Washington Department of FISH and WILDLIFE

RESULTS FROM THE 2001 TRANSBOUNDARY TRAWL SURVEY OF THE SOUTHERN STRAIT OF GEORGIA, SAN JUAN ARCHIPELAGO AND ADJACENT WATERS

by

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ABSTRACT

During May and June 2001, a synoptic survey of the southern Strait of Georgia, San Juan Archipelago and adjacent waters was conducted in the transboundary waters of Washington and British Columbia. The survey was designed to estimate the numerical and biomass abundances of key benthic species, identify population trends, and quantify the impact of fisheries. The 2001 survey was also designed to describe the distribution of key commercial fishes that inhabit the Strait of Georgia, San Juan Archipelago and adjacent waters. The survey was also designed to determine which species are likely move between Washington and British Columbian waters and which species are vulnerable to fisheries on either side of the border.

Standard trawl survey methodology was used to design the stratified random survey. A 400 mesh Eastern Trawl was towed by a chartered fishing vessel. The bottom trawl was fitted with a codend net liner with a 3 cm mesh opening, and the trawl was towed at predetermined stations for approximately10 minutes. The survey was stratified by country and by five depth strata: 5-20 fathoms, 21-40 fm, 41-60 fm, 60-120 fm, and >120 fm. A total of 115 trawl samples were collected in the 2,313 km^2 survey area. Fifty stations were sampled the in the 876 km^2 Washington Strait of Georgia, 19 samples were collected in the 361 km^2 of the B.C. Strait of Georgia, 40 samples in the 864 km^2 San Juan Archipelago, and 6 samples in the 274 km^2Canadian Haro Strait. The two shallowest strata were not sampled in BC waters due to extensive rocky habitats or a lack of time.

Ninety identifiable species of fish were collected during the trawl survey of the four regions. Sixty-seven species of fish were collected in the Washington Strait of Georgia, and 43 fishes were collected in the BC Strait of Georgia, 65 species were collected in the San Juan Archipelago, and 30 species were collected in the B.C. Haro Strait and Boundary Pass. An estimated 112,108 individual fish were caught during the trawl survey, and they weighed 18 mt.

There was an estimated population of 251.3 million fish weighing 39,535 mt living in the southern Strait of Georgia and Archipelago. Washington contained 220 million bottomfish while B.C. had 31 million. The B.C. bottomfish resource constituted an estimated 8,811 mt while the Washington resource weighed an estimated 30,723 mt.

Spotted ratfish was the most abundant taxon of any region surveyed. They comprised almost 40% of the fish in the WA Strait of Georgia, and almost 60% of the deep waters surveyed in the BC Strait of Georgia. Ratfish made up almost half of the San Juan Archipelago fish populations and almost 70% of the BC Haro Strait and Boundary Pass. Flatfish as a group was the second most dominant species group in WA and BC Strait of Georgia while other species contributed together to form the third most common group in these waters. Dogfish was the third most abundant species in the San Juan Archipelago and the second most abundant fish in the BC Haro Strait and Boundary Pass.

Biomass and numerical abundance estimates and occurrence patterns were presented for key species including spiny dogfish, spotted ratfish, Pacific cod, walleye pollock, Pacific whiting (hake), lingcod, English sole, rock sole, starry flounder, Pacific sanddab, sand sole, Dover sole,

Dungeness crab, and spotted prawn. This survey was the sixth bottom trawl survey conducted in the Washington Strait of Georgia since 1987. Overall, total fish biomass has not changed since the surveys were initiated, and the 2001 survey had the greatest point estimate of any survey. Most flatfish species have apparently increased in abundance in recent years, however, other key fishery species are in decline. In 2001, Pacific cod biomass was at an all-time low, and spiny dogfish biomass while higher in 2001 than the 1997 survey, is also at very low levels compared to the late 1980s and early 1990s.

The limited survey of the southern Strait of Georgia in 2001 confirmed the general observations made during the more extensive bottom trawl survey conducted in 1997. The earlier survey in the Strait of Georgia found that only deep water species such as Pacific cod, Pacific hake (whiting), walleye pollock, English sole, and Dover sole were candidates for transboundary management because the deep Malaspina Trough aggregated these species in the area around the international border. Shallow-water species such as the rock and sand soles and starry flounder in the Strait of Georgia were more restricted to the perimeter of the basin and were less likely candidates in their adult stages for two independent fisheries targeting a common stock..

The biomass estimates resulting from the 2001 bottom trawl were compared to the commercial catches from the subsequent 12-month period providing a robust measure of the annual exploitation rate. The exploitation rates for the Washington survey areas were greater for the British Columbian survey areas. The latter were far less than 1% per year but the Washington exploitation rates were as high as 15% for halibut, 11% for English sole. Most of the other Washington exploitation rates 3% to 6% for key species including skates, Pacific cod, starry flounder and sand sole, and the exploitation rate for dogfish was 1.1%, a rate that is likely commensurate for this late-maturing and long-lived species.

Transboundary bottom trawl surveys are needed on a periodic basis in the future and more resources are needed to conduct more effective surveys in British Columbian waters than were available for the 2001 survey. Clearly, many key fish and invertebrate resources intermingle between the common border and water bodies shared between the United States and Canada. Fish populations need to be assessed on a broader, synoptic scale so that fisheries and populations in common water bodies can be effectively evaluated for harvest rates, movement patterns, habitat preference, and productivity. Greater cooperation and shared resources between Washington and Canadian fishery scientists can be a key factor in achieving these understandings of shared fish populations.

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INTRODUCTION

During the past 20 years, significant groundfish resources have declined in the Washington Strait of Georgia (WASG) and the San Juan Archipelago (WASJA) prompting reductions in fishing opportunities and prompting reviews for several fish species under the federal Endangered Species Act. These areas border the international boundary between Canada and the United States (Figure 1) and include the Gulf Islands, Bellingham Bay, Padilla Bay, Rosario Strait, Haro Strait, and Boundary Pass. The WASG and SJA are surrounded by a variety of shorelines, marine riparian habitats, and urban and rural areas from metropolitan Vancouver and Victoria, British Columbia and Bellingham, WA, to industrialized Guemes Channel and Cherry Point, and to undeveloped and residential shorelines common throughout the entire study area. The U.S. portions of these waters, once provided for thriving commercial fisheries for bottomfish but commercial fisheries have been curtailed for Pacific cod, lingcod, and rockfishes. Most commercial fisheries for bottomfish now target flatfishes and spiny dogfish. Recreational fisheries have also diminished, particularly in the WASJA with substantial reductions in the harvest opportunities for rockfish and lingcod during the past 20 years. A number of species that occur in the U.S. portions were petitioned for consideration under the Endangered Species Act, and although none of these species were designated as threatened or endangered (Gustavson et al. 2000, Stout et al. 2001a, Stout et al. 2001b), conservation efforts require continued restrictions and special monitoring. Commercial and recreational fisheries in British Columbia (BC) were once more widespread in the British Columbian Strait of Georgia (BCSG) but have diminished due to market conditions or reduced populations.

In 1992, an Environmental Cooperative Agreement was signed by the Governor of Washington and the Premier of B.C. This cooperative agreement created the Marine Sciences Panel and identified the goal of monitoring the marine environment of the transboundary waters of Washington and B.C. In response to this recommendation and a need to assess fishery resources, The Washington Department of Fish and Wildlife (WDFW) began a series of transboundary studies seeking to describe the distribution and abundance of benthic fishes and macroinvertebrates in the shared waters between BC and WA. The bottom trawl conducted in 2001 was the second in the Strait of Georgia to be simultaneously conducted on the WA and BC sides of the international border. In 1997, the Washington Department of Fish and Wildlife conducted a transboundary survey that encompassed the WASG and a substantial amount of the BCSG including portions of the channels surrounding the Gulf Islands and the Strait of Georgia to a line from Nannoose Harbor to just north of the City of Vancouver (Palsson et al., unpublished report). The 1997 survey resulted in a better understanding of the distribution and relative abundance of bottomfish and key invertebrates that was useful for management of these resources. The survey found fish and invertebrates were roughly distributed in proportion to the amount of benthic habitats. The deep Malaspina trough was a key factor in limiting shallow water species to the rim of the Georgia Basin and decreasing the need for transboundary management for shallow-water species. In contrast, deep-water and ubiquitous species such as Pacific cod, Dover sole, English sole, and spiny dogfish appeared in continuous concentrations in the deep waters across the international boundary making international coordination in management more important for these species. In addition, bottom trawl surveys have been conducted in the WASG during previous years including 1987, (Quinnell and Schmitt 1991), 1989, 1991, and 1994 (Palsson et al. 1997).

The WDFW conducted a bottom trawl survey during the spring of 2001 that included both Washington and British Columbian (Canadian) waters of the Strait of Georgia, the San Juan Archipelago, Haro Strait, and Boundary Pass. The goals and objectives of this survey were to estimate the abundance and describe the distribution of key recreational and commercial groundfish and macroinvertebrate species, collect biological information from key species, and evaluate the relationship of abundance and distribution of key species to oceanographic features and the need for transboundary management.

