mortality rate (Z) of legal-sized urchins at this site was 0.25 ± 0.07.

RÉSUMÉ

Waddell, B.J., C.M. Crossley, D.P. Tzotzos, R.I. Perry, and D. Kensall. 2002. Survey results of green sea urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British Columbia, November, 1996 and February, 1997. Can. Tech. Rep. Fish. Aquat. Sci. 2419: 65 p.

Deux études de l'Oursin Vert (*Strongylocentrotus droebachiensis*) ont été effectuées conjointement par Pêches et Océans Canada (MPO), la Kwakiutl Territorial Fisheries Commission (KTFC) et l'industrie (West Coast Green Urchin Association - WCGUA) dans le détroit de la Reine-Charlotte, en Colombie-Britannique, les 3 et 4 novembre 1996 pour la première et du 18 au 20 février 1997 pour la seconde. Les études avaient pour principaux objectifs d'évaluer la variabilité des populations d'oursins verts résultant de facteurs environnementaux et de surveiller les impacts des pêches commerciales. Les études ont été effectuées immédiatement avant et après la campagne de pêche commerciale, sur trois sites, dans des secteurs ouverts ou fermés à la pêche. Des plongeurs équipés de scaphandres autonomes ont adopté la méthode des transects et des quadrats pour recueillir les données sur la taille et l'abondance des oursins verts ainsi que sur le poids et la qualité de leur gonade et sur la profondeur, le substrat et le couvert végétal de chaque quadrat.

La biomasse totale d'oursins verts faisant la taille réglementaire dans le site ouvert à la pêche (îlots Stephenson) a fait l'objet d'une diminution de 10,64 à 11,13 t (suivant la méthode de calcul), passant de 40,43 ± 8,34 t en novembre 1996 à 29,79 ou 29,30 ± 5,11 t en février 1997. La biomasse totale des oursins verts prélevés au cours de la saison de pêche (de novembre 1996 à février 1997) était de 9,56 t, ce qui équivaut à un taux d'exploitation des oursins verts de taille réglementaire dans les îlots Stephenson de 0,24. Si l'on néglige toute croissance éventuelle de la population pendant la saison de pêche et tout flux migratoire pendant la même période, le taux de mortalité instantané total (Z) pour les oursins verts faisant la taille réglementaire à ce site était de 0,25 ± 0.07.

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), an Individual Quota (IQ) system, and by restricting areas and fishing seasons (usually from November until February or March). 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 size frequencies, proportions of legal and sublegal-sized urchins, roe quality and quantity, or habitat associations. Therefore, detailed surveys were initiated in October 1995 and March 1996 (Waddell *et al.* 1997) 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 and the commercial industry, there has been improved confidence and acceptance of these data. This report presents the data collected from cooperative surveys performed during November 3-4, 1996 and February 18-20, 1997 in Pacific Fisheries Management Area (PFMA) 12 (Queen Charlotte Strait; Figs. 1a-c).

The first survey occurred November 3 and 4, 1996, just before the opening of the commercial green sea urchin fishery (November 15, 1996). It consisted of one day of surveying green sea urchins in the Stephenson Islets (50°34.5' N, 126°49.5' W; Fig. 1a), and one day of surveying nearby Stubbs Island (50°36.2' N, 126°49.2' W) and the Plumper Islands (50°34.6' N, 126°48.0' W) (Figs. 1b-c). This survey involved DFO, the Kwakiutl Territorial Fisheries Commission (KTFC), and industry divers from the West Coast Green Urchin Association (WCGUA). The second survey (February 18-20, 1997) was performed just after the closure of the fishery (February 5, 1997) and was a repeat of the first survey, involving the same parties and sites.

The main objectives of these green sea urchin scientific surveys are to monitor population changes due to environmental variations 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, 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) were obtained. 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 3 and 4, 1996), one day was spent surveying green sea urchins in the Stephenson Islets, at the north end of Johnstone Strait, near Telegraph Cove and Weynton Passage (Fig. 1b; ten transects). The following day was spent surveying nearby Stubbs Island (Fig. 1c; three transects), and the Plumper Islands (Fig. 1c; four transects). The vessels involved were the M/V '*K'uludas*', owned by the KTFC, and the CFV '*Sea Rebel*', owned by a commercial diver.

The second survey was performed from February 18-20, 1997, following the closure of the commercial fishery (closed February 15, 1997). This survey repeated the first survey, but took three days instead of two due to inclement weather. The two vessels involved in this survey, the CFV '*Clo-oose*' and the CFV '*Kuroshio*', were both owned by industry fishers.

In both surveys there were two dive teams (i.e., two boats), each with one industry and one KTFC diver, one boat driver/tender (KTFC or industry), and one DFO observer/recorder. The green urchin surveys were designed and supervised by DFO, while a KTFC diver organized and led the diving aspects of the surveys.

The same transects at Stephenson Islets were surveyed as in the two green urchin surveys from the previous fishing season (Waddell *et al.* 1997), except that Transects 10A, 11A and 11B were surveyed instead of Transects 10 and 11 (slightly different positions; Fig. 1b). The transects surveyed at Stubbs Island and the Plumper Islands were the same in the November, 1996, and February, 1997, surveys. This was the first time that Stubbs Island and the Plumper Islands had been scientifically surveyed for green sea urchins.

Transect positions for the Stephenson Islets had been randomly selected for the previous surveys (Waddell *et al.* 1997). Transect positions for Stubbs Island and the Plumper Islands were 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 9.23 m (5 fm) 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 TD (using calipers) of all sea urchins within the quadrat. Both green and red urchins were measured at the start of the survey, but due to a shortage of time, it was decided that all green urchins would be measured, while red urchins would only be counted. All urchins were removed from the quadrat as they were being measured to avoid repetitive 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 had to be 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 all along the transect line.

The surface personnel recorded the position 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 transects lines during the surveys to obtain weight and size information and to examine the quality of the roe. A deep water 'spot-dive' was also undertaken in the Plumper Islands (to a maximum depth of 92 ft (28 m)) during the first survey to collect samples for roe quality information only (i.e., density information was not recorded). During the first survey, the urchins were kept in seawater overnight, and then measured and dissected the following day. During the second survey, the 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

Test diameter frequency distributions were analysed using the software "MIX3aa" (available from Peter Macdonald at Ichthus Data Systems, 59 Arkell St., Hamilton, Ont., Canada, L8S 1N6) 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 analysed 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 $\geq$ 55 mm); sublegal-mature (25 mm $\geq$ 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:

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

and for the standard error of density is:

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

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 "EXCEL97" (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 Current 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 were not considered reliable. Therefore, the vegetation data have not been presented in this report.

The statistical software package "EXCEL97" (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, 1996 and February, 1997 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), 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 ($\overline{W}_j$) within each of these size classes (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 class. 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 "EXCEL97" 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 9.23 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 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, 1996 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:

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

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 ($\overline{W}_{Legal,Nov}$):

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

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, 1996 and February, 1997 surveys, we assume the net of these two terms to be zero.

These assumptions then leave an equation in the form:

(9) $$N_{Feb} = N_{Nov} - N_{fishing} - N_M,$$

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:

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

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 9.23 m below CD), the instantaneous fishing mortality (F) is :

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

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

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

and the instantaneous natural mortality rate (M) is

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

Please 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 3-4, 1996 SURVEY

Ten transect lines were surveyed in the Stephenson Islets on November 3, 1996 (Fig. 1b), and on November 4, three transects were surveyed at Stubbs Island, and four transects in the Plumper Islands (Fig. 1c). A few of the proposed transect lines at Stubbs Island and the Plumper Islands were abandoned due to a shortage of time and diving difficulties (mainly due to strong tidal currents).

Over all the sites sampled during this survey, data were recorded for 497 quadrats and test diameters were measured for all the green urchins (except for three). Of the 1,513 test diameters measured, 487 (32.1%) were of legal size, and 1,026 (67.7%) were of sublegal size (Table 1). Figure 2a shows the size frequency distribution for all the sites combined during the November, 1996 survey. When combining all the test diameters measured at all sites during the November 1996 survey, two distinct modes best fit (X^2 =200.9; df = 38; p <0.0001) the distribution, with test diameter means at 26 and 52 mm (Table 2). The proportions of these modes were 24% and 76%, respectively. Mean TD's and total wet weights for urchins from all sites combined were 61.4 mm and 92.8 g for legal-sized urchins, 42.0 mm and 38.1 g for sublegal-mature urchins, and 17.6 mm and 4.8 g for sublegal-immature urchins (Table 3).

The mean total density during this survey (all sites combined) was 3.05 ± 0.59 urchins/m^2 (Table 4). The mean overall legal density was 0.98 ± 0.23 urchins/m^2, the mean overall sublegal-mature density was 1.77 ± 0.38 urchins/m^2, and the mean overall sublegal-immature density was 0.30 ± 0.06 urchins/m^2.

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 (7.15 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) range, below CD. This range included the highest density of legal-sized green sea urchins (2.79 urchins/m^2), and the highest density of sublegal green sea urchins (4.36 urchins/m^2) for all sites combined.

Table 6a and Fig. 4a show the mean densities of green sea urchins by substrate type for all sites combined. While substrate with creviced bedrock was the most sampled substrate (352 quadrats), creviced bedrock with boulders had the highest total density (11.67 urchins/m^2).

(i) Stephenson Islets

Data were recorded for 1,031 green sea urchins from 339 quadrats. Of the 1,030 total TD measurements, 325 (31.5%) were of legal size, while 705 (68.4%) were of sublegal size (Table 1). The size frequency distribution can be seen in Fig. 2b. The test diameter frequency analysis for the November, 1996 survey is presented in Table 2. Stephenson Islets showed the best fit (X^2 = 145.6; df = 38; p <0.0001) with two dominant size modes with means occurring at 38 and 54

mm test diameter. The proportion of the length frequency data occurring in the first mode was 55%, with 45% occurring in the second mode. Mean TD's and total wet weights for urchins from Stephenson Islets were 60.0 mm and 86.9 g for legal-sized urchins, 42.2 mm and 38.5 g for sublegal-mature urchins, and 17.0 mm and 4.5g for sublegal-immature urchins (Table 3).

The mean overall density (all sizes combined) at Stephenson Islets was 3.04 ± 0.57 urchins/m^2, while the mean overall legal density was 0.96 ± 0.20 urchins/m^2, the mean overall sublegal-mature density was 1.81 ± 0.45 urchins/m^2, and the mean overall sublegal-immature density was 0.27 ± 0.07 urchins/m^2 (Table 4). The mean total densities per transect ranged from 0.19 urchins/m^2 in Transect 8 to 7.47 urchins/m^2 in Transect 13 (Table 4). The highest mean densities for legal-sized urchins occurred in Transects 7, 11A and 13 (1.58, 1.50, 1.50 urchins/m^2, respectively), while the highest mean density of sublegal-mature urchins occurred in Transect 13 (5.50 urchins/m^2; Table 4). The highest mean density of sublegal-immature urchins occurred in Transect 9 (0.83 urchins/m^2; Table 4).

The mean total densities were highest (3.94 to 4.27 urchins/m^2) between 1.5 to 6.1 m (5.1 to 20.0 ft) below CD, and lowest (0.50 to 1.20 urchins/m^2) at depths from 10.7 to 12.6 m (35.1 to 41.3 ft) below CD (Table 5b, Fig. 3b). Similarly, the highest mean densities of sublegal-sized green sea urchins (2.61 to 3.07 urchins/m^2) occurred between 1.5 to 6.1 m (5.1 to 20.0 ft) below CD, whereas the highest mean densities of legal-sized urchins (2.00 urchins/m^2) occurred between 0.2 to 0.0 m (0.6 to 0.0 ft) above CD (4 quadrats).

At Stephenson Islets, the most common substrate sampled was bedrock with crevices (282 quadrats), on which the mean total density was 2.87 urchins/m^2 (Table 6b, Fig. 4b). The lowest mean total density of green urchins (1.57 urchins/m^2; seven quadrats) occurred on substrate consisting of creviced bedrock with boulders, whereas the highest mean total density (8.50 urchins/m^2) occurred on creviced bedrock with boulders and cobble (two quadrats). Although creviced bedrock was the most common substrate type sampled, when the data were grouped by the main or primary substrate type, creviced bedrock had the lowest total density (2.88 urchins/m^2 over 291 quadrats), whereas smooth bedrock had the highest total density (4.36 urchins/m^2 over 14 quadrats).

(ii) Stubbs Island

Data were recorded for green sea urchins from a total of 61 quadrats, on three transects. Of the total 309 green sea urchins measured, 120 (38.8%) were of legal size, and 189 (61.2%) were of sublegal size (Table 1). When analyzing the size frequency distribution (Table 2 and Fig. 2c), the best fit occurred with three modes (X^2 = 73.3; df = 31; p = <0.0001), with the means at 30, 49 and 62 mm TD, with proportions of 32%, 24%, and 44%, respectively. Mean TD's and total wet weights for urchins from Stubbs Island 65.4 mm and 109.0 g for legal-sized urchins, 43.1 mm and 40.3 g for sublegal-mature urchins, and 18.6 mm and 5.1 g for sublegal-immature urchins (Table 3).

The mean overall (all transects combined) densities of legal, sublegal-mature, sublegal-immature, and total green sea urchins were 1.97, 2.62, 0.48, and 5.07 urchins/m^2, respectively

(Table 4). The mean total densities ranged from 0.71 urchins/m^2 in Transect 18 to 13.11 urchins/m^2 in Transect 15 (Table 4). The highest mean legal (5.21 urchins/m^2), sublegal-mature (6.74 urchins/m^2), and sublegal-immature (1.16 urchins/m^2) densities all occurred in Transect 15.

The highest legal, sublegal and total mean densities (7.89, 12.22 and 20.11 urchins/m^2, respectively; Table 5c and Fig. 3c) of green sea urchins for all sites during this survey, occurred at Stubbs Island between 0.1 and 1.5 m (0.1 and 5.0 ft) below CD. There were no green urchins of any size category occurring in the depth range above that. Mean total densities of green urchins were of medium values (1.30 to 4.82 urchins/m^2) from 1.5 to 7.6 m (5.1 to 25.0 ft) below CD, and were relatively low (0.71 to 1.00 urchins/m^2) from 7.6 to 10.9 m (25.1 to 35.9 ft) below CD

The most frequently sampled substrate was creviced bedrock (33 quadrats; Table 6c). This main substrate had a total density of 6.82 urchins/m^2 (Table 6c, Fig. 4c). Very high mean densities (relative to the area) of both legal-sized (15.00 urchins/m^2) and sublegal-sized (21.00 urchins/m^2) green sea urchins were observed on creviced bedrock with boulders (total density 36.00 urchins/m^2). However, this substrate occurred in only six of the 61 quadrats sampled at Stubbs Island. There were no green sea urchins observed at Stubbs Island in the four quadrats with a boulder substrate.

(iii) Plumper Islands

Data were recorded for 176 green sea urchins, from 97 quadrats on four transects in the Plumper Islands. Of the 174 total test measurements, 42 (23.9%) were of legal size, and 132 (75.0%) were of sublegal size (Table 1). As with the Stephenson Islets, the size frequency distribution for the Plumper Islands fits two modes ($X^2 = 36.8$; df = 31; p = 0.2190), with mean test diameters occurring at 27 and 52 mm (Table 2, Fig. 2d). The proportions were 44% and 56% in the first and second mode, respectively. Mean TD's and total wet weights for urchins from the Plumper Islands were 61.4 mm and 92.3 g for legal-sized urchins, 39.2 mm and 32.7 g for sublegal-mature urchins, and 18.9 mm and 5.5 g for sublegal-immature urchins (Table 3).

The mean overall densities of legal, sublegal-mature, sublegal-immature, and total green sea urchins at the Plumper Islands were 0.43 ± 0.19, 1.06 ± 0.39, 0.30 ± 0.16, and 1.81 ± 0.66 urchins/m^2, respectively (Table 4). The mean total densities ranged from 0.00 urchins/m^2 in Transect 24, to 2.69 urchins/m^2 in Transect 20. The highest mean density for legal-sized urchins occurred in Transect 21 (0.91 urchins/m^2), while the highest mean densities of sublegal-mature urchins occurred in Transects 23 (1.60 urchins/m^2) and 20 (1.52 urchins/m^2). The highest mean density of sublegal-immature urchins occurred in Transect 20 (0.62 urchins/m^2).

The mean total densities were highest (3.14 urchins/m^2; 14 quadrats) in the 3.0 to 4.8 m (10.1 to 15.0 ft) below CD and 10.7 m to 12.1 m (35.1 to 39.7 ft) below CD (3.00 urchins/m^2; 3 quadrats) depth ranges (Table 5d, Fig. 3d). The highest mean densities of sublegal-sized green urchins (2.43 and 3.00 urchins/m^2) also occurred in these depth ranges, whereas the highest legal mean densities (0.71 and 1.00 urchins/m^2) occurred between 3.0 to 4.8 m (10.1 to 15.0 ft) and between 9.1 to 10.7 m (30.1 to 35.0 ft), respectively. Like Stubbs Island, there were no urchins of any size in the Plumper Islands transects above CD.

The highest mean densities of green urchins of all size categories occurred on a substrate of boulders with cobble (2.50 urchins/m^2 for legal-sized, 3.00 urchins/m^2 for sublegal-sized, and 5.50 urchins/m^2 for all sizes combined from four quadrats; Table 6d and Fig. 4d). There was also a density of 3.00 urchins/m^2 for sublegal urchins on a similar substrate of boulders, cobble and gravel (two quadrats). The primary substrate with the highest total density of green urchins (3.06 urchins/m2) was boulders.

(iv) Dissection Data

There was a total of 127 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). Although it would have been preferred to dissect the urchins immediately after collection, due to circumstances, the urchins were kept in seawater overnight and dissected the following day. On the dissection days, it was observed that the majority of the stomach contents had been regurgitated (the vegetation had not been digested), therefore their weights were slightly lower than what they would have been if they had been dissected immediately after collection.

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 (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 = 1.29 with $p > 0.05$, df = 2, 125). This allowed the allometric equation ($W=\alpha TD^{\beta}$) to be used for all sites in the November 1996 survey when calculating the total wet weight (g) from the TD (mm).

Stubbs Island had the best quality roe (i.e., colour = 1 (orange/yellow) and texture = 1 (firm)), with 50.0% of the legal-sized green urchins having the highest quality, followed by Stephenson Islets with 39.0% and the Plumper Islands with 31.8% (Table 8). Stubbs Island also had the highest (25.7%) legal-sized overall roe recovery rate (total gonad weight (all grades) divided by total drained weight of all urchins collected), followed by the Plumper Islands (18.8%) and the Stephenson Islets (18.5%).

(v) Biomass Estimates

Stephenson Islets is estimated to have an area of 485,200 m^2 between 0.0 and 9.23 m (0.0 and 5.0 fm) below CD. By extrapolation of the total mean density (3.04 urchins/m^2; Table 4),

there were approximately 1,475,638 ± 278,574 green sea urchins of all sizes on November 3, 1996, 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, 465,162 (31.5%) were of legal size, and 1,009,044 (68.4%) were of sublegal size (880,230 mature-sized and 128,814 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, 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 86.9 g (Table 3). (Note that the mean individual weight for Stephenson Islets was previously calculated by Waddell *et al.* 1997 to be 85.8 g. This was calculated by determining the average test diameter and then applying the TD-weight relationship to that one TD value. The present method applies the TD-weight relationship to all TD's to find all of the individual weights, then calculates the mean overall weight or biomass, and is considered to be more accurate). Using the same TD-weight relationship, the mean weight per sublegal-mature-sized green urchin was determined to be 38.5 g, and the mean weight per immature-sized green urchin was 4.5 g (Table 3). Ignoring the green urchins of unknown size, the total biomass of legal-sized, sublegal-mature and immature green sea urchins at Stephenson Islets in November, 1996 was 40.43, 33.92 and 0.58 t, respectively, for an overall total biomass of 74.93 ± 11.90 t (Table 9).

Stubbs Island is estimated to have an area of 19,600 m^2 between 0.0 and 9.23 m (0.0 and 5.0 fm) below CD. By extrapolation from the mean densities (Table 4), there were approximately 99,285 ± 74,123 green sea urchins (38,557 legal-sized, 51,410 sublegal-mature-sized, and 9,318 immature-sized) at Stubbs Island on November 4, 1996 (Table 9). The mean weight for individual legal-sized, sublegal-mature, and sublegal-immature urchins at Stubbs Island was 109.0, 40.3, and 5.1 g (Table 3). The total biomass of legal-sized, sublegal-mature, and immature green sea urchins at Stubbs Island in November, 1996 was 4.20, 2.07 and 0.05 t, respectively, for an overall total biomass of 6.32 ± 3.67 t (Table 9).

The survey site in the Plumper Islands has an area of approximately 223,600 m^2 between 0.0 and 9.23 m (0.0 and 5.0 fm) below CD. By extrapolating the mean densities (Table 4), there was an abundance of approximately 405,707 ± 148,375 green sea urchins (96,816 legal-sized, 237,431 sublegal-mature-sized, and 66,849 immature) at the Plumper Islands on November 4, 1996 (Table 9). The mean weight of legal, sublegal-mature and sublegal-immature green urchins in the Plumper Islands in November, 1996 was 92.3, 32.7, and 5.5 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, 1996 was 8.94, 7.77 and 0.37 t, respectively, for an overall total biomass of 17.08 ± 4.88 t (Table 9).

