Density Estimates of Giant Red Sea Cucumber (*Parastichopus californicus*) Populations, by Dive Survey, in the Gulf Islands and Jervis Inlet Areas, British Columbia, Canada, in November 1997 and January 1998

S. Campagna and C.M. Hand

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9R 5K6

1999

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2495

Fisheries and Oceans Canada
Science

Pêches et Océans Canada
Sciences

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques ques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits a l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of

Fisheries and Aquatic Sciences 2495

1999

DENSITY ESTIMATES OF GIANT RED SEA CUCUMBER (*Parastichopus californicus*) POPULATIONS, BY DIVE SURVEY, IN THE GULF ISLANDS AND JERVIS INLET AREAS, BRITISH COLUMBIA, CANADA, IN NOVEMBER 1997 AND JANUARY 1998

by

S. Campagna[1] and C.M. Hand

Fisheries and Oceans Canada

Science Branch, Pacific Region

Pacific Biological Station

Nanaimo, British Columbia

V9R 5K6

[1] 160-15550 26th Avenue
White Rock, BC
V4P 1C6

Cat. No. Fs 97-4/2495E ISSN 0706-6473

Correct citation for this publication:

Campagna, S. and C.M. Hand. 1999. Density estimates of giant red sea cucumber (*Parastichopus californicus*) populations, by dive survey, in the Gulf Islands and Jervis Inlet areas, British Columbia, Canada, in November 1997 and January 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2495: 53 p.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Campagna, S. and C.M. Hand. 1999. Density estimates of giant red sea cucumber (*Parastichopus californicus*) populations, by dive survey, in the Gulf Islands and Jervis Inlet areas, British Columbia, Canada, in November 1997 and January 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2495: 53 p.

Dive surveys of sea cucumber (*Parastichopus californicus*) populations were conducted in the fall of 1997 in the Gulf Islands, and during the winter of 1998 in Jervis Inlet, BC, Canada. The Gulf Islands survey was a joint effort between the Department of Fisheries and Oceans (DFO), the Sea Cucumbers Harvesters Association of BC (PSCHA), and the Cowichan Band. The Jervis Inlet survey was completed without First Nations involvement by PSCHA and contracted third party participants.

Each survey area constituted approximately 400 km of shoreline. Field methods consisted of counting the number of sea cucumbers in 4-metre wide strip transects, randomly placed within six randomly selected sites in each area. In addition, three smaller sites, measuring 200 m wide each, were intensively surveyed with random and systematic transects, followed by a complete harvest to obtain the true population size. Transect sampling in the Gulf Islands survey produced a mean density estimate of 3.10 +/- 1.15 SE sea cucumbers per meter of shoreline while densities of 9.53 +/- 1.28 were found in the Jervis Inlet survey. Most sea cucumbers were found between 12 and 18 m in the Gulf survey and between 4.5 and 9 m depth (chart datum) for Jervis Inlet. The greatest density in the Gulf Islands survey was found on boulder and cobble substrate, while mixed soft and hard substrate produced the greatest density in Jervis Inlet.

For most of the intensive sites, estimates of the actual population size was within 90% of the confidence limits of the mean obtained from random transects. In the medium and low density sites of the Jervis Inlet, however, the population size was underestimated by transect sampling. Eight transects in one site in Jervis Inlet were surveyed twice. Half of these pairs had similar densities while the other half had densities that differed by a factor of as much as 14. The individual site means, however, were not significantly different.

RESUME

Campagna, S. and C.M. Hand. 1999. Density estimates of giant red sea cucumber (*Parastichopus californicus*) populations, by dive survey, in the Gulf Islands and Jervis Inlet areas, British Columbia, Canada, in November 1997 and January 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2495: 53 p.

Des campagnes de plongée sous-marine ont été effectuées à l'automne 1997 dans les îles du Golfe et au cours de l'hiver 1998 dans le passage Jervis Inlet (Colombie-Britannique) pour étudier les populations de concombres de mer (*Parastichopus californicus)*. L'étude effectuée dans les îles du Golfe bénéficiait de la participation du ministère des Pêches et des Océans (MPO), de la *Sea Cucumbers Harvesters Association of BC (PSCHA)* (Trad. : Association des exploitants du concombre de mer de Colombie-Britannique) et de la Bande indienne de Cowichan. L'étude portant sur le passage Jervis Inlet, à laquelle les Premières nations n'ont pas participé, a été effectuée par PSCHA et des entrepreneurs extérieurs.

Chacune des études couvrait approximativement 400 km de littoral. La méthode de recensement utilisée sur le terrain consistait à compter les concombres de mer trouvés dans des bandes de 4 m de large tracées au hasard à l'intérieur de six sites choisis au hasard dans chaque secteur. De plus, trois sites plus petits, d'une largeur de 200 m, ont fait l'objet d'un recensement intensif le long de transects systématiques ou aléatoires puis d'une récolte permettant d'obtenir la population réelle. Le recensement par transects a permis d'estimer la densité à 3,10 ± 1,15 SE concombres de mer par mètre de côte dans les îles du Golfe et à 9,53 ± 1,28 dans le passage Jervis Inlet. La plupart des concombres de mer ont été trouvés à une profondeur variant entre 12 et 18 m dans les îles du Golfe et entre 4,5 et 9 m (par rapport au zéro hydrographique) dans le passage Jervis Inlet. La plus grande densité à été relevée sur des rochers ou des lits de pierres dans les îles du Golfe et sur un substratum mixte mou-dur dans le passage Jervis Inlet.

Pour la plupart des sites ayant fait l'objet d'un recensement intensif, les estimations portant sur la taille de la population ne se sont pas éloignées d'une valeur supérieure à 90 % de la limite de précision de la moyenne obtenue à l'aide des transects aléatoires. Dans les sites à moyenne et à faible densité du passage Jervis Inlet, par contre, la taille des populations a été sous-estimée lors du recensement par transects. Huit transects de l'un des sites du passage Jervis Inlet ont été recensés deux fois. La moitié des paires de résultats obtenus présentait des densités similaires tandis que l'autre moitié comportait des variations allant jusqu'à un facteur 14. Les moyennes individuelles obtenues pour le site ne différaient cependant pas outre mesure.

1.0 INTRODUCTION

1.1 OVERVIEW

Sea cucumbers have been harvested by Coastal First Nations groups as traditional food since immemorial times (Suttles and Sturtevant 1990). Currently, the giant red sea cucumber (*Parastichopus californicus*) is harvested in B.C. for the Asian market, where the skin and muscle strips are a delicacy (Heizer and Thomas 1997). Sea cucumbers are hand picked by divers using either SCUBA or HOOKA gear.

Commercial sea cucumber harvesting began in British Columbia as an experimental fishery in 1980 (Sloan 1986) and commercial landings were first recorded on harvest logs in 1983. Interest and landings steadily increased until 1986 when arbitrary and precautionary quotas were introduced. In the following years, these quotas were steadily reduced, due to conservation concerns, and a variety of measures were employed to reduce or control effort (e.g. licence limitation, area rotation).

Following a major review of the fishery in 1996, a new strategy was developed for the 1997 fishery to address a serious lack of understanding of both the productivity and the available biomass of sea cucumber populations. Under this strategy, only 25% of the coast, based on shoreline length, is open to the regular fishery. The arbitrary 233.2 t quota was retained and justified over 25% of the B.C. coast by an assumed density of 2.5 sea cucumbers per metre of shoreline and a harvest rate of 4.2% (Boutillier *et al.* 1998). This quota is distributed over four licence areas (Prince Rupert District, Central Coast, West Coast Vancouver Island and East Coast Vancouver Island) which are each divided into stationary management areas. The assumed density is the lower bound of the 90% confidence interval estimates from biomass surveys conducted by the Alaska Department of Fish and Game. The harvest rate is the most conservative level of several theoretical exploitation rates suggested by researchers in Alaska and Washington State (Boutillier *et al.* 1998). An additional 25% of the coast was designated as experimental area, where biomass surveys and experimental fisheries would be conducted to gather the information required to properly manage the stocks. The remaining 50% of the coast is closed to fishing until defensible quotas can be set.

Two areas of investigation must be pursued before biologically-based quotas can be set for this fishery. Estimates of sea cucumber densities and biomass in various areas of the coast, can be obtained through transect surveys. The response of sea cucumber populations to harvesting and stock productivity in various areas can be addressed through experimental fisheries.

From 1993 to 1997, annual dive surveys to estimate sea cucumber density were conducted in the Central Coast (Statistical Areas 6-18, -19, -20, -24, -25, 7-09 and 7-29) by the Kitasoo band, funded by the Aboriginal Fisheries Strategy (Cripps and Campbell, in prep). Approximately 537 km of shoreline was covered during that period by 11 independent surveys. With the capping of commercial quotas and closure of 75% of the B.C. coast, the industry has become involved in funding and participating in transect surveys as a first step toward developing a coast wide sustainable fishery. Since both First Nations groups and the industry share the common goal of estimating stock abundance, joint surveys have been conducted when possible. In 1996, some initial survey work was done by industry and the Cowichan Band in the Gulf Islands (PFMA 18-6, 18-7 and 19-5), and by industry and KTFC in Quatsino Sound (PFMA 27-2 and 27-3).

Based on the results of these surveys, a survey protocol was established to estimate sea cucumber density. Mean density estimates, in number of sea cucumbers per meter of shoreline, are provided by random transect sampling within randomly selected sites in each survey area. An additional component in these studies, sites where intensive transect sampling was followed by total removal of all sea cucumbers, was included to provide a means of testing how well the random transect method estimated population size and to obtain estimates of individual sea cucumber weight. These 'intensive sites' also provided a future opportunity to monitor the recovery of a small area from total depletion and provide initial funding for the survey through sale of the product.

This report provides sea cucumber density estimates for two 400 km study areas, one in the Gulf Islands, the other in Jervis Inlet (Fig. 1). Density estimates per meter of shoreline are calculated for each random site, and an overall average was obtained by lumping all data within a survey area. Density/depth and density/substrate relationships are provided for each survey. The measurements of density and population size are compared for each intensive site.

1.2 SUMMARY OF BIOLOGY

P. californicus is the largest of over 30 holothurian species in BC and the only one commercially harvested (Lambert 1997). It is found from the Gulf of Alaska to Cedros Island west of Lower California; and from the intertidal to 249 m depth (Lambert 1997). Sexes are separate with no external evidence of sexual dimorphism (Cameron and Fankboner 1986).

Spawning occurs from spring through summer. The maximum gonadal index is in June and July when most spawning occurs, within the inland waters of southwestern BC (Cameron and Fankboner 1986). They are partially asynchronous broadcast spawners with a variable but lengthy larval stage. The larval period to settlement was found to be 65 to 125 days (temperature 10 - 12 C) in one study (Cameron and Fankboner 1989), while McEwen (1987) found it to be 60 to 61 days at comparable temperatures but can be as long as 131 days (11 +/- 0.5 C). The pelagic period to settlement can be as brief as 14 days in water at 20 to 23 C (McEwen 1987). Settlement is thought to occur over a period of 5 months, from August to December in southern British Columbia (Cameron and Fankboner 1989). Settling larvae probably attach themselves to the underside of rocks in calm coves, bays and fjords, since that is where juveniles (10 - 110 mm) are found (McEwen 1987). Juveniles were reported to be associated with mats of stringy red algae and tube worms (Cameron and Fankboner 1989). Size at maturity is not known.

Sea cucumbers exhibit an avoidance reaction when in close proximity to a variety of different sea stars, however there is no report of actual predation in the wild (Margolin 1976). In aquaria, only juveniles were readily consumed by *Solaster dawsoni.* (Cameron and Fankboner 1986).

P. californicus goes through a yearly cycle of resorbing and regenerating its internal organs (Fankboner and Cameron 1985). During this seasonal atrophy, *P. californicus* displays torpor, ceases to feed and looses up to 25% its eviscerated body weight. Visceral atrophy is essentially autumnal, but can occur from late July through March (Fankboner and Cameron 1985). Diapause is the period of dormancy between periods of activity which may be precipitated by photoperiod, temperature, moisture or nutrient availability (Fankboner and Cameron 1985). In *P. californicus*, diapause onset follows the end of plankton blooms and is therefore thought to be induced by decrease in food availability (Fankboner and Cameron 1985). Studies in California of *P. parvimensis* showed that it does not utilize the energy reserve available in plant detritus before its decomposition by bacteria and fungi (Yingst 1976). Even though algae is present during the winter months it may not be decomposed and ready to be consumed by the sea cucumbers.

The age structure of sea cucumber population is unknown, because a method to age them has yet to be found. Numerous tagging experiments have been conducted on sea cucumbers, the most successful technique used floy tags in the body wall (Conand 1991). Tag loss was reported, but the amount varied with the species. In another experiment, tags remained for up to 2 years (Muscat 1983). Da Silva *et al.* (1986) utilised floy tags on *P. californicus* and monitored the animals for 3 months without investigating or reporting tag loss. Shorter term experiments have been conducted using coded wire tags on tropical species; tag loss and detectability difficulties were reported (Lokani 1992). Cripps attempted a similar experiment over 5 months on *P. californicus* and had the found that the best retention was on the dorsal tubercules (K. Cripps, Kitasoo Fisheries Program, pers. comm.)

Holothurian size is thought to be determinate, with all individuals of one population being of the same size (Conand 1981).

Sea cucumbers have some mobility and may migrate. Muscat found that *Parastichopus parvimensis* migrate to deeper water from August to November (Muscat 1983). *P. parvimensis* is found in California from Baja California to Carmel Bay California; *P. californicus* is also found in California, and replaces *P. parvimensis* deeper than 60 meters and north from the range of *P. parvimensis* in shallow water (Muscat 1983). The data on migration are inconclusive for *P. californicus*. They are reported to migrate to shallow water to spawn from early April to August (Lambert 1997). In the central coast, surveys conducted in the same areas at different times of the year and found no significant difference between densities (Cripps and Campbell, in prep). In Indian Arm and Howe Sound in the summer, Da Silva *et al.* (1986) found no directional movements of these animals on gentle slope; they crawled an average of 3.9 m per day. During fishing operations, fishermen have observed mass movement of sea cucumbers toward deeper water, often when viscera from on-board procesing enter the water (K. Ridgway, PSCHA, pers. comm).

Information on depth distribution is scarce. In one study in Alaska, *P. californicus* displayed a bimodal distribution with the greatest densities found shallower than 60 m and between 100 and 150 m. This was attributed to the presence of a rock wall in both places, rather than the actual depth (Zhou and Shirley 1996). In the central coast, *P. californicus* was found in the greatest densities at depths between 1 m and 4 m for fjord-type habitats while more exposed areas (Kitasu Bay) showed highest densities between 4 m and 13 m (Cripps and Campbell, in prep). *P. californicus* seems to exhibit differential substrate preference. In a study conducted in Alaska, the greatest densities were found on rock walls over other substrate types of mud/sand, shell, debris, and algae (Zhou and Shirley 1996). A study in the central coast found the greatest densities on boulders and cobbles and mixed hard and soft substrates (Cripps and Campbell, in prep). Nonetheless, sea cucumbers of harvestable density can also be found on soft substrates, which is preferred by many fishers because the animals are easy to see (K. Ridgway, PSCHA, pers. comm.).

1.3 DESCRIPTION OF STUDY AREAS

Both study areas were situated in the Gulf of Georgia, inside of Vancouver Island, B.C. (Fig. 1). Commercial landings in the survey areas were recorded from 1983 to 1996. In most cases, it was not possible to determine if harvesting had occurred where transects were located because of incomplete landing information. Total landings from the Pacific Fishery Management Areas (PFMA) included in this survey are shown in the text table below. To preserve the confidentiality of the harvest log information, landings are pooled over years and PFMA Subareas.

Statistical Area - Subarea	Round Weight (t)	Split Weight (t)*
Gulf Islands		
17 – 1, -2, -4, -5, -17	175.1	64.1
18 – 2, -4, -6, -9	879.4	322.1
29 – 5	0	0
Total	1054.5	386.3
Jervis Inlet		
16 – 6, -7, -10, -11, -12, -16, -17, -18	144.2	52.8

* conversion factor of 2.73 used.

1.3.1 Gulf Islands

The study area chosen for the Gulf Islands survey was a 387 km stretch of shoreline that included the following adjacent Statistical Areas: 17-1 to 17-6, -8, -9, -17, 18-4, -9 and 29-5 (Fig. 2). The six individual sites ranged in topography from vertical rock cliffs to gently sloping sandy substrate, and from swift current to protected water. Algal cover was not very abundant, overall, except at the high density intensive site where *Agarum fimbriatum* was predominant.

Random sites: Site 1. Northeast Saltspring Island, PFMA 17-1, 17-2 (Fig. 3). This was a protected site with a sandy substrate, moderate to gentle slope and very little algal cover. One transect (16) had a large boulder, surrounded by cobbles (Appendix Table 2).

Site 2. Northwest Valdes Island, PFMA 17-17, 29-5 (Fig. 4). The West side of Valdes Island consisted of vertical cliffs extending from a few hundreds meters above the water to at least 50 meters below water. The subtidal landscape was steep to vertical walls with some boulders and shells on ledges. Transect 28 was very close to a log boom; the substrate there included submerged logs, bark and soft sediments.

Site 3. North of Ladysmith Harbour, PFMA 17-4, 17-5 (Fig. 4). Most of this site consisted of gentle slope with sand and shell bottom with moderate current. Some transects had some patchy rocky reefs and associated cobble.

Site 4. Moresby Island, PFMA 18-4, 18-6 (Fig. 5). The entire perimeter of the island was included in the survey site. The substrate was varied with bedrock and boulders predominant on a few transects and mud and cobbles on others; the slope was flat to vertical.

Site 6. Northwest Saltspring Island, PFMA 17-2, 17-6 and 17-9 (Fig. 3). The substrate consisted of sand and mud with some boulders and cobbles. The transects were long, over a gentle slope.

Site 8. Parker Island, PFMA 17-1, 17-2, 18-2 (Fig. 3). Rocky substrate was prevalent with some shell. Transects had steep slope with moderate algae cover.

Intensive Sites: High density site. East side of Kendrick Island, Area 29-5 (Fig. 4). The shallow part of this site consisted of cobble, while the deep end had a reef to the north and a sandy patch to the south. There was moderate to high current. Algae cover was patchy to abundant with Agarum being the predominant algae.