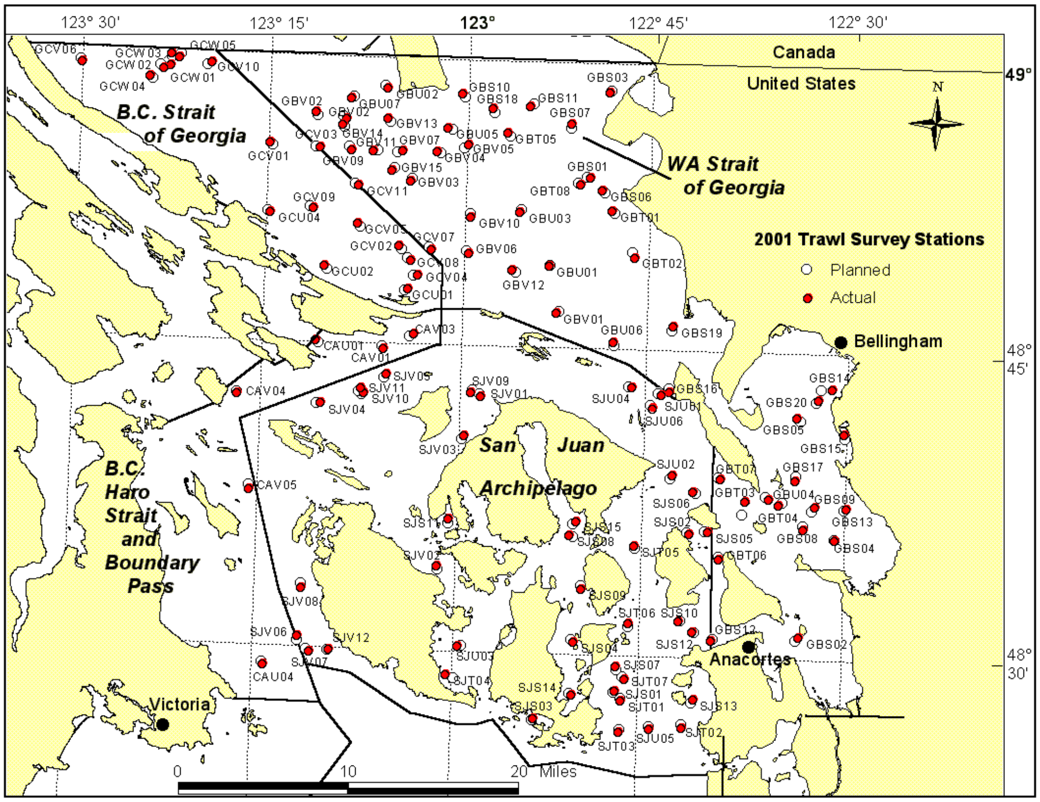

Figure 1. Planned and actual stations occupied during the 2001 Transboundary Trawl Survey of the Eastern Strait of Juan de Fuca and Discovery Bay.

METHODS

Survey Areas

The scope of the trawl survey included waters deeper than 5 fathoms (fms) in southern Strait of Georgia (SG), the San Juan Archipelago (SJA), Haro Strait and Boundary Pass (HB). Adjacent areas to some of these waters were also surveyed including Bellingham, Samish, and Padilla Bays, Guemes and Bellingham Channel, and Rosario Strait (Figure 1). The Washington survey area corresponded to WDFW Marine Fish Catch Areas 20A, 20B, 21A, 21B, 22A, and 22B. The BCSG and BCHB survey area included the waters from a line between Patos and Saturna Island south through Haro Strait to a line due east from Cadboro Point. These areas corresponded to Canadian Department of Fisheries and Oceans (CDFO) Minor Statistical Areas and 18-1, 18-4 to 6 and 19-5.

The southern SG, SJA and HB areas have a complex pattern of geology and bathymetry (Mosher and Johnson 2000). The SG is a deep body of water that is bordered by the North American mainland to the east, Vancouver Island to the west and the SJA to the south. The deep Malaspina Trough lies in the middle and ranges in depth to over 400 m. The southern Strait is influenced by past glaciation events and is influenced by the Fraser River and delta. Sand and mud habitats prevail in the east while the shores of Vancouver Island and the complex formation of the Gulf Islands have prominent slopes and skerries composed of bedrock and boulders. The SJA has a complex geology with many islets and outcroppings composed of bedrock and boulders but with channels and interior sounds that are dominated by shallow sand and mud bays. The SJA is bordered by Rosario Channel to the east and the deep Haro Strait to the west which reaches depths of 250 m. The HB study region along with being deep has many coarse sediments, boulders and bedrock outcroppings. Boundary Pass ranges to 230 m depth and is dominated by high currents as is Haro Strait. In contrast to Boundary Pass which is bordered steep rocky slopes of the Gulf and San Juan Islands, Haro Strait has many shallow bays and islets in the western portion and rocky banks in the middle, and a complex of sandy banks and rocky slopes in the eastern portions composed of the western shore of San Juan Island.

The survey areas were stratified by depth and prominent areas of untrawlable habitat was removed from the sampling frame in the two southern regions. Depth data were obtained from the National Ocean Service and rasterized with reference to the Washington State Plane South projection. Significant depth contours were generated with geographic information system (GIS) software, and the areas of each region and stratum were determined from the GIS. The potential WASG survey area was 876 km^2, the WASJA was 865 km^2, the BCSG was 361 km^2, and the HSBP was 298 km^2 (Table 1). However, for the WASJA and BCHB, survey areas were reduced to exclude charted and known rocky reefs that were identified by bottom type data from NOAA nautical charts. The amount of potential habitat for the WASJA survey was 801 km^2 and for the BCHB survey was 274 km^2. Areas of rocky habitats were not excluded from the BC or WA SG to maintain consistency with prior surveys.

Survey Design

The survey design consisted of sampling pre-selected stations at which one trawl sample or haul was taken by setting a bottom trawl and towing the net along the bottom for approximately ten minutes. The survey scheme and station selections were based upon a stratified random survey design stratified first on survey area and then by four or five depth strata. There were four depth strata for all regions except the BCSG. For the three regions, the depths were stratified as: 5-20 fms, 21-40 fms, 41-60 fms, and 60 fms or greater. For the BCSG there were five depth strata that corresponded to the five strata used in the 1997 survey and consisted of 5-20 fms, 21-40 fms, 41-60 fms, 61-120 fms, and 121 fms or greater. The survey was planned for 50 trawl stations in WASG, 25 stations in the BCSG, 40 stations in the WASJA, and 25 stations in the BCHB. The number of stations per stratum was based upon area of strata and measured variances of key groundfish species obtained from previous surveys in the WASG. This sampling effort was expected to render coefficients of variation of 30% or less for key species. The scientific crew processed the catch by identifying, counting, weighing, and recording each recognizable taxon. Anthropogenic debris collected by the net was separated and processed in a similar manner to the biological catch. Samples of key groundfish species were measured and subsamples retained for age determination, genetic stock analysis, and other purposes. Survey protocols for both the groundfish trawl survey were documented in Trawl Survey Field Plan and Manual (WDFW, unpublished manuscript) used for training and the execution of the surveys.

All data were recorded into databases maintained by the Washington Department of Fish and Wildlife. Data were error-checked after the trawl survey by comparing all computer data entries with data recorded on waterproof forms in the field. The data were processed into estimates of numerical and biomass abundance for each taxon and stratum.

Trawling Gear

The Fishing Vessel *Chasina*, a 17.7 m steel hull purse seiner, was chartered for the duration of the survey. Its captain and crew piloted the vessel and operated the fishing gear. The vessel was equipped with a 400-mesh Eastern otter trawl made with synthetic twine (Figure 2, Table 2). The main body of the net had meshes with an opening of 10 cm. The codend of the net contained a liner with a mesh size of 3.2 cm. The head rope of the net measured 21.4 m and the 28.7 m foot rope was rigged with 13 cm "cookie gear" (tightly packed, non-moving, rubber disks) to reduce both wear and snags. The opening of the net under fishing conditions had previously been measured and was found to vary with both the depth fished and the ratio of wire paid out to the depth fished (defined as the "scope"). Short scopes of 2:1 in shallow waters and 1:1 in deep waters resulted in net widths between 8.7 m and 12.7 m (Figure 3). Long scope ratios greater than 2.5:1 resulted in net widths between 10.8 m and 13.7 m.

The vessel was equipped with a video depth sounder, a differential Global Positioning System (dGPS), computer navigation, radar, and communications equipment.

Station Selection

Several techniques were developed to select trawling stations and ensure that the stratified random survey was implemented without bias. Each basin of interest was divided into sequentially numbered 0.25 nm^2 cells. The cells were numbered on a geographic basis: from west to east and then north to south. The area of each stratum within a cell was determined by GIS techniques, and these areas were then accumulated for sequential cells. The 0.25 nm^2 cell represented the practical operating area and navigational precision of the survey vessel and a trawl sample (towing distances generally ranged from 0.2 nm to 0.4 nm) and was the sample element of the survey. For the WASJA and the BCHB, cells that contained rocky habitat were removed from the sampling frame before the selection process began. The area for each stratum was accumulated for each region, and the register of cumulative areas was used as the sampling frame for drawing random cells. A random number generator was used to select the cells to be sampled based upon random numbers corresponding to the cumulative area number and cross-referencing the number to the cell. Once a cell was selected, it was located on the local nautical chart and the location inspected for charted obstructions, cables, bottom type and other factors that might prevent a successful tow. If the cell was free of obstructions, the station was designated and charted. If the station was not adequate for trawling, a new random number was selected and the process repeated until the desired sample size was obtained. Extra stations were selected in case stations were not adequate for trawling as determined during field operations.

The occupation of stations in the field occurred in several steps, and began with plotting the stations on a nautical chart. The chart and a list of station coordinates was provided to the captain and trawl technician before the survey. The station coordinates were transferred to navigation software that was interfaced with a dGPS in the wheelhouse of the survey vessel. To make a tow or successful trawl sample, a series of instructions were given to the skipper and scientific staff. The instructions began with piloting the vessel to the provided latitude and longitude corresponding to the geographic center of the randomly selected cell or the center of the depth stratum of interest of the selected cell. The skipper and scientists then referred to the nautical chart and determined the direction of the tow given current, wind, vessel traffic, and other environmental conditions. The criteria for successful trawling and sample completion included vessel and worker safety, safe and legal navigation, and avoiding charted or known obstructions. Once a station was determined to be safe and suitable, the skipper and scientists attempted to locate the entire trawl sample within the cell but could cross cell boundaries into adjacent cells as long as the net remained within the same depth stratum. If a pronounced depth gradient existed within the cell and stratum, the captain attempted to trawl across the depth gradient within the stratum as time and other conditions allowed. When a cell was unsuitable for trawling or when the net was fouled, an alternate tow site was found by using the extra randomly selected cells or when time conditions did not allow for occupying the extra station, alternate cells were occupied by moving to an adjacent cell of higher sequential number that was within the same stratum.