(b) FEBRUARY 18-20, 1997

The same transect lines were surveyed in February, 1997 as were surveyed in the November, 1996 survey (ten in the Stephenson Islets (Fig. 1b), three at Stubbs Island, and four in

the Plumper Islands (Fig. 1c)), except that Transect 11B was surveyed instead of Transect 11A (Transects 11 and 11A are difficult to locate in the field). The tidal current was strong throughout most of the survey.

There were 1,476 test diameter measurements recorded for green sea urchins (Table 1) from a total of 496 quadrats during the whole survey. It was found that 20.3% of the green urchins were of legal size, while 79.4% were sublegal. 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 = 137.7; df = 32; p <0.0001) with test diameter means of 42 and 52 mm (Table 2). The proportions for these modes were 85% and 15%, respectively. Mean TD's and total wet weights for urchins from all sites combined were 59.2 mm and 86.7 g for legal-sized urchins, 41.7 mm and 38.2 g for sublegal-mature urchins, and 18.1 mm and 5.2 g for sublegal-immature urchins (Table 10a).

The mean total density (all sizes combined) for all sites combined during this survey was 2.98 ± 0.43 urchins/m^2 (Table 11). The mean overall legal, sublegal-mature, and sublegal-immature densities for February, 1997 were 0.60 ± 0.10, 2.21 ± 0.36, and 0.16 ± 0.04 urchins/m^2, respectively (Table 11).

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 (4.12 ± 0.77 urchins/m^2) of green sea urchins (for all sites combined) were found in the 0.1 to 1.5 m (0.1 to 5.0 ft) range, below CD. The highest density of legal green sea urchins (1.02 urchins/m^2) occurred in this same range, whereas the highest density of sublegal urchins (3.11 urchins/m^2) occurred between 1.5 to 3.0 m (5.1 to 10.0 ft) below CD. Table 13a and Fig. 13a show the sample mean densities of green sea urchins by substrate type for all sites combined. While substrate with creviced bedrock was the most sampled substrate (294 quadrats), creviced bedrock with cobble and shell had the highest total density (9.00 urchins/m^2; 2 quadrats only).

A test for homogeneity of the regression slopes for the TD and the natural log of the total wet weight relationship showed that there was a significant difference between the three sites (F = 5.19, df = 2, 128, p < 0.05).

(i) Stephenson Islets

There were 324 quadrats surveyed, and 1,185 test measurements recorded for green sea urchins in the Stephenson Islets, of which 20.3% were of legal size and 79.4% were sublegal (Table 1). Fig. 11b shows the size frequency distribution. Stephenson Islets showed two dominant size modes (X^2 = 122.4; df = 31; p <0.0001) where mean test diameters occurred at 38 mm (41%) and 48 mm (59%; Table 2). Mean TD's and total wet weights for urchins from the Stephenson Islets were 58.5 mm and 82.5 g for legal-sized urchins, 42.2 mm and 39.2 g for sublegal-mature urchins, and 18.1 mm and 5.4 g for sublegal-immature urchins (Table 10a).

The mean overall density (all sizes combined) at the Stephenson Islets was 3.67 ± 0.47 urchins/m^2 (Table 11). The mean overall legal, sublegal-mature and sublegal-immature densities were 0.74 ± 0.13, 2.75 ± 0.43, and 0.16 ± 0.04 urchins/m^2, respectively. The mean total densities per transect ranged from 0.24 urchins/m^2 in Transect 8 to 5.76 urchins/m^2 in Transect 9 (Table 11). Transect 8 had no legal-sized green urchins while Transect 3 had the highest mean density (1.16 urchins/m^2) of legal urchins. The lowest mean density of sublegal-mature urchins occurred in Transect 8 (0.24 urchins/m^2), while the highest density occurred in Transect 9 (5.05 urchins/m^2). The lowest mean density of sublegal-immature urchins occurred in Transects 8 and 11B (0.00 urchins/m^2), while the highest density occurred in Transect 10A (0.75 urchins/m^2).

The highest mean total (6.68 urchins/m^2), legal (1.63 urchins/m^2), and sublegal (5.05 urchins/m^2) densities occurred between 0.1 and 1.5 m (0.1 and 5.0 ft) below CD (Table 12b, Fig. 12b). The lowest mean densities of total (1.59 urchins/m^2) green sea urchins occurred between 9.1 to 10.7 m (30.1 to 35.0 ft) below CD. There were no legal-sized or sublegal-sized urchins between 2.9 and 1.5 m (9.4 and 5.0 ft) above CD (one quadrat only), and also no legal urchins between 10.7 and 10.9 m (35.1 and 35.9 ft; one quadrat only). There were low mean densities of legal (0.12 urchins/m^2) and sublegal-sized (1.29 urchins/m^2) green urchins between 9.1 and 10.7 m (30.1 and 35.0 ft) below CD.

As in the November, 1996 survey, the most common substrate sampled at Stephenson Islets was bedrock with crevices (179 of 324 quadrats), where the mean total density was 4.46 urchins/m^2 (Table 13b, Fig. 13b). No green urchins occurred on substrates consisting of boulders with cobble and gravel (only one quadrat sampled), cobble with boulders (only one quadrat sampled), or pea gravel with shell (only two quadrats sampled; Table 13b). The highest mean total density (5.00 urchins/m^2) occurred on boulders with shell, but again, only one quadrat was sampled. If the substrate data are grouped by the main substrate type (ignoring substrates of second and third prominence), creviced bedrock had the highest total density (4.16 urchins/m^2), followed by smooth bedrock (3.89 urchins/m^2).

(ii) Stubbs Island

There were 68 quadrats surveyed at Stubbs Island and 134 green sea urchin TD's measured. Legal and sublegal-sized green urchins represented 25.2% and 74.1%, respectively, of the sample (Table 1). 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 = 33.3; df = 27; p = 0.1880; Table 2). The mean test diameters for these three modes with their proportions were 32 mm (65%), 52 mm (20%), and 67 mm (15%). Mean TD's and total wet weights for urchins from the Stephenson Islets were 62.8 mm and 103.9 g for legal-sized urchins, 39.3 mm and 32.4 g for sublegal-mature urchins, and 19.0 mm and 4.7 g for sublegal-immature urchins (Table 10a).

The mean overall total density for Stubbs Island was 1.99 ± 1.00 urchins/m^2 (Table 11). The overall legal, sublegal-mature, and sublegal-immature densities were 0.50 ± 0.07, 1.16 ± 0.78, and 0.31 ± 0.27 urchins/m^2, respectively. The mean total densities ranged from 0.53 urchins/m^2 in Transect 18 to 4.05 urchins/m^2 in Transect 15 (Table 11). The highest mean legal

densities (0.53 urchins/m^2 and 0.58 urchins/m^2) occurred in Transects 18 and 17 (respectively), whereas the highest mean sublegal-mature (2.77 urchins/m^2) and sublegal-immature (0.86 urchins/m^2) densities occurred in Transect 15.

The highest mean total densities of green sea urchins (4.33 to 4.50 urchins/m^2) occurred between 7.6 and 9.6 m (25.1 to 31.6 ft) below CD (Table 12c, Fig. 12c), consisting mainly of sublegal-sized urchins (4.00 urchins/m^2). The highest mean legal density (1.11 urchins/m^2) occurred between 6.1 and 7.6 m (20.1 and 25.0 ft) below CD. No urchins occurred between 1.5 m and 2.6 m (5.0 and 8.4 ft) above CD.

There were high mean total densities of green urchins on substrates consisting of creviced bedrock with boulders and cobble (10.00 urchins/m^2; only one quadrat sampled creviced), bedrock with cobble and shell (9.00 urchins/m^2; only two quadrats sampled), cobble with boulders (8.00/m^2; only one quadrat sampled), and boulders with shell and creviced bedrock (7.00 urchins/m^2; only one quadrat sampled; Table 13c; Fig. 13c). The highest mean legal densities (2.00 urchins/m^2) occurred on boulders with shell and creviced bedrock, and on cobble with boulders (one quadrat each; Table 13c). The highest mean sublegal densities occurred on creviced bedrock with boulders and cobble (9.00 urchins/m^2; one quadrat), and on creviced bedrock with cobble and shell (8.50 urchins/m^2; two quadrats).

(iii) Plumper Islands

There were 104 quadrats surveyed and 152 green urchin TD measurements recorded in the Plumper Islands. 15.8% of the urchins were of legal size and 84.2% were sublegal (Table 1). Figure 11d presents the size frequency distribution. Analyses of the test diameter frequency data showed the best fit ($X^2 = 53.1$; df = 30; p = 0.0057) resulted with two dominant size modes, at 38 mm (80%) and 55 mm (20%; Table 2). Mean TD's and total wet weights for urchins from the Stephenson Islets were 61.2 mm and 99.1 g for legal-sized urchins, 39.7 mm and 35.2 g for sublegal-mature urchins, and 14.5 mm and 3.5 g for sublegal-immature urchins (Table 10a).

The mean overall total density for the Plumper Islands was 1.46 ± 0.52 urchins/m^2 (Table 11). The overall legal, sublegal-mature, and sublegal-immature densities were 0.23 ± 0.07, 1.19 ± 0.48, and 0.04 ± 0.03 urchins/m^2, respectively. The mean total densities ranged from 0.24 urchins/m^2 in Transect 24 to 2.92 urchins/m^2 in Transect 21 (Table 11). The highest mean legal density (0.38 urchins/m^2) and the highest mean sublegal-mature density (2.54 urchins/m^2) both occurred in Transect 21, while the highest mean sublegal-immature density (0.14 urchins/m^2) occurred in Transect 23.

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 (0.67, 3.14, and 3.81 urchins/m^2 for legal, sublegal, and total urchins, respectively; Table 12d and Fig. 12d). No urchins occurred between 1.5 and 2.1 m (5.0 to 6.9 ft) above CD.

The highest mean total density of green urchins (4.00 urchins/m^2) occurred on substrate consisting of creviced bedrock with boulders (only one quadrat sampled), whereas there were no

urchins present on smooth bedrock with shell (again, only one quadrat sampled; Table 13d, Fig. 13d). The highest mean legal density (2.00 urchins/m^2; one quadrat) occurred on creviced bedrock with boulders, and the highest mean sublegal densities (2.00 urchins/m^2) occurred on both creviced bedrock with boulders (one quadrat) and creviced bedrock with shell (ten quadrats; Table 13d). Considering only the main substrate type (ignoring all substrates of second and third prominence), boulders (1.80 urchins/m^2) and creviced bedrock (1.76 urchins/m^2) had the highest mean total densities, while cobble (0.17 urchins/m^2) and smooth bedrock (0.33 urchins/m^2) had the lowest mean total densities.

(iv) Dissection Data

There were 131 green urchins collected from all the transects and dissected during this survey (Table 14). 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) of the randomly selected legal-sized urchins were highest for Stubbs Island, intermediate at the Plumper Islands, and lowest at the Stephenson Islets (Table 14). These results (for TD only) were the same as those found in the field survey data (Table 10a). The same lab measurements (as above) for sublegal-mature sized urchins were highest at Stubbs Island, intermediate at the Stephenson Islets, and lowest at the Plumper Islands.

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 a 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 ($F = 5.19$, $df = 2, 128$, $p < 0.05$). This does not allow the relationship to be used with all sites combined for the February 1997 survey when calculating the total wet weight (g) from the TD (mm). Therefore, we calculated relationships for each site separately (Fig. 17a-c), and these were used to calculate the biomass estimates (see Fig. 17a-c for the formulae).

The best quality roe (i.e., colour=1 (orange/yellow) and texture=1 (firm)) was observed at the Plumper Islands, with 66.7% of the legal-sized green urchins having the highest quality, followed by the Stephenson Islets with 21.1% and Stubbs Island with only 7.7% (Table 8). The overall roe recovery rates (total gonad weight (all grades) divided by total drained weight of all urchins collected) were similar for all sites, ranging from 27.5% at Stephenson Islets to 30.0% at Stubbs Island for legal-sized urchins (Table 8).

(v) Biomass Estimates

By extrapolating the total mean density (3.67 urchins/m^2; Table 11) over the area of Stephenson Islets, it was calculated that there were approximately 1,780,564 ± 227,951 green sea urchins of all sizes on February 18, 1997 (Table 15a). Of these, approximately 360,905 (20.2%)

were of legal size, 1,335,798 (75.0%) were of sublegal-mature size, and 77,872 (4.4%) were of an immature size. The mean weight per legal-sized green sea urchin at Stephenson Islets in February, 1997 was determined to be 82.5 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 February, 1997, 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 39.2 and 5.4 g, respectively (Table 10a). The biomass of legal-sized, sublegal-mature-sized, and immature-sized green sea urchins at Stephenson Islets in February, 1997 was 29.79, 52.32, and 0.42 t, respectively, for a total biomass (not including "unknowns") of 82.52 t ± 9.71 t (Table 15a).

On February 18, 1997, there were approximately 38,912 green sea urchins in total (9,800 legal-sized, 22,771 sublegal-mature, and 6,053 of an immature size) at Stubbs Island (Table 15a). Based on the TD-total wet weight relationship calculated for Stubbs Island in February, 1997 (Fig. 17b), the mean weight per legal-sized green urchin was 103.9 g (Table 10a). The mean weight per sublegal-mature and sublegal-immature green urchin was 32.4 g and 4.7 g, respectively (Table 10a). The total biomass was calculated as 1.78 t ± 0.52 t, of which 1.02, 0.74, and 0.03 t were comprised of legal, sublegal-mature and sublegal-immature urchins, respectively (Table 15a).

At the Plumper Islands survey site on February 18, 1997, there were approximately 326,800 green sea urchins (51,600 legal-sized, 266,600 sublegal-mature, and 8,600 immature; Table 15a). Based on the TD versus total wet weight relationship calculated for the Plumper Islands in February, 1997 (Fig. 17c), the mean weight per legal-sized, sublegal-mature-sized and immature green urchin was 99.1, 35.2, and 3.5 g (Table 10a). The total biomass was 14.54 t ± 4.11 t, of which 5.12 t was legal-sized, 9.39 t was of sublegal-mature size, and 0.03 t was immature green urchins (Table 15a).

(c) 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 decreased by 10.64 t between November, 1996 and February, 1997, using the biomass estimates from the TD-weight relationships calculated from the November, 1996 and February, 1997 surveys. Keeping the assumption that there is no growth of individual urchins during this time, (as described previously), it is more appropriate to use the November, 1996, relationship of TD versus total wet weight to calculate the biomass of green urchins present in February, 1997. Using this relationship (Fig. 7), the mean weight per legal, sublegal-mature and sublegal-immature green urchin was 81.2, 37.8, and 4.9 g, respectively (Table 10b). Consequently, the total legal, sublegal-mature, and sublegal-immature biomass at Stephenson Islets in February, 1997 was 29.30, 50.53, and 0.38 t, respectively, for an overall total biomass of 80.22 ± 9.72 t (Table 15b). The total biomass of legal-sized green sea urchins in the Stephenson Islets site then decreased by

11.13 t between November, 1996 and February, 1997. The total biomass of urchins removed by commercial harvest (as recorded in the harvest logbook records), $B_{fishing}$, was 9.56 t. The remainder, 1.57 t, represents a net loss, likely due to natural mortality and any net difference of immigration and emigration.

At Stephenson Islets the biomass of sublegal-mature urchins increased by 16.61 t, whereas the biomass of sublegal-immature urchins decreased by 0.20 t over the duration of the fishing season. As a result, the overall biomass at Stephenson Islets increased by 5.29 t. At Stubbs Island, the biomass of legal, sublegal-mature, and sublegal-immature urchins decreased by 3.24, 1.32, and 0.02 t, respectively, for an overall total decrease in biomass of 4.58 t. There was no commercial fishery for green sea urchins at Stubbs Island during the 1996/97 fishing season. At the Plumper Islands, there was an overall decrease in biomass of 3.59 t between November, 1996 and February, 1997. The biomass of legal-sized and sublegal-immature urchins decreased by 4.23 and 0.34 t, respectively, while the biomass of sublegal-mature urchins increased by 0.99 t.

(ii) Mortality Calculations

The exploitation of green sea urchins from Stephenson Islets during the November, 1996 to February, 1997 (3 months) fishing season, as calculated using equations 5 and 6, is 0.24 ± 0.05. Instantaneous mortality rates between the two surveys (where t equals one "fishing season" (3 months duration) [1]) are as follows:

Stephenson Islets: Number removed by fishing (eqn. 8):

$$N_{fishing} = \frac{9.56 \pm 0.10\,\text{t}}{86.9\times10^{-6}} = 110{,}011 \pm 1{,}100 \text{ urchins}$$

Difference in numbers of legal-sized urchins estimated from surveys:

$465{,}162 \pm 97{,}898 - 360{,}905 \pm 61{,}864 = 104{,}257 \pm 115{,}807$ urchins

Instantaneous total mortality (of legal size) (eqn. 10) [2]: $Z = 0.25 \pm 0.07$

Stubbs Island: Difference in numbers of legal-sized urchins estimated from surveys:

$38{,}557 \pm 30{,}605 - 9{,}800 \pm 1{,}390 = 28{,}757 \pm 30{,}636$ urchins

Instantaneous total mortality (of legal size): $Z = 1.37 \pm 1.10$

Plumper Islands: Difference in numbers of legal-sized urchins estimated from surveys:

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[1] Note that this report calculates Z differently than the last report (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 $Z * \left(\frac{\delta q}{q}\right)$.

$96{,}816 \pm 42{,}536 - 51{,}600 \pm 15{,}648 = 45{,}216 \pm 45{,}323$ urchins

Instantaneous total mortality (of legal size): $Z = 0.63 \pm 0.38$

Since the numbers of legal-sized urchins removed from the fishery at Stephenson Islets (110,011) was similar to the difference in numbers estimated between the two surveys (104,257), instantaneous exploitation and natural mortality rates (equations 11 to 13) were not calculated.

DISCUSSION

The percentage of legal-sized urchins was lowest in the Plumper Islands, intermediate at Stephenson Islets, and highest at Stubbs Island in both November, 1996 and February, 1997. The percentage of legal-sized urchins decreased between November, 1996 and February, 1997 at all sites (34 to 37%), whereas the percentage of sublegal-sized urchins increased between the two surveys at all sites (12 to 21%). In addition, the mean overall total, legal, and sublegal densities were all lowest in the Plumper Islands in both November, 1996 and February 1997, but were highest at Stubbs Island in November, 1996 and highest in the Stephenson Islets in February, 1997. It is interesting to note that the total densities decreased between November, 1996 and February, 1997 at all sites except at the Stephenson Islets, where it increased from 3.04 to 3.67 urchins/m^2 (Tables 4 and 11). This was mainly due to the increase in density of sublegal-mature urchins from 1.81 to 2.75 urchins/m^2. The densities of legal-sized urchins decreased at all sites between November, 1996 and February, 1997. The large decrease in total density at Stubbs Island from November, 1996 to February, 1997 (5.07 to 1.99 urchins/m^2), is likely due to the influence of one transect (Transect 15) that had an extremely high density in November, 1996. In that survey, the transect ran through a large crevice, and it was noted that densities were much lower on either side of it. Transects never fall on exactly the same line from survey to survey. Besides being an area closed to commercial green sea urchin fishing since the fall of 1995, Stubbs Island has been considered locally as a "park-like" reserve, so there should have been very little or no commercial or sports fishing at this site for several years prior to the surveys.

Changes in size frequencies between November and February are difficult to analyze, as test size is not a reliable index of age, especially for older individuals, due to their discontinuous growth, which fluctuates with the availability of vegetation. Also, emigration/immigration to and from deeper waters may influence the results of the analyses.

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 distinct frequency modes for both surveys. At Stephenson Islets, the first mode stayed the same at 38 mm between the two surveys, but the proportion decreased, while the second mode decreased from 54 to 48 mm, while the proportion increased. The urchins that made up the second mode in the first survey likely grew to legal size and were harvested between the two surveys. The urchins in the first mode of the first survey also likely grew, and then became part of the second mode in the second survey, therefore increasing the proportion and decreasing the mean size of the mode. Growth of smaller urchins and emigration likely contributed to the urchins at Stephenson Islets in the first mode of the second survey. At Stubbs Island, all of the three frequency modes increased slightly,

as one might expect in a population of growing individuals with no mortality due to harvesting. The proportion of the smallest mode increased greatly between the two surveys, while the proportion of the largest mode decreased. This was similar at the Plumper Islands, where both of the modes increased slightly between the two surveys, and the proportion of the smallest mode increased while the proportion of the largest mode decreased between the two surveys.

From field survey results, it appears that the largest legal-sized green urchins (largest TD's and weights) were located at Stubbs Island, and the smallest legal-sized urchins occurred in the Stephenson Islets during both the November, 1996 and February, 1997 surveys. The dissection data also supports this trend. This makes sense since 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. The NW section of the Plumper Islands has been closed to commercial fishing of green sea urchins since the fall of 1995, but was harvested prior to that. 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 would more likely be removed. The mean TD's for legal urchins in the Stephenson Islets decreased from 60.0 mm in November, 1996 to 58.5 g in February, 1997. 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, 1996 and February, 1997. However, the largest decrease in mean legal-sized TD between November, 1996 and February, 1997 occurred at Stubbs Island, which supposedly, had no fishing.