Medium density site. South of Dodd Narrows, Area 17-16 (Fig. 4). The slope was gentle, with *Agarum* in the shallower end. Substrate consisted mainly of cobbles and boulder with some sand and shell.

Low density site. South side of Mudge Island, Area 17-16 (Fig. 4). This site has a long gentle slope with cobble, gravel and some boulders and some shell in the shallower part. Little algae cover was present.

1.3.2. Jervis Inlet

The Jervis Inlet study area was a 404 km stretch of shoreline in PFMA 16 that included subareas: -2, -6, -7, -8, -10, -11, -12, -16, -17 and -18. (Fig. 6). Most sites were protected, with Sites 3 and 6 being the least protected and more vulnerable to southeast winds. All sites had moderate to vertical slope with a predominantly rocky substrate. Transects often started with bedrock or boulders in the shallow part and then turned to cobble and gravel with some sand, shell or silt in the deeper part. Algae were not abundant in the random sites but, where present, *Agarum* was predominant.

Random Sites: Site 1. Hotham Sound, PFMA 16-12 (Fig. 7). This site was characterized by steep hills, which were densely forested to the water edge. The shore consisted of large boulders or bedrock and the submarine terrain slope varied from steep to vertical. The substrate was mainly bedrock and boulders covered with silt.

Site 2. Nine Mile Point, PFMA 16-6, 16-7 (Fig. 8). Transects had moderate to steep slopes with gravel, boulders and sand mixed. Some fish farms were located at the south end of the site.

Site 3. Saltery Bay, PFMA 16-11 (Fig. 9). Most transects had moderate to steep slope and rocky substrate with the exception of transects 37 and 39 that had a gentle slope and a sandy and silty substrate. This site was surveyed twice; transects were labeled 30 to 39 the first time and 90 to 99 the second time (Appendix Table 4).

Site 4. Skaiakos Point, PFMA 16-6 (Fig. 8). This site had similar characteristics to site 2.

Site 5. Kunechin Point, PFMA 16-6, 16-7, (Fig. 8). Most transects had a steep slope with a rocky substrate with some cobble and gravel.

Site 6. Cockburn Bay, PFMA 16-16, 16-17, 6-18 (Fig. 9). Substrate consisted of bedrock and boulders with a moderate to steep slope.

Intensive Sites: High density site. Agnew Passage, PFMA 16-11 (Fig. 6). This site was at the Northwestern tip of Nelson Island, between Nelson Island and an unnamed islet. The substrate consisted of boulders and cobbles with some sand and shell with abundant algae, Agarum mainly, over bedrock and boulders in the shallower part. The slope was gentle. The subtidal landscape was diverse with rockwalls, boulders and flat areas.

Medium density. Between Kelly and Nelson Islands, PFMA 16-16 (Fig. 6). This site was located between islands with moderate to steep bedrock faces turning to boulders, cobbles and then gravel when leveling off at 30 to 50 feet (gauge depth). Some algae were present, especially in shallow water.

Low density site. Agnew Passage, PFMA 16-11 (Fig. 6). This site was on the other side of the gravel bar from the high density site. The southern part of this site, between Nelson Island and the islet, was shallow with a silty substrate covered with stringy red algae (*Gracillaria* type).

2.0 METHODS

2.1 FIELD METHODS

2.1.1 Site selection and transect placement

Random Sites: A survey area was arbitrarily defined as 400 km of shoreline. Within each survey area, six sites, measuring 10 km of shoreline, were randomly selected. To accomplish this, PFMA's in each survey area were numerically ordered and their shoreline lengths added up. Shoreline lengths were determined from Compugrid Geographic Information System (Boutillier et al. 1998). Six random numbers between 0 and 1 were multiplied by the total shoreline length of the survey area to give the location of the midpoint of each site. Sites extended 5 km to either side of the midpoint.

In each of these sites, ten transects were randomly located. Ten random numbers between 0 and 1 were selected. These numbers were multiplied by 10,000, the shoreline length (m) of the site, and the transect locations determined by measuring the shoreline distance from south to north. It was determined in the field whether the location could safely be worked (e.g. high vessel traffic, ferry terminals), was unsuitable (e.g. intertidal flats) or was inaccessible (e.g. tidal lakes). In any of these situations, transect locations are reassigned using back-up random numbers. Transects located on vertical cliffs were swim surveyed only; no line was laid.

Site 3 in Jervis Inlet was surveyed twice because of mid-survey difficulties. In the second series, attempts were made to place the transects in exactly the same spot as the first series. For the replicated transects, the number of sea cucumbers were averaged, by quadrat, so that each transect was represented only once in the bootstrapping process. New random locations were picked for two of the transects in the second set because of the dangerous proximity of a ferry terminal. Therefore, transects 37 and 39 in the first series and transects 98 and 99 in the second series were not repeated (Fig. 9). A total of 12 transects were used to estimate densities for Site 3.

Intensive Sites: Each intensive site measures 200 m of shoreline and extends from 0 to 60 feet gauge depth. Three intensive sites, one of high, medium and low density, were selected. Selections were based on initial information from the random sites and from information provided by commercial harvesters. High density sites are considered to be commercially harvestable, medium density sites are possibly worth harvesting and low density sites have sea cucumbers present but are probably not worth harvesting (according to fishers).

Each site was measured and the corners marked with concrete blocks and floats. The locations of the five systematic transects were marked with floats at each 33 m interval along the length of the site. The random transect placement was determined by selecting five random numbers, between 0 and 1, and multiplying by 200. The locations of these transects were visually estimated using the marked systematic transect locations. GPS coordinates were recorded.

2.1.2 Transect sampling

The survey protocol followed a two-stage design, where transect locations were randomly determined at the first stage and a complete census of quadrats taken at the second stage. The field locations of each transect was determined by matching the topography, bathymetry and landscape with chart features. GPS coordinates were recorded for both deep and shallow ends. Transects were numbered from 1 to 10 within each site. The number recorded on the dive sheet included the site number as the first digit and the transect number as the second digit; transect 10 within each site was given 0 as second digit.

The lead-core transects were laid perpendicular to the shore and extended from the intertidal to approximately 60 feet gauge depth. The transect lines were marked every 5 m with a plastic locking strap to define the end of 5 m by 2 m quadrat. Underwater, two divers worked together, one on either side of the transect, and counted all sea cucumbers within 2 m of each side of the transect. At each marker, the divers stopped to record the number of sea cucumbers, along with the depth, the substrate type, and the algal type and percent algal cover in each 10 m^2 quadrat. Any sea cucumber on or under the lead line was counted by the diver on the left. The gauge depth of only one diver in the team was used, except transects completed by the Cowichan Band personnel who averaged the depth from both divers. In situations where the number of quadrats differed between divers in a transect, substrate and depths were matched and a 0 count was added at the skipped quadrat.

Substrates were recorded for each quadrat from the most to the least abundant, using the codes listed in Appendix Table 1. The two most prevalent types were then used to convert them to the analysis substrate codes. The two most abundant algae genera, and total percent cover of all algae, with the exception of encrusting algae, were recorded per quadrat. For the Gulf Islands survey, a code based on the two first letters of the genus name was used. For the Jervis Inlet survey, "herring codes" (general algae code used during herring spawn surveys) were used so as to simplify the number of codes required.

Gauge depths were converted to chart datum using the tide height from the closest harmonic tide station. The quadrat depths were obtained by averaging the depth at the beginning and at the end of the 5-m length.

2.1.3 Intensive site harvest

The systematic transects in the intensive sites formed 6 grids, each of which were harvested separately. This allowed the divers to be more thorough in searching and harvesting, and provided counts of animals for each grid. As each systematic transect was surveyed, and before the leadline was removed, all sea cucumbers were harvested from between adjacent lines. Animals were hand picked by divers, put into mesh bags and, on board the boat, emptied into a tote. There they were split longitudinally with a knife and placed into plastic lined cages. All animals were counted, cages were labeled with the grid number and the number of animals it contained. Once at the dock, the cages were weighted, sold to the buyer and then transported to the processing plant.

About 25 DNA samples were taken from each intensive site by cutting off a small piece of the skin of an animal. These samples may be used in the future to determine the genetic structure of sea cucumber populations for stock delineation.

2.2 ANALYTICAL METHODS

2.2.1 Inter-diver comparisons

The transects that were completed by the same pairs of divers were grouped, and the number of sea cucumbers counted on each side of the transect line tested against the null hypothesis that the counts are equal. Data were tested for normality, and either a paired t-test or a Wilcox paired test were used, as appropriate.

2.2.2 Calculation of mean density

The parametric estimate of mean density of sea cucumbers per meter of shoreline for each site *j* (d_j) were calculated as the sum of the sea cucumbers counted in all transects in the site divided by the meters of shoreline covered by the transects.

$$d_j = \frac{\sum_{i=1}^{n} c_i}{4n} \qquad (1)$$

where c_i is the number of sea cucumbers in transect *i* and *n* is the total number of transects sampled, multiplied by 4, the width (m) of a transect.

The variance (s^2) of the density and standard error of the mean density were calculated as

$$s^2 = \frac{1}{(n-1)\sum_{i=1}^{n}(d_i - d_j)^2} \qquad (2)$$

$$se = \sqrt{\frac{s^2}{n}} \qquad (3)$$

where d_i is the transect density ($c_i/4$).

To examine the degree of clumping in the populations, an index of dispersion (I) was calculated as

$$I = \frac{s^2}{d_j} \quad (4)$$

A small index value indicates that the animals have a relatively constant spatial distribution, while a large value indicates that there are dense clumps of sea cucumbers on the sea floor

Since the distribution of transect counts are skewed (Fig. 10), non-parametric confidence intervals for the mean sea cucumber density were calculated using bootstrap techniques (Efron and Tibshirani 1993). The procedure randomly samples n transects with replacement from the n sampled transects. The number of sea cucumbers counted in the n transects are added, as are the corresponding shoreline lengths (4n) for the resampled transects, and the mean density d_j^* calculated as in equation (1). The process was repeated 1000 times to obtain 1000 estimated mean densities: $d^*_1, d^*_2, ..., d^*_{1000}$. Bootstrap 95% confidence intervals were then constructed using the percentile method. The 1000 bootstrap estimates of the mean were sorted and the $1000(0.025)^{th}$ value and $1000(1\text{-}0.025)^{th}$ value were used as the bounds of the 95% confidence interval.

2.2.3 Population number and biomass

The population size of each survey area was estimated by multiplying the mean density (#/m-sh) for all sites combined by 400,000 m, the shoreline length of the study area. The overall mean split-weight of all sea cucumbers harvested in the intensive sites was used to estimate the biomass from each survey area.

2.2.4. Density-depth and density-substrate relationships

Depths, in meters below chart datum, and substrate data were classified into depth and substrate codes (Appendix Table 1). All random transects were pooled and mean densities per m^2 were calculated for each depth and substrate code.

A non-parametric approach was used to compare mean densities for the four depth ranges. For each depth range, the density of sea cucumbers was resampled, with replacement, from the quadrat values. The size of the resample is the same as the number of quadrats in a depth range. An average was calculated for the resample. The resampling was repeated 1000 times and $A(d_j,r)$ is the average density of sea cucumbers in the jth depth range and the rth resampling. As a further step,

$$diff(d_j,d_i,r) = A(d_j,r) - A(d_i,r) \quad (5)$$

was also calculated. This was used to compare mean densities from two depth ranges at a time. The confidence level that zone j has a greater mean density of sea cucumbers than zone i is the fraction of times that the value is greater than zero for all resampling. Values greater than 0.95 and less than 0.05 are considered significant.

The same method was used to test for differences between substrate categories, where i indexes substrate.

3.0 RESULTS

3.1 SUMMARY OF SURVEY LOGISTICS

Transect length and algae cover are the main variables that influence the time required to survey a transect. Dense algae cover can easily double or triple the time required to survey a transect. Diver experience decreases the time required to survey a transect, as divers with survey or harvesting experience are better at locating the animals.

3.1.1 Gulf Islands

The average dive time per transect ranged between 15 min and 30 min for both the random and the intensive sites (Tables 1a, 1b). A total dive time of 1,330 min (22 h) and 688 min (11.5 h) was required to complete all transects in the six random sites and the three intensive sites, respectively. Mean transect lengths for the random sites ranged from 49 to 157 m and averaged 104 m. In the intensive sites, transect lengths ranged from 104 to 219 m and averaged 180 m.

In the random sites, two random transect placements were in unsuitable locations; one because of high current (Gabriola Passage) and the other because no subtidal habitat was available. These transects were randomly reassigned. Transect 27 (Fig. 4. Appendix Table 2) was aborted after 280 m. Transects 22 to 25 were completed without a leadline due to the steepness of the shore. Transect 28 was located close to a log boom where the substrate included boulders, shell, silt, bark and woody debris; very little life was observed.

Only four of the five systematic transects were completed at the high density intensive site (Appendix Table 3). Due to high tidal amplitude, some of the buoys disappeared as the tide flooded. Since the site was long and the waves prevented the tender to see all buoys at once, this resulted in one transect being laid on the wrong buoy.

3.1.2 Jervis Inlet

The average dive time per site ranged between 10 min and 13 min for the random sites and between 13 min and 30 min for the intensive sites (Tables 2a, 2b). A total dive time of 701 min (11.7 h) were required to complete all transects of the 6 random sites and 640 min (10.7 h) to complete the transects in the three intensive sites. Mean transect lengths for the random sites ranged from 31 to 46 m and averaged 37 m. In the intensive sites, transect lengths ranged from 70 and 109 m and averaged 96 m.

There were numerous short transects on vertical walls in the Jervis Inlet survey. Transect 12 (Fig. 7) was laid but fell down the steep wall beyond diving depth. Transects 12, 14, 18, 19, 30, 42, 50, 56 and 57 (Fig. 7 to 9) were completed without a leadline due to the steepness of the shore. Transect 22 (Fig. 8) was relocated due to the presence of a fish farm whose lines prevented the boat from laying the transect. The locations of transects 60 and 69 (Fig. 9) were reassigned using back-up random numbers because the entrance to Hidden Basin was unnavigable. The location of transect 38 (Fig. 9) was reassigned due to the presence of a ferry terminal.

Site 3 (Fig. 9) was surveyed twice. Transects 37 and 39 were not resurveyed because they were close to a ferry terminal; the positions of transects 98 and 99 were therefore relocated. Transects 30 (90) to 36 (96) and 38 (97) were all surveyed twice in the same location, based on a visual estimation.

The transects in the high density intensive site (Fig. 6) took longer than usual to complete (50 min vs. 10 to 20 min) due to the large amount of algal cover (Appendix Table 5). The low density intensive site was between a rock wall and an islet; some of the transects were short and in very shallow water.

3.2 INTER-DIVER COMPARISON

Since the animals were often densely aggregated, there was often a large difference in counts from each side of the transect. There was, however, no significant difference between the pooled paired-diver counts in either of the surveys (Wilcox test, $p > 0.05$) (Fig 11). Analyses could not be conducted for all divers because the test requires a minimum of two transects completed by the same pair of divers.

3.3 SEA CUCUMBER DENSITY AND BIOMASS

3.3.1 Gulf Islands

In the Gulf Islands, 6 random sites with 10 transects each were surveyed, for a total of 60 transects (Appendix Table 2). Of those, 28 transects had 0 sea cucumbers (Table 3, Fig. 10). The overall average number of sea cucumbers per meter of shoreline was 3.10 over all sites. Site 1 had the highest mean density with 5.55 sea cucumbers per meter of shoreline while site 6 had the lowest with 0.13 cucumbers per meter of shoreline.

The estimated population size differs between sites, from 1,300 animals at Site 6 to 55,100 animals in Site 1 (Table 3). The sea cucumber populations in this area were highly aggregated and the 95% confidence bounds were often greater than 100% of the mean estimate. In sites 2 and 6, the lower bootstrapped 95% confidence limit was 0 animals. The mean population estimate for the entire 400 km survey area, obtained by pooling all transects, was 1.2 million animals, ranging from 0.5 to 2.2 million animals. The estimated mean biomass for the survey area was 324.2 t (Table 3).

3.3.2 Jervis Inlet

In Jervis Inlet, a total of 70 transects were completed. Sixteen of the transects were replicates which were averaged to produce a single observation for each transect location (Appendix Table 4). An estimated overall mean density of 9.53 sea cucumbers per m of shoreline was obtained. The estimated density by site ranged between 3.58 for Site 2 and 15.53 for Site 4 (Table 4). Only 2 transects, both in Site 3(9) had 0 sea cucumbers (Table 4). The degree of clumping was less than in the Gulf Islands and confidence limits of the mean density were, on average, within 25% of the mean density estimate. The total population estimate for the 400 km (shoreline length) survey area was 3.8 million animals, while the mean biomass estimate was of 751.8 t (Table 4).

3.4 SEA CUCUMBER DISTRIBUTION

3.4.1 Gulf Islands

Very clumped distribution: The distribution of sea cucumbers in Sites 1 and 2 was very clumped, with dispersion indexes of 45.35 and 39.39 respectively (Table 3). All transects in Site 1 had very low densities (between 0 and 1.75 cuc/m-sh), with the exception of transect 16 which had a mean density of 50.75 sea cucumbers per meter of shoreline (Appendix Table 2). Most of the sea cucumbers that were found in transect 16 were clustered on and around a large boulder and associated cobble. In Site 2, only 1 animal was counted in the 8 transects completed on the west side of Valdez Island, while around the point in the same site, densities were 5.25 and 45.0 cuc/m-sh (Appendix Table 2). The highest density was found on transect 20, which was also the location chosen for the high-density intensive site.

Moderate clumping: Dispersion indexes ranged from 2.93 to 4.00 for Sites 3, 4 and 8 (Table 3). In Site 3, 6 transects had 0 sea cucumbers, 3 transects had densities between 0.25 and 0.50 cuc/m-sh; the furthest south transect (31) had the highest density of 5 sea cucumbers per meter (Appendix Table 2). This transect was close to patches of rocky reef that were associated with moderate densities of sea cucumbers. All transects in Site 4 had sea cucumbers in densities ranging from 0.25 to 12.5 sea cucumbers per meter of shoreline (Appendix Table 2). Densities were higher on the east side of Moresby Island. Only 3 transects in Site 8 (85, 87, 89) had 0 sea cucumbers. The highest density of 7.0 cucs/m-sh was found on transect 81 (Appendix Table 2). Densities were higher in the south end of the site.