Once a tow was initiated, information was recorded on towing conditions, reasons for unsuccessful tows, and any other conditions that might have influenced net performance. Other recorded information included station identification information, time, latitude and longitude of where the net began fishing (where the trawl cable was paid out and vessel powered up), retrieval location (where net retrieval was initiated), duration in minutes, and distance fished. Tow duration or effective fishing time was defined as the time in whole minutes from when the cable was paid out and vessel powered up to the time when net retrieval was begun, and this time was usually 10 minutes and the vessel speed was at 1.5 to 2.5 knots over ground. Occasionally, trawl conditions were poor due to obstructions or vessel safety. In these circumstances effective fishing was less than 10 minutes, but a minimum fishing time of five minutes was usually required for a valid station. Occasionally, tow durations exceeded 10 minutes due to current or other conditions.

Once the tow duration was completed, the skipper and fishing crew retrieved the trawl gear by winching the net and catch aboard the vessel. The catch was usually dumped onto a sorting table, but at times the catch was too large to winch aboard the vessel. In these circumstances, sections of the net were pinched off and winched aboard for processing. After removing the bulk of the catch from the net, the fishing crew searched the net for entangled or sequestered specimens. These were added to the catch for processing.

Table 1. Survey area and stratum characteristics.

Stratum	1	2	3	4	5	Total
Depth Range (fms)	5 - 20	21 - 40	41-60	>60 or 60-120	>120	
Washington Strait of Georgia						
Area (ha)	37,003	15,321	7,997	27,321		87,642
Number of Stations	20	8	7	15		50
Area Sampled (ha)	13.9	6.8	5.7	15.4		41.8
British Columbian Strait of Georgia						
Area (ha)	2,404	2,864	5,173	23,948	1,758	36,147
Number of Stations			3	11	5	19
Area Sampled (ha)			2.6	10.7	5.0	18.3
San Juan Archipelago						
Area (ha)	21,928	24,088	17,934	22,499		86,449
Area w/o rocky area (ha)	18,159	22,171	17,299	22,499		80,128
Number of Stations	15	7	6	12		40
Area Sampled (ha)	9.2	4.9	4.9	10.0		29.1
British Columbian Haro Strait and Boundary Pass						
Area (ha)	10,477	7,002	3,304	9,023		29,806
Area w/o rocky area (ha)	8,688	6,621	3,078	9,023		27,410
Number of Stations			2	4		6
Area Sampled			1.8	3.5		5.3

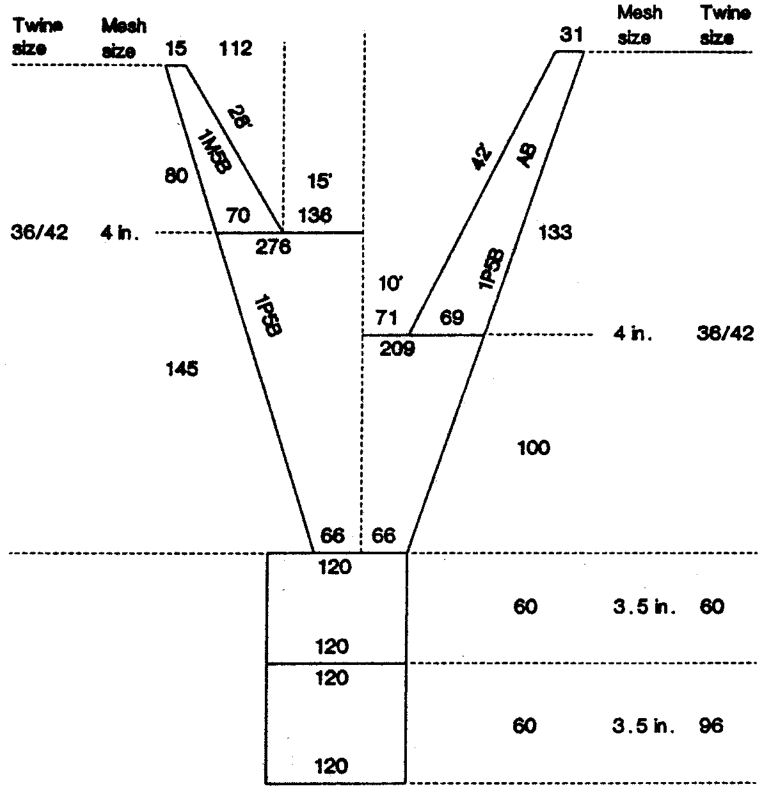

Figure 2. Schematic of the 400 mesh Eastern bottom trawl used in the 2000 Transboundary Trawl Survey.

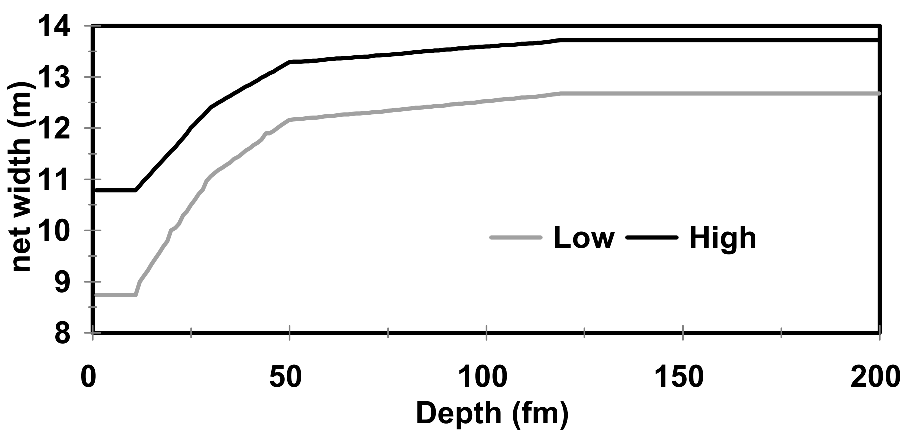

Figure 3. Net width as a function of low and high scope (wire out to depth) and depth.

Catch Processing

Most catches did not exceed 700 kg and were within the capacity of the scientific staff to sort and process the entire catch before the next station was occupied. The scientific personnel and fishing crew (when available) sorted, identified, enumerated and otherwise processed the catch. Attempts were made to hold rare and vital specimens in live tanks before processing. Once all specimens were counted and weighed, specimens not retained for scientific purposes were discarded overboard.

Specimens were separated into their lowest identifiable taxon and placed into containers. Rare specimens or unidentifiable species were frozen for subsequent identification in the laboratory and retention as voucher specimens in a museum. Weighing containers were tared, and the specimens were weighed with a mechanical scale to the nearest one hundredth kilogram. After the catch weight of a species was recorded, the number of specimens was counted and recorded on a data form. One designated staff member recorded species composition on a waterproof form and assured the data were completely and legibly recorded.

In addition to processing animals, man-made debris was sorted from each trawl sample. All debris was emptied of water and attached plants or animals removed. The debris was separated into five categories: Glass, Metal, Plastic, Fishing Gear and Other Man-made Debris. The type of fishing gear debris was identified and recorded. In most cases, man-made debris was retained aboard the vessel and discarded in sanitary landfills. Unless large catches were sub-sampled, natural debris, rocks, and vegetation were not weighed and were discarded overboard.

Subsampling

Several strategies were invoked for processing catches or species that were too numerous to directly count or weigh. The lead scientist decided the sub-sampling method before the catch was sorted and processed. The sub-sampling protocols were as follows:

A. When the catch was large and overflowed the capacity of the table or exceeded sorting time:

   Large catches were split into two components: a portion that was unsorted, weighed, and discarded and a portion that was completely processed. The net was pinched off and sequentially winched aboard the vessel and portions dumped onto the sorting table. Every attempt was made to assure representative portions of the net were placed in the portion to be completely sorted. Excess catch was placed into baskets, weighed, and recorded without further processing. The remaining portion was separated to the lowest identifiable taxonomic level, weighed, and counted (as described above). Using these procedures, rocks, vegetation, and other material were separated and weighed to correctly represent the weight and composition of the unsorted catch.

Table 2. Net specifications for the 400 mesh Eastern Research Trawl.

Feature	Description
Head rope	21.6 m with thimbled eyes, 11.4 cm x 6 cm x 19 cm galvanized wire rope (full rap) served with 11.4 cm polyproplyene rope
Fishing line	28.6 m with thimbled eyes of 11.4 cm 6 cm x 19 cm galvanized wire rope (footrope) served with 11.4 cm. polypropylene rope (web laced or "hung") to the fishing line
Disk foot rope	12.7 cm disks on 15.2 cm long link deck, Beacon 7 deck lashing chain
Breast Lines	1.8 m of 11.4 cm 6 cm x 19 cm galvanized wire rope served with 11.4 cm polypropylene rope
Seams	Side seams shall consist of lacing 3 knots (2 meshes) from each panel with No. 36 nylon twine, tie each full mesh
Hanging head rope	wings - 2 meshes to 15.2 cm, Bosom - 4 meshes to 13.3 cm, foot rope wings- 4 bars to 19.2 cm, lower bosom - 4 meshes to 17.8 cm
Puckering rings	0.8 cm by 5.7 cm galvanized steel (approx. 33 pieces), secured with No.48 braided polypropylene
Splitting rings	15.2 cm by 10.2 cm galvanized steel (4 pieces) set up 12 meshes from the bottom
Bag liner	3.2 cm mesh, No. 18 nylon; 360 meshes around, 200 meshes deep (60 cm of liner extending from the end of the bag)
Chafing gear	Hula skirt chafing 20 cm. - 5 mm double bar mesh
Webbing	10.2 cm mesh (including one knot) polyethylene, depth stretched and heat set; twine: 2 ½ mm top - 3 mm bottom
Floats	15, 20 cm Deep Sea Floats, evenly spaced. (2.5 kg buoyancy each)
Dandylines	4, 27.4 m, 15.2 cm 6 x 19 galvanized wire rope

B. When species were too numerous to individually count.

Frequently when processing the catch of any size, abundant species were too numerous to count. The species group was divided into two portions: The sampled portion from which numbers, weights, and length frequencies were taken, and the uncounted portion that was weighed and discarded. The sampled weights and counts were expanded with the uncounted portion to estimate the total number of individuals of the species group. As many containers as possible were weighed and counted, but when time was limited, at least three or third of the containers were counted. The counted containers were randomly selected or systematically-selected from early, middle, and late portions of the processed catch.