In general, mean total densities were highest in the shallower depths (generally to 6.1 m (20.0 ft) below CD) and lowest in the deeper depths (below approximately 7.6 m beneath CD) in November, 1996 and February, 1997 for all sites. There were a few exceptions to this rule, but in general, the urchins were likely highest in density in shallower waters to feed on algae, most notably kelp. At Stubbs Island in November, 1996 the mean density was extremely high (for the area) between 0.1 to 1.5 m (0.1 to 5.0 ft) below CD (12.22 urchins/m^2, the highest mean total density of the whole survey), then became lower at greater depths. In contrast, in February, 1997 the mean density was greatest (4.00 urchins/m^2) at 7.6 to 9.6 m (25.1 to 31.6 ft) below CD.

The main substrate type where green urchins occurred in highest densities was different at each of the three sites during both the November, 1996 and February, 1997 surveys. In November, 1996, the highest mean densities occurred on smooth bedrock in the Stephenson Islets, creviced bedrock at Stubbs Island, and boulders in the Plumper Islands. In February, 1997, the mean densities occurred in creviced bedrock in the Stephenson Islets, in boulders at Stubbs Island, and almost equally high in creviced bedrock and boulders in the Plumper Islands. Part of these differences may have been because different divers were involved in the two surveys, and they may 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 never fall on exactly the same line between surveys.

Legal-sized green sea urchins collected at Stubbs Island had the best quality roe and the highest roe recovery in November, 1996. Stubbs Island also had the highest roe recovery in February, 1997 but the lowest quality roe, whereas the best quality roe occurred at the Plumper Islands. The percentage of legal-sized green sea urchins with high quality roe decreased at both Stephenson Islets and Stubbs Island between the November, 1996 and the February, 1997 surveys (from 39.0 and 50.0% to 21.1 and 7.7%, respectively). The reverse was true for the Plumper Islands where the percentage increased (from 31.8 to 66.7%). The roe recovery increased at all sites between November, 1996, and February, 1997 for both legal and sublegal green sea urchins, as expected, 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 February, 1997 survey (for that season).

The exploitation of legal-sized green urchins at Stephenson Islets (0.24 ± 0.05) was identical to the instantaneous total mortality rate calculated for legal-sized urchins (0.25 ± 0.07). This is reflected by the equivalence of the estimated numbers removed by fishing (110,011) and the difference between the numbers of legal-sized urchins in each survey (104,257), although the latter has large uncertainty. Apparently, all of mortality exerted on legal-sized green sea urchins during this three month period (mid-November to mid-February) was due to the fishery. This is not surprising considering this is a key location for commercial urchin fishing operations, and its urchin densities have been reported to be consistently high relative to other locations within the this Pacific Fisheries Management Area. 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 some natural mortality. Obviously, natural mortality will dominate during the remaining nine months of the year.

Other factors in addition to fishing may influence changes in the population structure of green sea urchins. One of these factors is the mobile nature of this species. Anecdotal observations from fishers during the commercial fishing season report that green sea urchins will not be present in a particular area one week, and then the following week will appear in great numbers. The fishers believe they are moving up from deep waters, and that they will remain in areas where food (fleshy algae) is present. The population size structure and abundance of legal-sized urchins are further modified by growth of sublegal animals between the November, 1996 and February, 1997 surveys. Growth, as previously mentioned, is discontinuous, especially in older individuals, and fluctuates with density and the availability of food.

The instantaneous mortality rates calculated for Stubbs and Plumper Islands presumably represent natural mortality, as removals due to fishing in these sitens was minimal. These natural mortality rates are much larger (two to five times) than the fishing mortality rate at Stephenson Islets. However, these natural mortality rates also have very large uncertainties. In fact, these instantaneous mortality rates, including their uncertainties, overlap among the three survey sites, suggesting that they could actually be of similar magnitudes. These large uncertainties result from the patchy and highly variable aggregating behaviour of green urchins in non-key habitats

such as Stubbs and Plumper Islands. They also show the importance of including uncertainties in the calculation of these quantities when based on field survey data.

SUMMARY

(a) NOVEMBER, 1996 SURVEY:

The mean densities for all sites combined were 0.98/m^2 for legal-sized green sea urchins (32.1%), 2.06/m^2 for sublegal urchins (67.7%), and 3.05/m^2 for all sizes combined in November, 1996. Dissections were performed on a total of 127 green urchins from all locations. The mean TD and individual weights for legal-sized urchins from all sites combined was 61.4 mm and 92.8 g, respectively. The mean roe recovery rates for legal-sized green urchins were 18.5%, 25.7%, and 18.8% for Stephenson Islets, Stubbs Island, and the Plumper Islands, respectively. Stubbs Island had the best quality roe, 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, 1996 was 40.43, 4.20, and 8.94 t, respectively.

(b) FEBRUARY, 1997 SURVEY:

The mean densities for all sites combined were 0.60/m^2 for legal-sized green sea urchins (20.3%), 2.36/m^2 for sublegal urchins (79.4%), and 2.98/m^2 for all sizes combined in February, 1997. Dissections were performed on a total of 131 green urchins from all sites. The mean TD and individual weight for legal-sized urchins from all sites combined was 59.2 mm and 86.7 g, respectively (or 59.2 mm and 83.9 g using the TD versus total wet weight relationship from the November, 1996 survey). The mean roe recovery rates were 27.5%, 30.0%, and 28.4% for Stephenson Islets, Stubbs Island, and the Plumper Islands, respectively. The Plumper Islands had the best quality roe, with 66.7% 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 February, 1997 was 29.79, 1.02, and 5.12 t, respectively (or 29.30, 0.96 and 4.71 t using the November, 1996 TD-weight relationship on February, 1997 field data).

(c) COMPARISON BETWEEN SURVEYS:

The percentage of legal-sized urchins decreased between the two surveys at all sites (34 to 37%)(not just where the commercial fishery occurred), while the percentage of sublegal-sized urchins increased (12 to 21%). Additionally, the mean densities of legal-sized and sublegal-immature-sized urchins decreased at all sites between November, 1996 and February, 1997, whereas the densities of sublegal-mature-sized urchins increased between the two surveys at Stephenson Islets and the Plumper Islands (but not at Stubbs Island). The total biomass of legal-sized green urchins in the Stephenson Islets decreased by 10.64 t, from 40.43 t in November,

1996 to 29.79 t in February, 1997 (or if using the Nov. TD-weight relationships for both surveys, the total biomass decreased by 11.13 t from 40.43 t to 29.30 t). Of this decrease, 9.56 t is accounted for by commercial landings. The exploitation at Stephenson Islets was 0.24. Assuming no net growth over the fishing season, and ignoring the net result of emigration and immigration, the annual instantaneous total mortality (Z) for legal-sized green urchins at Stephenson Islets was 0.25 ± 0.07.

ACKNOWLEDGEMENTS

Funding for the green urchin surveys came from the WCGUA. Many thanks go to: Darren Matilpi of the KTFC, and Doug Glover, Kelly Korol and Dennis Poff of the WCGUA for performing the dive surveys; and Ross Henderson and Carol Perrault of the KTFC, and Lawrence (Jig) Glover, David McRae and Mark Sutton of the WCGUA for operating the boats and boat tending. Many thanks also go to Glenn Ross for the use of his vessel, the '*Sea Rebel*', Lawrence Glover for the '*Clo-oose*', and David McRae for the '*Kuroshio*' for the surveys. Thanks to Steve Lacasse for the use of the lab facilities at the Sun Fun Dive Shop in Port McNeill. Thanks also to Leslie Barton of the PBS Shellfish Data Unit for providing the area calculations, and to Dominique Bureau of PBS for providing comments and suggestions on the manuscript.

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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, 1996 and February, 1997 surveys. (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. 1996	Number	487	878	148	3	1,516
		Percent	32.1%	57.9%	9.8%	0.2%	
	Feb. 1997	Number	299	1,095	77	5	1,476
		Percent	20.3%	74.2%	5.2%	0.3%	
Stephenson Islets	Nov. 1996	Number	325	615	90	1	1,031
		Percent	31.5%	59.7%	8.7%	0.1%	
	Feb. 1997	Number	241	892	52	4	1,189
		Percent	20.3%	75.0%	4.4%	0.3%	
Stubbs Island	Nov. 1996	Number	120	160	29	0	309
		Percent	38.8%	51.8%	9.4%	0.0%	
	Feb. 1997	Number	34	79	21	1	135
		Percent	25.2%	58.5%	15.6%	0.7%	
Plumper Islands	Nov. 1996	Number	42	103	29	2	176
		Percent	23.9%	58.5%	16.5%	1.1%	
	Feb. 1997	Number	24	124	4	0	152
		Percent	15.8%	81.6%	2.6%	0%	

Table 2. Green sea urchin test diameter frequency distribution analysis for the November, 1996 and February, 1997 surveys. Results were obtained using the analysis software "Mix 3aa". (X^2 = chi-square goodness of fit value, DF = degrees of freedom, P-value = the p-value of the chi-square test, sigma = standard deviation).

Site	Survey	Frequency Mode	Mode Mean (mm)	Sigma (mm)	Proportion Of Population	X^2	DF	P-value
All Sites Combined	Nov. 1996	1	26	9.1	0.24	200.9	38	<0.0001
		2	52	10.3	0.76			
	Feb. 1997	1	42	11.8	0.85	137.7	32	<0.0001
		2	52	4.9	0.15			
Stephenson Islets	Nov. 1996	1	38	14.5	0.55	145.6	38	<0.0001
		2	54	6.7	0.45			
	Feb. 1997	1	38	11.4	0.41	122.4	31	<0.0001
		2	48	8.1	0.59			
Stubbs Island	Nov. 1996	1	30	10.8	0.32	73.3	31	<0.0001
		2	49	3.9	0.24			
		3	62	10.3	0.44			
	Feb. 1997	1	32	10.7	0.65	33.3	27	0.1880
		2	52	3.3	0.20			
		3	67	4.2	0.15			
Plumper Islands	Nov. 1996	1	27	8.6	0.44	36.8	31	0.2190
		2	52	10.2	0.56			
	Feb. 1997	1	38	9.4	0.80	53.1	30	0.0057
		2	55	9.3	0.20			

Table 3. Means and standard errors (SE) of test diameters (TD) (using field survey data) and weight (using test diameter-total wet weight relationships from November, 1996 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, 1996 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = size unknown).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	487	61.4	0.3	92.8	1.2
	Sublegal-Mature	878	42.0	0.3	38.1	0.6
	Sublegal-Immature	148	17.6	0.4	4.8	0.2
Stephenson Islets	Legal	325	60.0	0.3	86.9	1.1
	Sublegal-Mature	615	42.2	0.3	38.5	0.7
	Sublegal-Immature	90	17.0	0.6	4.5	0.3
Stubbs Island	Legal	120	65.4	0.7	109.0	3.1
	Sublegal-Mature	159	43.1	0.6	40.3	1.3
	Sublegal-Immature	30	18.6	0.7	5.1	0.4
Plumper Islands	Legal	42	61.4	0.9	92.3	3.8
	Sublegal-Mature	103	39.2	0.9	32.7	1.7
	Sublegal-Immature	29	18.9	1.0	5.5	0.5

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, 1996 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 3 to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transects 20 to 24).

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3	45	0.82	1.87	0.24	0.00	2.93
5A	35	1.09	1.86	0.17	0.00	3.11
6	29	0.41	0.69	0.24	0.00	1.34
7	64	1.58	1.69	0.09	0.02	3.36
8	21	0.10	0.10	0.00	0.00	0.19
9	24	1.13	1.79	0.83	0.00	3.00
10A	18	0.67	0.67	0.17	0.00	1.50
11A	24	1.50	0.96	0.33	0.00	2.79
13	36	1.50	5.50	0.47	0.00	7.47
14	43	0.14	1.40	0.65	0.00	2.19
Stephenson Islets Totals	339	0.96 ± 0 .20	1.81 ± 0.45	0.27 ± 0.07	0.00	3.04 ± 0.57
15	19	5.21	6.74	1.16	0.00	13.11
17	28	0.39	1.14	0.25	0.00	1.79
18	14	0.71	0.00	0.00	0.00	0.71
Stubbs Island Totals	61	1.97 ± 1.56	2.62 ± 1.92	0.48 ± 0.32	0.00	5.07 ± 3.78
20	29	0.55	1.52	0.62	0.00	2.69
21	22	0.91	1.23	0.09	0.09	2.23
23	20	0.30	1.60	0.45	0.00	2.35
24	26	0.00	0.00	0.00	0.00	0.00
Plumper Islands Totals	97	0.43 ± 0.19	1.06 ± 0.39	0.30 ± 0.16	0.02	1.81 ± 0.66
OVERALL TOTAL	497	0.98 ± 0.23	1.77 ± 0.38	0.30 ± 0.06	0.01	3.05 ± 0.59

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, 1996 survey.

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-1.3 to 0.0	-0.4 to 0.0	7	1.14	1.00	0.00	2.14 ± 1.58
0.1 to 5.0	0.1 to 1.5	33	2.79	4.36	0.00	7.15 ± 2.64
5.1 to 10.0	1.5 to 3.0	52	1.52	2.12	0.00	3.63 ± 0.81
10.1 to 15.0	3.0 to 4.8	66	0.94	2.62	0.00	3.56 ± 0.52
15.1 to 20.0	4.8 to 6.1	72	0.92	2.42	0.00	3.33 ± 0.42
20.1 to 25.0	6.1 to 7.6	88	0.55	1.95	0.00	2.50 ± 0.34
25.1 to 30.0	7.6 to 9.1	92	0.73	1.36	0.00	2.09 ± 0.28
30.1 to 35.0	9.1 to 10.7	76	0.82	1.41	0.04	2.26 ± 0.27
35.1 to 40.0	10.7 to 12.2	9	0.22	1.56	0.00	1.78 ± 0.94
40.1 to 41.3	12.2 to 12.6	2	0.50	0.00	0.00	0.50 ± 0.50

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, 1996 survey.

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	2.00	1.75	0.00	3.75 ± 2.59
0.1 to 5.0	0.1 to 1.5	19	1.11	1.68	0.00	2.79 ± 1.00
5.1 to 10.0	1.5 to 3.0	33	1.33	2.61	0.00	3.94 ± 0.96
10.1 to 15.0	3.0 to 4.8	42	1.17	3.07	0.00	4.24 ± 0.69
15.1 to 20.0	4.8 to 6.1	45	1.29	2.98	0.00	4.27 ± 0.54
20.1 to 25.0	6.1 to 7.6	58	0.50	1.95	0.00	2.45 ± 0.39
25.1 to 30.0	7.6 to 9.1	69	0.87	1.52	0.00	2.39 ± 0.35
30.1 to 35.0	9.1 to 10.7	62	0.85	1.53	0.02	2.40 ± 0.31
35.1 to 40.0	10.7 to 12.2	5	0.40	0.80	0.00	1.20 ± 0.37
40.1 to 41.3	12.2 to 12.6	2	0.50	0.00	0.00	0.50 ± 0.50

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, 1996 survey.

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-1.3 to 0.0	-0.4 to 0.0	2	0.00	0.00	0.00	0.00
0.1 to 5.0	0.1 to 1.5	9	7.89	12.22	0.00	20.11 ± 8.27
5.1 to 10.0	1.5 to 3.0	11	3.09	1.73	0.00	4.82 ± 2.48
10.1 to 15.0	3.0 to 4.8	10	0.30	1.00	0.00	1.30 ± 0.30
15.1 to 20.0	4.8 to 6.1	8	0.63	3.25	0.00	3.88 ± 1.37
20.1 to 25.0	6.1 to 7.6	7	0.57	2.29	0.00	2.86 ± 1.37
25.1 to 30.0	7.6 to 9.1	7	0.29	0.43	0.00	0.71 ± 0.42
30.1 to 35.0	9.1 to 10.7	6	0.17	0.67	0.00	0.83 ± 0.54
35.1 to 35.9	10.7 to 10.9	1	0.00	1.00	0.00	1.00 ± 0.00

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, 1996 survey.

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density
-0.3 to 0.0	-0.4 to 0.0	1	0.00	0.00	0.00	0.00
0.1 to 5.0	0.1 to 1.5	5	0.00	0.40	0.00	0.40 ± 0.40
5.1 to 10.0	1.5 to 3.0	8	0.13	0.63	0.00	0.75 ± 0.41
10.1 to 15.0	3.0 to 4.8	14	0.71	2.43	0.00	3.14 ± 1.23
15.1 to 20.0	4.8 to 6.1	19	0.16	0.74	0.00	0.89 ± 0.32
20.1 to 25.0	6.1 to 7.6	23	0.65	1.87	0.00	2.52 ± 0.75
25.1 to 30.0	7.6 to 9.1	16	0.31	1.06	0.00	1.38 ± 0.52
30.1 to 35.0	9.1 to 10.7	8	1.00	1.00	0.25	2.25 ± 0.70
35.1 to 39.7	10.7 to 12.1	3	0.00	3.00	0.00	3.00 ± 3.00

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, 1996 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
100	Bedrock (smooth)	41	0.68	2.39	0.00	3.07	3.07 ± 0.62
200	Bedrock (crevices)	352	0.84	1.67	0.00	2.52	3.06 ± 0.30
230	Bedrock crevices)/boulders	21	4.76	6.81	0.10	11.67	
234	Bedrock crevices)/boulders/ Cobble	2	6.50	2.00	0.00	8.50	
300	Boulders	20	0.90	2.65	0.00	3.55	3.26 ± 0.42
340	Boulders/cobble	20	0.70	2.75	0.00	3.45	
345	Boulders/cobble/gravel	2	0.50	3.00	0.00	3.50	
370	Boulders/sand	1	0.00	3.00	0.00	3.00	
380	Boulders/shell	27	0.59	2.30	0.00	2.89	
400	Cobble	3	0.00	4.00	0.00	4.00	1.30 ± 0.72
456	Cobble/gravel/pea gravel	6	0.00	0.17	0.00	0.17	
458	Cobble/gravel/shell	1	0.00	0.00	0.00	0.00	
800	Shell	1	0.00	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, 1996 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
100	Bedrock (smooth)	14	1.00	3.36	0.00	4.36	4.36 ± 1.26
200	Bedrock (crevices)	282	0.97	1.90	0.00	2.87	2.88 ± 0.21
230	Bedrock crevices)/boulders	7	0.43	1.14	0.00	1.57	
234	Bedrock crevices)/boulders/ cobble	2	6.50	2.00	0.00	8.50	
300	Boulders	14	1.29	3.79	0.00	5.07	3.90 ± 0.66
340	Boulders/cobble	16	0.25	2.69	0.00	2.94	
370	Boulders/sand	1	0.00	3.00	0.00	3.00	
400	Cobble	3	0.00	4.00	0.00	4.00	4.00 ± 1.53

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, 1996 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
100	Bedrock (smooth)	18	0.56	1.83	0.00	2.39	2.39 ± 0.69
200	Bedrock (crevices)	33	0.61	0.91	0.00	1.52	6.82 ± 2.30
230	Bedrock (crevices)/boulders	6	15.00	21.00	0.00	36.00	
300	Boulders	4	0.00	0.00	0.00	0.00	0.00

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, 1996 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
100	Bedrock (smooth)	9	0.44	2.00	0.00	2.44	2.44 ± 1.49
200	Bedrock (crevices)	37	0.11	0.65	0.00	0.76	1.02 ± 0.30
230	Bedrock (crevices)/boulders	8	0.88	1.13	0.25	2.25	
300	Boulders	2	0.00	0.00	0.00	0.00	3.06 ± 0.58
340	Boulders/cobble	4	2.50	3.00	0.00	5.50	
345	Boulders/cobble/gravel	2	0.50	3.00	0.00	3.50	
380	Boulders/shell	27	0.59	2.30	0.00	2.89	
456	Cobble/gravel/pea gravel	6	0.00	0.17	0.00	0.17	0.14 ± 0.14
458	Cobble/gravel/shell	1	0.00	0.00	0.00	0.00	
800	Shell	1	0.00	0.00	0.00	0.00	0.00

Table 7. Summary results of gonad sampling during the November, 1996 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; SEX: 1=male, 2=female, 3=juvenile or unknown).