Moderately uniform: Site 6 (Fig. 3) had a dispersion index of 0.58, indicating a uniform distribution. It had the lowest density (0.13) of all sites within the study area (Table 3). Eight transects had 0 sea cucumbers, the highest density found was 0.75 cucs/m-sh.

3.4.2 Jervis Inlet

Very clumped distribution: Sea cucumbers at Site 3 were clumped with a dispersion index of 25.08 (Table 4). The mean density was 11.73 sea cucumbers per meter of shoreline. Densities in Site 3 ranged from 0 (transect 37 & 98) to 62.25 (transect 99) (Appendix Table 4).

Moderately clumped: The five remaining sites in Jervis Inlet had fairly similar indices of dispersion, ranging between 4.02 and 5.60 (Table 4). There was no obvious trend in distribution within these sites; transect densities alternated between high and low. All transects in Sites 4 and 5 had densities greater than 2.5 cuc/m-sh. Most densities in these sites were high, especially in Site 4 (Appendix Table 4). One half of the transects in Site 2 had densities less than 2.5 cuc/m-sh, the overall density for this site was 3.58.

3.5 REPLICABILITY

The estimated mean density for the eight replicated transects in Site 3 of Jervis Inlet was 10.84 cuc/m-sh for the first series and 8.69 cuc/m-sh for the second series. Four of the replicated transects showed similar densities (less than 2 fold difference), while the remaining transect pairs differed in density by as much as 14 times. This is despite the fact that efforts were made to place the transect in same location. The difference between replicates was without spatial trend.

Transect	SITE 3	SITE 9
30/90	3.5	6.25
31/91	12.75	12.0
32/92	14.25	1.0
33/93	18	4.25
34/94	15.5	5.0
35/95	2.75	2.0
36/96	6.75	7.0
38/97	13.25	32.0
Mean Density (cucs/m-sh)	**10.84**	**8.69**
se	2.02	3.53
Bootstrap Confidence Intervals		
lower 95%	7.44	3.66
upper 95%	14.47	16.07

3.6 DENSITY/DEPTH AND DENSITY/SUBSTRATE RELATIONSHIPS

Figure 12 shows scatter plots of density against depth for the Gulf Islands and Jervis Inlet surveys. The highest densities of sea cucumbers in the Gulf Islands were in deeper water, whereas the higher densities in Jervis Inlet were at mid depths (Table 5). The comparisons of bootstrapped densities between depth categories for Gulf Islands reveals that, for all but the two deepest zones, densities were significantly greater in deeper water (Table 6). For Jervis Inlet, it appears that the sea cucumber densities are significantly higher in the two middle ranges of depth.

Soft substrates (code 4) produced the lowest densities for both surveys (Table 7). In the Gulf Islands, 63% of the seabed area surveyed was of soft substrate, whereas only 35% of the bottom was soft in the Jervis Inlet area. Densities in the Gulf Islands were significantly higher on boulder/cobble substrate (code 2) than on any other substrate category, whereas in Jervis Inlet, densities were significantly higher on mixed hard and soft substrate (code 3) than on any other substrate (Table 8).

3.7 INTENSIVE SITES – SURVEY AND HARVEST RESULTS

3.7.1 Gulf Islands

Harvesting of the low, medium and high density intensive sites was accomplished in 3 days, 4 days and 7 days, respectively. The mean individual weight of sea cucumbers for the high, medium and low-density sites and for all sites combined were 240, 299, 379 and 263 g, respectively (Table 9). A total of 12,423 lb., split weight, was harvested over all three intensive sites in the Gulf Islands. The overall percent recovery was 21.81% (Table 11).

In the Gulf Islands, the number of sea cucumbers per meter of shoreline in the intensive sites (random transects) was estimated to be 75.1, 25.9 and 3.5 for the high, medium and low sites, respectively (Table 12). Estimates of density obtained from the harvest are similar at 71.7, 30.8 and 4.7 cucs/m-sh (Table 14a). Figure 13 compares the estimated mean population size (number of sea cucumbers) from the random transects with the population as determined from the harvest (circles) and the population estimated from the systematic transects (squares). The 90% and 95% confidence bounds were calculated by applying bootstrapping techniques to the random transects results. Confidence bounds were not calculated with respect to the systematic transects because of difficulties establishing variances for systematic surveys (Thompson 1992, Kronlund *et al.* 1995). In each intensive site, the estimated population size falls within the 90% confidence bounds of the mean population estimate from random transects (Figure 13).

3.7.2 Jervis Inlet

Harvest of the Jervis Inlet intensive sites took only 7 days to complete. The mean individual weight of sea cucumbers for the high, medium and low density sites and for all sites combined were 163, 251, 200, and 198 g respectively (Table 10). A total of 2,055 lb., 3,578 lb. and 3,608 lb. were harvested from the low, medium and high density sites, respectively. The recovery rate was 18.21% for Jervis Inlet (Table 11).

In Jervis Inlet, the estimated densities were 77.7, 20.9 and 16.1 sea cucumbers per meter of shoreline for the high, medium and low density sites, respectively (Table 13). The actual density of sea cucumbers removed during the harvest were 50.25, 32.30 and 23.35 sea cucumbers per meter, for the high, medium and low sites, respectively (Table 14b). The density obtained from harvests in the high density site was within the very wide 90% confidence interval obtained by bootstrapping the random transect data. Harvest densities in the medium and low density sites, however, were higher than estimated by the random transects (Fig. 13).

4.0 DISCUSSION

The estimated density of sea cucumbers was lower in Gulf Islands than Jervis Inlet. This is in spite of the fact that transect lengths were longer. The two areas have experienced different fishing histories, with the Gulf Islands sustaining heavier fishing pressure than the Jervis Inlet area (text table, pg. 4). Since no data on density and distribution are available from either area prior to the fishery, it cannot be ascertained whether these differences in density or distribution are a result of harvest activities. Differences in density between areas, even with similar substrate types, may be explained in part by differences in exposure and current regimes. Fishers suggest that the right amount of current is an important factor in sea cucumber density. In any case, it would seem that the Gulf Island area would not be suitable for either experimental fishing or for an open fishery. The small but dense aggregations that exist in this area can hopefully function as spawning stock for the Gulf Islands.

The distribution of sea cucumbers is more clumped in the Gulf Islands, with almost half of the transects containing no animals compared to Jervis Inlet where only 3% of the transects were devoid of sea cucumbers. The lower density and patchier distribution of sea cucumbers in the Gulf Islands may be due to the fact that the preferred substrate was twice as abundant in Jervis Inlet as it was in the Gulf Islands. Sea cucumbers seem to favor a hard complex substrate and/or a mixed hard and soft substrate with hard substrate dominant. However, a similar substrate can produce much different densities, dependent on its depth and algal cover. Sea cucumbers seem to avoid surge and swells and in areas that are exposed to waves, the animals are found deeper. Often though, we failed to understand why similar areas had very different densities and why some transects only a few meters appart differed so much. Even the 8 transects that were repeated in Site 3 in Jervis Inlet differed in density, although the averages of each set of transects are comparable. Transects moved by as little as a few meters can produce very different results. It is possible that sea cucumbers aggregate and move in groups while foraging. It was noticed, on occasion, that fecal casts were abundant, but a thorough search found no animals in the vicinity (observ. Jan 1999).

On the micro-scale, the distribution of the animals within the intensive sites of Jervis Inlet seemed patchier than in the Gulf Islands. The random transects underestimated the actual population in the low and medium sites of Jervis Inlet. The random transects tended to miss the higher density, compared to the systematic transects (Appendix Table 5). The number of animals harvested in the high density site of Jervis Inlet, however, was close to the lower 90% confidence bound of the estimated population size from transects. In this case, a possible explanation may be the fact that the animals were split on board the boat and the guts were thrown overboard as the divers were harvesting. When harvest stopped one afternoon, it was estimated that a few cages remained in the plot. The following morning, there were no animals left in the plot and it is possible that they moved away in response to the viscera in the water.

In both the Gulf and the Jervis intensive harvest sites, there was a general trend of decreasing mean weight with increasing density (Fig. 14). The mean weight estimate from the low density site in the Jervis Inlet area, however, did not follow this pattern. Here it was noted that the dominant algae was filamentous red, which has been associated with newly-settled sea cucumbers (Cameron and Fankboner 1989). Also of note is the fact that the sea cucumbers were heavier in the Gulf Islands sites than in the Jervis Inlet sites. The high-density/low-weight site in the Gulf is associated with moderate to high water current, and it is possible that the lower overall weight of the Jervis Inlet animals is due to a generally higher level of current activity in this area of inlets and channels.

Nearly all of the sea cucumbers harvested in the Gulf Island survey showed visceral atrophy, whereas fewer animals in the Jervis Inlet survey had no viscera. The survey in Jervis occurred two months later than the survey in the Gulf Islands but the seasonal variability of visceral atrophy is poorly understood. The skin thickness was highly variable among individuals. It was noticed that overall Jervis Inlet's animals had a thinner skin and muscles than the Gulf Islands'. Fankboner and Cameron (1985) report that the lowest mean drained weight is found during the months of January and February. This could explain why the recovery was much lower in Jervis Inlet.

These survey results provide the basis for further investigations into sea cucumber productivity by means of experimental fisheries.

ACKNOWLEDGMENTS

The generous help of Ken Cripps for suggestions on reading material, data analysis, logistics and report format was invaluable. The help of Ian Davison, Alain Omer Duranceau and Chris Fox with logistics was greatly appreciated. We would like to thank Graham Gillespie and Norm Sloan for reviewing the manuscript.

FIELD: Henning Andersen, Bob Antifave, Doug August, Pat Biraithwaite, Dean Burke, Cory Carmen, Brian Crawford, Don Christian, Tim Kilchyski, Doug C. Miller, Guy Parker, Clint Ridgway, Ken Ridgway Sr., Ken Ridgway Jr., Almudena Supple, Brendan Vaughan

TECHNICAL: Jennifer Bond and Wayne Hajas for assistance with statistical analysis, Leslie Barton, Dominique Bureau, Joanne Lessard and Brendan Vaughan for assistance with computer software.

REFERENCES

Boutillier, J. A., A. Campbell., R. Harbo and S. Neifer. 1998. Scientific advice for management of the sea cucumber (*Parastichopus californicus*) fishery in British Columbia. P. 309-340. *In*: G. E. Gillespie and L. C. Walthers [eds.]. Invertebrate working papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1996. Can Tech. Rep. Fish. Aquat. Sci. 2221.

Cameron, J. L. and P. V. Fankboner. 1986. Reproductive biology of the commercial sea cucumber *Parastichopus californicus* (Stimpson) (Echinodermata: Holothuroidea). I. Reproductive periodicity and spawning behavior. Can. J. Zool. 64: 168-175.

Cameron, J. L. and P. V. Fankboner. 1989. Reproductive biology of the commercial sea cucumber *Parastichopus californicus* (Stimpson) (Echinodermata: Holothuroidea). II. Observations on the ecology of development, recruitment, and the juvenile life stage. J. Exp. Mar. Biol. Ecol. 127: 43-67.

Conand, C. 1981. Sexual cycle of the three commercially important holothurian species (Echinodermata) from the lagoon of New Caledonia. Bull. Mar. Sc. 31(3):523-543.

Conand, C. 1991. Long-term movements and mortality of some tropical sea cucumbers monitored by tagging and recapture. P. 169-175. *In*: Yanagisawa, Yasumasu, Oguro, Suzuki & Motawa [eds.]. Biology of Echinodermata. Balkema, Rotterdam.

Cripps, K. and A. Campbell. Survey of sea cucumber populations in the central coast of British Columbia during 1993 to 1997. in prep.

Da Silva, J., J.L. Cameron and P. Fankboner. 1986. Movement and orientation patterns in the commercial sea cucumber *Parastichopus californicus* (Stimpson) (Holothuroidea: Aspidochirotida). Mar. Behav. Physiol. 12: 133-47.

Efron, B. and R.J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall, New York. xvi + 436 p.

Fankboner, P. V. and J. L. Cameron. 1985. Seasonal atrophy of the visceral organs in a sea cucumber. Can. J. Zool. 63: 2888-2892.

Heizer, S. and G. Thomas. 1997. Sea cucumber *Parastichopus californicus* dive fishery. P 116-131. *In*: R. M Harbo and K. Hobbs [eds.] Pacific Fishery Updates for invertebrate resources (1994). Can. Manuscr. Rep. Fish. Aquat. Sci. 2369.

Kronlund, A.R., G.E. Gillespie and G.D. Heritage. 1998. Survey methodology for intertidal bivalves. P 127-244. *In*: B.J. Waddell, G. E. Gillespie and L.C. Walthers [eds.]. 1998. Invertebrate working Papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1995. Part1. Bivalves. Can. Tech. Rep. Fish. Aquat. Sci. 2214.

Lambert, P. 1997. Sea cucumbers of British Columbia, Southeast Alaska and Puget Sound, Royal British Columbia Museum handbook, UBC Press, Vancouver, Canada. 166 p.

Lokani, P. 1992. First results of an internal tag retention experiment on sea cucumbers. SPC Beche-de-mer Information Bulletin #4. 23p.

McEwen, F. S. 1987. Phylum Echinodermata: Class Holothuroidea p.574-596. *In*: M.Strathman [ed.]. Reproductive Biology and Development of Marine Invertebrates of the Northern Pacific Coast, edited by M. Strathman, University of Washington Press, Seattle.

Margolin, A. S. 1976 Swimming of the sea cucumber *Parastichopus californicus* (Stimpson) in response to sea stars. Ophelia 15(2): 105-114.

Muscat, A. M. 1983. Population dynamics and the effect on the infauna of the deposit-feeding holothurian *Parastichopus parvimensis* (Clark). Ph. D. Thesis, Univ. Southern California. 328 p.

Sloan, N. A. 1986. World jellyfish and tunicate fisheries and the Northeastern Pacific echinoderm fishery. p.23-33. *In*: G. S Jamieson and N. Bourne [ed.] North Pacific

Workshop on stock assessment and management of invertebrates. Can. Spec. Publ. Fish. Aquat. Sci. 92.

Suttles, W. and W.C. Sturtevant. 1990. Handbook of North American Indians. Volume 7. Northwest Coast. Smithsonian Institute.

Thompson, S.K. 1992. Sampling. John Wiley and Sons, Inc. 343 p.

Yingst, J. Y. 1976. The utilization of organic matter in shallow marine sediments by an epibenthic deposit-feeding holothurian. J. Exper. Mar. Biol. Ecol. 23:55-69.

Zhou, S. and T. C. Shirley. 1996. Habitat and depth distribution of the red sea cucumber *Parastichopus californicus* in a Southeast Alaska Bay. Alaska Fishery Research Bulletin Vol. 3-2: 123-131.

Table 1a. Logistics for the random sites of the 1997 Gulf Islands survey, with survey dates, number of transects per site, and the mean and range of transect lengths and dive times.

Random sites	1	2	3	4	6	8	All Sites
Dates surveyed	Nov.18 19, 21	Nov. 20	Nov. 21	Nov. 22 Dec. 4	Nov. 17	Dec. 5, 6	
Number of days	3	1	1	2	1	2	10
Number of transects	10	10	10	10	10	10	60
Transect length (m)							
Mean	150	105	157	89	72	49	104
Min.	80	25	50	35	30	20	20
Max.	310	285	270	205	130	105	310
Total	1,500	1,045	1,565	890	715	485	6,200
Dive time (min.) per transect							
mean	30	15	25	25	19	18	22
min.	10	3	7	17	4	10	3
max.	71	48	74	43	42	28	74
Total	302	149	249	254	193	183	1,330

Table 1b. Logistics for the intensive sites of the 1997 Gulf Islands survey, with survey dates, number of transects per site, and mean and range of transect lengths and dive times.

Intensive sites	High	Medium	Low	All Sites
Dates surveyed	Nov. 24 Dec. 3, 4, 5	Nov. 24 25, 28	Nov. 25, 26, 30 Dec. 1, 2	
Number of days	5	4	5	14
Number of transects	9	10	10	29
Transect length (m)				
mean	219	104	216	180
min.	135	80	145	80
max.	265	130	255	265
Total	1,970	1,035	2,155	5,160
Dive time (min.) per transect				
mean	28	15	29	21
min.	20	7	14	7
max.	41	29	37	41
Total	251	151	286	688

Table 2a. Logistics for the random sites of the 1998 Jervis Inlet survey with survey dates, number of transects per site, and the mean and range of transect lengths and dive times.

Random sites	1	2	3	4	5	6	All Sites
Dates surveyed	Jan. 13	Jan. 14, 15	Jan. 16, 19	Jan. 14	Jan. 15	Jan. 12	
Number of days	1	2	2	2	1	1	9
Number of transects	10	10	12	10	10	10	62
Transect length (m)							
mean	39	36	46	31	31	41	37
min.	25	40	45	35	20	25	20
max.	100	90	135	90	105	140	140
Total	4,835	4,575	8,030	3,225	3,030	5,130	28,825
Dive time (min.) per transect							
mean	11	10	12	11	11	13	11
min.	7	5	7	7	6	6	5
max.	18	12	23	15	15	26	26
Total	109	99	144	114	108	127	701

Table 2b. Logistics for the intensive sites of the Jervis Inlet survey with survey dates, number of transects per site, and mean and range of transect lengths and dive times.

Intensive sites	High	Medium	Low	All Sites
Dates surveyed	Jan. 19, 20, 21	Jan. 30, 31 Feb. 1, 2	Jan. 20, 21	
Number of days	3	4	2	9
Number of transects	10	10	10	30
Transect length (m)				
mean	109	109	70	96
min.	60	90	40	40
max.	135	170	90	170
Total	1,085	1,090	700	2,875
Dive time (min.) per transect				
mean	30	21	13	21
min.	12	18	9	9
max.	49	29	16	16
Total	299	211	130	640

Table 3. Results of the random sites of the Gulf Islands survey, including classical estimates of the mean density (cucs/m-sh), with standard error and standard deviation, and bootstrapped estimates of confidence intervals around the mean density, population number and biomass, by site and for all sites combined. The biomass estimates were calculated using the mean split weight of 263 g obtained during the experimental harvest of the intensive sites.