C. When species were too numerous for biological samples.

For a species requiring length frequencies or samples for age structures, a random sample of the catch was required. If too many individuals were present in the catch, a random sample was taken by mixing the sorted catch and selecting baskets or portions of the specimens by random numbers.

Once the catch was sub-sampled, processed, and recorded, calculations were automatically made in data entry programs to expand numbers on a density-weight basis to reconstruct the complete numerical catch.

Biological Samples

Biological sampling included collecting frequencies of length measurements from key species; specimens for age, growth, and maturity studies; fin samples for genetic studies; and fish and invertebrate specimens for identification at museums and other scientific purposes.

For length frequency samples, total lengths to the nearest whole centimeter were tallied for all, or a random sample of at least one hundred specimens of a key fish species at each station. Key species included English sole, rock soles, Pacific sanddab, starry flounder, sand sole, Dover sole, Pacific halibut, spiny dogfish, longnose skate, big skate, copper rockfish, quillback rockfish, brown rockfish, Pacific cod, walleye pollock, Pacific whiting (hake), sablefish, lingcod, and cabezon. In addition, when time permitted, other fish species were measured to gain information on poorly known fish populations. Individual total lengths were tallied on a “Length Frequency Strip” that was marked with sequential boxes representing the nearest whole centimeter. The strips were marked with the species, station number, and date, and the length frequency data were later entered into a computer database. The strips were retained until after the cruise had ended for confirmation of all data entries. When Dungeness crabs were present in a haul, random samples of males and females were measured for carapace width and evaluated for shell condition according to WDFW criteria.

Biological sampling also included retaining a sample of selected species for laboratory analysis and aging. English sole and starry flounder were selected at random for the extraction of age structures in the laboratory. At each station, a sample of 25 specimens of each species was randomly selected, and each species bagged separately, labeled, and frozen. These fish were processed after the cruise in the laboratory for total length (cm), weight (gm), sex, maturity, parasite load, and age structure. Spotted prawns were also frozen and taken to the laboratory for the determination of carapace length and sex.

Other biological sampling included collecting fin clips from copper rockfish, quillback rockfish, brown rockfish, Pacific cod, walleye pollock, and lingcod for DNA genetic tissue samples. For each surveyed region, up to 200 fin clips were collected and stored individually. Only specimens that had been positively identified were collected as genetic samples. A fin clip sample was collected by cutting a centimeter of the distal portion of soft-rayed fins including the soft connective tissue from an individual fish. Fin clips were preserved in full strength ethanol in a labeled and covered vial.

Data Management

Primary data consisted of station information, catch composition, length measurements, and date. These were entered onto permanent forms and into a computer database. The forms and instructions for data entry are documented in the Trawl Survey Field Monitoring Plan and Manual (WDFW, unpublished). Data were entered into a computer database in the field that consisted of three separate files corresponding to the three respective data types. Other data retained on permanent forms included a field journal, deck record of data and collected specimens, specimen disposition, and genetic specimens from each station.

At the end of the cruise, the station, catch, and length data recorded on the permanent forms were compared with the data entered in the computer database. Any discrepancies were rectified on the forms and in the computer databases. Error checked copies of the three key databases consisted of station information, catch composition, and length frequencies.

Estimation Procedures

After the data were verified, population abundance and biomass estimates were made for each stratum and each surveyed area. Methods for estimating total abundances and associated variances are modified from Gunderson (1993) and are further explained for stratified random surveys in Schaeffer et al. (1979).

The first step in estimation was determining the density of each fish and invertebrate taxon found at each station. The area swept for each station was determined by multiplying the net width by the distance fished. For each station, the net width was determined using the results of a special measurement study (Figure 2) and relating the average depth fished at a station to the amount of trawl cable deployed. To determine density, the sample numbers or weights were divided by the area sampled at the station. These density values in terms of number or kilograms per hectare were added to the catch database.

For each stratum in each region, population abundance and biomass estimates were made from the observations of fish density averaged among stations, and variances were computed for the station observations of individual and biomass densities. Where f_{ij} is the i-th density observation (either in terms of numbers or weight) of n stations in the j-th stratum, and A_j is the area of the j-th stratum and N_j is the species population estimate of the j-th stratum:

$$N_j = A_j \overline{f_j} = A_j \sum_{i=1}^{n} \frac{f_{ij}}{n}$$

Regional estimates of numerical and biomass population abundances were made by summing the point estimates and their variances over the all strata. The variance of stratum population estimates was calculated as:

$$Var(N_j) = A_j^2 Var(\overline{f_j}) = A_j^2 \sum_{i=1}^{n} \frac{\left(f_{ij} - \overline{f_j}\right)^2}{n(n-1)}$$

Coefficients of variation were calculated as the percentage of the square root of the variance divided by the population estimate. Estimates of numerical population at length were obtained by multiplying the stratum estimate of the numerical population by the proportion of each length category in the sampled population. The proportion was determined by summing the product of the proportion of each length category in each trawl sample by the weighted contribution of the station density to the total density. Data management for estimates included compiling estimates of populations, variances, and percentages of the Coefficients of Variation (%C.V.s) for significant taxonomic categories or key species into two databases.

RESULTS

Survey Frame and Area Sampled

The trawl survey began on April 26th in the WASG and concluded on June 16th in the WASJA (Table 3). There were 24 days of active sampling: 9 days were spent exclusively in WASG, three days in the BCSG, 6 days in WASJA, and 6 days switching among adjacent areas. Two hiatuses were taken to accommodate other vessel activities and to minimize the sampling during spring tide series. The station selection process resulted in a random geographic pattern covering the WASG and WASJA, and portions of the BCSG and BCHB (Figure 1, Table 3). The BCSG and BCHB were not completely sampled, because of a lack of suitable habitat for trawling in the 5-20 fm and 21-40 strata of the BCSF and because of a lack of survey time to survey the 5-20 fm and 21-40 fm strata of the BCHB.

The actual area surveyed totaled 216,000 ha (Table 1). The Washington component comprised 78% of the entire sampling frame. The WASG and WASJA were of roughly equal area (87,642 ha and 80,128 ha, respectively). The 5-20 fm was the largest stratum of any surveyed stratum. The >60 fm stratum was the second largest stratum for the WASG and the 41-60 fm stratum the least. There was very little area in the shallowest strata of the BCSG compared to the WASG and this consisted of rocky habitats and very steep walls. The 61-120 fm and >120 fm strata of the BCSG almost were almost as large in area as the WASG >60 fm stratum. The stratum areas of the WASJA were approximately equal and size to each other. In the BCHB, the shallowest and deepest strata were the largest and the 41-60 fm stratum the least in size.

A total of 115 stations were successfully trawled during the 2001 trawl survey (Tables 1 and 3). Among these stations, the trawl swept over a total area of 94.5 ha which was 0.04% of the survey area. Fifty stations were located in the WASG, 19 stations were conducted in the BCSG, 40 stations were occupied in the WASJA, and 6 stations were sampled in the BCHB. In the WASG, from 5 to 8 stations were conducted in shallowest 3 strata, but 15 were conducted in the >60 fm stratum. In the BCSG only 3 stations were occupied in the 41-60 fm stratum, 11 in the 60-120 fm stratum, and 5 in the >120 fm stratum. Fifteen stations were sampled in the WASJA's 5-20 fm stratum, 12 in the >60 fm stratum, and either 5 or 6 stations were sampled in the 2 intermediate depth strata. In the BCHB, only 2 stations were sampled in the 41-60 fm stratum and only 4 stations were sampled in the >60 fm stratum. Most of the actual locations of the sampled stations were closely located to the preselected coordinates (Figure 1). Four trawl stations had to be repeated because the net was fouled with mud or the net became stuck on an underwater obstruction. Six trawl stations had to be relocated because the bottom was too irregular to conduct a successful tow.

Fish Samples and Diversity

Eighty-nine identified species of fish were collected during trawl survey (Table 4). Sixty-seven species of fish were collected in the WASG, 43 species were collected in the BCSG, 64 species were collected in the WASJA, and 30 species were collected in BCHB. An estimated 112.1 thousand individual fish were caught during the trawl survey, and these samples weighed a total of 18 mt. The trawl survey in WASG resulted in 74,700 captured individuals that weighed 9.1 mt. In BCSG, 11,400 individual fish were caught which weighed 3.4 mt. In the WAJSA, 22,500 fish were captured with a combined weight of 4.7 mt, and in the BCHB, the 3,443 specimens weighed 800 kg.

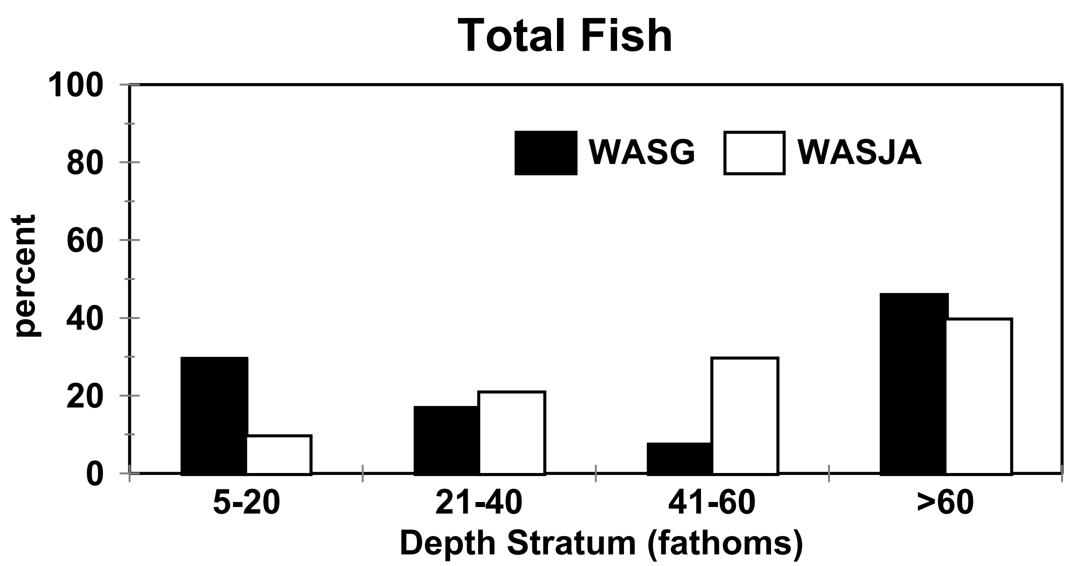

Figure 4. Depth distribution of the total fish populations in the Washington Strait of Georgia and San Juan Archipelago.