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			41	28	3	14	5	0	22	13	1
Mean Test Height (mm) ± SE			33.17 (± 0.82)	21.25 (± 1.06)	11.00 (± 0.58)	37.00 (± 1.60)	26.20 (± 0.86)	0.00	33.59 (± 0.95)	22.77 (± 1.46)	1.00 (± 0.00)
Mean Test Diameter (mm) ± SE			63.76 (± 0.96)	43.71 (± 1.55)	21.67 (± 1.33)	70.57 (± 2.50)	48.20 (± 2.69)	0.00	66.14 (± 1.76)	43.85 (± 2.25)	4.00 (± 0.00)
Mean Total Wet Weight (g) ± SE			97.33 (± 3.67)	42.25 (± 3.75)	7.37 (± 3.34)	141.29 (± 15.18)	44.32 (± 5.35)	0.00	116.86 (± 8.13)	42.24 (± 4.73)	0.10 (± 0.00)
Mean Drained Weight (g) ± SE			68.63 (± 2.51)	32.58 (± 2.77)	5.93 (± 2.39)	102.74 (± 10.79)	33.28 (± 3.68)	0.00	78.56 (± 4.99)	30.88 (± 3.65)	0.00 (± 0.00)
Mean Gutted Weight (g) ± SE			61.25 (± 2.27)	29.30 (± 2.52)	4.37 (± 2.60)	91.61 (± 8.96)	28.68 (± 3.60)	0.00	69.86 (± 4.47)	26.78 (± 3.02)	0.00 (± 0.00)
Sex (%)	Male		42	21	0	36	0	0	32	23	0
	Female		56	64	0	64	80	0	68	69	0
	Unknown		2	14	100	0	20	0	0	8	100
Gonad	Mean Weight (g) ± SE		12.85 (± 1.06)	4.97 (± 0.83)	0.00	26.44 (± 3.77)	4.50 (± 1.37)	0	14.74 (± 1.58)	4.28 (± 0.93)	0.00
	Colour Proportion	0	0.02	0.14	1	0	0	0	0	0.08	0
		1	0.49	0.54	0	0.57	0.80	0	0.40	0.31	0
		2	0.32	0.25	0	0.29	0.20	0	0.55	0.62	0
		3	0.17	0.07	0	0.14	0	0	0.05	0	0
	Texture Proportion	0	0.02	0.14	1	0	0	0	0	0.08	0
		1	0.63	0.29	0	0.71	0.40	0	0.36	0.38	0
		2	0.34	0.50	0	0.29	0.60	0	0.59	0.54	0
		3	0.00	0.07	0	0	0	0	0.05	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, 1996 and February, 1997 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 1996	41	28	39.0%	28.6%	18.5%	15.3%
February 1997	19	47	21.1%	10.6%	27.5%	18.0%
Stubbs Island						
November 1996	14	5	50.0%	40.0%	25.7%	13.5%
February 1997	13	12	7.7%	25.0%	30.0%	20.0%
Plumper Islands						
November 1996	22	12	31.8%	25.0%	18.8%	14.2%
February 1997	12	18	66.7%	22.2%	28.4%	20.1%

Table 9. Calculated total abundance (number) and biomass (tonnes) of green sea urchins, by site, in November, 1996. (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	465,162 ± 95,898	38,557 ± 30,605	96,816 ± 42,536
Number of Sublegal-mature	880,230 ± 219,969	51,410 ± 37,695	237,431 ± 86,894
Number of Sublegal-immature	128,814 ± 33,036	9,318 ± 6,251	66,849 ± 35,467
Number of Unknown	1,431 ± 1,296	0	4,610 ± 4,766
Number of all sizes	1,475,638 ± 278,574	99,285 ± 74,123	405,707 ± 148,375
Biomass of Legal-size (t)	40.43 ± 8.34	4.20 ± 3.34	8.94 ± 3.94
Biomass of Sublegal-mature (t)	33.92 ± 8.49	2.07 ± 1.52	7.77 ± 2.86
Biomass of Sublegal-immature (t)	0.58 ± 0.15	0.05 ± 0.03	0.37 ± 0.20
Total Biomass (t)	74.93 ± 11.90	6.32 ± 3.67	17.08 ± 4.88

Table 10a. Means and standard errors (SE) of test diameter (TD) (using field survey data) and weight (using TD-total wet weight relationships from February, 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 February, 1997 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = size unknown).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	299	59.2	0.5	86.7	1.0
	Sublegal-Mature	1095	41.7	0.2	38.2	0.5
	Sublegal-Immature	77	18.1	0.5	5.2	0.3
Stephenson Islets	Legal	241	58.5	0.3	82.5	0.9
	Sublegal-Mature	892	42.2	0.2	39.2	0.5
	Sublegal-Immature	52	18.1	0.6	5.4	0.4
Stubbs Island	Legal	34	62.8	1.1	103.9	4.8
	Sublegal-Mature	79	39.3	1.0	32.4	2.0
	Sublegal-Immature	21	19.0	1.0	4.7	0.4
Plumper Islands	Legal	24	61.2	1.1	99.1	4.9
	Sublegal-Mature	124	39.7	0.7	35.2	1.5
	Sublegal-Immature	4	14.5	3.4	3.5	1.8

Table 10b. Means and standard errors (SE) of test diameter (TD) (using field survey data) and weight (using TD-total wet weight relationships from November, 1996 lab measurements and applying to February, 1997 field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites during the February, 1997 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = size unknown).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	299	59.2	0.5	83.9	1.0
	Sublegal-Mature	1095	41.7	0.2	36.9	0.5
	Sublegal-Immature	77	18.1	0.5	5.0	0.3
Stephenson Islets	Legal	241	58.5	0.3	81.2	0.9
	Sublegal-Mature	892	42.2	0.2	37.8	0.5
	Sublegal-Immature	52	18.1	0.6	4.9	0.4
Stubbs Island	Legal	34	62.8	1.1	97.7	4.2
	Sublegal-Mature	79	39.3	1.0	32.7	1.9
	Sublegal-Immature	21	19.0	1.0	5.4	0.5
Plumper Islands	Legal	24	61.2	1.1	91.2	4.4
	Sublegal-Mature	124	39.7	0.7	32.8	1.3
	Sublegal-Immature	4	14.5	3.4	3.3	1.7

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 February, 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 3 to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transects 20 to 24).

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3	57	1.16	3.14	0.14	0.00	4.44
5A	22	0.73	4.09	0.18	0.18	5.18
6	20	0.35	0.50	0.10	0.00	0.95
7	64	1.02	1.91	0.06	0.00	2.98
8	17	0.00	0.24	0.00	0.00	0.24
9	38	0.47	5.05	0.24	0.00	5.76
10A	16	1.06	3.81	0.75	0.00	5.63
11B	19	0.74	0.79	0.00	0.00	1.53
13	27	0.85	3.41	0.19	0.00	4.44
14	44	0.34	2.89	0.18	0.00	3.41
Stephenson Islets Totals	324	0.74 ± 0.13	2.75 ± 0.43	0.16 ± 0.04	0.01	3.67 ± 0.47
15	22	0.36	2.77	0.86	0.05	4.05
17	31	0.58	0.58	0.06	0.00	1.23
18	15	0.53	0.00	0.00	0.00	0.53
Stubbs Island Totals	68	0.50 ± 0.07	1.16 ± 0.78	0.31 ± 0.27	0.01	1.99 ± 1.00
20	35	0.29	0.89	0.03	0.00	1.20
21	26	0.38	2.54	0.00	0.00	2.92
23	22	0.05	1.14	0.14	0.00	1.32
24	21	0.14	0.10	0.00	0.00	0.24
Plumper Islands Totals	104	0.23 ± 0.07	1.19 ± 0.48	0.04 ± 0.03	0.00	1.46 ± 0.52
OVERALL TOTAL	496	0.60 ± 0.10	2.21 ± 0.36	0.16 ± 0.04	0.01	2.98 ± 0.43

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 February, 1997 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
-9.4 to -5.0	-2.9 to -1.5	7	0.00	0.00	0.00	0.00
-4.9 to 0.0	-1.5 to 0.0	30	0.70	1.43	0.00	2.13 ± 0.65
0.1 to 5.0	0.1 to 1.5	43	1.02	3.07	0.02	4.12 ± 0.77
5.1 to 10.0	1.5 to 3.0	64	0.69	3.11	0.00	3.80 ± 0.65
10.1 to 15.0	3.0 to 4.8	87	0.64	2.70	0.00	3.34 ± 0.49
15.1 to 20.0	4.8 to 6.1	85	0.55	1.53	0.00	2.08 ± 0.30
20.1 to 25.0	6.1 to 7.6	99	0.60	2.41	0.00	3.01 ± 0.43
25.1 to 30.0	7.6 to 9.1	56	0.45	2.77	0.02	3.23 ± 0.47
30.1 to 35.0	9.1 to 10.7	24	0.13	1.50	0.13	1.75 ± 0.46
35.1 to 35.9	10.7 to 10.9	1	0.00	3.00	0.00	3.00 ± 0.00

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 February, 1997 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
-9.4 to -5.0	-2.9 to -1.5	1	0.00	0.00	0.00	0.00
-4.9 to 0.0	-1.5 to 0.0	13	1.46	2.38	0.00	3.85 ± 1.28
0.1 to 5.0	0.1 to 1.5	19	1.63	5.05	0.00	6.68 ± 1.31
5.1 to 10.0	1.5 to 3.0	30	0.93	4.10	0.00	5.03 ± 0.92
10.1 to 15.0	3.0 to 4.8	57	0.91	3.86	0.00	4.77 ± 0.67
15.1 to 20.0	4.8 to 6.1	59	0.68	1.86	0.00	2.54 ± 0.40
20.1 to 25.0	6.1 to 7.6	82	0.57	2.57	0.00	3.15 ± 0.48
25.1 to 30.0	7.6 to 9.1	45	0.49	2.84	0.02	3.36 ± 0.54
30.1 to 35.0	9.1 to 10.7	17	0.12	1.29	0.18	1.59 ±0.40
35.1 to 35.9	10.7 to 10.9	1	0.00	3.00	0.00	3.00 ± 0.00

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 February, 1997 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
-8.4 to -5.0	-2.6 to -1.5	2	0.00	0.00	0.00	0.00
-4.9 to 0.0	-0.3 to 0.0	7	0.00	0.29	0.00	0.29 ± 0.29
0.1 to 5.0	0.1 to 1.5	9	0.89	2.78	0.11	3.78 ± 1.52
5.1 to 10.0	1.5 to 3.0	13	0.15	0.77	0.00	0.92 ± 0.54
10.1 to 15.0	3.0 to 4.8	10	0.30	0.00	0.00	0.30 ± 0.30
15.1 to 20.0	4.8 to 6.1	9	0.78	0.78	0.00	1.56 ± 0.44
20.1 to 25.0	6.1 to 7.6	9	1.11	2.22	0.00	3.33 ± 1.52
25.1 to 30.0	7.6 to 9.1	6	0.50	4.00	0.00	4.50 ± 1.41
30.1 to 31.6	9.1 to 9.6	3	0.33	4.00	0.00	4.33 ± 2.60

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 February, 1997 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
-6.9 to -5.0	-2.1 to -1.5	4	0.00	0.00	0.00	0.00
-4.9 to 0.0	-1.5 to 0.0	10	0.20	1.00	0.00	1.20 ± 0.66
0.1 to 5.0	0.1 to 1.5	15	0.33	0.73	0.00	1.07 ± 0.50
5.1 to 10.0	1.5 to 3.0	21	0.67	3.14	0.00	3.81 ± 1.34
10.1 to 15.0	3.0 to 4.8	20	0.05	0.75	0.00	0.80 ± 0.36
15.1 to 20.0	4.8 to 6.1	17	0.00	0.76	0.00	0.76 ± 0.34
20.1 to 25.0	6.1 to 7.6	8	0.25	1.00	0.00	1.25 ± 0.75
25.1 to 30.0	7.6 to 9.1	5	0.00	0.60	0.00	0.60 ± 0.40
30.1 to 31.5	9.1 to 9.6	4	0.00	0.50	0.00	0.50 ± 0.50

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 February, 1997 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
100	Bedrock (smooth)	40	0.35	2.45	0.00	2.80	
130	Bedrock (smooth)/boulders	6	0.67	2.67	0.00	3.33	
140	Bedrock (smooth)/cobble	3	0.67	2.33	0.00	3.00	2.76 ± 0.66
143	Bedrock (smooth)/cobble/ boulders	1	0.00	0.00	0.00	0.00	
180	Bedrock (smooth)/shell	1	0.00	0.00	0.00	0.00	
200	Bedrock (crevices)	294	0.70	2.55	0.00	3.25	
230	Bedrock (crevices)/boulders	25	0.64	1.32	0.00	1.96	
234	Bedrock (crevices)/boulders/ cobble	2	1.50	5.50	0.00	7.00	
238	Bedrock (crevices)/boulders/ shell	2	0.00	3.50	0.00	3.50	3.20 ± 0.23
240	Bedrock (crevices)/cobble	3	0.00	5.33	0.00	5.33	
248	Bedrock (crevices)/cobble/ shell	2	0.50	8.50	0.00	9.00	
280	Bedrock (crevices)/shell	11	0.45	1.91	0.00	2.36	
300	Boulders	67	0.45	1.81	0.04	2.30	
310	Boulders/bedrock (smooth)	1	1.00	0.00	0.00	1.00	
320	Boulders/bedrock (crevices)	4	0.25	2.25	0.00	2.50	
328	Boulders/bedrock (crevices)/ shell	1	0.00	5.00	0.00	5.00	
340	Boulders/cobble	17	0.76	2.29	0.06	3.12	2.52 ± 0.33
345	Boulders/cobble/gravel	2	0.00	0.50	0.00	0.50	
348	Boulders/cobble/shell	1	0.00	3.00	0.00	3.00	
380	Boulders/shell	1	0.00	5.00	0.00	5.00	
382	Boulders/shell/ bedrock (crevices)	1	2.00	5.00	0.00	7.00	
400	Cobble	6	0.00	0.17	0.00	0.17	1.13 ± 0.99
430	Cobble/boulders	2	1.00	2.50	0.50	4.00	
680	Pea gravel/shell	2	0.00	0.00	0.00	0.00	0.67 ± 0.67
683	Pea gravel/shell/boulders	1	0.00	2.00	0.00	2.00	

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 February, 1997 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
100	Bedrock (smooth)	26	0.54	3.58	0.00	4.12	
130	Bedrock (smooth)/boulders	6	0.67	2.67	0.00	3.33	3.89 ± 0.90
140	Bedrock (smooth)/cobble	3	0.67	2.33	0.00	3.00	
200	Bedrock (crevices)	179	0.93	3.53	0.00	4.46	
230	Bedrock (crevices)/boulders	23	0.61	1.35	0.00	1.96	
234	Bedrock (crevices)/boulders/ cobble	1	2.00	2.00	0.00	4.00	4.16 ± 0.32
240	Bedrock (crevices)/cobble	1	0.00	3.00	0.00	3.00	
280	Bedrock (crevices)/shell	1	0.00	1.00	0.00	1.00	
300	Boulders	63	0.41	1.86	0.05	2.32	
340	Boulders/cobble	14	0.86	2.29	0.07	3.21	
345	Boulders/cobble/gravel	1	0.00	0.00	0.00	0.00	2.49 ± 0.37
348	Boulders/cobble/shell	1	0.00	3.00	0.00	3.00	
380	Boulders/shell	1	0.00	5.00	0.00	5.00	
430	Cobble/boulders	1	0.00	0.00	0.00	0.00	0.00
680	Pea gravel/shell	2	0.00	0.00	0.00	0.00	0.67 ± 0.67
683	Pea gravel/shell/boulders	1	0.00	2.00	0.00	2.00	

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 February, 1997 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
143	Bedrock (smooth)/cobble/ Boulders	1	0.00	0.00	0.00	0.00	0.00
200	Bedrock (crevices)	48	0.54	0.46	0.00	1.00	
230	Bedrock (crevices)/boulders	1	0.00	0.00	0.00	0.00	
234	Bedrock (crevices)/boulders/ Cobble	1	1.00	9.00	0.00	10.00	
238	Bedrock (crevices)/boulders/ Shell	2	0.00	3.50	0.00	3.50	1.71 ± 0.42
240	Bedrock (crevices)/cobble	2	0.00	6.50	0.00	6.50	
248	Bedrock (crevices)/cobble/ Shell	2	0.50	8.50	0.00	9.00	
320	Boulders/bedrock (crevices)	4	0.25	2.25	0.00	2.50	
328	Boulders/bedrock (crevices)/ Shell	1	0.00	5.00	0.00	5.00	
340	Boulders/cobble	3	0.33	2.33	0.00	2.67	3.10 ± 0.86
345	Boulders/cobble/gravel	1	0.00	1.00	0.00	1.00	
382	Boulders/shell/ Bedrock (crevices)	1	2.00	5.00	0.00	7.00	
430	Cobble/boulders	1	2.00	5.00	1.00	8.00	8.00 ± 0.00

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 February, 1997 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
100	Bedrock (smooth)	14	0.00	0.36	0.00	0.36	0.33 ± 0.16
180	Bedrock (smooth)/shell	1	0.00	0.00	0.00	0.00	
200	Bedrock (crevices)	67	0.18	1.43	0.00	1.61	
230	Bedrock (crevices)/boulders	1	2.00	2.00	0.00	4.00	1.76 ± 0.42
280	Bedrock (crevices)/shell	10	0.50	2.00	0.00	2.50	
300	Boulders	4	1.00	1.00	0.00	2.00	1.80 ± 1.32
310	Boulders/bedrock (smooth)	1	1.00	0.00	0.00	1.00	
400	Cobble	6	0.00	0.17	0.00	0.17	0.17 ± 0.17

Table 14. Summary results of gonad sampling during the February, 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; SEX: 1=male, 2=female, 3=juvenile or unknown).

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			19	48	3	13	13	1	12	21	1
Mean Test Height (mm) ± SE			29.89 (± 0.55)	21.48 (± 0.64)	9.33 (± 1.86)	33.69 (± 1.55)	24.38 (± 1.27)	11.00 (± 0.00)	30.58 (± 1.22)	18.38 (± 1.07)	13.00 (± 0.00)
Mean Test Diameter (mm) ± SE			59.11 (± 0.74)	43.44 (± 1.00)	20.33 (± 2.19)	64.62 (± 1.53)	47.69 (± 1.69)	24.00 (± 0.00)	62.17 (± 1.64)	38.19 (± 1.99)	24.00 (± 0.00)
Mean Total Wet Weight (g) ± SE			88.40 (± 3.06)	41.92 (± 2.33)	6.83 (± 1.14)	109.71 (± 7.34)	50.62 (± 4.49)	8.50 (± 0.00)	104.98 (± 9.62)	32.40 (± 4.21)	11.80 (± 0.00)
Mean Drained Weight (g) ± SE			71.08 (± 3.24)	33.68 (± 1.84)	6.03 (± 0.60)	88.78 (± 5.27)	42.53 (± 3.84)	8.20 (± 0.00)	85.37 (± 9.03)	28.98 (± 3.79)	10.70 (± 0.00)
Mean Gutted Weight (g) ± SE			63.11 (± 2.88)	29.12 (± 1.61)	4.77 (± 0.62)	81.05 (± 4.79)	37.73 (± 3.37)	6.10 (± 0.00)	76.63 (± 8.36)	25.91 (± 3.54)	8.30 (± 0.00)
Sex (%)	Male		47	31	0.00	38	46	0	17	43	0
	Female		53	58	0.00	62	46	0	83	43	0
	Unknown		0	10	100	0	8	100	0	14	100
Gonad	Mean Weight (g) ± SE		19.52 (± 1.87)	6.01 (± 0.62)	0.23 (± 0.23)	26.61 (± 1.98)	8.31 (± 1.20)	0.00	24.24 (± 3.83)	5.76 (± 1.23)	0.00
	Colour Proportion	0	0.00	0.04	0.67	0.00	0.08	1.00	0.00	0.14	1.00
		1	0.42	0.29	0.33	0.62	0.38	0.00	0.75	0.67	0.00
		2	0.42	0.48	0.00	0.31	0.38	0.00	0.17	0.19	0.00
		3	0.16	0.19	0.00	0.08	0.15	0.00	0.08	0.00	0.00
	Texture Proportion	0	0.00	0.04	0.67	0.00	0.08	1.00	0.00	0.14	1.00
		1	0.26	0.13	0.00	0.15	0.23	0.00	0.67	0.19	0.00
		2	0.63	0.69	0.33	0.85	0.62	0.00	0.17	0.67	0.00
		3	0.11	0.15	0.00	0.00	0.08	0.00	0.17	0.00	0.00

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

Size Category	Stephenson Islets	Stubbs Island	Plumper Islands
Number of Legal-sized	360,905 ± 61,864	9,800 ± 1,390	51,600 ± 15,648
Number of Sublegal-mature	1,335,798 ± 210,692	22,771 ± 15,324	266,600 ± 107,426
Number of Sublegal-immature	77,872 ± 19,828	6,053 ± 5,328	8,600 ± 6,286
Number of Unknown	5,990 ± 6,284	288 ± 298	0
Number of all sizes	1,780,564 ± 227,951	38,912 ± 19,601	326,800 ± 116,387
Biomass of Legal-size (t)	29.79 ± 5.11	1.02 ± 0.15	5.12 ± 1.56
Biomass of Sublegal-mature (t)	52.32 ± 8.30	0.74 ± 0.50	9.39 ± 3.80
Biomass of Sublegal-immature (t)	0.42 ± 0.11	0.03 ± 0.03	0.03 ± 0.03
Total Biomass (t)	82.52 ± 9.71	1.78 ± 0.52	14.54 ± 4.11

Table 15b. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site, in February, 1997 by size category. (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. Biomass estimates were calculated using TD-weight relationships determined from November, 1996 lab measurements for each of the three sites separately, and applied to the field survey TD measurements).