	SITE						
	1	2	3	4	6	8	All
Shoreline length (m)	10,000	10,000	10,000	10,000	10,000	10,000	400,000
Number of transects	10	10	10	10	10	10	60
Classical Estimates							
Mean density (cucs/m-sh)	5.55	5.05	0.60	5.35	0.13	1.90	3.10
se	5.02	4.46	0.49	1.46	0.09	0.75	1.15
S	15.87	14.10	1.55	4.60	0.27	2.36	8.88
I (variance/mean)	45.35	39.39	4.00	3.96	0.58	2.93	25.45
# transects with 0 cucs	4	7	6	0	8	3	28
Bootstrap Estimates							
Mean density (cucs/m-sh)							
lower 95%	0.23	0.00	0.05	2.85	0.00	0.63	1.24
upper 95%	15.68	14.05	1.60	8.10	0.30	3.38	5.51
lower 90%	0.30	0.03	0.05	3.12	0.00	0.85	1.48
upper 90%	15.53	13.53	1.55	7.70	0.28	3.10	5.13
Population Number (x 1,000)							
Mean	55.1	50.6	6.0	53.8	1.3	18.7	1,232.8
lower 95%	2.3	0.0	0.5	28.5	0.0	6.3	496.6
upper 95%	156.8	140.5	16.0	81.0	3.0	33.8	2,202.1
lower 90%	3.0	0.3	0.5	31.2	0.0	8.5	591.6
upper 90%	155.3	135.3	15.5	77.0	2.8	31.0	2050.1
Population Biomass (t)							
Mean	14.5	13.3	1.6	14.1	0.3	4.9	324.2
lower CI 95%	0.6	0.0	0.1	7.5	0.0	1.6	130.6
upper CI 95%	41.2	37.0	4.2	21.3	0.8	8.9	579.2
lower CI 90%	0.8	0.1	0.1	8.2	0.0	2.2	155.6
upper CI 90%	40.8	35.6	4.1	20.3	0.7	8.2	539.2

Table 4. Results of the random sites of the Jervis Inlet survey. Classical estimates of the mean density (cucs/m-sh), with standard error and standard deviation, by site and for all sites combined. Bootstrapped estimates of confidence intervals around the mean density, population number and biomass, by site and for all sites combined. The biomass estimates were calculated using the mean split weight of 198 g obtained during the experimental harvest of the intensive sites.

	SITE						
	1	2	3/9	4	5	6	All
Shoreline length (m)	10,0 00	10,000	10,000	10,000	10,000	10,000	400,000
Number of transects	10	10	12	10	10	10	62
Classical Estimates							
Mean Density (cucs/m-sh)	6.53	3.58	11.73	15.53	10.90	8.48	9.53
se	1.62	1.25	4.95	2.84	2.47	2.07	1.28
s	5.12	3.95	17.15	8.98	7.81	6.55	10.08
I (variance/mean)	4.02	4.36	25.08	5.19	5.60	5.06	10.66
# transects with 0 cucs	0	0	2	0	0	0	2
Bootstrap Estimates							
Mean Density (cucs/m-sh)							
lower CI 95%	4.05	1.65	4.39	10.47	6.48	4.92	7.18
upper CI 95%	9.63	6.18	22.00	21.33	16.00	12.45	12.11
lower CI 90%	4.30	1.83	5.10	11.13	7.15	5.40	7.53
upper CI 90%	9.13	5.60	20.11	20.25	14.88	11.90	11.68
Population Number (x 1, 000)							
Mean	65.0	35.4	114.1	154.9	109.7	84.6	3,797
lower CI 95%	40.5	16.5	43.9	104.7	64.7	49.2	2,872
upper CI 95%	96.3	61.8	220.0	213.3	160.0	124.5	4,844
lower CI 90%	43.0	18.3	51.0	111.3	71.5	54.0	3,011
upper CI 90%	91.3	56.0	201.0	202.5	148.8	119.0	4,673
Population Biomass (t)							
Mean	12.9	7.0	22.6	30.7	21.7	16.8	751.8
lower CI 95%	8.0	3.3	8.7	20.7	12.8	9.7	568.7
upper CI 95%	19.1	12.2	43.6	42.2	31.7	24.7	959.1
lower CI 90%	8.5	3.6	10.1	22.0	141.6	10.7	596.2
upper CI 90%	18.1	11.1	39.8	40.1	29.5	23.6	925.2

Table 5. Sea cucumber density (#/m^2), by depth category, for the random sites of the Gulf Islands and Jervis Inlet surveys. The original data, including all original sites, were used to calculate the density per depth category.

Depth Category (m)	Area (m^2)	Number of Sea Cucumbers	Density (#/m^2)
Gulf Islands			
<5	8,480	59	0.007
5 to 7.5	5,020	132	0.026
7.5 to 10	8,560	399	0.047
>10	2,720	157	0.056
Jervis Inlet			
<5	6,820	817	0.120
5 to 7.5	2,640	626	0.237
7.5 to 10	3,700	679	0.184
>10	1,860	241	0.130

Table 6. Summary of comparisons of bootstrapped density estimates between depth categories for the Gulf Islands and Jervis Inlet surveys. Values greater than 0.95 and less than 0.05 are considered significant.

Deep Depth (m)	Shallow Depth (m)	Confidence Level that Mean Density is Greater at Deeper Depth	
		Gulf Islands	Jervis Inlet
5 to 7.5	<5	>0.99	>0.99
7.5 to 10	<5	>0.99	>0.99
>10	<5	>0.99	0.66
7.5 to 10	5 to 7.5	0.97	0.04
>10	5 to 7.5	0.98	<0.01
>10	7.5 to 10	0.70	0.02

Table 7. Sea cucumber density (#/m^2), by substrate code, for the random sites of the Gulf Islands and Jervis Inlet surveys. The original data, including all original sites, were used to calculate the density per substrate code.

Substrate Code[1]	Number of Quadrats	Area (m^2)	% of Total Area	Number of Sea Cucumbers	Density (#/m^2)
Gulf Islands					
1	161	3,220	13	117	0.036
2	112	2,240	9	259	0.116
3	179	3,580	14	171	0.048
4	787	15,740	63	196	0.013
Jervis Inlet					
1	133	2,660	18	390	0.147
2	251	5,020	33	1,084	0.216
3	104	2,080	14	601	0.289
4	263	5,260	35	288	0.055

[1] See Appendix Table 1 for information on substrate codes.

Table 8. Summary of comparisons of bootstrapped density estimates between substrate categories for the Gulf Islands and Jervis Inlet surveys. Substrate categories are defined in Appendix Table 1.

Substrate j	Substrate i	Confidence Level that Mean Density is Greater in Substrate j	
		Gulf Islands	Jervis Inlet
2	1	1.00	1.00
3	1	0.80	1.00
2	3	0.99	0.01
1	4	0.99	1.00
2	4	1.00	1.00
3	4	1.00	1.00

Table 9. Harvest summary in the intensive sites for the Gulf Islands survey, including the number of cages harvested per grid and gross and net split weight, and individual sea cucumber weights.

Grid	Number of cages	Number of cuc.	Gross Split Weight (lb)	Net Split Weight (lb)[1]	Individual Weight g
H1	16	1,564	1,117	1,037	301
H2	14	1,716	978	908	240
H3	18	2,266	1,257	1167	234
H4	30	3,851	2,095	1,945	229
H5	39	4,932	2,724	2,529	233
H	117	14,329	8,171	7,586	240
M1	10.5	1,052	728	676	291
M2	3.5	340	243	225	301
M3	14	1,380	971	901	296
M4	12	1,189	832	772	295
M5	14	1,339	971	901	305
M6	9	849	624	579	309
M	63	6,149	4,370	4,055	299
L1	0	13	11	11	379
L2	1	76	68	63	379
L3	3	244	219	204	379
L4	4	329	295	275	379
L5	2	165	148	138	379
L6	2	109	101	91	379
L	12	936	842	782	379
All	192	21,414	13,383	12,423	263

[1] Calculated by deducting the cage weight of 5 lb

* weight estimated based on the number of sea cucumbers per grid and the number of cages. Gross weights were calculated per day not per grid, only the number of sea cucumbers were calculated per grid.

Table 10. Summary of harvest of the intensive sites for the Jervis Inlet survey, including the number of cages harvested per grid and gross and net split weight, and individual sea cucumber weights.

Grid	Number of cages	Number of cuc.	Gross Split Weight (lb)	Net Split Weight (lb)[1]	Individual Weight g
H1	8	1,676	660	620	168
H2	13	2,536	975	910	163
H3	12	2,643	983	923	158
H4	7	1,518	569	534	160
H5	6	1,131	454	424	170
H6	3	546	212	197	164
H	49	10,050	3,853	3,608	163
M1	13	1,849	1,031	966	237
M2	13	1,828	1,013	948	235
M3	9	1,075	677	632	267
M4	10	1,126	724	674	272
M5	3	394	258	243	280
M6	2	187	125	115	279
M	50	6,459	3,828	3,578	251
L1	3	522	254	239	208
L2	4	575	282	262	207
L3	9	1,491	688	643	196
L4	6	1,054	484	454	195
L5	4	611	289	269	200
L6	3	416	203	188	205
L	29	4,669	2,200	2,055	200
All	128	21,178	9,881	9,241	198

[1] Calculated by deducting the cage weight of 5 lb

Table 11. Summary of the number of cages, gross split weight, net split weight, processing plant split weight, meat weight and percent recovery for the Gulf Islands and Jervis Inlet surveys. Net split weight = gross split weight - (Number of cages X 5 lb. (cage weight))

			Split Weight (lb)				
Date Fished	Site	Number of cages	Gross	Net	Plant	Meat	% Meat Recovery
Gulf Islands							
Nov. 25, 26	M1, 2, 3	28	1,965	1,825	1,827	406	22.22
Nov. 28	M4, 5	26	1,826	1,696	1,605	342	21.31
Nov. 30	M6	9	579	534	540	118	21.85
Dec. 1	L1, 2, 3, 4	8	610	570	552	128	23.19
Dec. 2	L5, 6	4	232	212	210	48	22.86
Dec. 3	H1	16	920	840	807	180	22.30
Dec. 4, 5	H2, 3, 4	43	3,220	3,005	2,953	620	20.99
Dec. 6	H4	14	971	901	893	192	21.50
Dec. 9	H5	34	2,294	2,124	2076	460	22.16
Dec. 10	H5	10	766	716	697	158	22.66
Total		192	13,383	12,423	12,160	2,652	21.81
Jervis Inlet							
Jan. 21	H1, 6	11	872	817	817	146	17.80
Jan. 22	H2, 3	23	1,793	1,678	1,678	292	17.40
Jan. 27	H3, 4, 5	14	1,136	1,066	1,066	204	19.14
Jan. 28	L4, 5, 6	13	976	911	911	158	17.34
Jan. 29	H5, L1, 2, 3	17	1,276	1,191	1,191	216	18.14
Jan. 31	M1	13	1,031	966	966	174	18.01
Feb. 1	M4, 5, 6	14	1,106	1,036	1,036	184	17.76
Feb. 2, 3	M2, 3, 4	23	1,691	1,576	1,376*	276	20.06
Total		128	9,881	9,241	9,041	1,650	18.21

* This weight was initially given to the processing plant; it is short of 200 lb. The actual weight is in the weight column. The associated percent recovery has been adjusted based on the net weight.

Table 12. Density estimates and population size from the high, medium and low density intensive sites, random and systematic transects, in the of the Gulf Islands survey.

	High		Medium		Low	
	Random	Systematic	Random	Systematic	Random	Systematic
Shoreline (m)	200	200	200	200	200	200
Number of transects	5	4	5	5	5	5
Classical Estimates						
mean number per m	75.15	53.38	25.85	22.85	3.50	5.10
Bootstrap Estimates						
mean number per m	75.45	53.71	25.77	22.76	3.52	5.15
lower CI 95%	48.25	33.50	16.65	15.20	0.55	2.00
upper CI 95%	101.05	73.37	35.60	31.65	7.70	8.20
lower CI 90%	50.40	33.50	19.40	15.90	0.70	2.15
upper CI 90%	99.05	72.38	32.75	29.70	7.10	7.70
Population Number (x 1,000)						
mean	15.1	10.7	5.2	4.6	0.7	1.0
lower CI 95%	9.7	6.7	3.3	3.0	0.1	0.4
upper CI 95%	20.2	14.7	7.1	6.3	1.5	1.6
lower CI 90%	10.1	6.7	3.9	3.2	0.1	0.4
upper CI 90%	19.8	14.5	6.6	5.9	1.4	1.5
Population Biomass (t)[1]						
mean	3.6	2.6	1.5	1.4	0.3	0.4
lower CI 95%	2.3	1.6	1.0	0.9	0.0	0.2
upper CI 95%	4.9	3.5	2.1	1.9	0.6	0.6
lower CI 90%	2.4	1.6	1.2	1.0	0.1	0.2
upper CI 90%	4.8	3.5	2.0	1.8	0.5	0.6

[1]The biomass estimates were calculated using the mean split weights obtained during the harvest of the intensive sites. The following mean split weights of 240 g, 299 g and 379 g were used for the high, medium and low sites respectively.

Table 13. Density estimates and population size from the high, medium and low density intensive sites, random and systematic transects, in the of the Jervis Inlet survey.

	High		Medium		Low	
	Random	Systematic	Random	Systematic	Random	Systematic
Shoreline (m)	200	200	200	200	200	200
Number of transects	5	5	5	5	5	5
Classical Estimates						
mean number per m	77.70	60.15	20.90	26.00	16.10	22.05
Bootstrap Estimates						
mean number per m	79.38	60.46	20.92	25.92	15.96	22.29
lower CI 95%	34.80	43.34	13.35	12.50	11.34	14.15
upper CI 95%	122.30	76.90	29.15	39.30	20.05	33.80
lower CI 90%	45.95	45.50	14.39	15.00	12.10	14.75
upper CI 90%	116.40	75.20	28.05	36.60	21.05	32.15
Population Number (x 1,000)						
mean	15.9	12.1	4.2	5.2	3.2	4.5
lower CI 95%	7.0	8.7	2.7	2.5	2.3	2.8
upper CI 95%	24.5	15.4	5.8	7.9	4.2	6.8
lower CI 90%	9.2	9.1	2.9	3.0	2.4	3.0
upper CI 90%	23.3	15.0	5.6	7.3	4.0	6.4
Population Biomass (t)[1]						
mean	2.6	2.0	1.1	1.3	0.6	0.9
lower CI 95%	1.1	1.4	0.7	0.6	0.5	0.6
upper CI 95%	4.0	2.5	1.5	2.0	0.8	1.4
lower CI 90%	1.5	1.5	0.7	0.8	0.5	0.6
upper CI 90%	3.8	2.5	1.4	1.8	0.8	1.3

[1]The biomass estimates were calculated using the mean split weights obtained during the harvest of the intensive sites. The split weights of 163 g, 200 g and 251 g were used for the high, medium and low sites respectively.

Table 14a. Estimated mean density of sea cucumbers with 90% confidence intervals, compared to actual numbers harvested from the intensive harvest sites of the Gulf Islands survey. Comparisons of biomass are also made.

Site	Est. Number of cuc. per m	Bootstrap 90% CI	Act. Number of cuc. per m	Est. Net weight(lb.)	Bootstrap 90% CI lb.	Act. Net weight lb.
H	75.15	50.40 - 99.05	71.65	7,985	5,333 - 10,481	7,586
M	25.85	19.40 - 32.75	30.75	3,395	2,557 - 4,317	4,055
L	3.50	0.70 - 7.10	4.68	589	117 - 1,186	782
All	34.83	20.57 - 51.04	35.69	12,125	7,154 - 17,756	12,423

Table 14b. Estimated mean density of sea cucumbers with 90% confidence intervals, compared to actual numbers harvested from the intensive harvest sites of the Jervis inlet survey. Comparisons of biomass are also made.

Site	Est. Number of cuc. per m	Bootstrap 90% CI	Act. Number of cuc. per m	Est. Net weight (lb.)	Bootstrap 90% CI lb.	Act. Net weight lb.
H	77.7	45.95 - 116.40	50.25	5,706	3303 - 8367	3,608
M	20.9	14.39 - 28.05	32.30	2,315	1592 - 3104	3,578
L	16.1	12.10 - 20.05	23.35	1,407	1067 - 1768	2,055
All	38.23	22.01 - 57.42	35.30	9,960	5765 - 15040	9,241

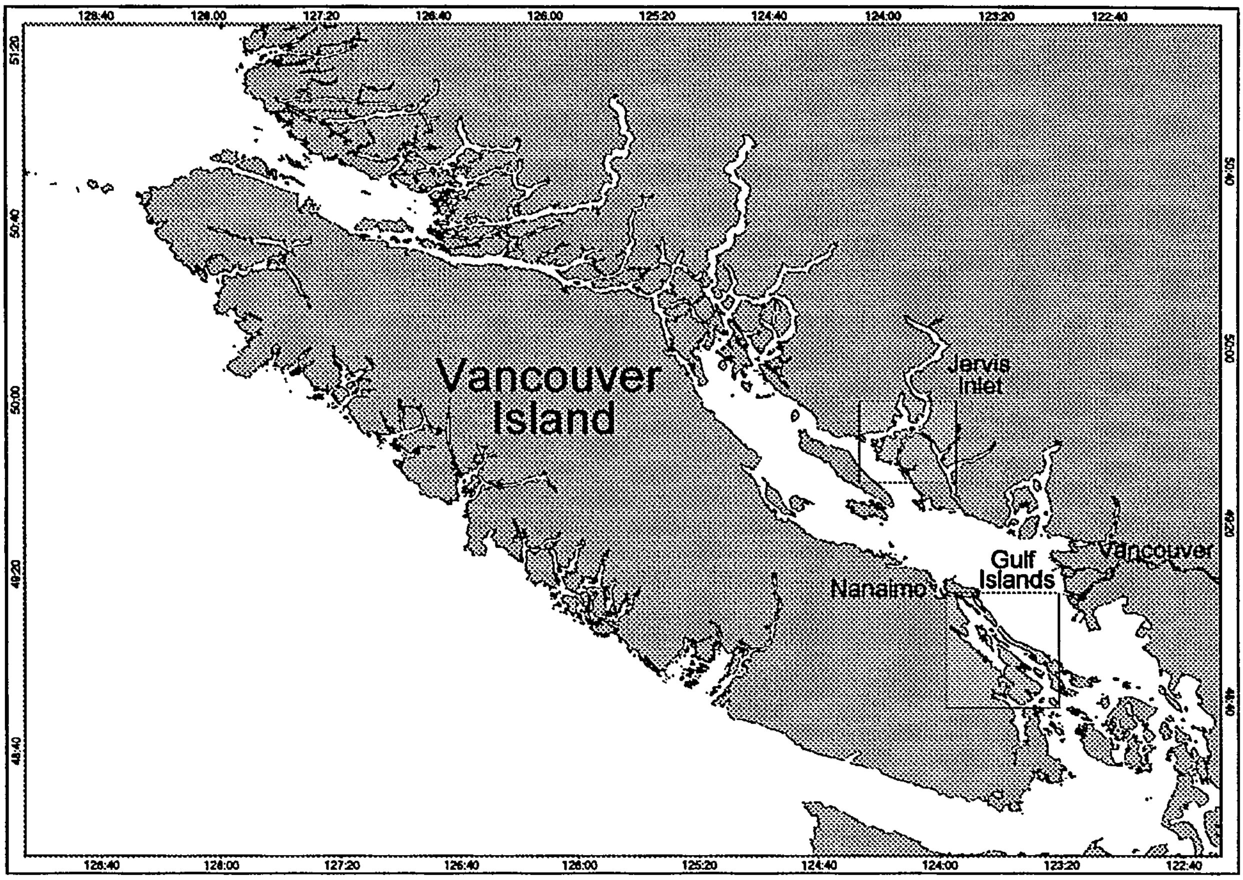


Figure 1. Map of South Western British Columbia with the Gulf Islands and Jervis Inlet survey areas.