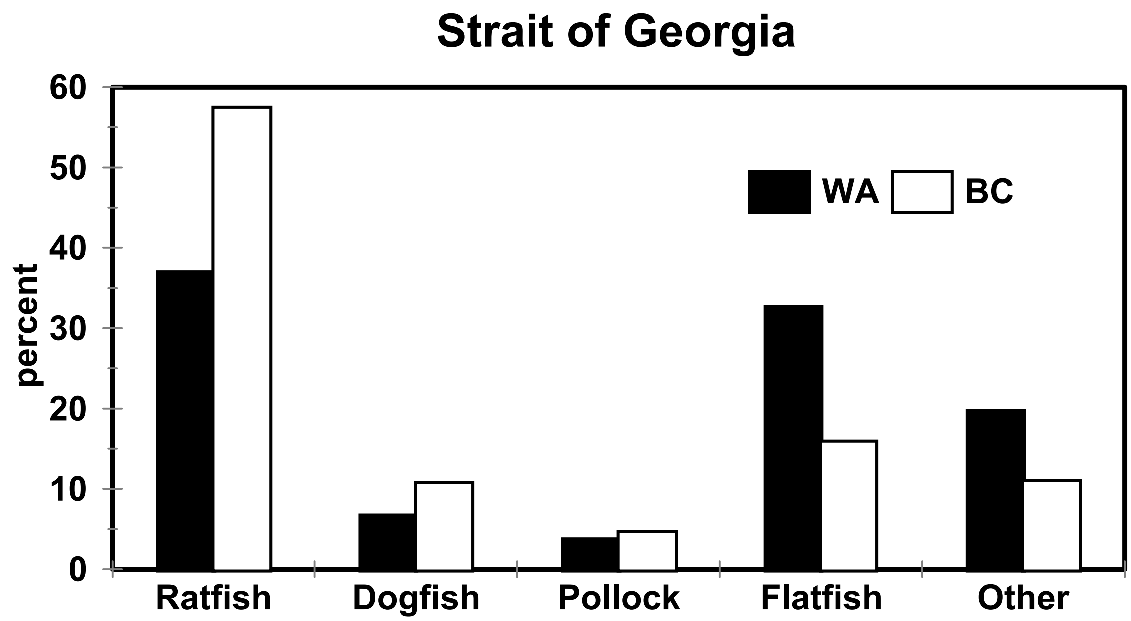

Figure 5. Species composition of fish populations surveyed by bottom trawl in the southern Strait of Georgia based upon biomass.

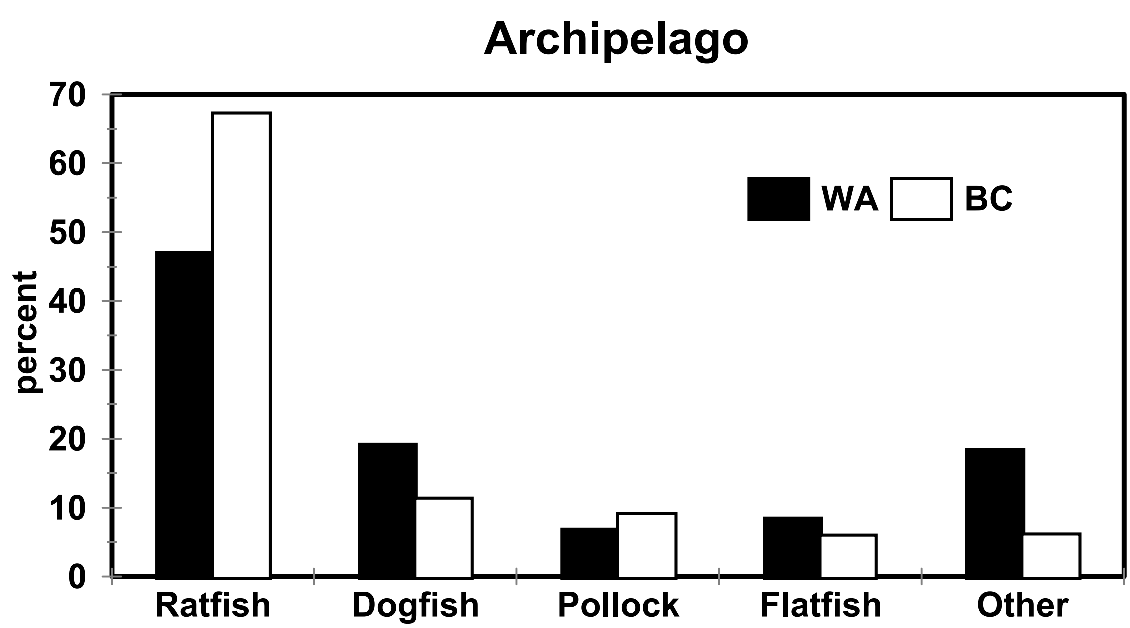

Figure 6. Species composition of fish populations surveyed by bottom trawl in Washington San Juan Archipelago and British Columbian Haro Strait and Boundary Pass.

Table 3. Station characteristics for the 2001 trawl survey of the Southern Strait of Georgia, the San Juan Archipelago, and adjacent waters.

Date	Station Identity	Latitude	Longitude	Duration (m)	Stratum (fms)	Avg. Depth (fms)	Width (m)	Length (km)
26-Apr	01GBU06	48 45.657	122 47.877	10	41-60	52	12.18	0.630
27-Apr	01GBT07	48 39.144	122 39.575	11	21-40	36	12.68	0.593
27-Apr	01GBT06	48 35.100	122 39.436	5	21-40	37	11.44	0.556
30-Apr	01GBS02	48 30.907	122 33.376	10	5-20	14	11.05	0.704
30-Apr	01GBT03	48 37.252	122 37.721	10	21-40	29	12.32	0.778
30-Apr	01GBU04	48 38.181	122 35.895	10	41-60	50	12.16	0.722
1-May	01GBV01	48 47.352	122 52.179	10	>60	94	13.56	0.778
1-May	01GBU01	48 49.676	122 52.991	10	41-60	49	13.25	0.185
1-May	01GBU03	48 52.499	122 55.194	10	41-60	55	12.20	0.741
1-May	01GBV10	48 52.187	122 59.161	10	>60	116	13.69	0.685
1-May	01GBT05	48 56.211	122 56.236	10	21-40	24	11.90	0.796
2-May	01GBS03	48 58.677	122 48.571	10	5-20	6	10.79	0.648
2-May	01GBV05	48 55.516	122 59.748	10	>60	67	13.39	0.945
2-May	01GBV07	48 55.248	123 4.903	11	>60	67	13.39	0.852
2-May	01GBV03	48 53.905	123 3.696	10	>60	77	13.45	0.685
2-May	01GBV15	48 54.432	123 5.082	11	>60	69	13.40	0.741
2-May	01GBV11	48 55.282	123 6.420	10	>60	66	13.38	0.926
2-May	01GBV09	48 55.421	123 8.645	11	>60	66	13.38	0.704
2-May	01GBV08	48 56.959	123 9.152	10	>60	61	13.35	0.667
3-May	01GBU02	48 58.583	123 6.009	11	41-60	42	12.94	0.667
3-May	01GBV02	48 56.996	123 11.119	11	>60	67	13.39	0.722
3-May	01GBV14	48 56.415	123 9.053	10	>60	63	13.36	0.611
3-May	01GBU07	48 58.014	123 8.389	11	41-60	59	13.34	0.741
3-May	01GBV13	48 56.785	123 5.484	10	>60	73	13.42	0.778
3-May	01GBV04	48 55.252	123 1.583	11	>60	73	13.42	0.778
3-May	01GBU05	48 56.476	123 0.750	11	41-60	52	12.18	0.833
4-May	01GBS10	48 58.131	122 59.846	10	5-20	8	10.79	0.796
4-May	01GBS18	48 57.403	122 57.515	10	5-20	14	11.05	0.759
4-May	01GBS11	48 57.890	122 54.570	10	5-20	16	9.45	0.833
4-May	01GBS07	48 56.674	122 51.632	11	5-20	12	10.88	0.741
4-May	01GBS16	48 43.529	122 43.519	11	5-20	16	9.45	0.611
14-May	01SJS12	48 31.216	122 41.173	7	5-20	16	9.45	0.370
14-May	01SJS10	48 31.758	122 42.219	6	5-20	17	11.30	0.407
14-May	01SJS05	48 36.371	122 40.544	9	5-20	18	9.68	0.685
14-May	01GBS12	48 30.889	122 39.718	8	5-20	7	8.74	0.519
15-May	01SJS02	48 36.284	122 41.900	10	5-20	16	11.22	0.593
15-May	01SJS06	48 38.314	122 41.253	10	5-20	14	11.05	0.667
15-May	01SJU06	48 42.687	122 44.911	10	41-60	53	13.30	0.574
15-May	01GBV12	48 49.264	122 55.537	12	>60	105	13.62	0.852
15-May	01GBV06	48 50.299	122 59.333	10	>60	120	13.72	0.704
16-May	01GCU01	48 48.176	123 4.016	9	41-60	57	13.32	0.648
16-May	01GCV04	48 48.966	123 3.392	12	60-120	98	13.59	0.778
16-May	01GCV08	48 49.862	123 3.882	10	60-120	113	13.67	0.741
16-May	01GCV02	48 50.276	123 4.391	10	60-120	111	13.66	0.722

Table 3. Station characteristics for the 2001 trawl survey of the Southern Strait of Georgia, the San Juan Archipelago, and adjacent waters.