Size Category	Stephenson Islets	Stubbs Island	Plumper Islands
Biomass of Legal-size (t)	29.30 ± 5.11	0.96 ± 0.15	4.71 ± 1.56
Biomass of Sublegal-mature (t)	50.53 ± 8.30	0.75 ± 0.50	8.76 ± 3.80
Biomass of Sublegal-immature (t)	0.38 ± 0.11	0.03 ± 0.03	0.03 ± 0.03
Total Biomass (t)	80.22 ± 9.71	1.74 ± 0.52	13.49 ± 4.11

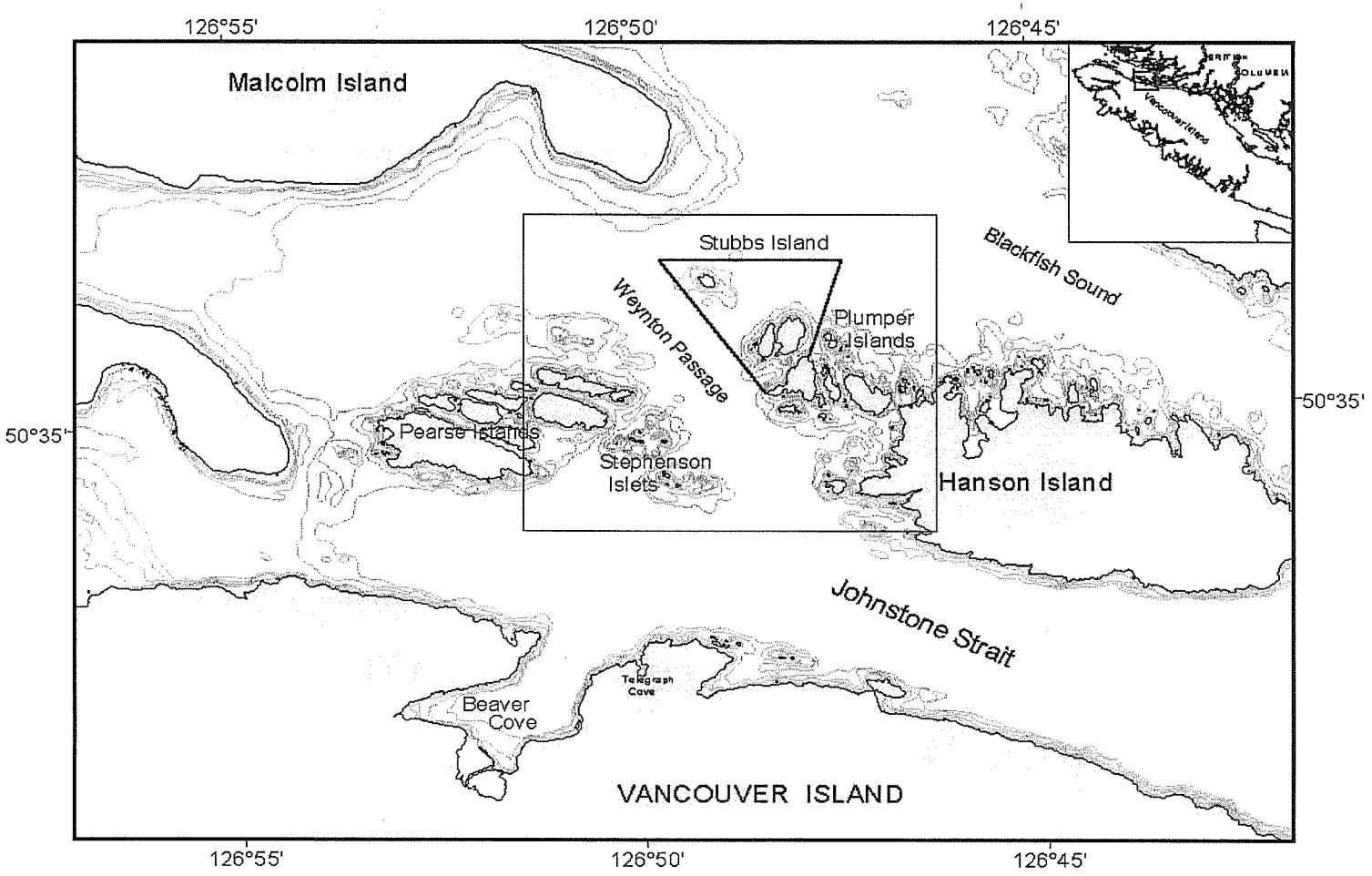

Fig. 1a. Site locations for the November, 1996 and February, 1997 green urchin surveys (Stephenson Islets, Stubbs Island and the Plumper Islands). The red border represents the boundaries of the research closure area. No commercial fishing may occur within these boundaries.

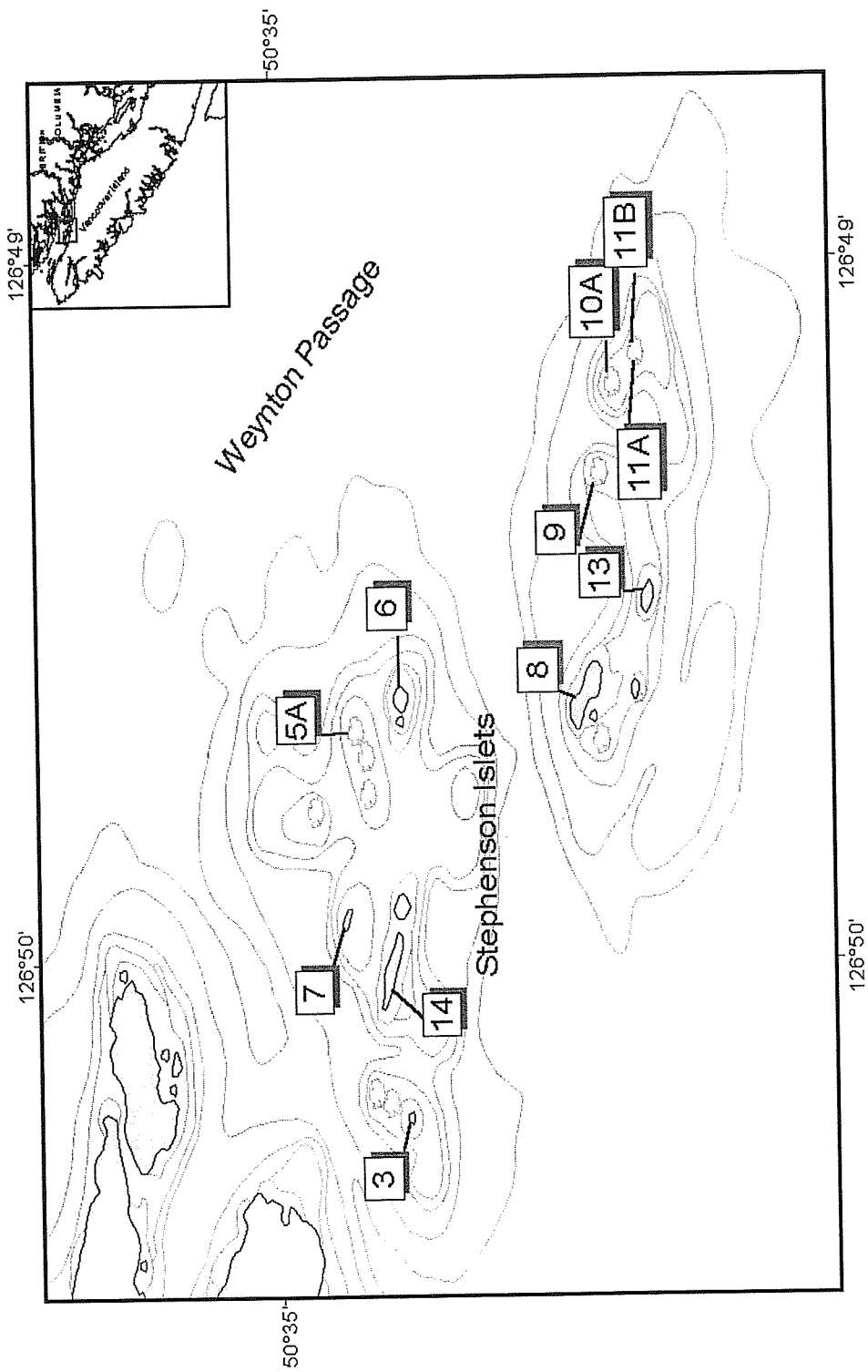

Fig. 1b. Transect locations (black lines) for the November, 1996 and February, 1997 green sea urchin surveys, Stephenson Islets.

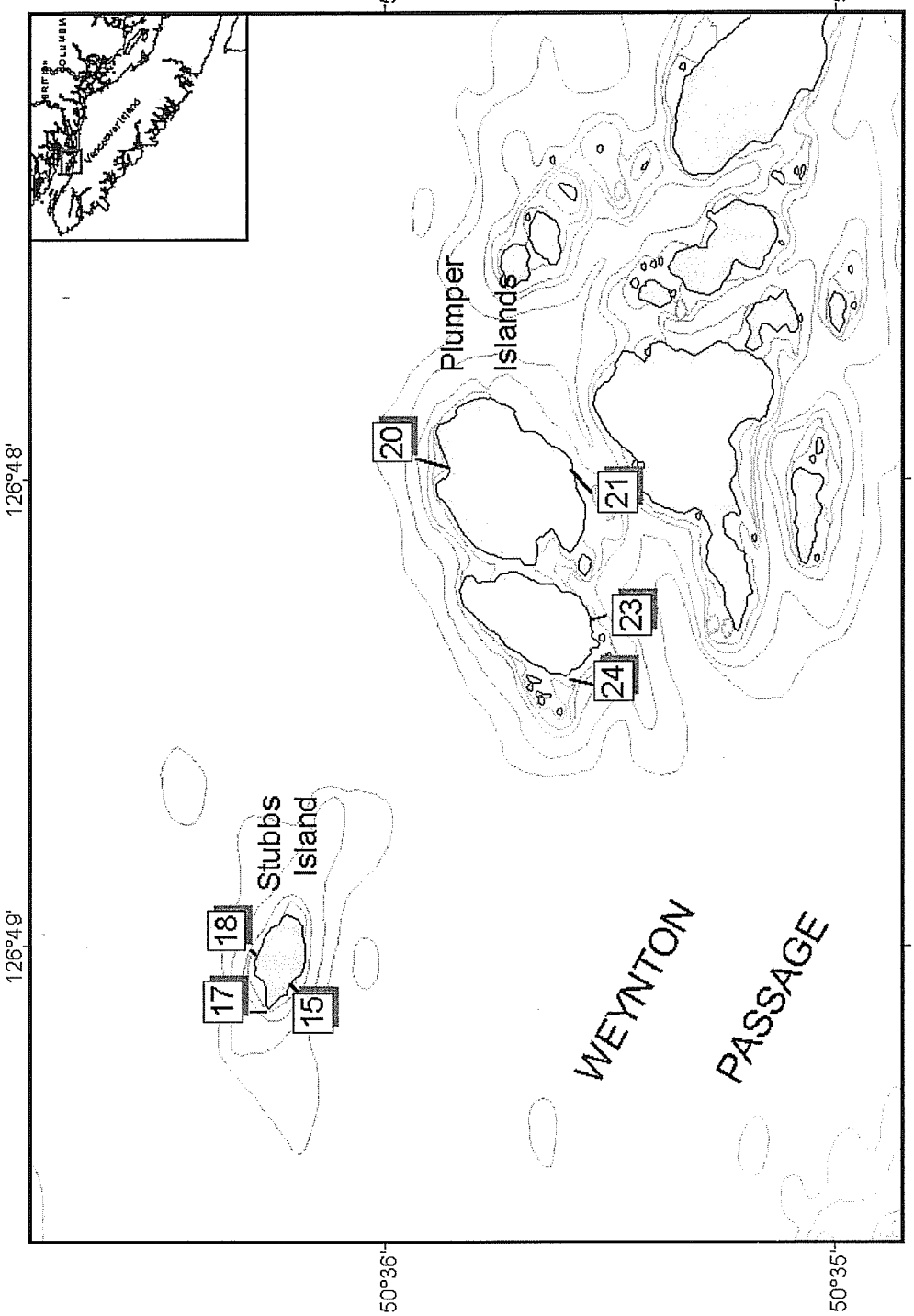

Fig. 1c. Transect locations (black lines) for the November, 1996 and February, 1997 green sea urchin surveys, Stubbs Island and the Plumper Islands.

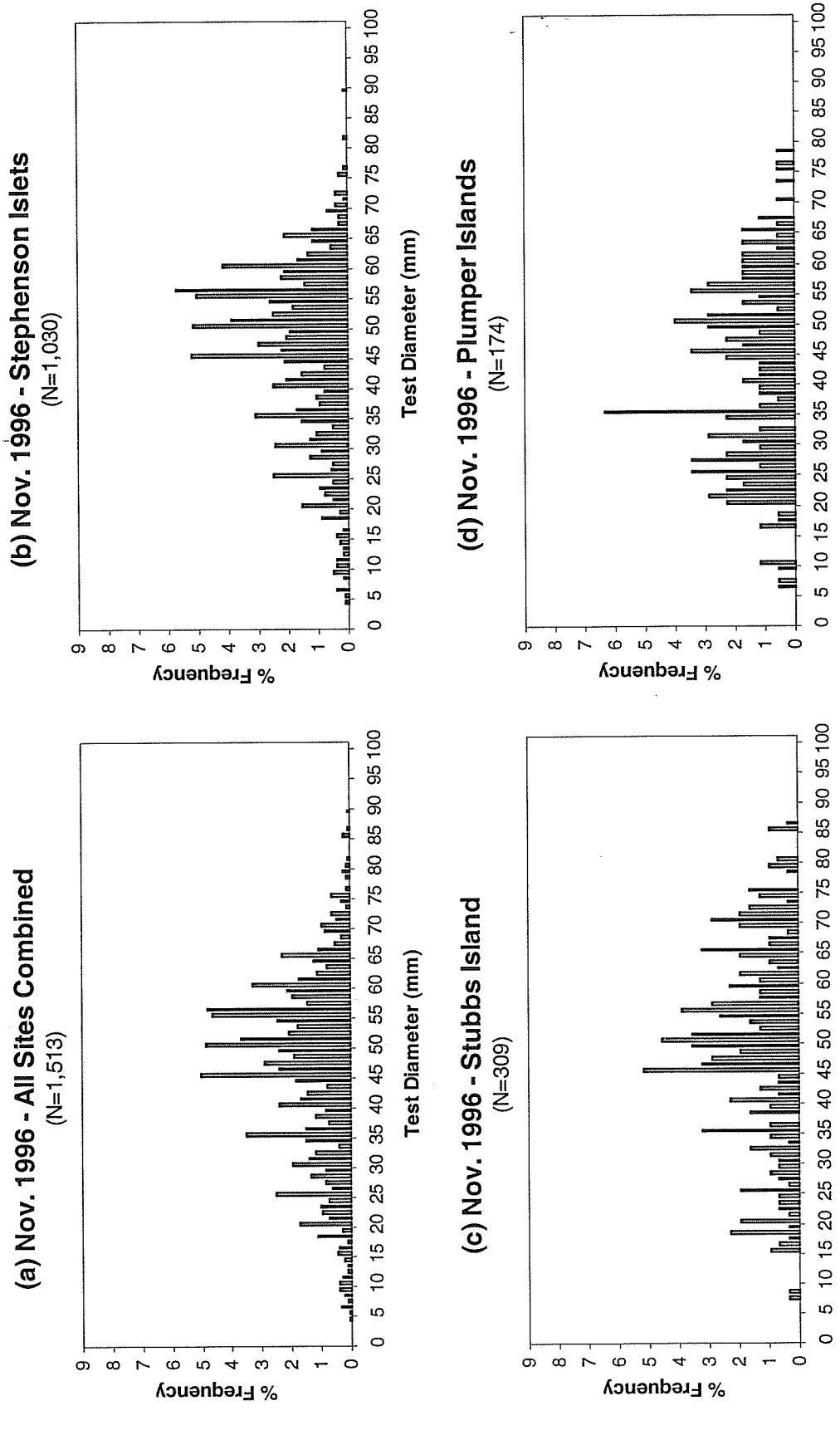

Fig. 2. Size (TD in millimeters) distribution of green sea urchins collected in November, 1996 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. (Note the size limit is 55 mm).

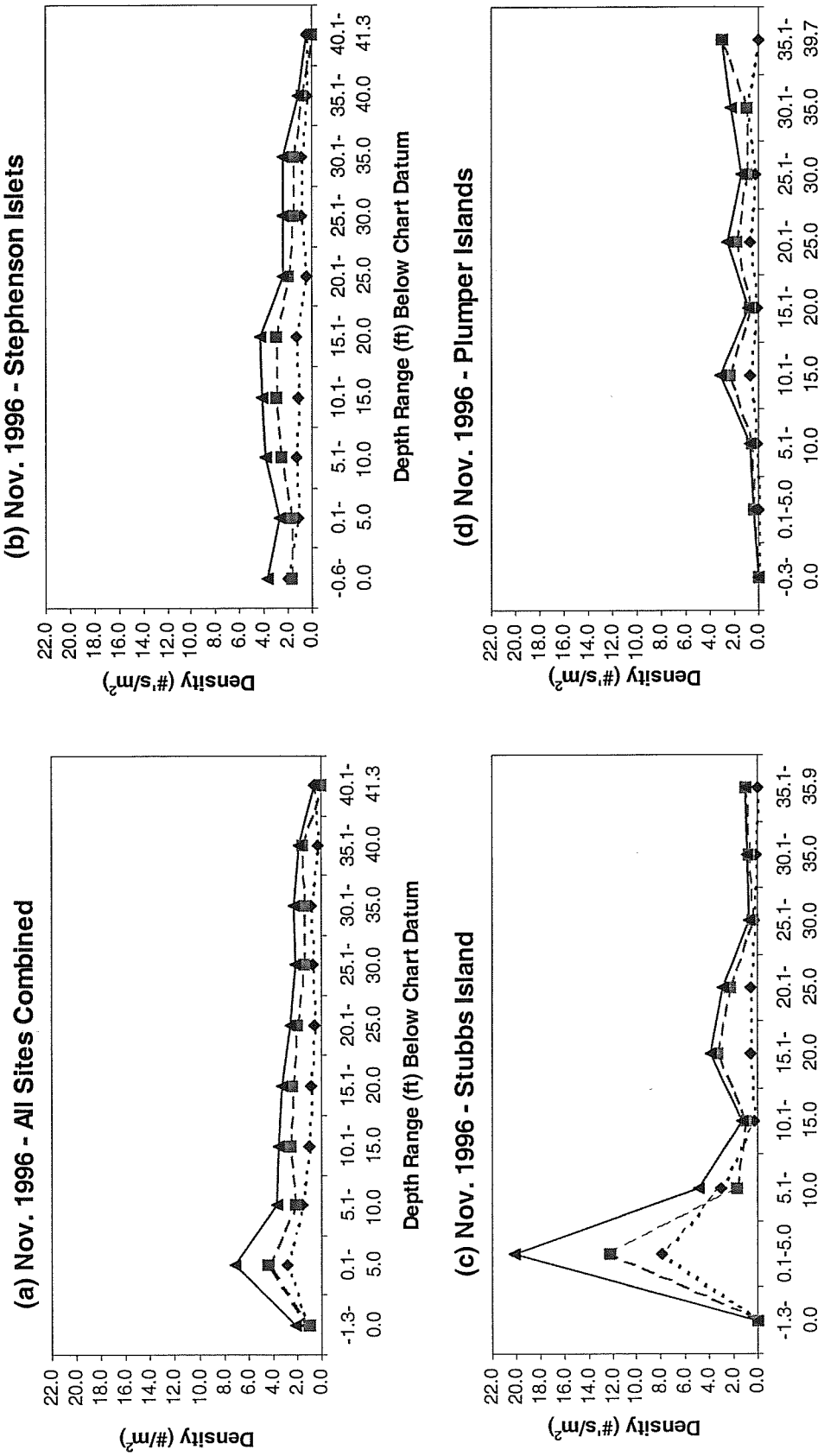

Fig. 3. November, 1996 mean densities (number per square meter) of green sea urchins of all sizes (total - triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. (Totals include urchins of unknown size (not presented separately)).