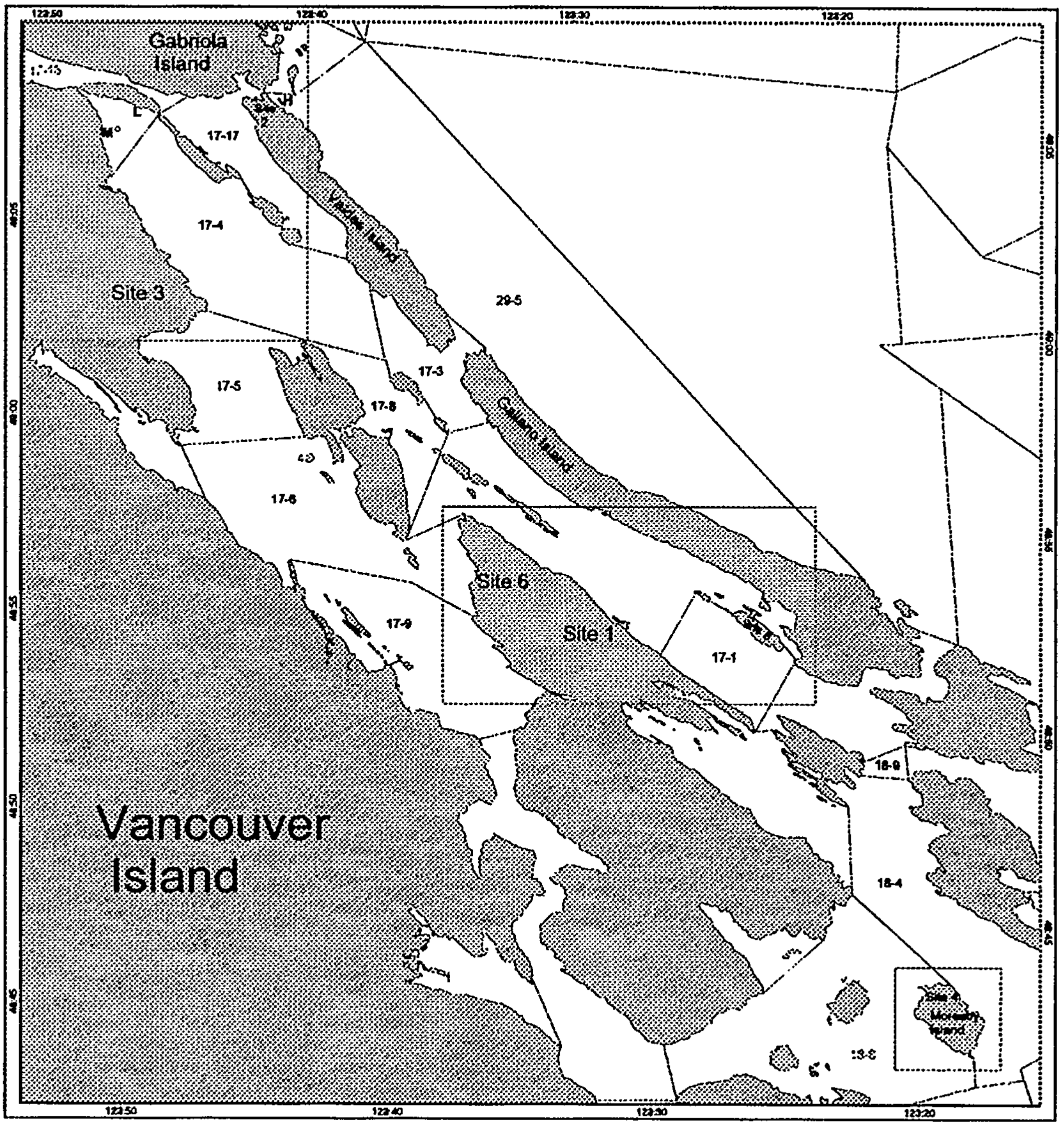


Figure 2. Locations of survey sites in the Gulf Islands area, showing random (1, 2, 3, 4, 6 and 8) and intensive (L, M and H) sites.

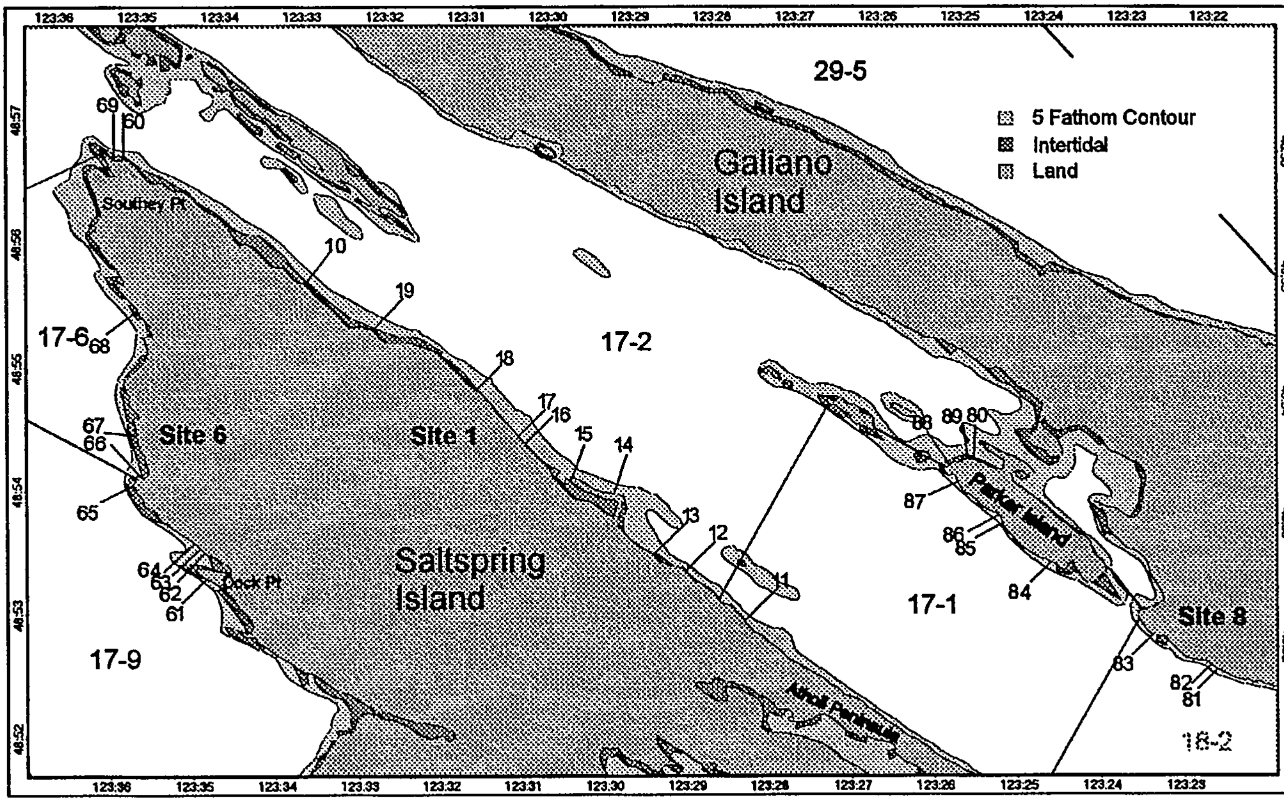


Figure 3. Gulf Islands random sites 1, 6 and 8, showing random transect locations.

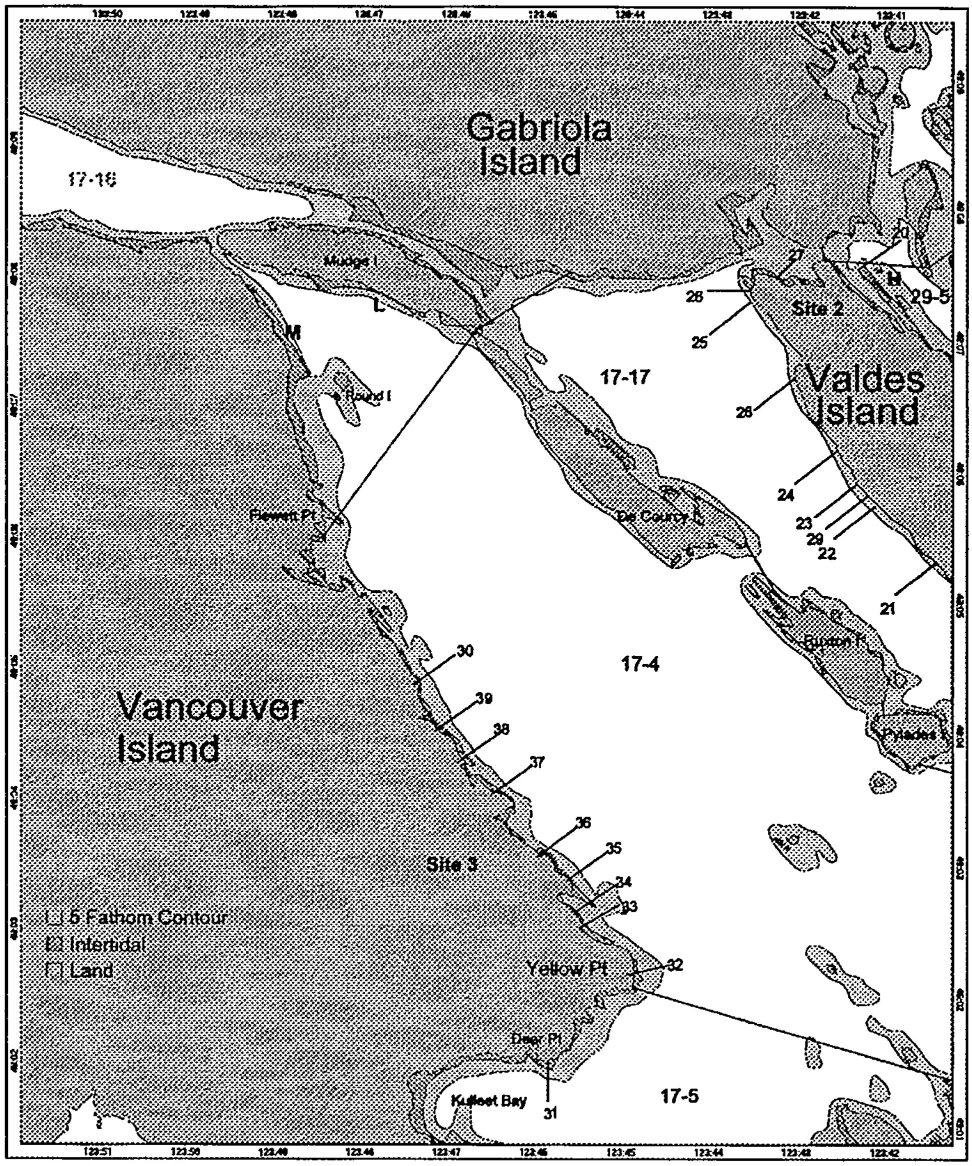


Figure 4. Map of Gulf Islands random sites 2 and 3, with associated transects, and the low (L), medium (M) and high (H) density intensive sites.

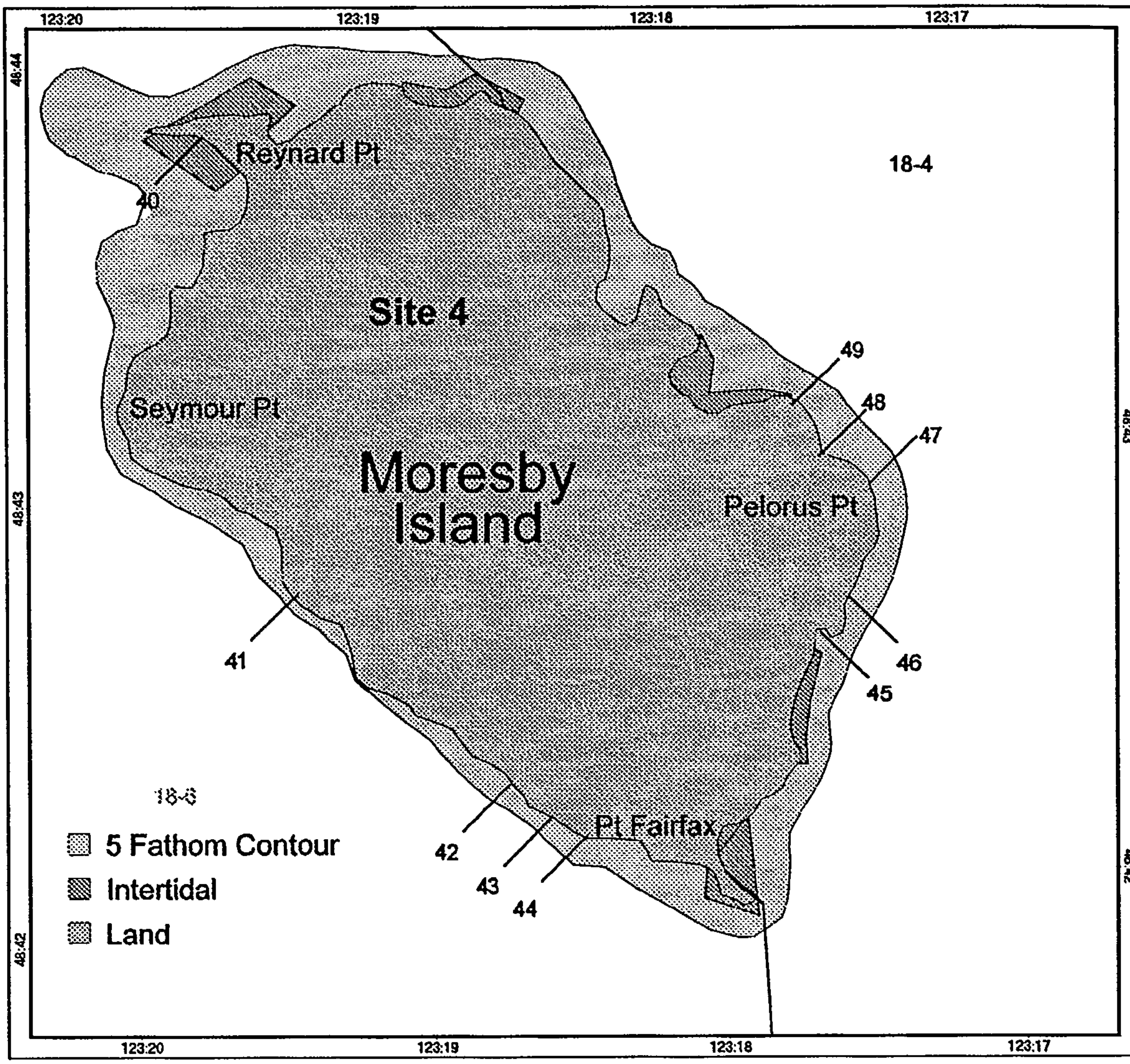


Figure 5. Map of Gulf Islands random site 4, with associated transects.