Date	Station Identity	Latitude	Longitude	Duration (m)	Stratum (fms)	Avg. Depth (fms)	Width (m)	Length (km)
16-May	01GCV09	48 52.336	123 11.471	11	60-120	84	13.50	0.648
16-May	01GCV11	48 53.550	123 8.069	10	60-120	71	13.41	0.704
17-May	01GCV03	48 55.382	123 11.236	10	60-120	70	13.40	0.796
17-May	01GCV10	48 59.409	123 19.748	10	60-120	111	13.66	0.741
17-May	01GCW05	48 59.903	123 21.867	11	>120	131	13.72	0.741
17-May	01GCW01	48 59.444	123 22.843	11	>120	140	13.72	0.722
17-May	01GCW03	48 59.702	123 22.520	11	>120	137	13.72	0.722
17-May	01GCW02	48 59.290	123 23.402	12	>120	145	13.72	0.778
18-May	01GCV06	48 59.457	123 29.616	11	60-120	94	13.56	0.704
18-May	01GCW04	48 58.599	123 23.975	10	>120	132	13.72	0.685
18-May	01GCV01	48 55.398	123 14.574	11	60-120	81	13.48	0.648
18-May	01GCV05	48 51.361	123 7.622	11	60-120	83	13.49	0.704
31-May	01SJT06	48 31.424	122 46.174	10	21-40	29	12.32	0.556
31-May	01SJT05	48 35.410	122 45.805	7	21-40	30	12.41	0.426
31-May	01SJU02	48 39.030	122 43.275	9	41-60	50	13.29	0.556
31-May	01SJU01	48 43.309	122 44.350	10	41-60	50	13.29	0.704
31-May	01SJU04	48 43.611	122 46.638	10	41-60	55	12.20	0.648
31-May	01SJV09	48 43.184	122 58.589	10	>60	89	13.53	0.611
1-Jun	01SJV01	48 43.014	122 58.055	10	>60	93	13.56	0.630
1-Jun	01SJV03	48 40.765	122 59.300	9	>60	97	13.58	0.556
1-Jun	01SJV10	48 42.833	123 7.114	10	>60	71	13.41	0.500
1-Jun	01SJV11	48 42.973	123 7.331	10	>60	75	12.34	0.630
1-Jun	01SJV04	48 42.314	123 10.509	10	>60	87	13.52	0.648
4-Jun	01GBS08	48 36.721	122 32.968	10	5-20	13	10.97	0.704
4-Jun	01GBS04	48 36.104	122 30.544	5	5-20	7	8.74	0.315
4-Jun	01GBS17	48 39.295	122 33.616	11	5-20	11	8.74	0.963
5-Jun	01GBS14	48 43.659	122 31.818	11	5-20	13	10.97	0.722
5-Jun	01GBS20	48 42.985	122 32.212	11	5-20	15	11.13	0.648
5-Jun	01GBS05	48 42.064	122 33.335	11	5-20	15	11.13	0.778
5-Jun	01GBS15	48 41.225	122 29.913	12	5-20	7	8.74	0.833
5-Jun	01GBS13	48 37.589	122 29.833	6	5-20	8	8.74	0.407
6-Jun	01GBS09	48 37.521	122 32.315	10	5-20	7	8.74	0.833
6-Jun	01GBT04	48 37.909	122 34.641	10	21-40	33	11.23	0.833
6-Jun	01GBS19	48 46.522	122 43.424	10	5-20	12	9.00	0.667
6-Jun	01GBT02	48 50.431	122 46.671	10	21-40	23	10.30	1.056
6-Jun	01GBT01	48 52.397	122 48.115	11	21-40	26	12.08	0.630
6-Jun	01GBS06	48 53.450	122 48.894	11	5-20	15	11.13	0.630
7-Jun	01GBS01	48 54.224	122 50.291	11	5-20	16	11.22	0.667
7-Jun	01GBT08	48 53.933	122 50.978	11	21-40	22	11.72	0.611
7-Jun	01SJS15	48 36.545	122 50.600	11	5-20	13	10.97	0.741
7-Jun	01SJS08	48 35.892	122 50.632	10	5-20	15	11.13	0.741
11-Jun	01SJT07	48 28.822	122 46.493	8	21-40	25	12.00	0.444
11-Jun	01SJT01	48 27.731	122 46.605	10	21-40	24	11.90	0.574
11-Jun	01SJU05	48 26.359	122 44.379	11	41-60	43	12.99	0.611
11-Jun	01SJT03	48 26.143	122 46.654	10	21-40	32	12.50	0.611

Table 3. Station characteristics for the 2001 trawl survey of the Southern Strait of Georgia, the San Juan Archipelago, and adjacent waters.

Date	Station Identity	Latitude	Longitude	Duration (m)	Stratum (fms)	Avg. Depth (fms)	Width (m)	Length (km)
11-Jun	01SJT02	48 26.497	122 41.878	10	21-40	36	12.68	0.833
11-Jun	01SJS13	48 27.568	122 41.230	11	5-20	19	11.47	0.648
12-Jun	01SJS11	48 36.436	123 0.129	11	5-20	14	11.05	0.741
12-Jun	01GCV07	48 50.430	123 2.238	10	>60	108	13.64	0.685
12-Jun	01GCU04	48 52.079	123 14.744	10	41-60	53	13.30	0.593
12-Jun	01GCU02	48 49.152	123 10.077	11	41-60	52	13.30	0.741
13-Jun	01CAV01	48 45.312	123 5.625	7	>60	94	13.56	0.556
13-Jun	01CAV03	48 45.873	123 3.530	11	>60	106	13.63	0.815
13-Jun	01CAU01	48 45.404	123 10.522	11	41-60	47	13.16	0.704
13-Jun	01SJV05	48 43.696	123 5.359	11	>60	81	13.48	0.667
13-Jun	01CAV04	48 42.757	123 16.692	5	>60	81	13.48	0.352
13-Jun	01CAV05	48 38.087	123 15.537	11	>60	93	13.56	0.833
14-Jun	01SJV08	48 33.125	123 11.284	11	>60	136	13.72	0.852
14-Jun	01SJV06	48 30.205	123 11.399	11	>60	131	13.72	0.778
14-Jun	01SJV07	48 29.772	123 10.712	11	>60	124	13.72	0.704
14-Jun	01SJV12	48 29.785	123 9.055	11	>60	177	13.72	0.204
14-Jun	01CAU04	48 29.081	123 14.039	10	41-60	49	13.25	0.648
14-Jun	01SJT04	48 28.526	122 59.387	9	21-40	35	11.33	0.574
15-Jun	01SJV02	48 34.058	123 0.839	11	>60	77	13.45	0.648
15-Jun	01SJU03	48 30.221	122 58.829	11	41-60	44	11.90	0.778
15-Jun	01SJS03	48 26.484	122 53.332	6	5-20	11	8.74	0.389
15-Jun	01SJS04	48 30.670	122 50.500	10	5-20	14	9.22	0.759
15-Jun	01SJS09	48 33.418	122 49.912	10	5-20	15	9.34	0.722
16-Jun	01SJS14	48 27.929	122 50.566	9	5-20	7	8.74	0.648
16-Jun	01SJS01	48 28.051	122 47.177	5	5-20	16	9.45	0.241
16-Jun	01SJS07	48 29.175	122 47.023	10	5-20	17	11.30	0.574

Among the four survey areas, spotted ratfish was by far the most common fish sampled in terms of biomass and in most cases in terms of numbers (Table 4). This species alone, accounted for 84% of the sampled weight in the WASG, 57% in the BCSG, 50% in the WASJA, and 67% in the BCHB. After ratfish, the four most common fishes captured in the WASG in terms of weight were English sole, spiny dogfish, walleye pollock, and shiner perch. In terms of number, the five most dominant species were shiner perch, English sole, spotted ratfish, walleye pollock, and Pacific tomcod. In the BCSG, the four most common fishes in terms of weight were spotted ratfish, English sole, spiny dogfish, Pacific whiting, and walleye pollock (Table 4). By number, the five most dominant fishes in the BCSG were spotted ratfish, walleye pollock, English sole, Pacific whiting, and Dover sole. In the WASJA, spotted ratfish dominated the catch followed by spiny dogfish, walleye pollock, big skate, and great sculpin. In terms of number, the catch of the WASJA was dominated by walleye pollock, Pacific tomcod, English sole, and southern rock sole. In the BCHB, spotted ratfish, spiny dogfish, walleye pollock, English sole, and Pacific cod dominated the catch weight, while walleye pollock, spotted ratfish, English sole, Dover sole, and rex sole were the five most common species in terms of numbers.

Twenty-six fish species were collected in all of the regions during the survey (Table 4). As expected, the lack of sampling in the shallow strata in BC limited the commonality among regions to deepwater species particularly dogfish, skates, codfishes, eelpouts, and deepwater flatfishes such as Dover sole and arrowtooth flounder. Seventeen species were only captured in both the WASG and WASJA reflecting greater sampling effort and including shallow zones. Some of these species were shallow water flatfishes such as sand sole, starry flounder, butter sole, speckled sanddab longfin smelt, kelp greenling, shiner perch, and pile perch. There were no species only found in the two BC survey areas. There were 33 species collected that were only collected from one of the 4 survey areas, and 12 of these were from the WASG. Only 2 of the unique species, the smalldisk snailfish, *Careproctus gilberti*, and the giant wrymouth, *Delolepis gigantea*, could be considered rare. The giant wrymouth, however, was collected on the eastern edge of Point Roberts reef where they have been encountered during previous trawl surveys. The other occurrences are of species that are uncommon, small, or live on rocky habitats poorly sampled by the bottom trawl.

Almost 20,108 individual fish and 36 species of fish were measured for length. In addition, 4,556 individual Dungeness crabs and spotted prawn were measured. Selected observations of average length and sample size are presented in Table 5.