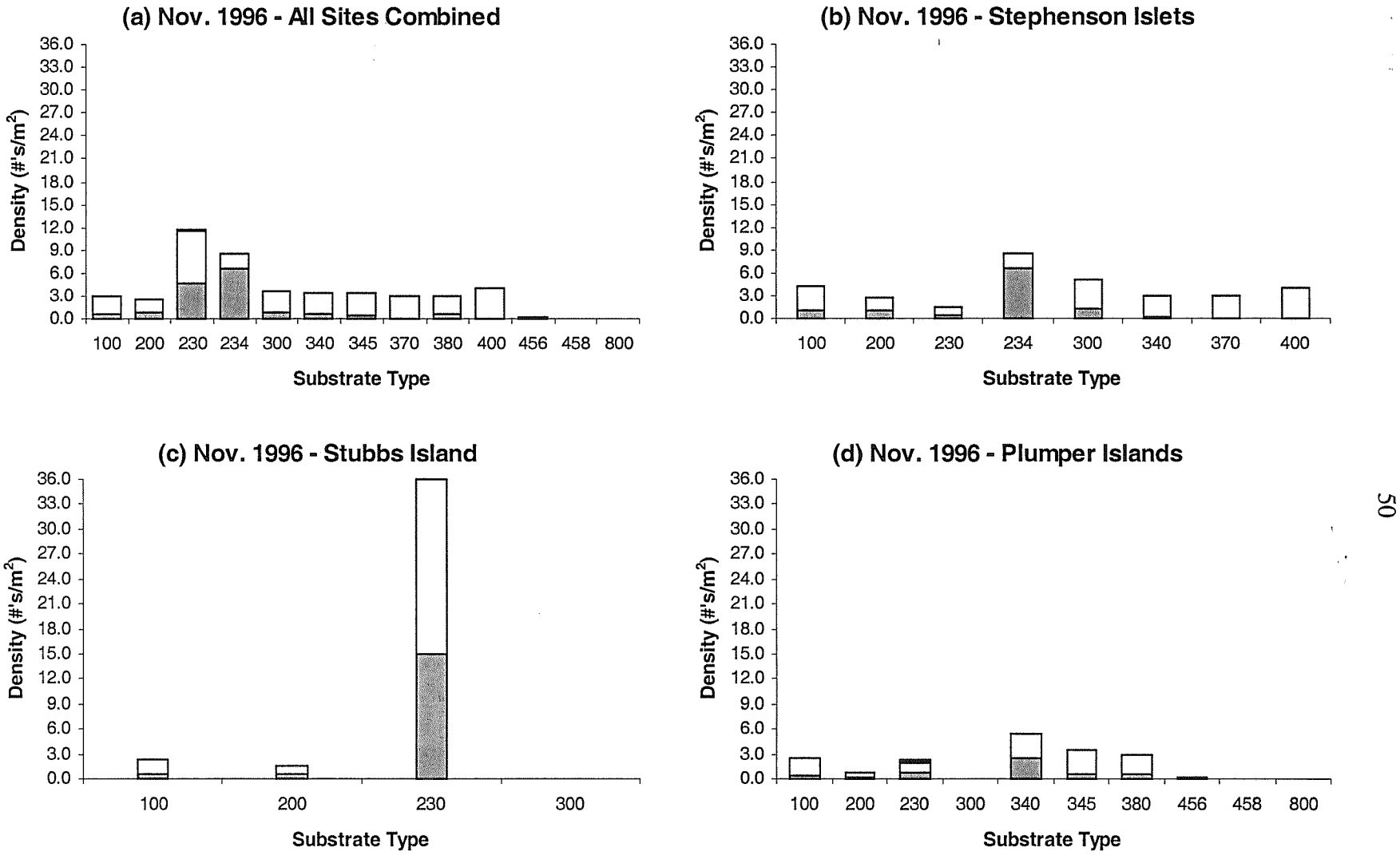

Fig. 4. November, 1996 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal size (white), and unknown size (black) by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 8a-d for the keys to the substrate codes.

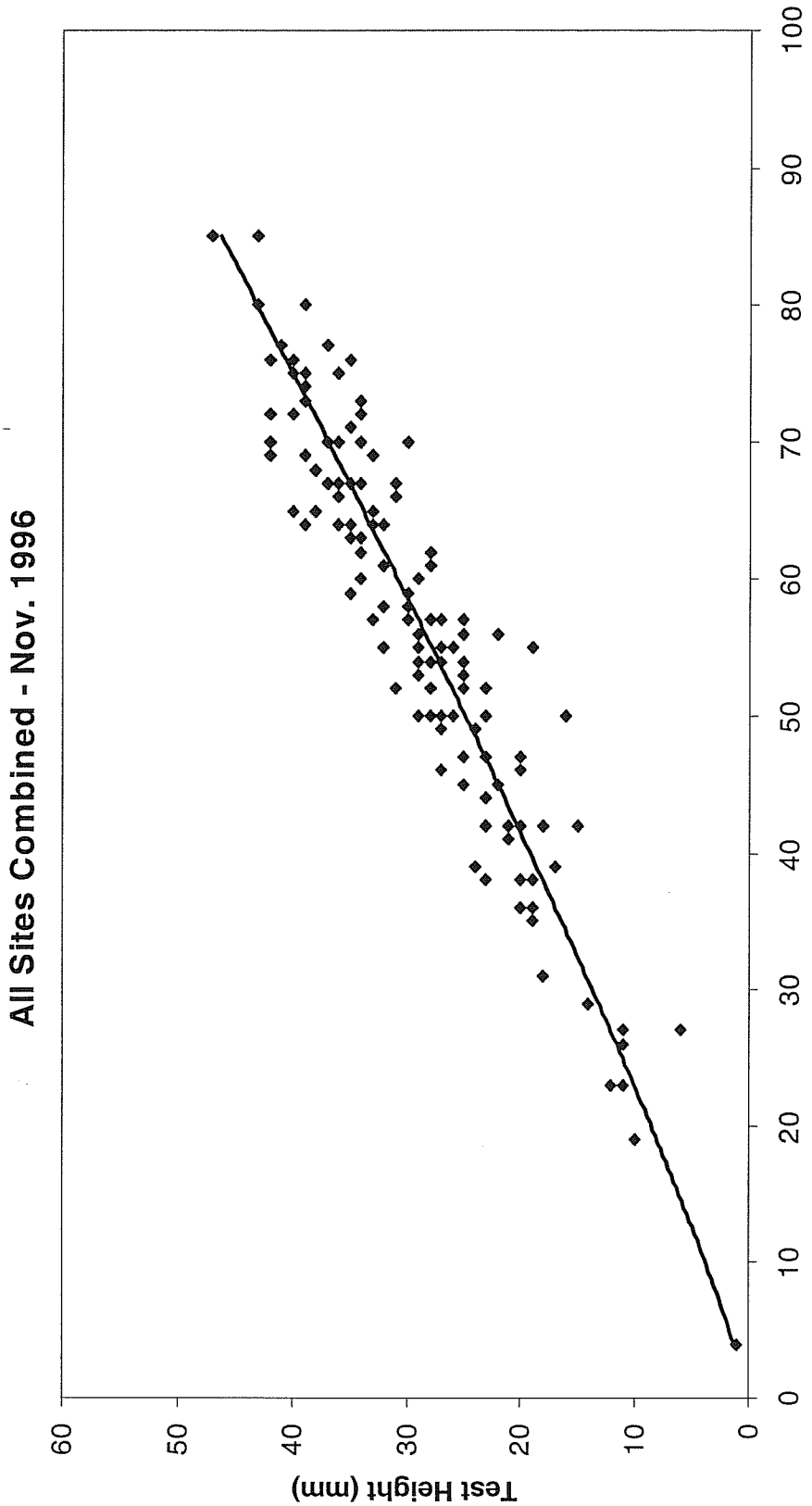

Fig. 5. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in November, 1996, all sites combined: TEST HEIGHT (mm) = $0.2539(TD^{1.1719})$, $R^2 = 0.9123$, n=128.

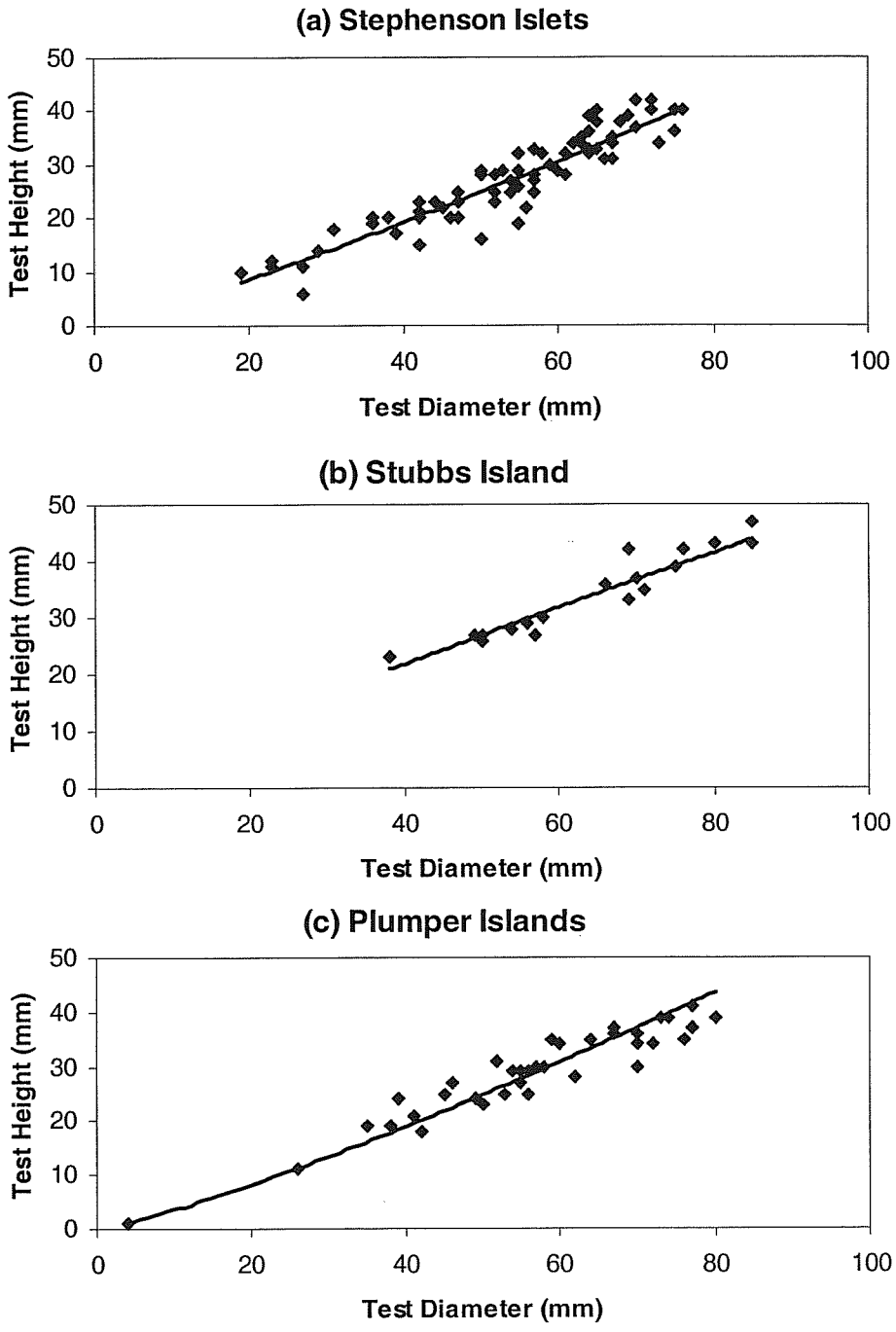

Fig. 6. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in November, 1996 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = $0.2748(TD^{1.1509})$, $R^2 = 0.8392$, n=73);
(b) Stubbs Island (TEST HEIGHT (mm) = $0.7230(TD^{0.9244})$, $R^2 = 0.9038$, n=19);
(c) Plumper Islands (TEST HEIGHT (mm) = $0.2248(TD^{1.2020})$, $R^2 = 0.9672$, n=36).

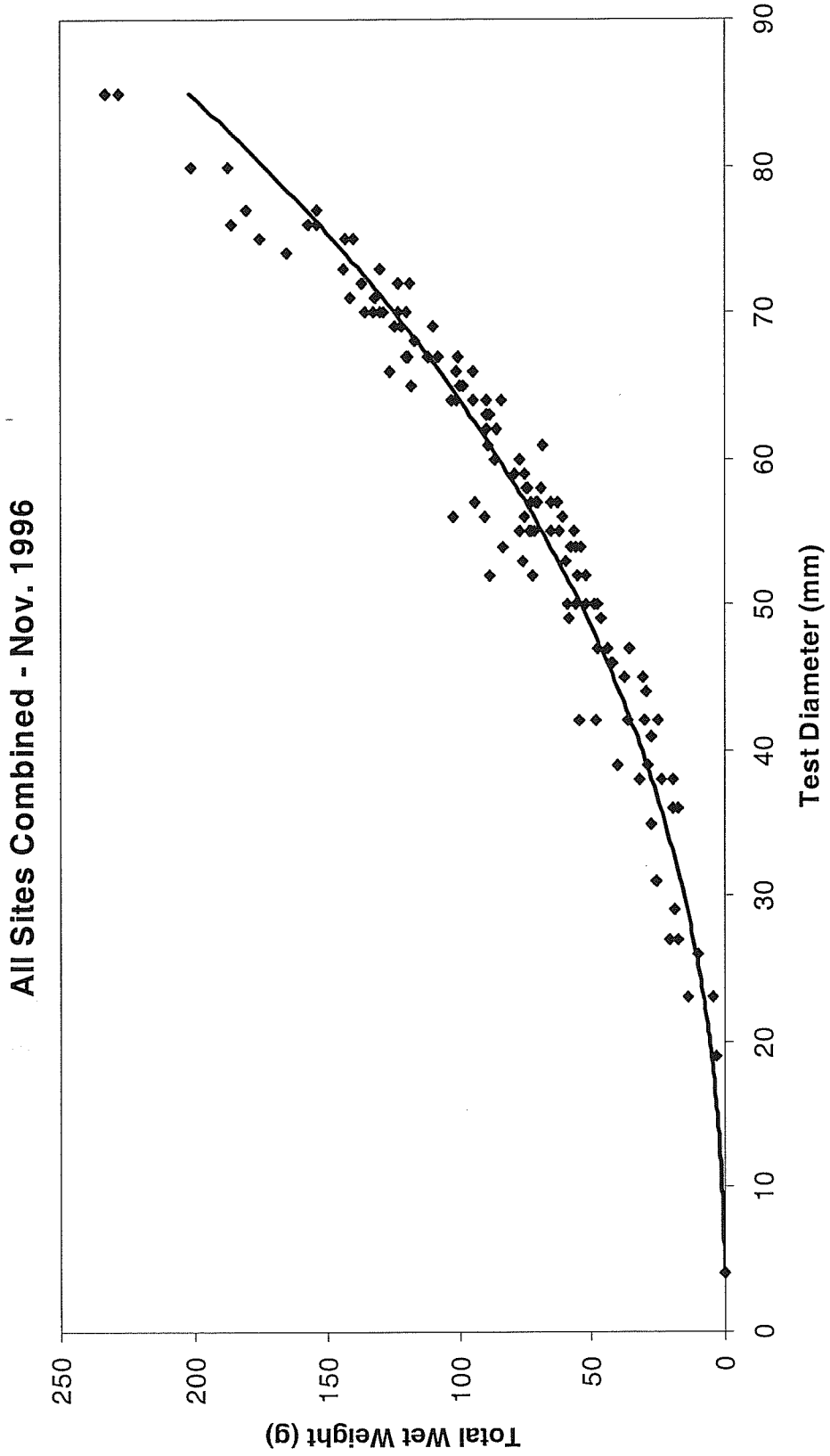

Fig. 7. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in November, 1996, calculated from all sites combined. TOTAL WET WEIGHT (g) = $0.0034(\text{TD}^{2.4756})$, $R^2 = 0.9626$, n=127.

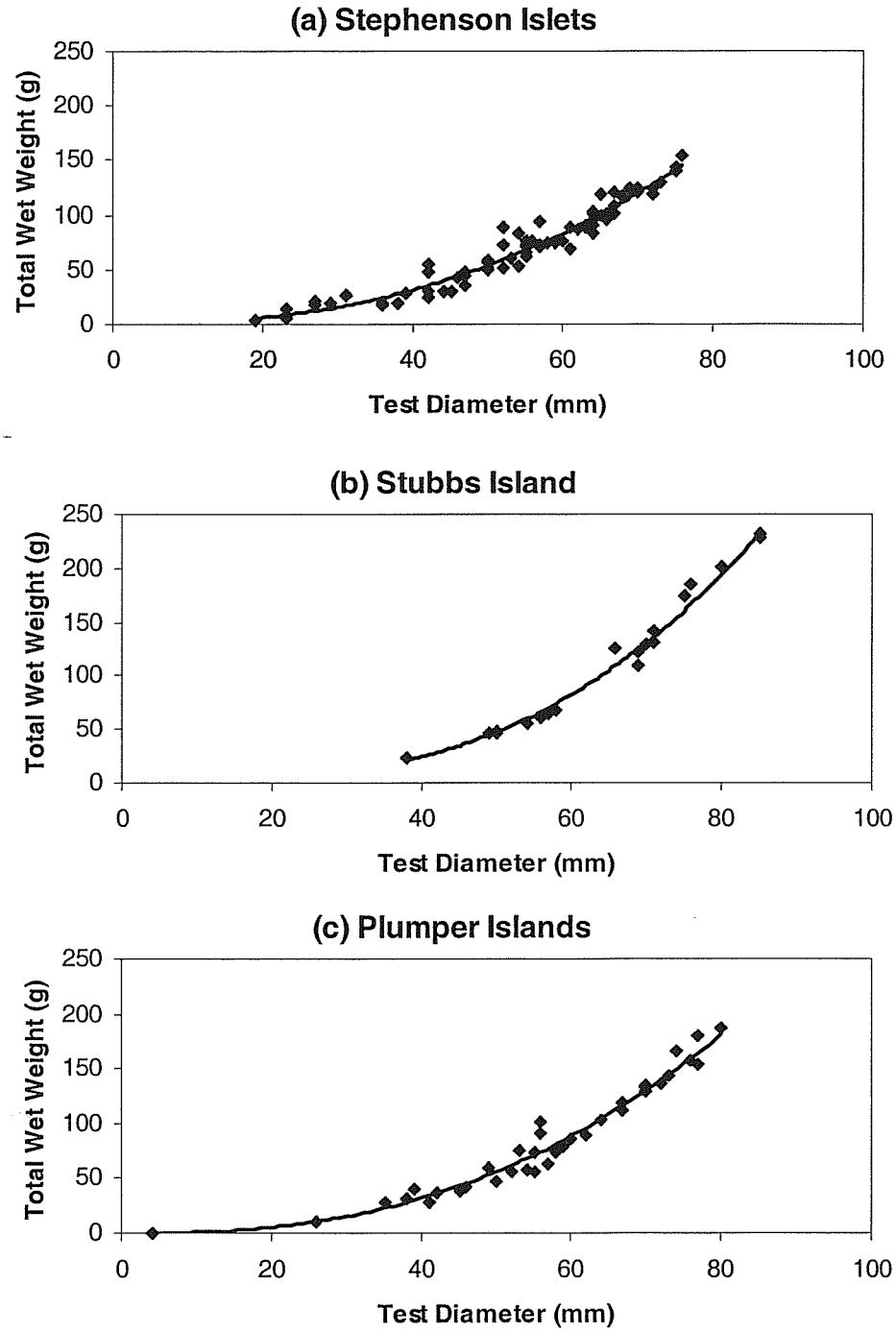

Fig. 8. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in November, 1996 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = $0.0049(TD^{2.3775})$, R^2=0.9243, n=72);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = $0.0004(TD^{2.9767})$, R^2=0.9858, n=19);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = $0.0031(TD^{2.5015})$, R^2=0.9896, n=36).

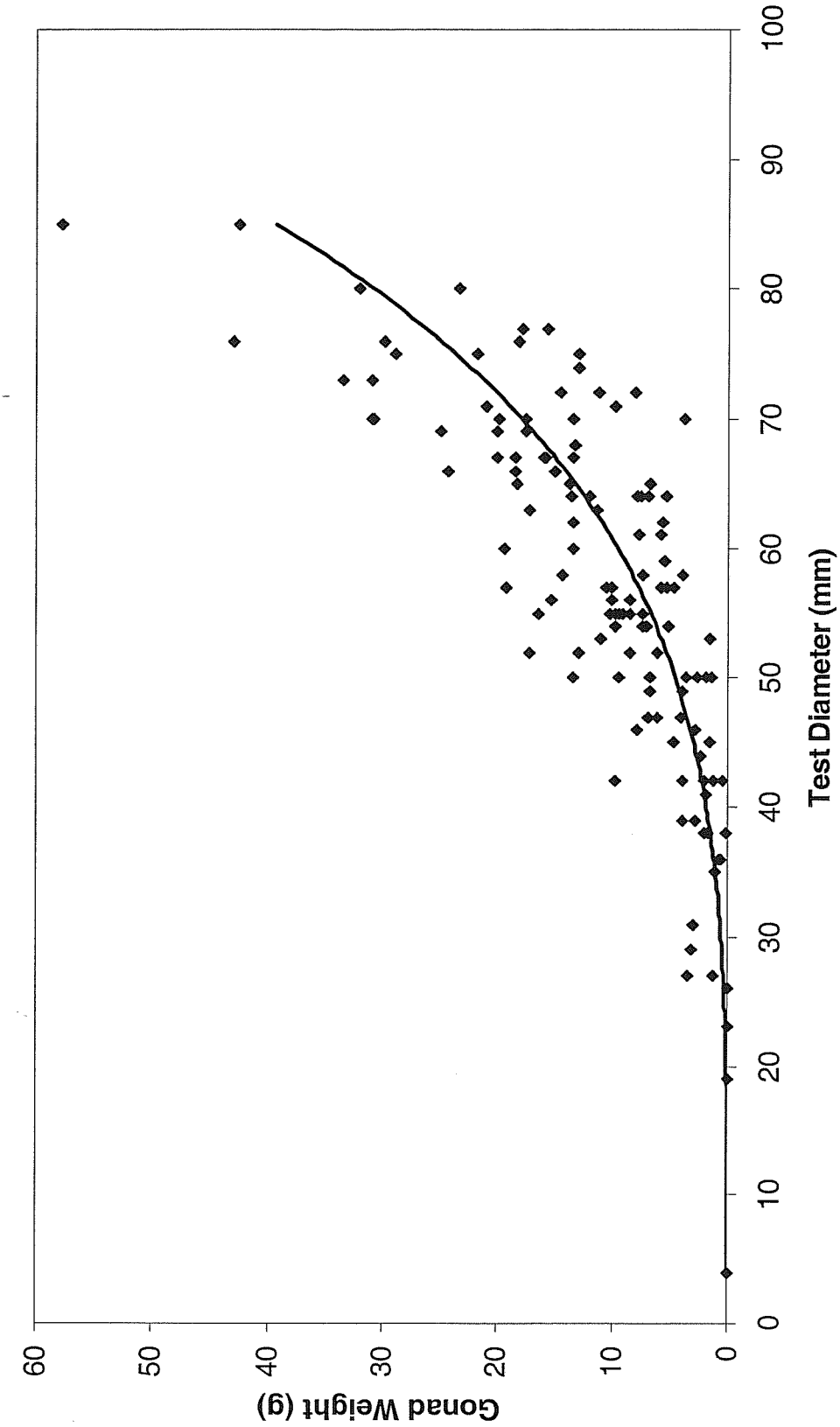

Fig. 9. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in November, 1996, calculated from all sites combined: GONAD WEIGHT (g) = $6 \times 10^{-7}(\text{TD}^{4.0623})$; $R^2 = 0.7616$, n = 128.