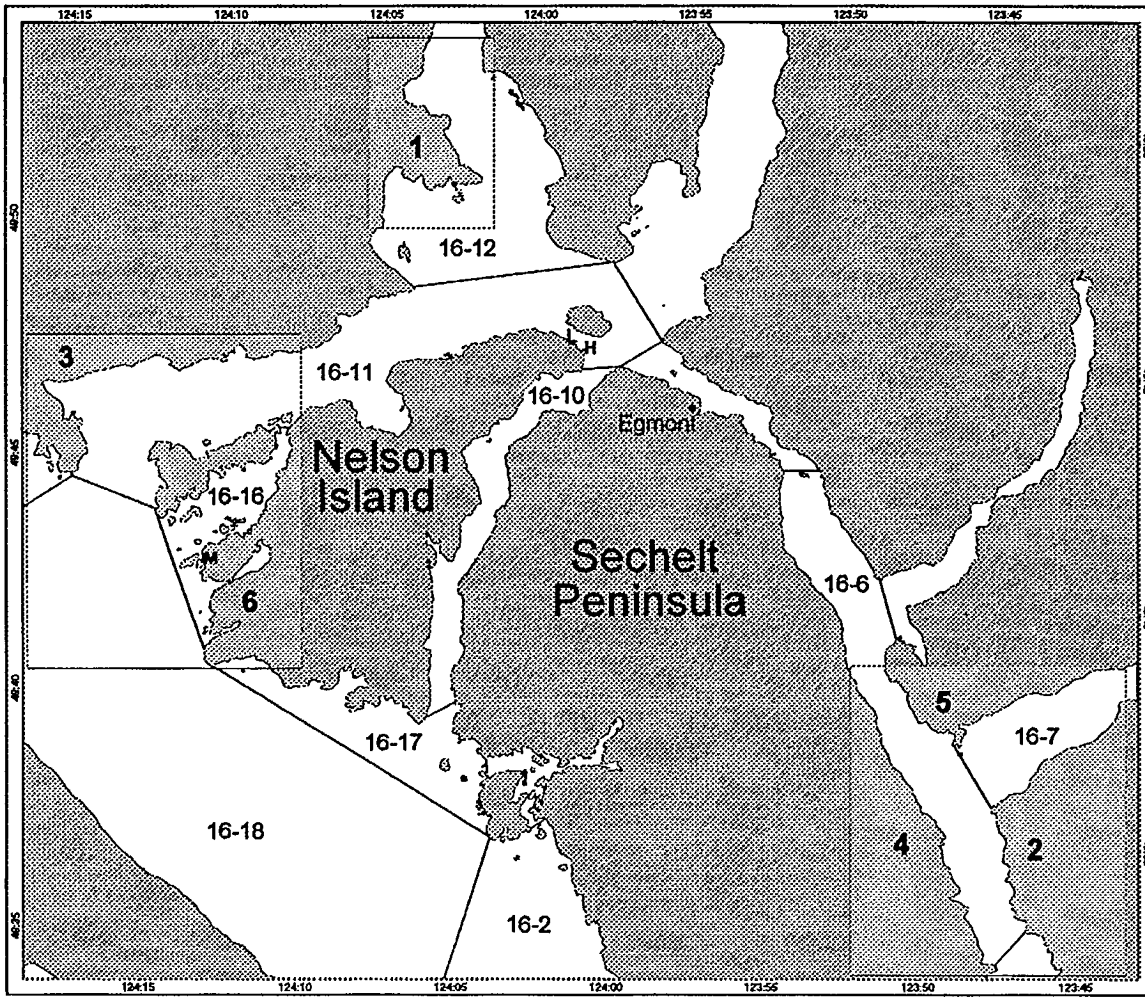


Figure 6. Maps of the Jervis Inlet survey area with the random (1, 2, 3, 4, 5 and 6) and intensive (L, M and H) sites.

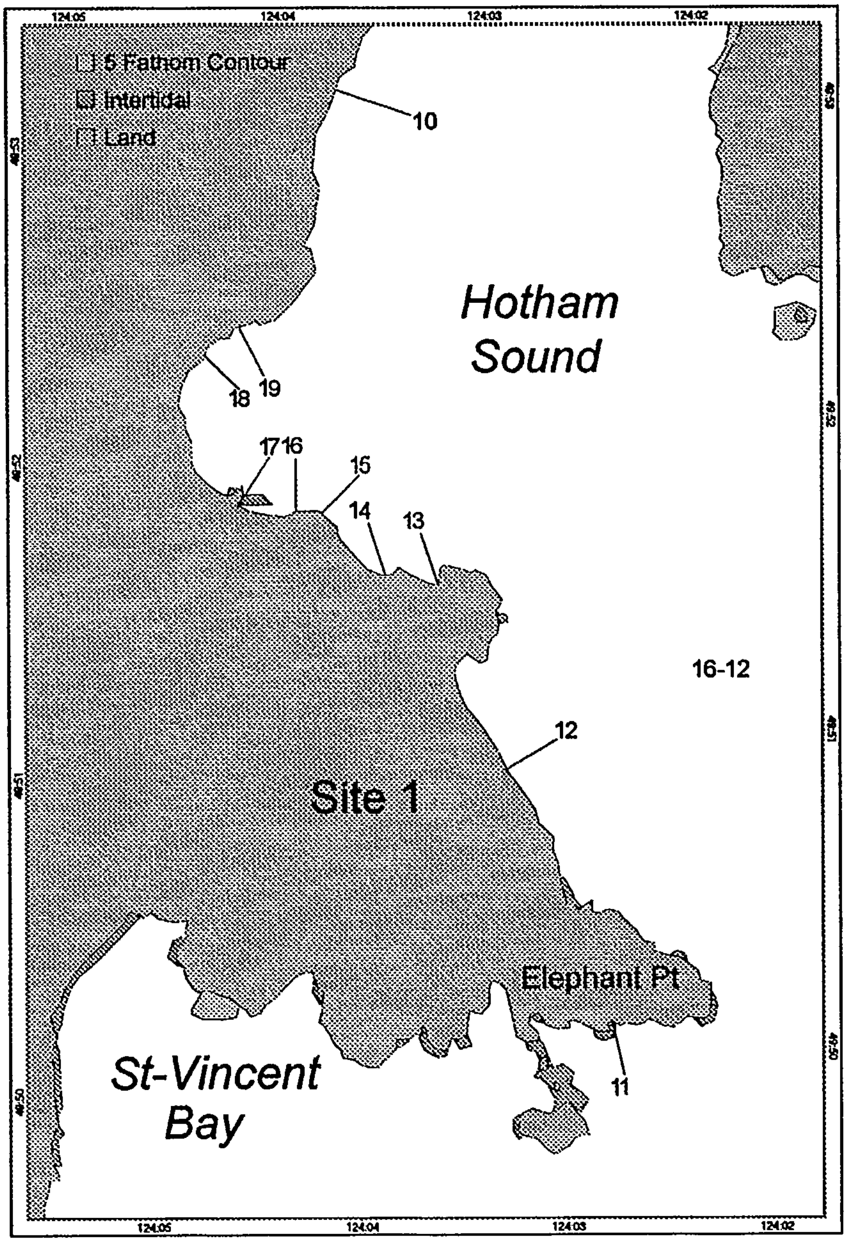


Figure 7. Map of Jervis Inlet random site 1, with associated transects.

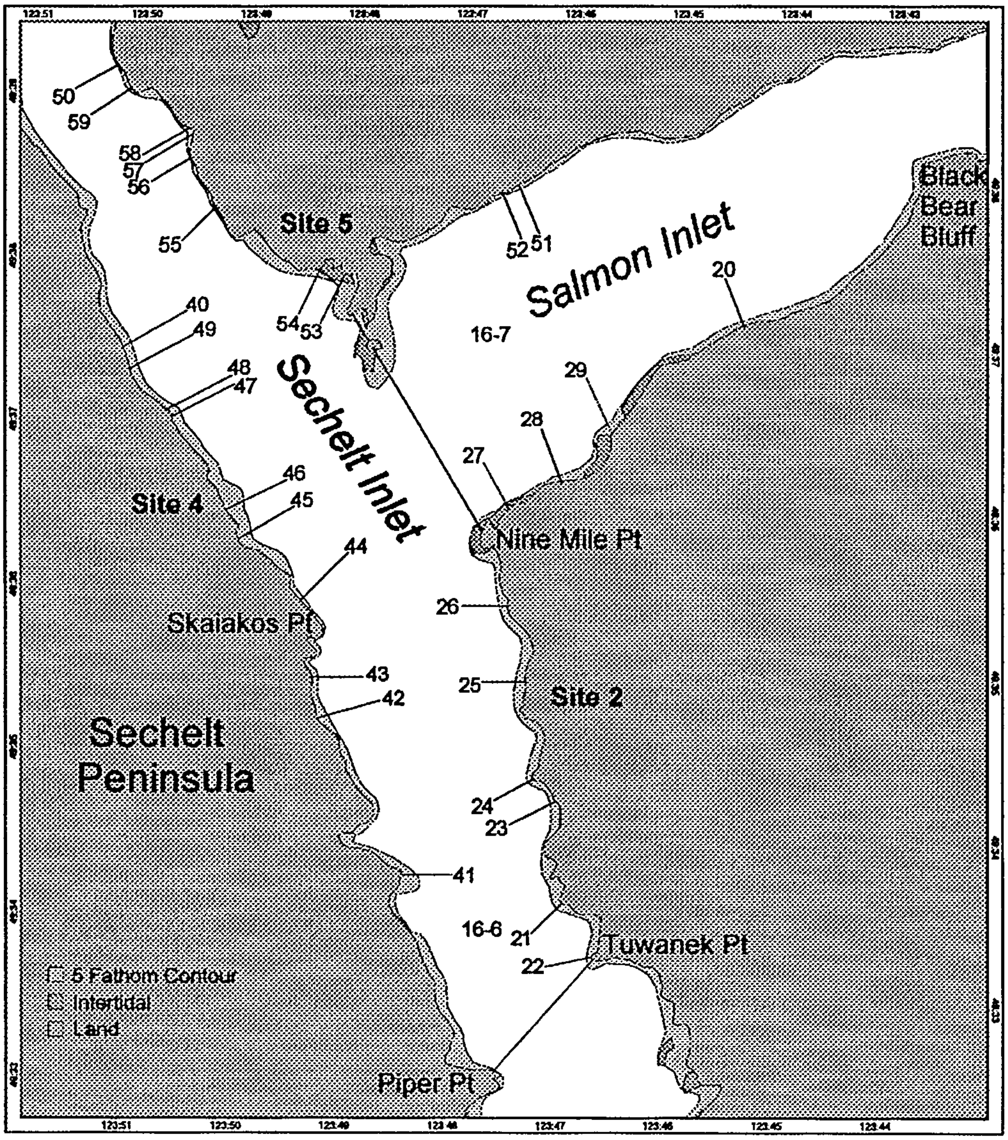


Figure 8. Map of Jervis Inlet random sites 2, 4 and 5, with associated transects.

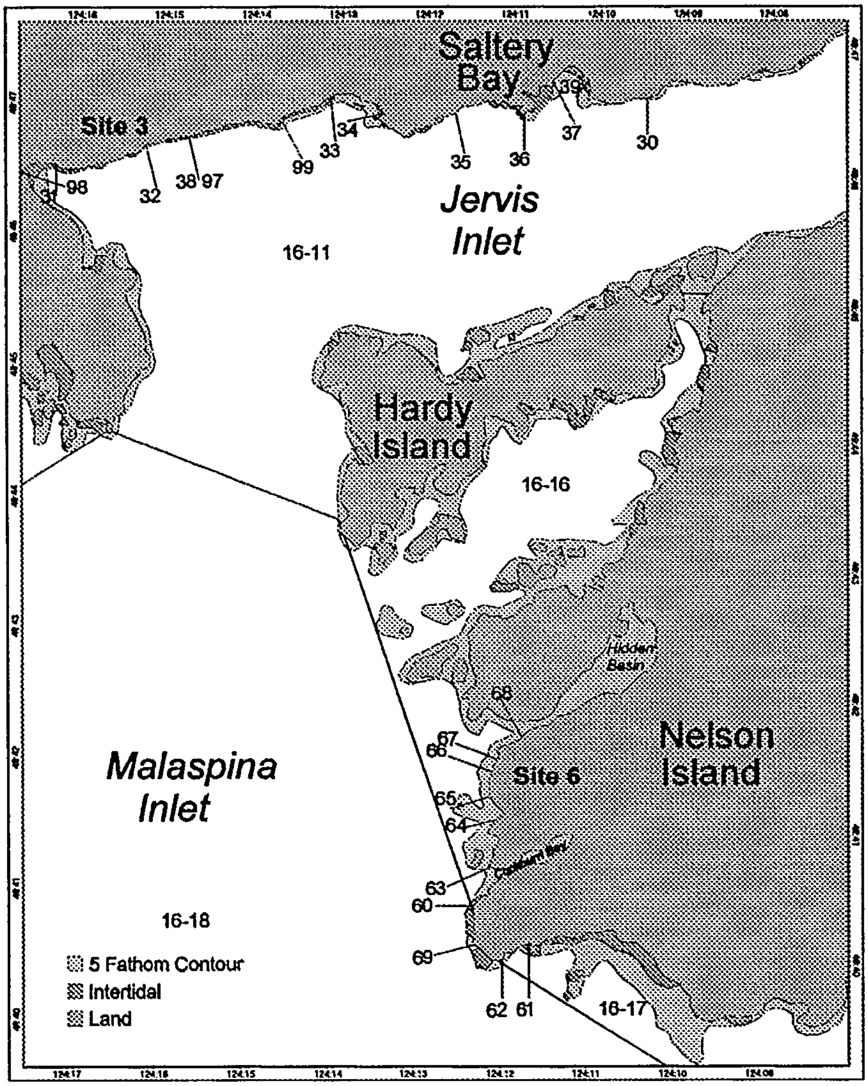


Figure 9. Map of Jervis Inlet random site 3 and 6, with associated transects.

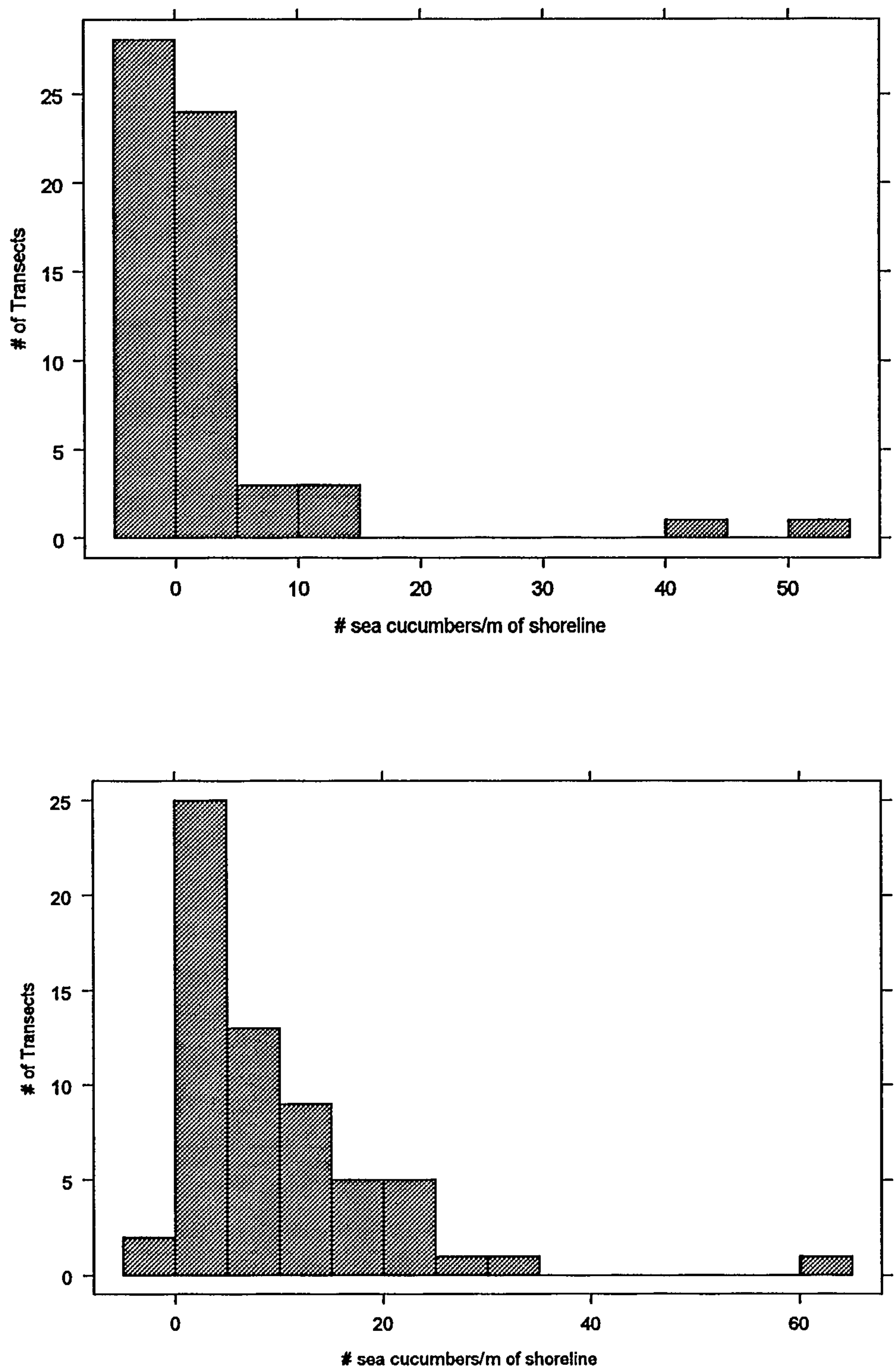
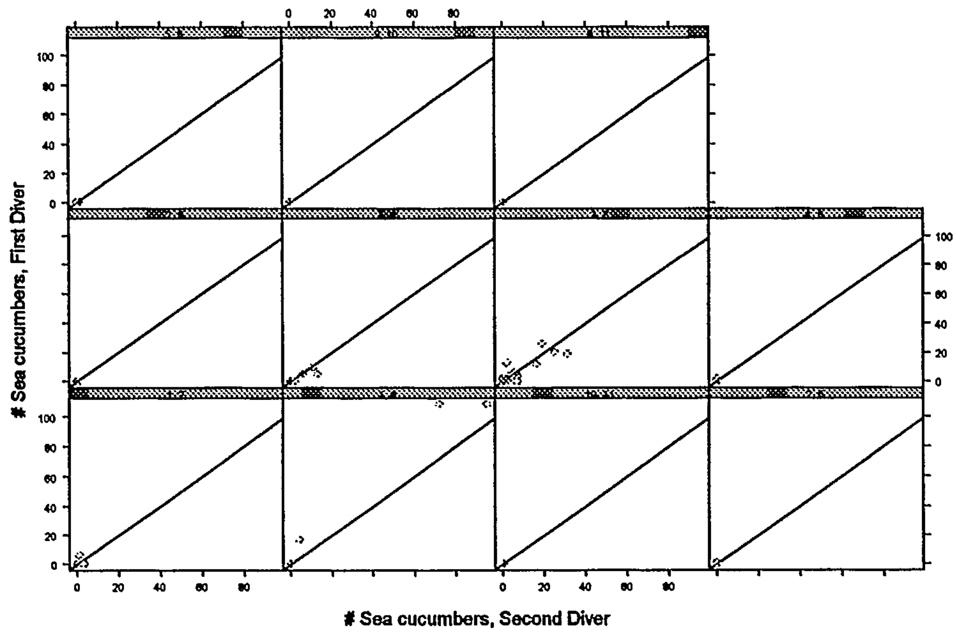


Figure 10. Distribution of transect counts. Top Gulf Islands, Bottom Jervis Inlet.