Fish Abundance and Distribution

Total Fish and Species Composition

There were an estimated 251.3 million fish weighing 39,500 mt living in near bottom habitats in the southern SG, WASJA, and BCHB (Table 6). These numerical and biomass population estimates had %CVs of 20.8% and 11%, respectively. The WASG contained 160 million individual bottomfish (32.0% CV) which was more than half of the total abundance estimated for all regions, and which had a biomass of 18,370 mt (21.4% CV). The WASJA contained an estimated 60.5 million bottomfish (14.6% CV) that had a biomass of 12,400 mt (11.8% CV). As expected the limited survey of the BC regions resulted in lower biomass estimates than the Washington survey regions. Only 23.7 million (19.7% CV) and 7.4 million (41.5% CV) individual bottomfish were estimated for the deeper strata, and the corresponding biomasses were 7,000 mt (17.8% CV) and 1,800 mt (39.0%), respectively.

Stratification by the four zones revealed that the >60 fm zone contained the highest estimated biomasses of bottomfish for the Washington survey areas (Table 6, Figure 4). In the WASG, 46% of the biomass occurred in the deepest zone. The 41-60 fm had the least proportion of the biomass (8%), and the 5-20 fm zone contained 30% of the biomass. The 21-40 fm zone had 17% of the biomass. This pattern contrasted with that of the WASJA where the shallowest stratum had the least proportion of the biomass (10%). Greater proportions of biomass progressively occurred in the deeper depth zones with 20% in the 21-40 fm stratum, 30% in the 41-60 fm stratum, and 40% in the >60 fm stratum. Comprehensive comparisons of depth distribution were not possible for the surveyed regions in BC due to the limitations in sampling. The greatest biomass, however, occurred in the 61-120 fm depth stratum in the BCSG or in the >60 fm stratum in the BCHB. The >120 fm stratum only contained 102 mt of bottomfish with was less than 2% of the biomass estimated for that region.

The species compositions of the estimated population biomasses were consistent, in general, with the amounts and proportions of fishes sampled (Table 7). Spotted ratfish comprised more than 37% of the fish populations in the WASG and 58% of the populations estimated for the BCSG (Figure 5). In the WASJA, ratfish comprised 48% of the fish biomass and in the BCHB (Figure 6), they comprised 68% of the surveyed depth strata. In the WASG and the BCSG, flatfish as a group was the second most dominant group followed by the "other species" as a group (Figure 5). In the WASJA and BCSG, spiny dogfish was the second most dominant species followed by the other species category. In examining which individual species contributed the most the biomass of bottomfish populations (Table 7), the most abundant species were found to include spotted ratfish, English sole, spiny dogfish, starry flounder, and shiner perch in the WASG; spotted ratfish, English sole, spiny dogfish, walleye pollock, and Pacific whiting in the BCSG; spotted ratfish, spiny dogfish, walleye pollock, great sculpin, and big skate in the WASJA; and spotted ratfish, spiny dogfish, walleye pollock, English sole, and Pacific cod in the BCHB.

Table 4. Sampled fish numbers and weights encountered during the 2001 trawl survey.

		WA Strait of Georgia		BC Strait of Georgia		San Juan Archipelago		BC Haro Strait & Boundary Pass	
Common Name	**Scientific Name**	**Nos**	**Kg**	**Nos**	**Kg**	**Nos**	**Kg**	**Nos**	**Kg**
Brown cat shark	*Apristurus brunneus*			4	0.16				
Spiny dogfish	*Squalus acanthias*	505	516.54	246	376.79	576	824.72	40	84.87
Big skate	*Raja binoculata*	115	212.74	20	77.66	55	165.31	3	14.46
Sandpaper skate	*Raja kincaidi*	3	1.75	7	5.73	3	2.15		
Longnose skate	*Raja rhina*	41	36.81	37	23.11	15	10.80	1	2.70
Spotted ratfish	*Hydrolagus colliei*	8846	3706.63	6034	1933.86	5665	2374.86	1353	567.74
American shad	*Alosa sapidissima*	1	0.18			1	0.65		
Pacific herring	*Clupea harengus pallasi*	2768	76.45	35	2.34	460	13.32	7	0.25
Longfin smelt	*Spirinchus thaleichthys*	2638	20.78			11	0.14		
Eulachon	*Thaleichthys pacificus*	139	4.29	84	2.43	37	1.09	3	0.11
Plainfin midshipman	*Porichthys notatus*	3102	164.28	11	0.51	18	0.79		
Pacific cod	*Gadus macrocephalus*	75	78.82	56	70.22	122	85.23	48	18.69
Pacific tomcod	*Microgadus proximus*	3505	181.96	34	2.49	1360	86.72	5	0.53
Walleye pollock	*Theregra chalcogramma*	8653	444.54	2398	153.67	7709	292.91	1442	75.80
Pacific whiting (hake)	*Merluccius productus*	171	70.45	369	186.69	8	1.76	2	0.58
Shortfin eelpout	*Lycodes brevipes*	35	0.83						
Black eelpout	*Lycodes diapterus*			1	0.04				
Wattled eelpout	*Lycodes palearis*	60	6.20	1	0.20	1	0.03	17	1.14
Blackbelly eelpout	*Lycodopsis pacifica*	164	4.29			172	2.22		
Tubesnout	*Aulorhynchus flavidus*	1	0.01						
Copper rockfish	*Sebastes caurinus*			3	2.06				
Greenstriped rockfish	*Sebastes elongatus*			22	4.35				
Puget Sound rockfish	*Sebastes emphaeus*	4	0.15			136	4.08		
Quillback rockfish	*Sebastes maliger*	2	1.22	22	12.74	2	1.11	2	1.84
Yelloweye rockfish	*Sebastes ruberrimus*			1	3.43				
Shortspine thornyhead	*Sebastolobus alascanus*	3	1.00	19	8.81			1	0.74
Kelp greenling	*Hexagrammos decagrammus*	4	1.44			6	1.93		
Whitespotted greenling	*Hexagrammos stelleri*	178	12.36			470	35.46		
Lingcod	*Ophiodon elongatus*	15	5.50	9	2.88	15	13.95		
Sablefish	*Anoplopoma fimbria*	2	0.67			1	0.40		
Longspine combfish	*Zaniolepis latipinnis*	1	0.03						
Padded sculpin	*Artedius fenestralis*					2	0.04		

Table 4. Sampled fish numbers and weights encountered during the 2001 trawl survey.

		WA Strait of Georgia		BC Strait of Georgia		San Juan Archipelago		BC Haro Strait & Boundary Pass	
Common Name	**Scientific Name**	**Nos**	**Kg**	**Nos**	**Kg**	**Nos**	**Kg**	**Nos**	**Kg**
Smoothhead sculpin	*Artedius lateralis*	1	0.13						
Spinyhead sculpin	*Dasycottus setiger*	47	2.96	11	0.46	50	6.28	17	1.97
Buffalo sculpin	*Enophrys bison*	399	85.35			32	6.05		
Red Irish lord	*Hemilepidotus hemilepidotus*	4	2.35			92	56.30		
Brown Irish lord	*Hemilepidotus spinosus*	1	0.06						
Northern sculpin	*Icelinus borealis*	5	0.06	2	0.02	44	0.47	2	0.03
Threadfin sculpin	*Icelinus filamentosus*			1	0.03				
Spotfin sculpin	*Iclinus tenuis*			1	0.11				
Pacific staghorn sculpin	*Leptocottus armatus*	126	21.67			11	2.87		
Blackfin sculpin	*Malacocottus kincaidi*			18	0.90				
Great sculpin	*Myoxocephalus polyacanthocephalus*	542	287.73			412	156.65	10	6.98
Sailfin sculpin	*Nautichthys oculofasciatus*			1	0.08	9	0.55		
Slim sculpin	*Radulinus asprellus*	10	0.10	9	0.08	3	0.02		
Grunt sculpin	*Rhamphocottus richardsoni*					9	0.13		
Cabezon	*Scorpaenichthys marmoratus*					2	2.94		
Ribbed sculpin	*Triglops pingeli*	48	1.23	2	0.03	564	16.79		
Roughback sculpin	*Chitonotus pugetensis*	26	0.70			45	1.49		
Longfin sculpin	*Jordania zonope*	271	1.34						
Northern spearnose poacher	*Agonopsis emmelane*	27	0.80	138	3.70	102	3.00	27	0.82
Smooth alligatorfish	*Anoplagonus inermis*					2	0.01		
Gray starsnout	*Asterotheca alascana*	9	0.04	7	0.06	10	0.09	7	0.04
Blacktip poacher	*Xeneretmus latifrons*	3	0.03						
Sturgeon poacher	*Agonus acipenserinus*	197	4.29			16	0.61	50	1.59
Snailfish uniden.	Cyclopteridae (Liparidinae) spp.					1	0.02		
Smalldisk snailfish	*Careproctus gilberti*			1	0.02				
Pacific spiny lumpsucker	*Eumicrotremus orbis*					5	0.07		
Spotted snailfish	*Liparis callyodon*	1	0.03						
Marbled snailfish	*Liparis dennyi*					4	0.22		
Slipskin snailfish	*Liparis fucensis*	2	0.05			12	0.31	2	0.06
Showy snailfish	*Liparis pulchellus*	8	0.26						
Ringtail snailfish	*Liparis rutteri*					1	0.01		
Shiner perch	*Cymatogaster aggregata*	23242	327.63			34	0.62		

Table 4. Sampled fish numbers and weights encountered during the 2001 trawl survey.