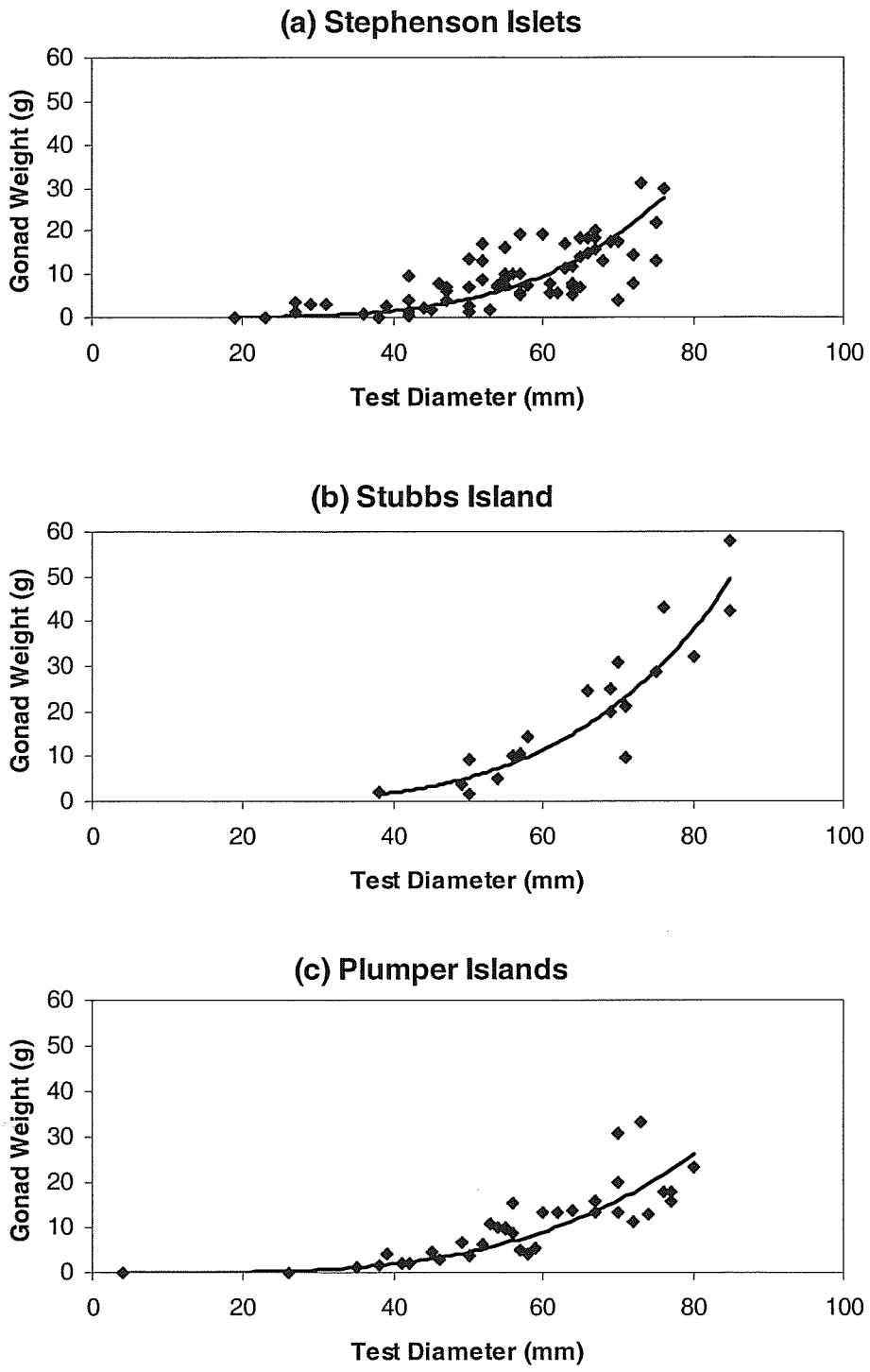

Fig. 10. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in November, 1996 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 1 x 10^{-7} ($TD^{4.4447}$), R^2 = 0.6750, n=72);
(b) Stubbs Island (GONAD WEIGHT (g) = 1 x 10^{-7} ($TD^{4.5107}$), R^2 = 0.8006, n=20);
(c) Plumper Islands (GONAD WEIGHT (g) = 2 x 10^{-6} ($TD^{3.6977}$), R^2 = 0.8611, n=36).

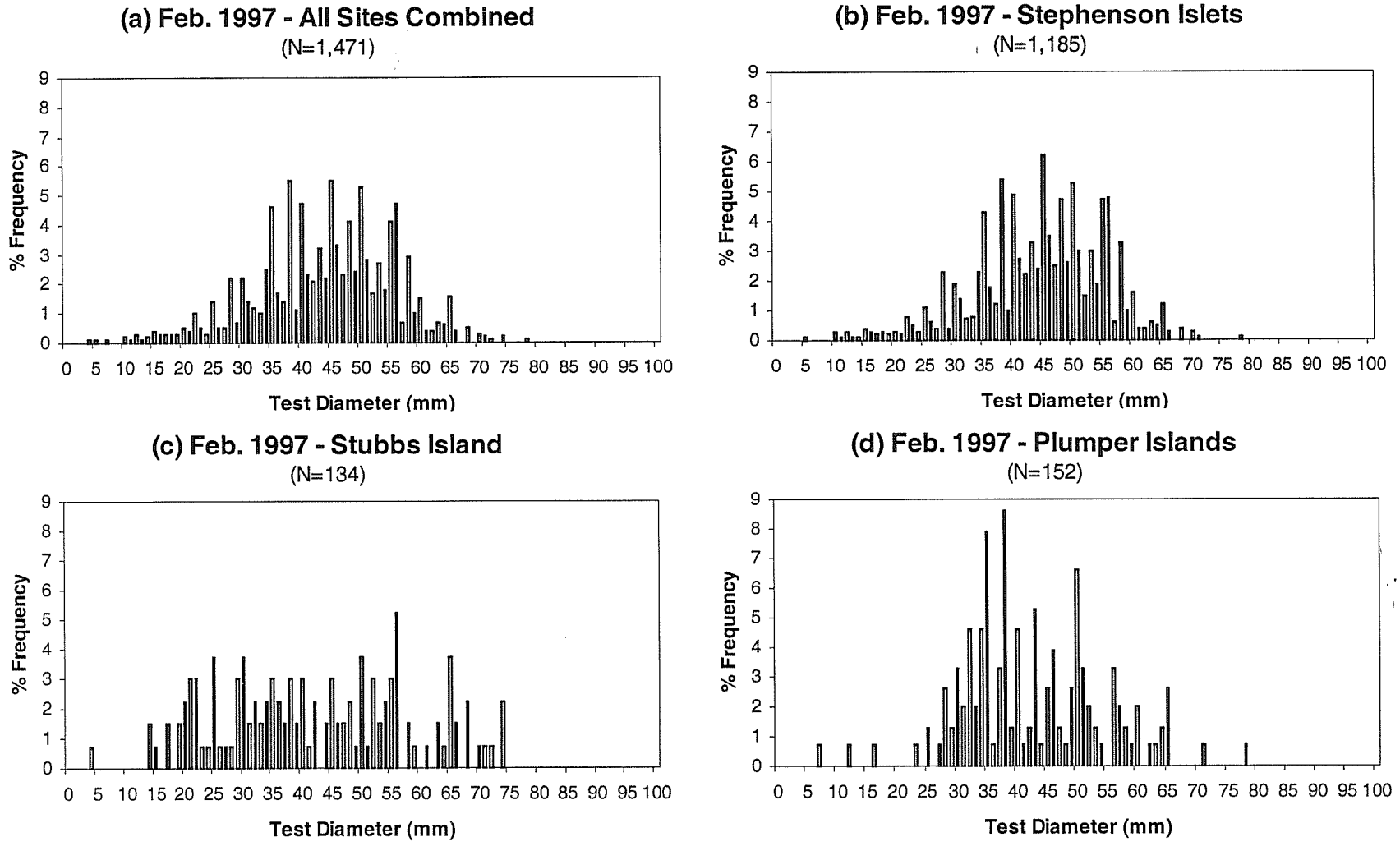

Fig. 11. Size (test diameter in millimeters) distributions of green sea urchins collected in February, 1997 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the legal size limit is 55 mm.

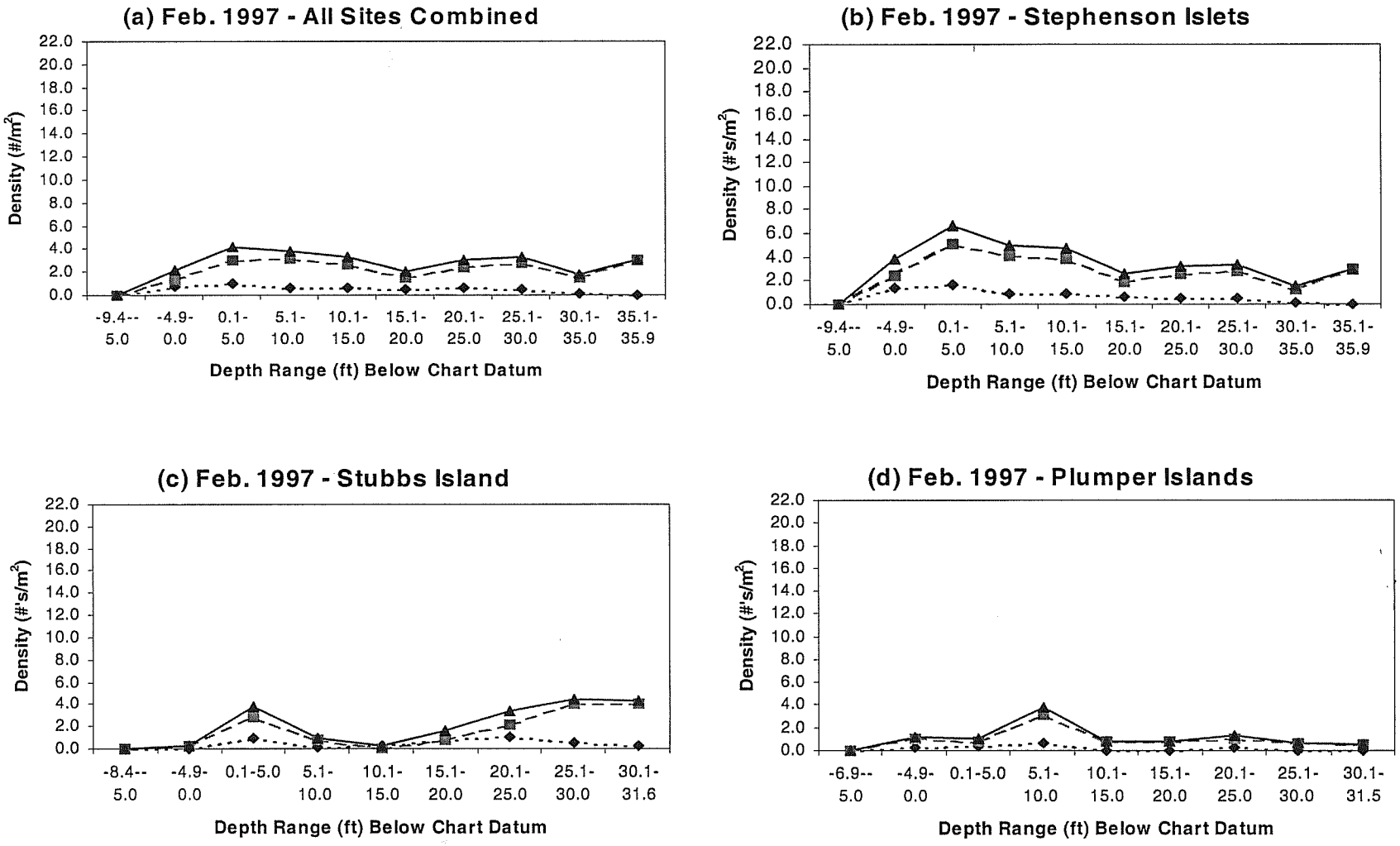

Fig. 12. February, 1997 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds) and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. (Totals include urchins of unknown size (not presented separately)).

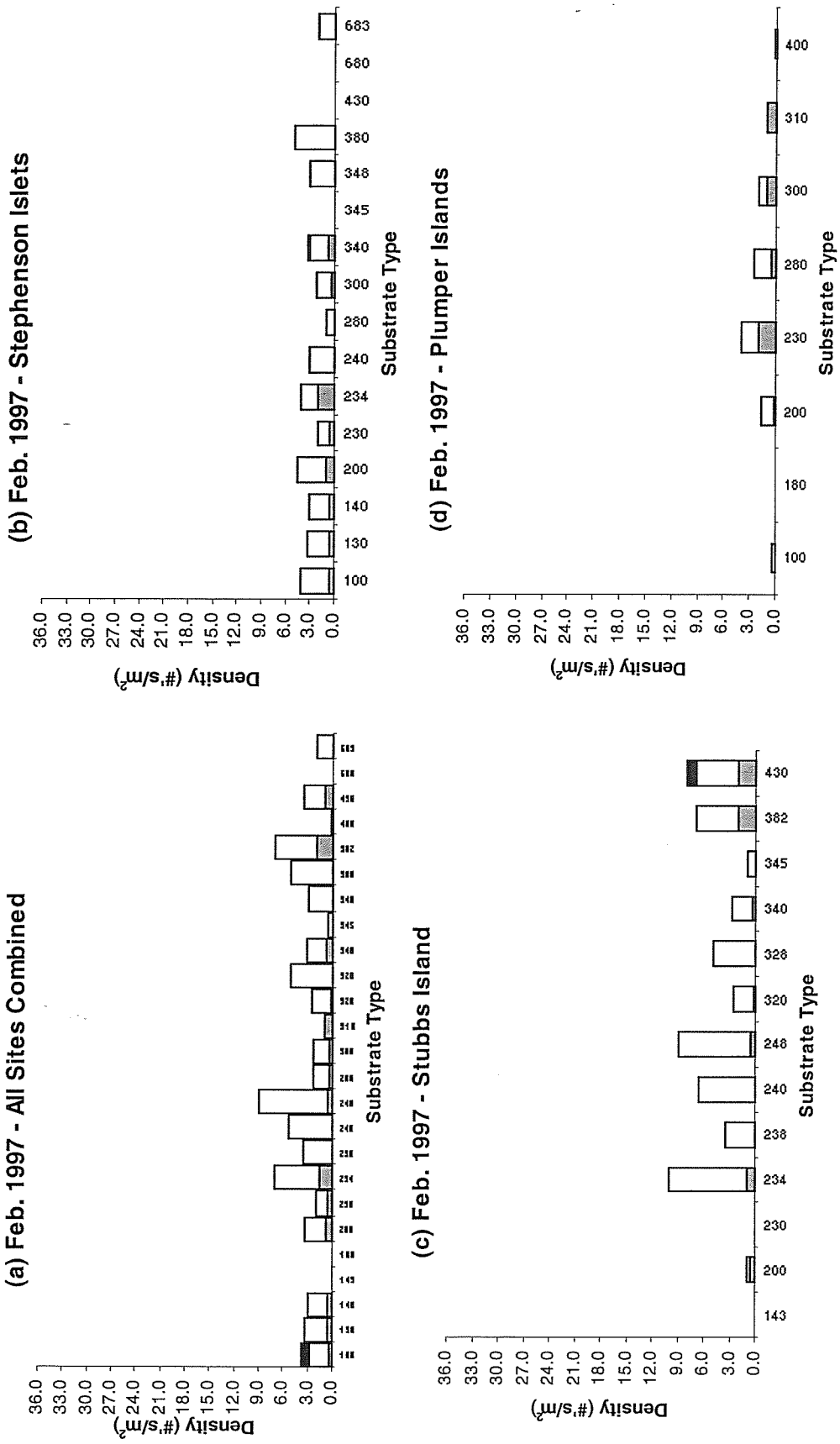

Fig. 13. February, 1997 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal (white), and unknown size (black) by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Table 15a-d for the keys to the substrate codes.

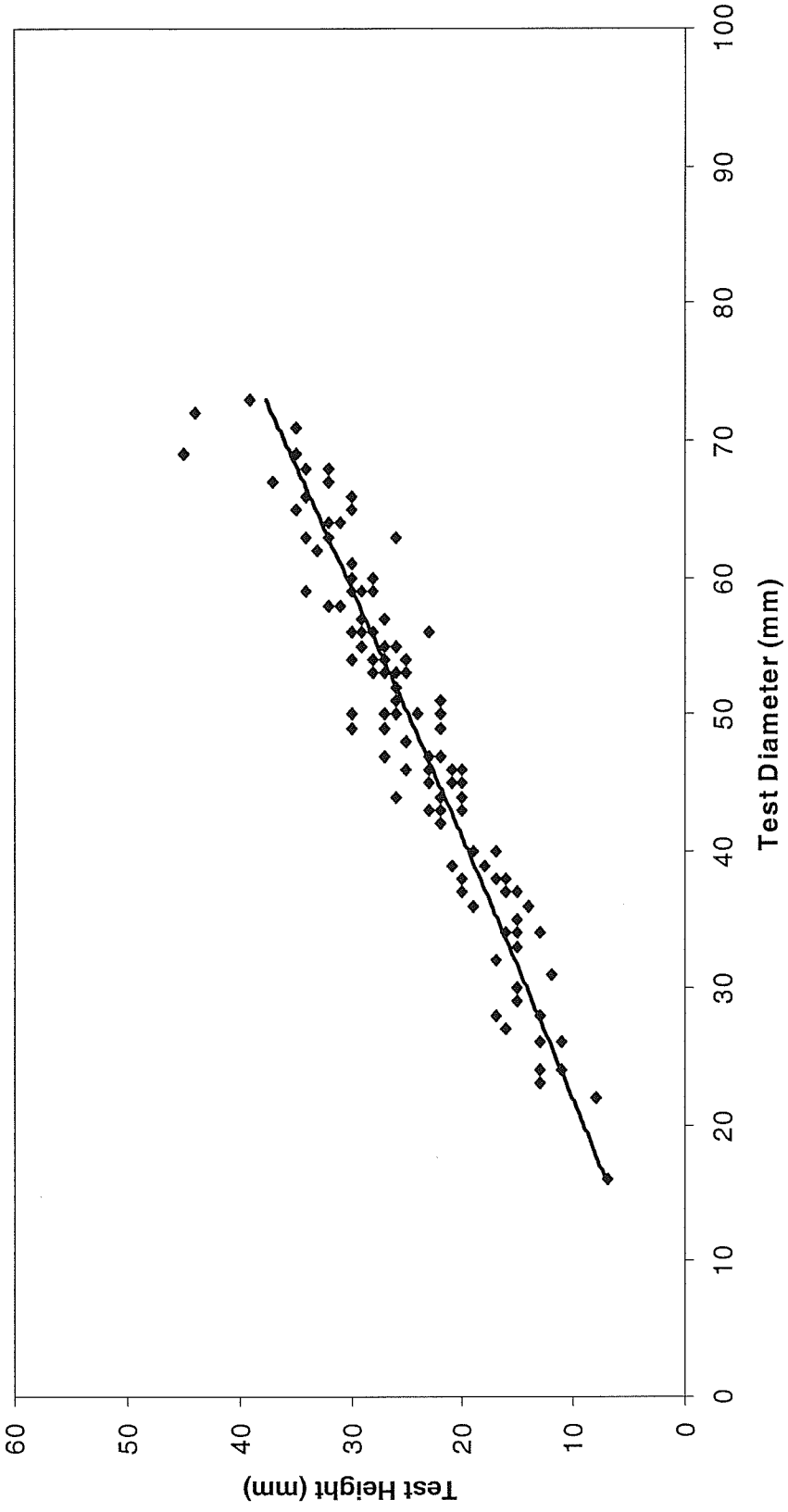

Fig. 14. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in February, 1997, all sites combined: TEST HEIGHT (mm) = 0.3380 ($TD^{1.0986}$), R^2 = 0.9115, n = 131.