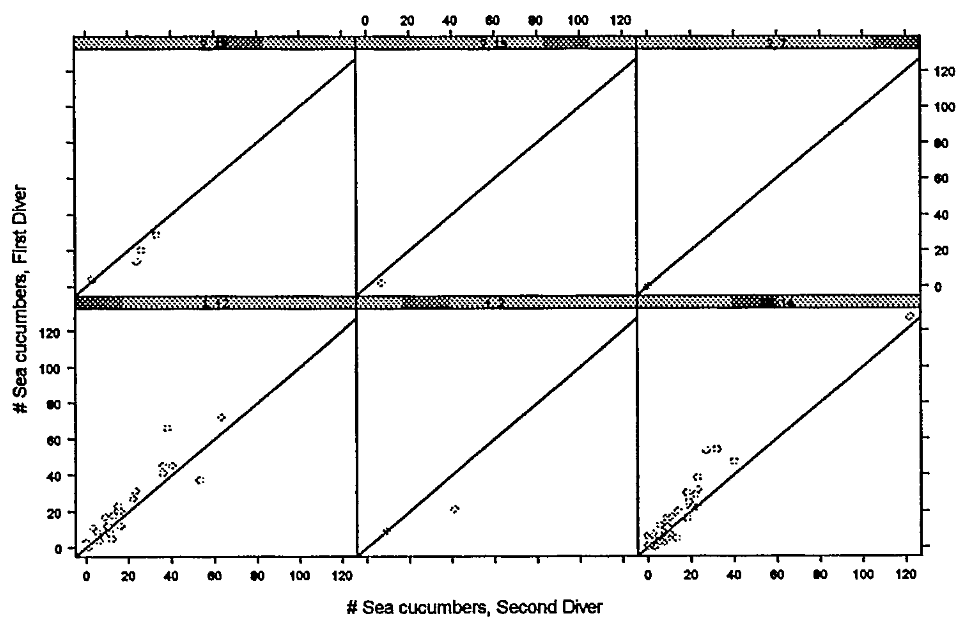


Figure 11. Comparison of the number of sea cucumbers counted on the left and right sides of the transects that were completed by the same pair of divers. Top: Gulf Islands survey. Bottom: Jervis Inlet.

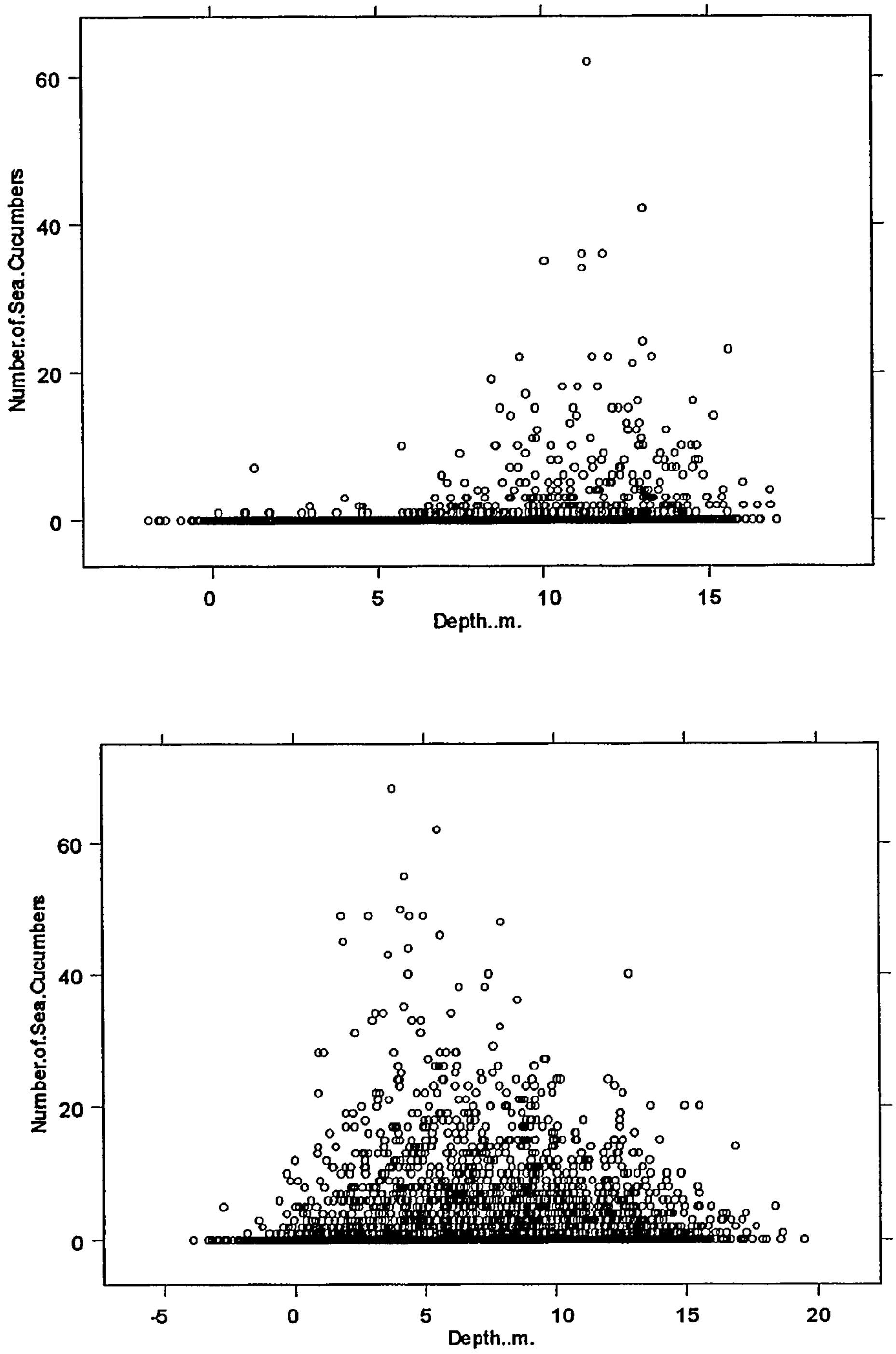
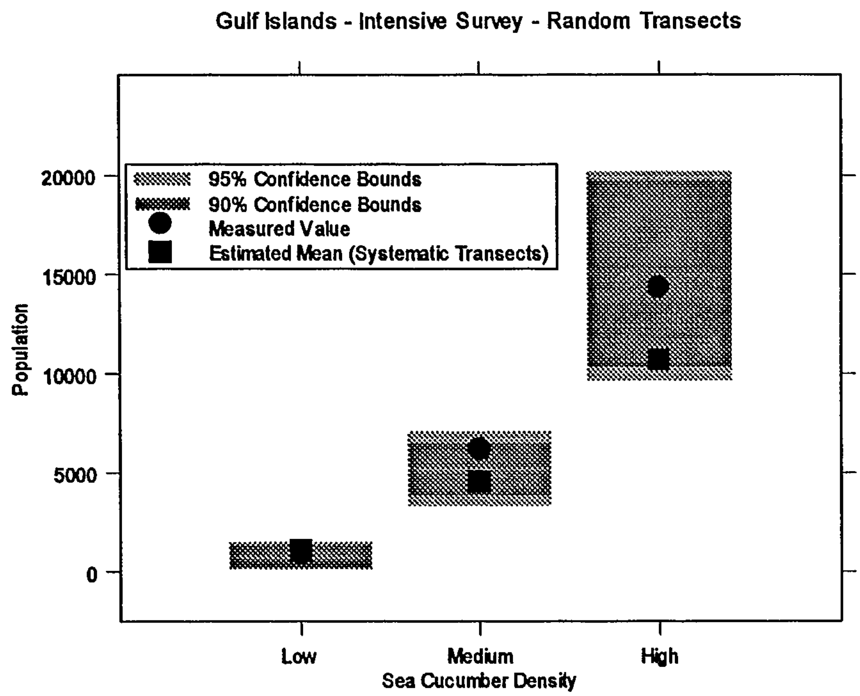


Figure 12. Density (number of sea cucumbers per quadrat) against depth (m) for the Gulf Islands (top) and Jervis Inlet (bottom) surveys.



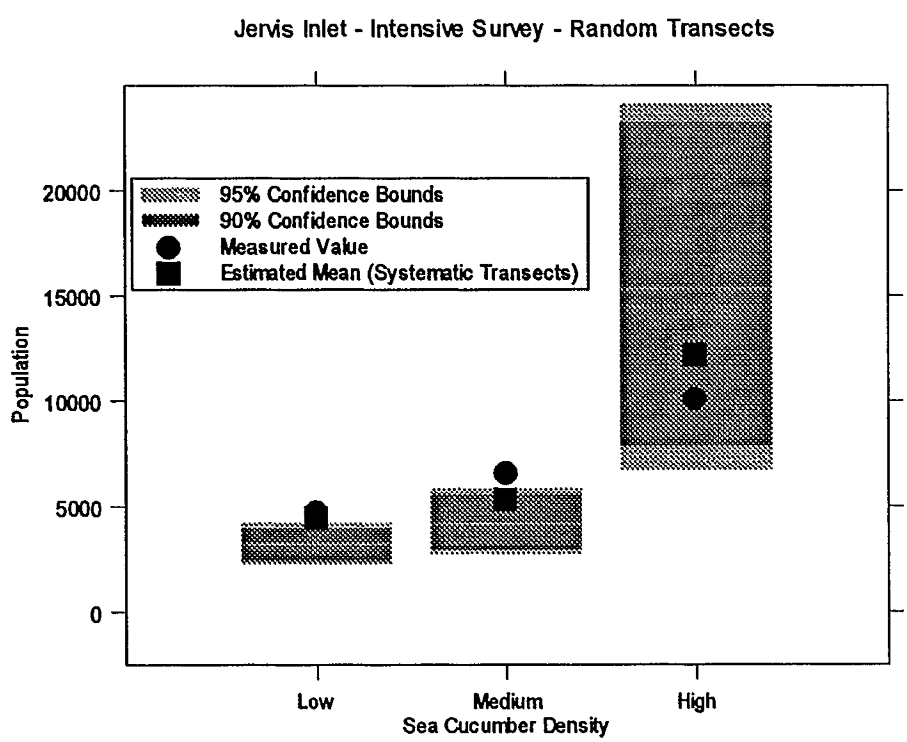


Figure 13. Confidence bounds (90% and 95%) of the estimated population (number of animals) from random transects with the actual number harvested (measured value) from the low, medium and high density intensive sites of the Gulf Islands survey (top) and the Jervis Inlet survey (bottom). The estimated mean population size from systematic transects is also shown.

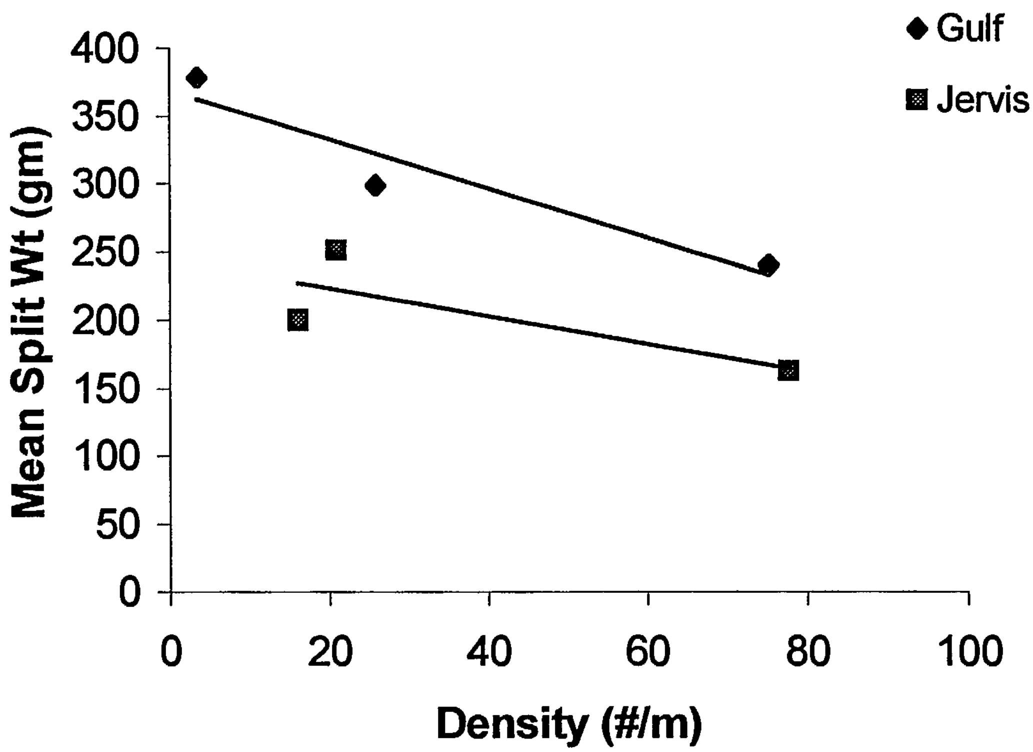


Figure 14. Mean split weight (gm) against density for intensive harvest sites in the Gulf Islands and Jervis Inlet surveys. A linear trend line is shown.

Appendix Table 1. Depth codes used to describe depth and substrate in the Gulf Islands and Jervis Inlet surveys. The depth (below chart datum) was taken at the mid point of the quadrat.

Analysis depth codes

Code	Depth (m)
1	< 5 m
2	5 – 7.5 m
3	7.5 – 10.0 m
4	> 10 m

Substrate codes

Code	u/w Codes	Description
1	RS	Smooth bedrock
2	RC	Creviced bedrock
3	B	Boulders
4	C	Cobbles
5	G	Gravel
6	PG	Pea gravel
7	S	Sand
8	Sh	Shell
9	M	Mud
0	W	Wood

Substrate categories

Code	Description
1	Hard, smooth and creviced bedrock.
2	Complex boulder and cobbles.
3	Mixed, hard and soft substrate, hard dominant.
4	Soft substrate, gravel, sand, mud, shell.

Appendix Table 2. Summary of transect information, by site, with dive team, date surveyed, time in, bottom time, min. and max. depth , number of quadrats, transect length, number of sea cucumbers per transect and per meter of shoreline, and substrate for the random sites of the Gulf Islands survey.

Transect	Dive Team[1]	Date	Time in	Bottom Time	Depth (ft) min-max	Number of Quadrats	Transect Length (m)	Number of Sea Cucumbers /Transect	Number of Sea Cucumbers /m of shoreline	Substrate [2]
Site 1										
10	PSCHA	Nov. 18	9:32	46	17-58	29	145	7	1.75	M/S/Sh
11	CB	Nov. 21	15:09	17	5-55	20	100	2	0.50	M/S/Sh
12	CB	Nov. 21	14:01	30	9-60	20	100	0	0.00	M/S/Sh
13	PSCHA	Nov. 19	9:32	20	10-59	41	205	1	0.25	M
14	PSCHA	Nov. 18	14:33	19	16-53	16	80	0	0.00	B/Sh/S
15	CB	Nov. 18	14:54	10	3-58	19	95	2	0.50	M/S/Sh
16	PSCHA	Nov. 18	12:29	71	46-60	62*	310	203	50.75	B/M/C
17	CB	Nov. 18	13:15	30	9-45	34	170	7	1.75	M/S
18	PSCHA	Nov. 18	11:07	18	20-59	26	130	0	0.00	S/M
19	CB	Nov. 18	11:25	41	10-43	33	165	0	0.00	S/M/C
Site 2										
20	PSCHA	Nov. 20	11:33	48	12-60	57	285	180	45.00	R/G
21	PSCHA	Nov. 20	9:21	10	8-61	14	70	0	0.00	Sh/S
22*	PSCHA	Nov. 20	9:44	3	15-60	6	30	0	0.00	R/Sh
23*	PSCHA	Nov. 20	9:53	3	10-60	5	25	0	0.00	Sh/B
24*	PSCHA	Nov. 20	10:06	5	10-60	5	25	0	0.00	R/B
25*	PSCHA	Nov. 20	10:23	4	10-60	6	30	0	0.00	Sh/R
26	PSCHA	Nov. 20	10:35	10	6-60	10	50	0	0.00	Sh/S/R
27	PSCHA	Nov. 20	13:22	30	13-55	56	280	21	5.25	R/G
28	PSCHA	Nov. 20	14:29	28	12-62	42	210	1	0.25	B/W/M
29	PSCHA	Nov. 20	15:22	8	5-63	8	40	0	0.00	Sh/R
Site 3										
30	PSCHA	Nov. 21	9:17	7	15-64	10	50	0	0.00	Sh/S/R
31	PSCHA	Nov. 21	13:36	27	9-61	35	175	20	5.00	Sh/R/S
32	DFO	Nov. 21	14:22	74	14-55	51	255	0	0.00	R/B
33	DFO	Nov. 21	13:08	30	15-58	32	160	1	0.25	R/Sh
34	PSCHA	Nov. 21	12:37	29	16-49	54	270	0	0.00	S/Sh/R
35	DFO	Nov. 21	12:10	22	11-59	20	100	0	0.00	Sh/R
36	PSCHA	Nov. 21	11:32	11	12-61	24	120	0	0.00	S/Sh
37	PSCHA	Nov. 21	11:00	9	15-63	18	90	0	0.00	S/R/C
38	PSCHA	Nov. 21	10:27	13	14-60	20	100	1	0.25	S/R
39	PSCHA	Nov. 21	9:40	27	10-60	49	245	2	0.50	S/Sh/R

Appendix Table 2, cont'd.