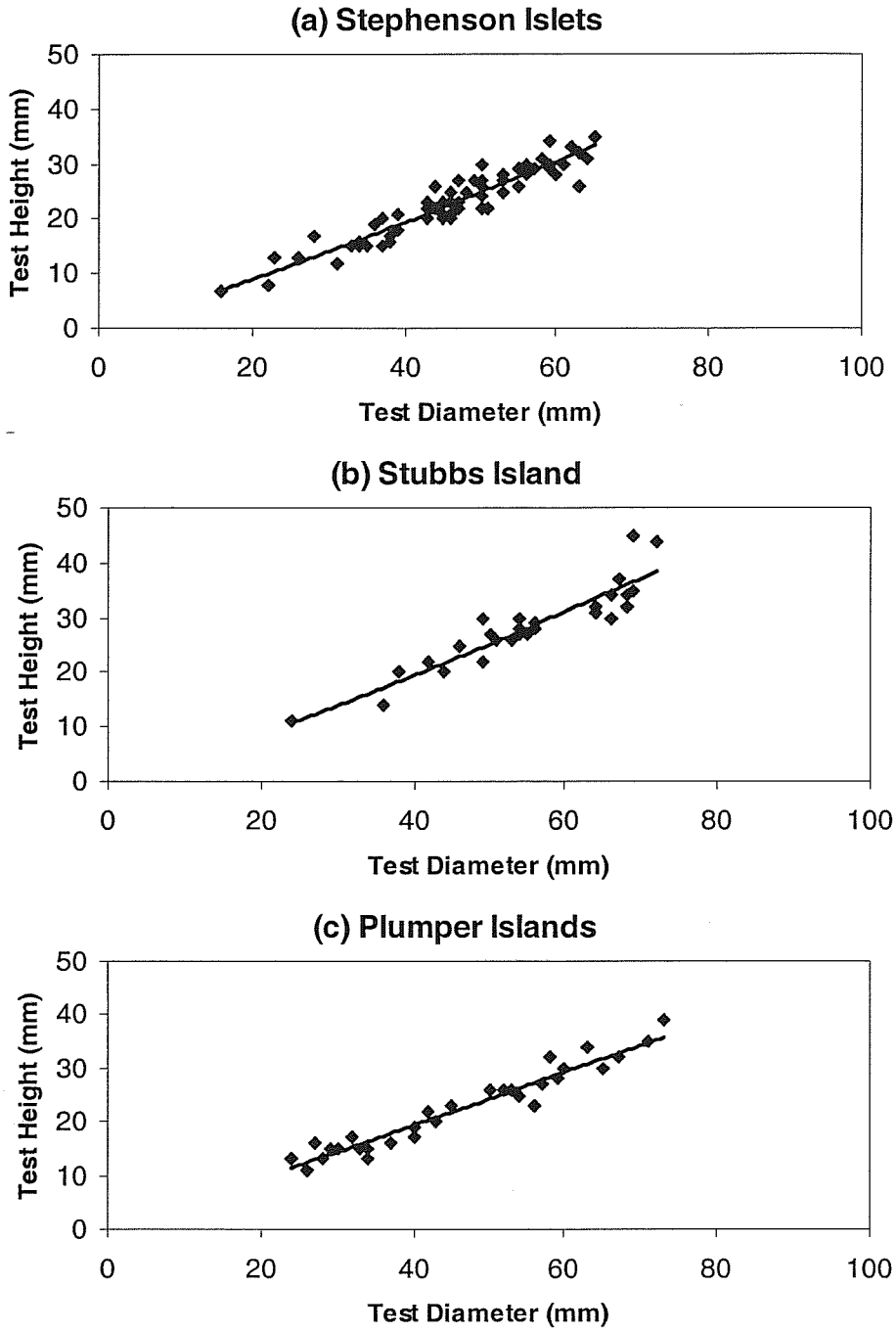

Fig. 15. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in February, 1997 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = 0.3194 ($TD^{1.1134}$), R^2=0.8981, n=70);
(b) Stubbs Island (TEST HEIGHT (mm) = 0.2709 ($TD^{1.1587}$), R^2=0.8954, n=27);
(c) Plumper Islands (TEST HEIGHT (mm) = 0.4405 ($TD^{1.0248}$), R^2=0.9311, n=34).

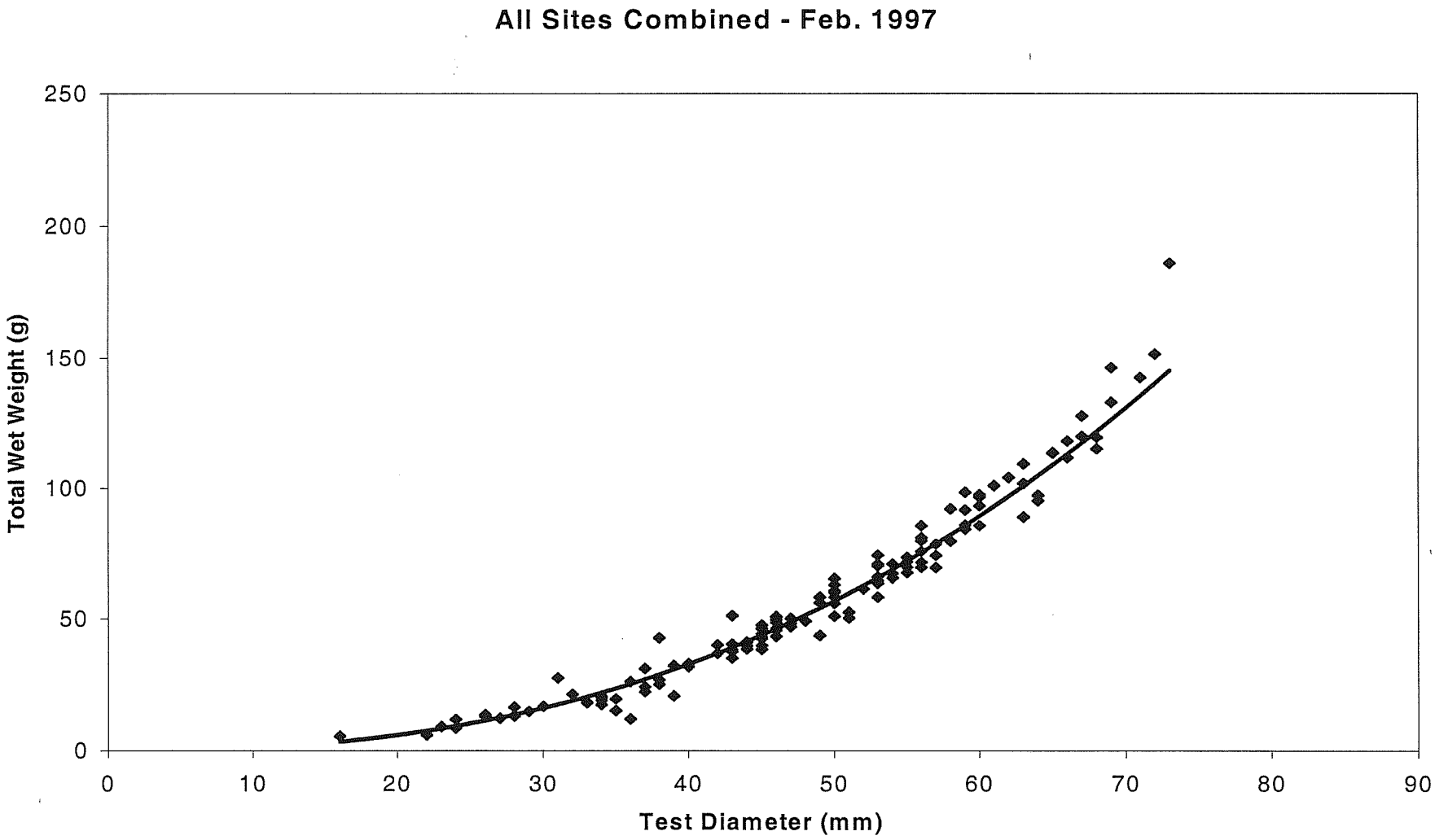

Fig. 16. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in February, 1997, calculated from all sites combined: TOTAL WET WEIGHT (g) = 0.0036 ($TD^{2.4698}$), $R^2 = 0.9618$, n=131.

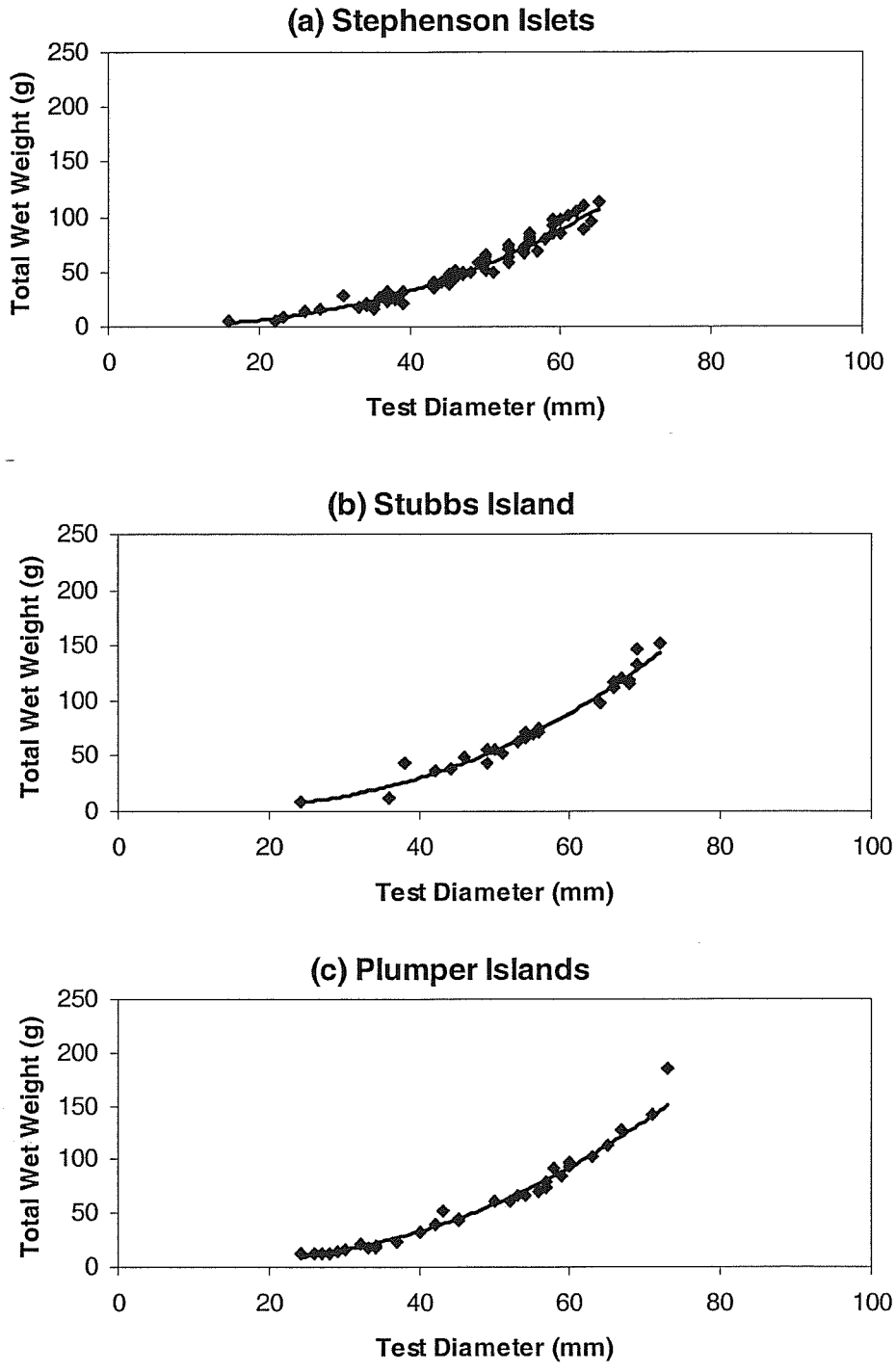

Fig. 17. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in February, 1997 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = 0.0045 ($TD^{2.4109}$), R^2=0.9549, n=70);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = 0.0017 ($TD^{2.6571}$), R^2=0.9354, n=27);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = 0.0032 ($TD^{2.5104}$), R^2=0.9840, n=34).

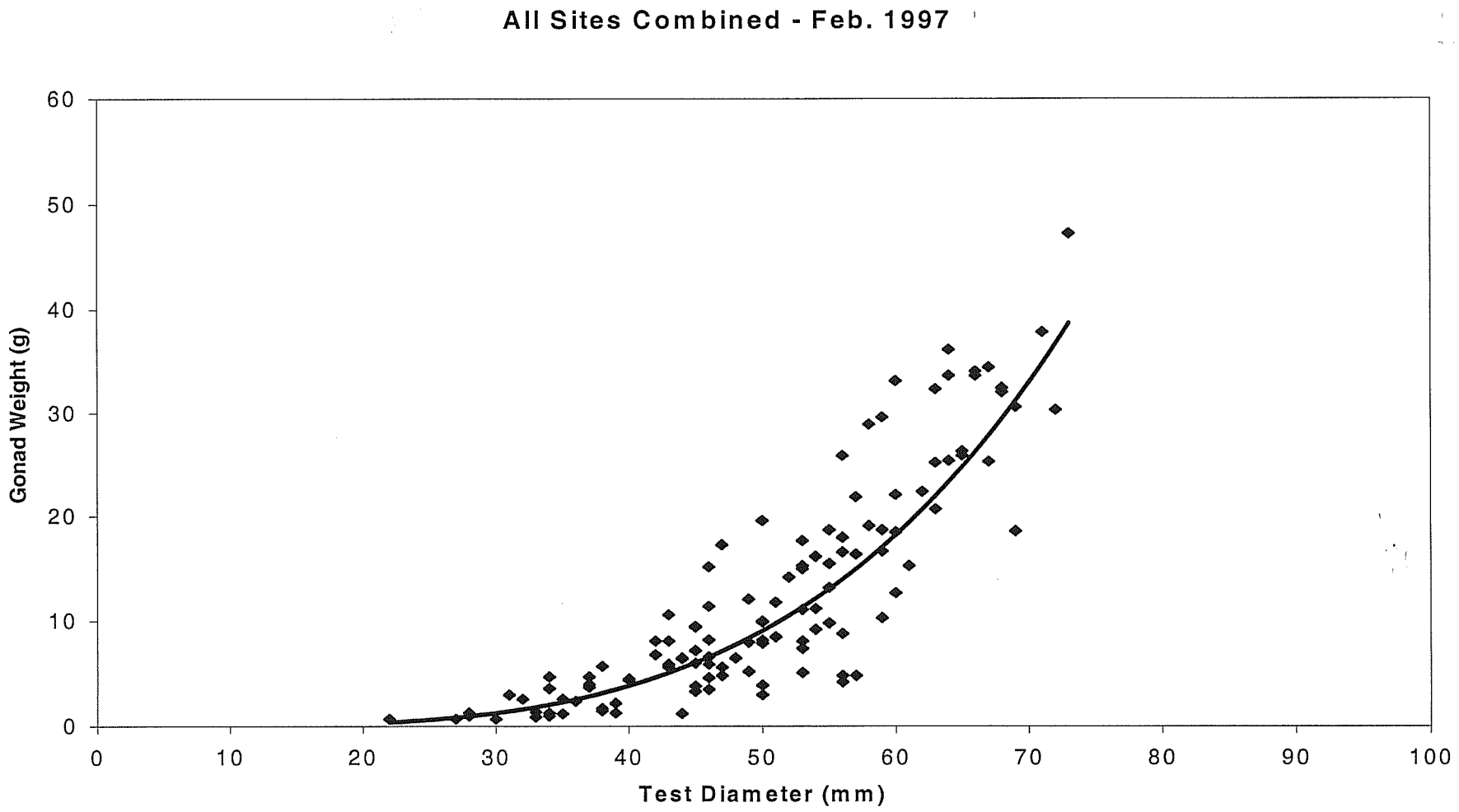

Fig. 18. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in February, 1997, calculated from all sites combined: GONAD WEIGHT = 3×10^{-6} ($TD^{3.8345}$), R^2=0.7916, n=121.

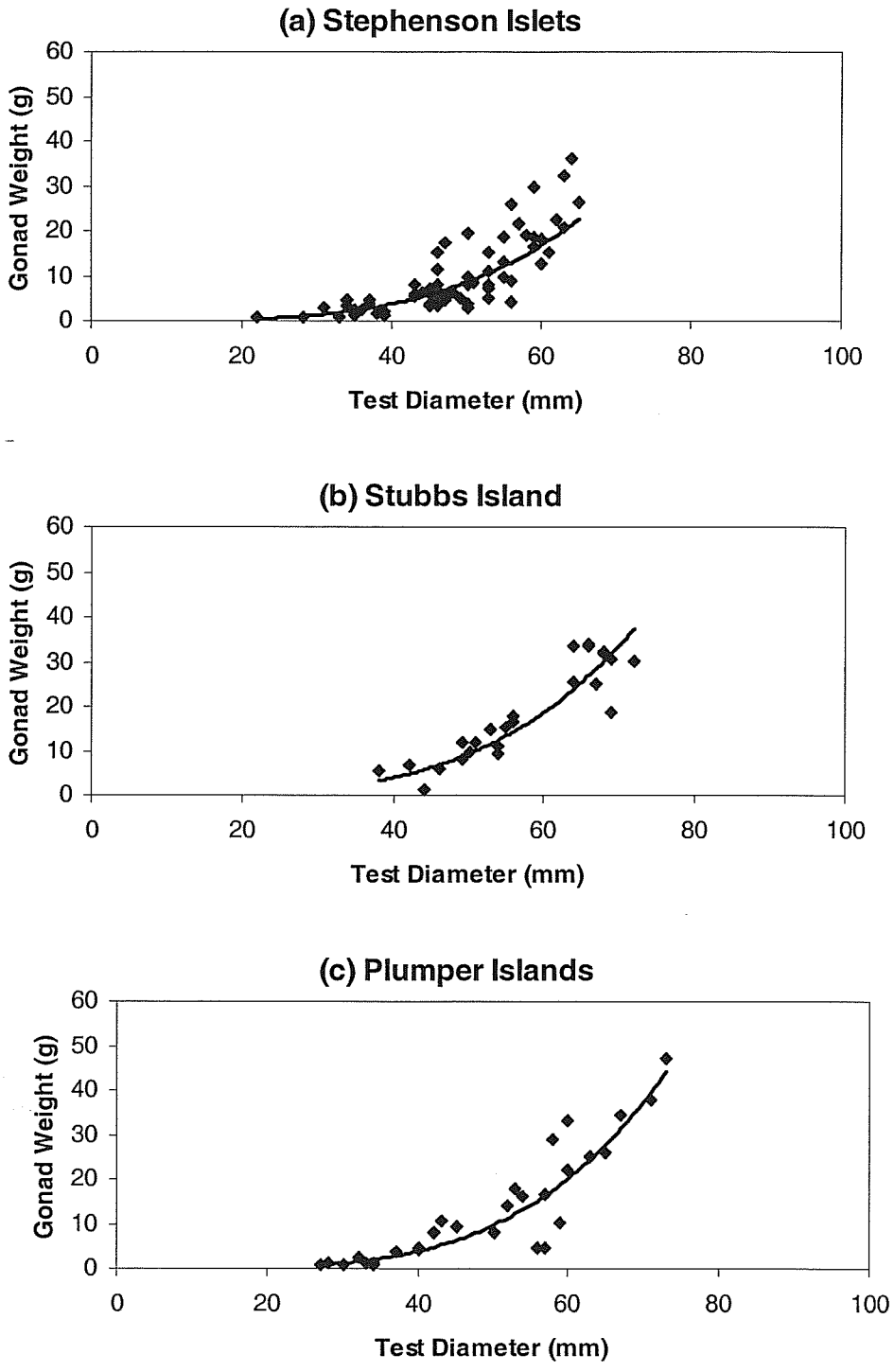

Fig. 19. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in February, 1997 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 5 x 10^{-6}(TD$^{3.6556}$), R^2=0.7218, n=66);
(b) Stubbs Island (GONAD WEIGHT (g) = 3 x 10^{-6}(TD$^{3.8062}$), R^2=0.7338, n=25);
(c) Plumper Islands (GONAD WEIGHT (g) = 1 x 10^{-6}(TD$^{4.0158}$), R^2=0.8554, n=30).