Transect	Dive Team[1]	Date	Time in	Bottom Time	Depth (ft) min-max	Number of Quadrats	Transect Length (m)	Number of Sea Cucumbers /Transect	/m of shoreline	Substrate [2]
Site 4										
40	CB	Nov. 22	14:40	35	9-58	31	155	4	1.00	M/S/B
41	CB	Nov. 22	12:26	18	7-56	12	60	1	0.25	C/S/B
42	CB	Nov. 22	11:22	19	11-60	9	45	21	5.25	C/R/S
43	CB	Nov. 22	10:34	17	10-64	10	55	11	2.75	M/C/R
44	CB	Nov. 22	9:44	21	9-59	7	35	18	4.50	R/C
45	CB	Dec. 4	9:50	43	11-63	41	205	45	11.25	S/C/R
46	CB	Dec. 4	11:18	26	18-65	17	85	45	11.25	M/R
47	CB	Dec. 4	12:11	24	8-66	15	75	12	3.00	R/Sh
48	CB	Dec. 4	13:58	31	9-80	21	105	7	1.75	R/Sh
49	CB	Dec. 4	15:04	20	5-64	14	70	50	12.50	R/Sh
Site 6										
60	PSCHA	Nov. 17	14:05	33	33-58	20	100	3	0.75	S/B
61	PSCHA	Nov. 17	10:52	8	30-60	11	55	0	0.00	C/Sh
62	CB	Nov. 17	11:09	19	6-61	9	45	0	0.00	S/M/B
63	PSCHA	Nov. 17	11:19	4	30-60	6	30	0	0.00	Sh/B
64	CB	Nov. 17	11:56	11	3-67	8	40	2	0.50	S/M
65	PSCHA	Nov. 17	11:52	15	27-60	20	100	0	0.00	R/Sh
66	CB	Nov. 17	12:42	35	7-65	26	130	0	0.00	S/R
67	PSCHA	Nov. 17	12:30	13	22-58	13	65	0	0.00	M/S
68	CB	Nov. 17	14:11	42	6-58	20	100	0	0.00	M/S/Sh
69	PSCHA	Nov. 17	13:24	13	15-58	10	50	0	0.00	
Site 8										
80	CB	Dec. 6	10:44	21	9-51	21	105	1	0.25	M/S
81	CB	Dec. 5	10:06	28	0-65	7	35	28	7.00	R
82	CB	Dec. 5	11:06	16	0-64	6	30	15	3.75	R/Sh
83	CB	Dec. 5	11:57	13	0-68	5	25	15	3.75	R/Sh
84	CB	Dec. 5	12:58	22	4-63	12	60	11	2.75	R/Sh
85	CB	Dec. 5	13:47	10	11-51	4	20	0	0.00	Sh/B
86	CB	Dec. 6	14:30	13	2-60	6	30	5	1.25	R/B
87	CB	Dec. 6	13:19	20	5-67	7	35	0	0.00	R/Sh
88	CB	Dec. 6	12:25	21	24-58	8	40	1	0.25	Sh/S
89	CB	Dec. 6	11:30	19	10-58	21	105	0	0.00	M/Sh
Site 10										
106	CB	Nov. 26	15:15	32	16-59	32	160	13	3.25	S
107	CB	Nov. 26	13:16	49	24-45	43*	220	3	0.75	R/B/S

*No leadline used
[1]PSCHA: Pacific Sea Cucumber Harvesters Association
CB: Cowichan Band
DFO: Department of Fisheries and Oceans
[2]See Appendix Table 1.

Appendix Table 3. Summary of transects information, by site, with dive team, date surveyed, time in, bottom time, min. and max. depth number of quadrats, transect length, number of sea cucumbers per transects and per meter of shoreline, and substrate for the intensive sites of the Gulf Islands survey.

Transect	Dive Team [1]	Date	Time in	Bottom Time	Depth (ft) min.-max.	Number of Quadrats	Transect Length (m)	Sea Cucumbers /m of shoreline	Sea Cucumbers per m^2**	Substrate [2]
High Density										
HR1	PSCHA	Nov. 24	8:57	33	29-58	41	205	100.5	0.490	Sh/B
HR2	PSCHA	Nov. 24	9:38	37	24-58	48	240	104.75	0.511	Sh/B/R
HR3	PSCHA	Nov. 24	10:46	21	39-70	41	205	94.75	0.462	R/G
HR4	PSCHA	Nov. 24	11:16	22	10-65	53	265	43.25	0.211	B/R/Sh
HR5	PSCHA	Nov. 24	11:51	20	18-60	45	225	32.5	0.159	B/R
HS1	PSCHA	Dec. 3	9:50	41	8-62	53	265	22.5	0.110	R/S/Sh
HS2	PSCHA	Dec. 4	9:25	32	16-56	51	255	44.5	0.217	C/Sh/B
HS3	PSCHA	Dec. 4	10:10*	25	20-59	27	135	89	0.434	C/S
HS4	PSCHA	Dec. 5	9:30*	20	18-51	35	175	57.5	0.280	Sh
Medium Density										
MR1	PSCHA	Nov. 24	13:03	16	25-60	16	80	24.5	0.120	C/Sh
MR2	PSCHA	Nov. 24	13:20	16	24-63	19	95	26	0.127	C/Sh
MR3	PSCHA	Nov. 24	13:40	14	34-65	17	85	10.5	0.051	C/Sh
MR4	PSCHA	Nov. 24	14:07	9	28-63	18	90	42.5	0.207	C
MR5	PSCHA	Nov. 24	14:26	14	14-60	19	95	25.75	0.126	C
MS1	MX	Nov. 25	10:04	21	14-60	22	110	13.75	0.067	B/S
MS2	MX	Nov. 25	10:44	7	5-64	26	130	15	0.073	B/S
MS3	MX	Nov. 25	11:44	11	23-60	21	105	28.25	0.138	B/S
MS4	MX	Nov. 25	12:12	14	14-60	24	120	38.75	0.189	B/S
MS5	DFO	Nov. 28	11:31*	29	12-63	25	125	18.5	0.090	Sh/S
Low Density										
LR1	CB	Nov. 25	9:59	31	21-60	48	240	0.25	0.001	G/S/Sh
LR2	CB	Nov. 25	11:20	33	23-57	44	225	11.25	0.055	C/Sh
LR3	CB	Nov. 25	13:36	29	18-60	45	225	4.25	0.021	C/B/S
LR4	CB	Nov. 25	14:35	34	22-60	31	155	0.5	0.002	C/S/G
LR5	CB	Nov. 26	9:50	37	21-61	29	145	1.25	0.006	C/Sh
LS1	PSCHA	Nov. 30	13:27	31	16-59	50	250	1	0.005	Sh/C
LS2	PSCHA	Nov. 30	14:50	14	19-58	51	255	0.75	0.004	C/G
LS3	PSCHA	Dec. 1	10:42	24	20-60	48	240	10.25	0.050	C/G/B
LS4	PSCHA	Dec. 1	12:51	28	19-60	46	230	6.5	0.032	C/S/Sh
LS5	PSCHA	Dec. 2	11:38	25	13-59	38	190	7	0.034	S/C

* Estimated time
** Sea cucumbers per m2: (Sea cucumbers per meter X 4 m) / (Number of Quadrats X 20 m2)
[1]PSCHA: Pacific Sea Cucumber Harvesters Association
CB: Cowichan Band
DFO: Department of Fisheries and Oceans
MX: Transect surveyed by members of 2 teams
[2]See Appendix Table 1

Appendix Table 4. Summary of transect information, by site, with dive team, date surveyed, time in, bottom time, min. and max. depth, number of quadrats, transect length, number of sea cucumbers per transect and per meter of shoreline, and substrate for the random sites of the Jervis Inlet survey.

Transect	Dive Team [1]	Date	Time in	Bottom Time	Depth (ft) min-max	Number of Quadrats	Transect Length (m)	Sea Cucumbers /transect	Sea Cucumbers /m of shoreline	Substrate [2]
Site 1										
10	PSCHA	Jan. 13	10:13	11	23-70	20	100	22	5.50	B/S
11	PSCHA	Jan. 13	13:12	11	16-70	20	100	17	4.25	S/G/R
12*	PSCHA	Jan. 13	12:42	11	12-60	13	65	35	8.75	R/B
13	PSCHA	Jan. 13	12:41	11	10-55	13	65	24	6.00	C/G/R
14*	PSCHA	Jan. 13	12:24	10	12-63	7	35	6	1.50	M/C
15	PSCHA	Jan. 13	12:03	7	7-60	9	45	9	2.25	R/B
16	PSCHA	Jan. 13	11:37	9	11-65	16	80	14	3.50	S/G/B
17	PSCHA	Jan. 13	11:14	12	12-60	15	75	38	9.50	R/B/S
18*	PSCHA	Jan. 13	10:54	18	10-60	5	25	77	19.25	B/C
19*	PSCHA	Jan. 13	10:42	9	18-60	6	30	19	4.75	B/S
Site 2										
20	PSCHA	Jan. 14	11:29	10	10-60	11	55	54	13.50	S/C
21	PSCHA	Jan. 14	9:42	11	9-62	11	55	8	2.00	R/B/S
22	PSCHA	Jan. 15	9:59	12	8-63	14	70	9	2.25	G/S/B
23	PSCHA	Jan. 14	10:10	5	6-60	9	45	2	0.50	S/G
24	PSCHA	Jan. 14	10:27	12	15-60	14	70	16	4.00	R/B/G
25	PSCHA	Jan. 14	10:44	7	10-58	8	40	10	2.50	R
26	PSCHA	Jan. 14	10:23	11	10-60	14	70	26	6.50	S/G
27	PSCHA	Jan. 14	11:06	11	11-65	9	45	14	3.50	R/B
28	PSCHA	Jan. 14	11:27	10	7-55	18	90	1	0.25	S/G
29	PSCHA	Jan. 14	11:47	10	10-60	18	90	3	0.75	S/G
Site 3/9										
30*/90	PSCHA	Jan. 16	10:02	13/10	10-64	7/8	35/40	14/25	3.5/6.25	R/C
31/91	PSCHA	Jan. 16	11:48	10/13	14-55	15/18	75/90	51/48	12.75/12	G/B/S
32/92	PSCHA	Jan. 16	12:09	8/7	17-60	7/10	35/50	57/4	14.25/1	B/C
33/93	PSCHA	Jan. 16	12:08	13/10	8-56	18/15	90/75	72/17	18/4.25	B/C/S
34/94	PSCHA	Jan. 16	11:39	12/11	15-56	12/18	60/90	62/20	15.5/5	R/B/S
35/95	PSCHA	Jan. 16	11:06	11/16	8-53	18/19	90/95	11/8	2.75/2	S/R
36/96	PSCHA	Jan. 16	10:58	9/11	12-60	11/9	55/45	27/28	6.75/7	R/S
37	PSCHA	Jan. 16	10:33	17	10-56	25	125	0	0	S/Sh/G
38/97	PSCHA	Jan. 16	12:29	9/10	16-60	9/11	45/55	53/128	13.25/32	C/B
39	PSCHA	Jan. 16	10:37	10	17-57	27	135	1	0.25	S/M/G
98	PSCHA	Jan. 19	11:03	7	13-60	12	60	0	0.00	M/G
99	PSCHA	Jan. 19	12:07	23	9-60	18	90	249	62.25	R/G/B

Appendix Table 4, cont'd.

Transect	Dive Team [1]	Date	Time in	Bottom Time	Depth (ft) min-max	Number of Quadrats	Transect Length (m)	Sea Cucumbers /transect	Sea Cucumbers /m of shoreline	Substrate [2]
Site 4										
40	PSCHA	Jan. 14	12:32	13	7-67	9	45	55	13.75	C/S
41	PSCHA	Jan. 14	15:01	15	15-49	10	50	62	15.50	C/G
42*	PSCHA	Jan. 14	14:27	9	7-59	7	35	18	4.50	S/B/R
43	PSCHA	Jan. 14	14:43	10	6-70	11	55	48	12.00	C/B
44	PSCHA	Jan. 14	14:08	11	8-60	7	35	18	4.50	R/S
45	PSCHA	Jan. 14	13:12	13	12-60	18	90	135	33.75	G/C
46	PSCHA	Jan. 14	13:38	7	15-65	14	70	85	21.25	C/R
47	PSCHA	Jan. 14	13:42	10	5-56	8	40	86	21.50	C/S
48	PSCHA	Jan. 14	13:20	12	6-62	9	45	34	8.50	C/G
49	PSCHA	Jan. 14	12:56	14	10-63	11	55	80	20.00	C/B
Site 5										
50*	PSCHA	Jan. 15	11:53	15	13-50	7	35	44	11.00	R/B
51	PSCHA	Jan. 15	11:08	7	10-60	8	40	14	3.50	G/S
52	PSCHA	Jan. 15	10:57	14	10-60	10	50	51	12.75	C/B
53	PSCHA	Jan. 15	13:42	13	12-56	21	105	81	20.25	R/C
54	PSCHA	Jan. 15	13:25	11	10-63	10	50	61	15.25	R/S/B
55	PSCHA	Jan. 15	12:53	11	13-60	9	45	104	26.00	C/B
56*	PSCHA	Jan. 15	13:10	6	10-60	8	40	36	9.00	R
57*	PSCHA	Jan. 15	13:10	7	20-60	4	20	10	2.50	R/B
58	PSCHA	Jan. 15	12:48	11	12-54	10	50	18	4.50	R/B
59	PSCHA	Jan. 15	12:23	13	11-66	10	50	17	4.25	B/C
Site 6										
60	PSCHA	Jan. 12	12:49	6	13-67	6	30	9	2.25	R
61	PSCHA	Jan. 12	13:39	11	9-59	14	70	62	15.50	G/S/R
62	PSCHA	Jan. 12	13:18	6	10-55	5	25	7	1.75	R/C
63	PSCHA	Jan. 12	13:40	9	15-60	11	55	3	0.75	R/B
64	PSCHA	Jan. 12	12:30	12	8-65	15	75	28	7.00	R/B
65	PSCHA	Jan. 12	11:56	13	6-62	10	50	46	11.50	R/C
66	PSCHA	Jan. 12	11:52	19	10-76	14	70	25	6.25	R/B
67	PSCHA	Jan. 12	11:30	15	11-61	12	60	38	9.50	R/C
68	PSCHA	Jan. 12	11:06	26	6-67	28	140	87	21.75	R/G/C
69	PSCHA	Jan. 12	13:13	10	15-65	10	50	34	8.50	B/S

* No leadline used
[1]PSCHA: Pacific Sea Cucumber Harvesters Association
[2]See Appendix Table 1

Appendix Table 5. Summary of transect information, by site, with dive team, date surveyed, time in, bottom time, min. and max. depth, number of quadrats, transect length, number of sea cucumbers per transect and per meter of shoreline and, substrate for the intensive sites of the Jervis Inlet survey.

Transect	Dive Team	Date	Time in	Bottom Time	Depth (ft) min-max	Number of Quadrats	Transect Length (m)	Sea Cucumbers / m of shoreline	Sea Cucumbers / m^2 **	Substrate [2]
High Density										
HR1	PSCHA	Jan. 19	14:13	22	6-60	20	100	30.5	0.305	C/G
HR2	PSCHA	Jan. 19	14:44	40	9-60	27	135	133.25	0.987	R/B
HR3	PSCHA	Jan. 20	9:40	49	12-65	27	135	142.25	1.054	B/G
HR4	PSCHA	Jan. 20	10:46	49	10-65	26	130	60.5	0.465	R/B/G
HR5	PSCHA	Jan. 20	11:54	17	17-64	12	60	22	0.367	C/R/B
HS1	PSCHA	Jan. 21	10:10	22	10-63	23	115	47.5	0.413	C/G
HS2	PSCHA	Jan. 21	9:22	31	12-62	26	130	81.5	0.627	R/B/C
HS3	PSCHA	Jan. 21	9:24	34	12-60	20	100	71	0.710	C/G/R
HS4	PSCHA	Jan. 20	13:32	23	10-62	24	120	75.25	0.627	R/C/B
HS5	PSCHA	Jan. 20	14:22	12	10-61	12	60	25.5	0.425	R/B
Medium Density										
MR1	PSCHA	Jan. 20	15:02	27	15-32	22	110	34	0.309	B/C
MR2	PSCHA	Jan. 20	12:16	21	18-42	18	90	28.5	0.317	C/G/R
MR3	PSCHA	Jan. 20	12:41	18	10-42	19	95	17.25	0.182	R/C/S
MR4	PSCHA	Jan. 20	10:06	18	9-46	20	100	15.25	0.153	R/C/S
MR5	PSCHA	Jan. 20	9:19	18	16-46	18	90	9.5	0.106	C/G
MS1	PSCHA	Jan. 21	10:26	29	21-61	34	170	42.5	0.250	C/Sh/S
MS2	PSCHA	Jan. 21	10:51	21	19-47	23	115	43.5	0.378	S/C/R
MS3	PSCHA	Jan. 21	10:29	18	19-45	24	120	25.5	0.213	C/S/R
MS4	PSCHA	Jan. 21	9:42	21	12-46	21	105	12	0.114	C/S/R
MS5	PSCHA	Jan. 21	8:40	20	16-47	19	95	6.5	0.068	C/S/R
Low Density										
LR1	PSCHA	Jan. 30	12:31	12	6-23	16	80	7.75	0.097	C/B/M
LR2	PSCHA	Feb. 2	12:50	11	10-27	13	65	17	0.262	G/M/C
LR3	PSCHA	Feb. 2	13:04	14	8-60	17	85	22	0.259	G
LR4	PSCHA	Jan. 31	13:39	15	10-55	11	55	22.25	0.405	G/C/B
LR5	PSCHA	Jan. 31	14:08	14	7-55	8	40	11.5	0.288	R/B
LS1	PSCHA	Jan. 31	10:14	9	8-27	16	80	11.75	0.147	M/G
LS2	PSCHA	Feb. 1	10:28	12	9-35	18	90	20.75	0.231	G/S/C
LS3	PSCHA	Feb. 1	10:45	16	8-55	15	75	44.5	0.593	C/R/G
LS4	PSCHA	Jan. 31	10:43	15	7-60	16	80	17.75	0.222	G/C
LS5	PSCHA	Jan. 31	11:08	12	10-58	10	50	15.5	0.310	C/G/B

* Estimated time

** Sea cucumbers per m2: (Sea cucumbers per meter X 4 m) / (Number of Quadrats X 20 m2)

[1]PSCHA: Pacific Sea Cucumbers Harvesters Association

[2]See Appendix Table 1