		WA Strait of Georgia		BC Strait of Georgia		San Juan Archipelago		BC Haro Strait & Boundary Pass	
Common Name	**Scientific Name**	**Nos**	**Kg**	**Nos**	**Kg**	**Nos**	**Kg**	**Nos**	**Kg**
Striped seaperch	*Embiotoca lateralis*			1	0.05				
Pile perch	*Rhacochilus vacca*	9	0.49			1	0.03		
Pacific sandfish	*Trichodon trichodon*	1	0.11						
Northern ronquil	*Ronquilus jordani*	3	0.12	5	0.15	61	3.00	4	0.18
Decorated warbonnet	*Chirolophis decoratus*							3	0.19
Snake prickleback	*Lumpenus sagitta*	21	0.39			42	0.43	1	0.03
Giant wrymouth	*Delolepis gigantea*	4	1.68						
Saddleback gunnel	*Pholis ornata*					3	0.03		
Pacific sandlance	*Ammodytes hexapterus*					1	0.01		
Bay goby	*Lepidogobius lepidus*	1	0.00						
Pacific sanddab	*Citharichthys sordidus*	515	84.67	10	2.21	323	48.28	6	1.34
Speckled sanddab	*Citharichthys stigmaeus*	261	7.21			228	8.53		
Arrowtooth flounder	*Atheresthes stomias*	13	4.28	13	13.92	7	1.04	1	0.24
Petrale sole	*Eopsetta jordani*	1	0.14	1	0.12	1	0.12		
Slender sole	*Lyopsetta exilis*	233	7.92	181	8.80	12	0.60		
Flathead sole	*Hippoglossoides elassodon*	2451	246.18	24	4.20	86	3.54	47	6.91
Rock sole uniden.	Lepidopsetta spp.	15	4.53						
Northern rock sole	*Lepidopsetta polyxystra*	434	125.19			231	79.47		
Southern rock sole	*Lepidopsetta bilineata*	573	123.90	15	4.29	802	105.95	4	1.42
Dover sole	*Microstomus pacificus*	708	83.52	363	80.11	780	59.99	105	11.45
Starry flounder	*Platichthys stellatus*	707	324.65			21	15.52		
Butter sole	*Isopsetta isolepis*	637	66.12			210	23.22		
English sole	*Parophrys vetulus*	11675	1668.80	1200	421.34	1160	107.02	145	32.13
C-O sole	*Pleuronichthys coenosus*	1	0.06						
Sand sole	*Psettichthys melanostictus*	278	73.53			30	4.64		
Pacific halibut	*Hippoglossus stenolepis*					1	7.30		
Rex sole	*Glyptocephalus zachirus*	182	9.32	10	1.01	210	14.08	88	3.57
Total		74723	9119.47	11427	3411.83	22515	4657.89	3443	838.39
Number of Taxa		67		43		64		30	

Table 5. Number of length samples and average population lengths or widths of selected species collected during the 2001 trawl survey (all fish measured as total length in centimeters, invertebrates in millimeters).

Species	WA Strait of Georgia		BC Strait of Georgia		San Juan Archipelago		BC Haro Strait & Boundary Pass	
	Avg.	n	Avg.	n	Avg.	N	Avg.	n
Male Dungeness crabs	119.5	1359	161.3	6	122.7	485	178.9	12
Female Dungeness crabs	101.6	1282	131.0	54	121.7	452	147.0	24
Spotted prawn	32.3	18	33.0	48	36.4	597	36.5	33
Spiny dogfish	61.7	502	71.4	245	67.1	575	77.7	40
Big skate	43.1	107	60.0	18	54.9	55	68.1	3
Longnose skate	46.5	41	43.0	37	40.2	15	76.0	1
Pacific cod	41.6	74	45.7	53	31.9	122	33.2	33
Walleye pollock	18.5	2615	19.3	433	17.5	1642	18.4	330
Pacific whiting (hake)	38.8	171	40.0	368	31.7	8	35.5	2
Copper rockfish			33.3	3				
Greenstriped rockfish			25.9	20				
Quillback rockfish	30.5	2	30.4	22	29	2	30.4	2
Yelloweye rockfish			60.0	1				
Shortspine thornyhead	29.1	3	30.2	19				
Kelp greenling	32.2	3			28.7	5		
Whitespotted greenling	18.3	49			18.8	107		
Lingcod	30.6	15	32.4	9	36.3	15		
Sablefish	32.0	1			35.0	1		
Cabezon					44.5	2		
Great sculpin	31.2	170			29.1	349	35.6	10
Red Irish lord	26.7	3			32.0	90		
Buffalo sculpin	20.3	4			19.6	30		
Rock sole (unidentified)	27.4	16						
Northern rock sole	27.4	246			25.0	176		
Southern rock sole	22.9	464	28.1	15	20.0	661	29.7	4
Dover sole	22.2	692	26.2	363	18.5	743	22.8	95

Table 5. Number of length samples and average population lengths or widths of selected species collected during the 2001 trawl survey (all fish measured as total length in centimeters, invertebrates in millimeters).

Species	**WA Strait of Georgia**		**BC Strait of Georgia**		**San Juan Archipelago**		**BC Haro Strait & Boundary Pass**	
	Avg.	**n**	**Avg.**	**n**	**Avg.**	**N**	**Avg.**	**n**
English sole	24.0	4076	33.0	683	20.4	696	27.7	142
Starry flounder	32.2	533			37.0	21		
Sand sole	26.7	242			17.3	30		
Pacific halibut					90 .0	1		
Pacific sanddab	24.8	279	26.9	10	23.5	322	27.7	6

Table 6. Numerical (x 1,000) and biomass (mt) abundance of all fishes in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	95,026.3	21,609.0	19,528.8	23,532.4		159,696.3
(% CV)	52.2	38.5	31.7	28.4		32.0
Biomass (mt)	5,429.2	3,112.4	1,384.3	8,444.6		18,370.5
(% CV)	13.3	3435	26.5	43.7		21.4
British Columbia Strait of Georgia						
Abundance			8,346.9	15,109.2	201.9	23,658.0
(% CV)			49.9	13.7	20.1	19.7
Biomass (mt)			1,397.4	5,472.7	102.2	6,972.3
(% CV)			69.4	14.2	24.1	17.8
San Juan Archipelago						
Abundance	8,831.3	10,471.7	22,563.0	18,641.5		60,507.3
(% CV)	16.7	25.1	32.4	21.1		14.6
Biomass (mt)	1,191.3	2,588.4	3,667.0	4,905.6		12,353.3
(% CV)	14.1	25.8	17.6	22.5		11.8
British Columbia Haro Strait and Boundary Pass						
Abundance			629.6	6,807.8		7,437.5
(% CV)			42.5	45.1		41.5
Biomass (mt)			132.6	1,706.5		1,839.1
(% CV)			6.56	42.0		39.0

Table 7. Numerical and biomass abundance of fishes encountered during the 2001 trawl survey.

	Nos X 1000	%CV	mt	%CV	Nos X 1000	%CV	mt	%CV
Northern Areas	**WA Strait of Georgia**				**BC Strait of Georgia**			
Brown cat shark					1.39	72.48	0.06	78.29
Spiny dogfish	1170.95	18.07	1239.32	18.11	463.44	63.51	751.68	62.47
Total sharks	1170.95	18.07	1239.32	18.11	464.83	63.32	751.74	62.46
Big skate	244.69	17.85	567.16	35.56	44.77	40.37	176.18	42.45
Longnose skate	78.99	26.16	65.88	29.66	58.07	22.13	34.4	27.5
Other skates & rays	5.15	53.59	3.04	63.23	16.2	44.03	13.14	44.23
Total skates & rays	328.83	15.75	636.09	31.82	119.04	18.72	223.71	35.23
Spotted ratfish	15676.02	43.36	6801.99	52.07	12683.88	18.42	4010.07	20.4
Pacific herring	6199.49	24.46	160.39	22.05	70.37	47.14	4.79	54.85
Other clupeids	1.16	100	0.21	100				
Total clupeids	6200.65	24.46	160.6	22.02	70.37	47.14	4.79	54.85
Other smelt	8976.47	35.48	79.61	36.94	178.83	22.7	5.15	21.74
Total smelts	8976.47	35.48	79.61	36.94	178.83	22.7	5.15	21.74
Plainfin midshipman	4832.46	47.97	251.13	49.8	24.49	62.04	1.14	65.61
Pacific cod	139.37	36.8	138.37	28.6	122.45	25.36	152.73	32.41
Pacific tomcod	9552.49	44.79	495.75	43.35	68.74	32.64	5.1	26.41
Walleye pollock	13045.04	36.5	691.81	29.84	5064.49	63.05	328.07	58.66
Pacific whiting (hake)	308.35	24.77	127.87	49.98	654.27	21.82	311.78	27.2
Blackbelly eelpout	357.68	57.63	9.62	56.5				
Other eelpout	171.56	49.21	11.82	39.87	2.87	87.93	0.51	97.48
Total eelpouts	529.24	53.59	21.45	41.16	2.87	87.93	0.51	97.48
Tubesnout	2.54	100	0.03	100				
Copper rockfish					5.99	100	4.11	100
Greenstriped rockfish					46.93	69.85	9.34	74.59
Puget Sound rockfish	9.95	61.38	0.36	58.83				
Quillback rockfish	2.25	100	1.37	100	46.55	58.91	26.81	56.71
Yelloweye rockfish					0.37	100	1.28	100
Shortspine thornyhead	5.34	74.52	1.79	75.86	14.98	46.13	6.33	45.78
Total rockfish	17.55	41.79	3.53	54.2	114.82	50.54	47.88	44.34
Kelp greenling	10.1	49.67	3.44	54.49				
White-spotted greenling	523.16	47.76	35.21	42.78				
Total greenlings	533.25	47.37	38.65	40.47				

Table 7. Numerical and biomass abundance of fishes encountered during the 2001 trawl survey.

	Nos X 1000	%CV	mt	%CV	Nos X 1000	%CV	mt	%CV
Lingcod	36.15	55.88	10.94	41.59	18.27	62.34	5.88	52.34
Longspine combfish	2.2	100	0.07	100				
Sablefish	3.7	70.79	1.24	71.23				
Buffalo sculpin	1012.98	53.27	214.25	54.73				
Red Irish lord	11.04	81.31	6.22	73.9				
Pacific staghorn sculpin	281.84	36.71	48.59	36.72				
Great sculpin	1177.72	73.94	611.2	77.88				
Roughback sculpin	70.23	48.65	1.92	52.03				
Other sculpin	866.1	68.98	13.21	31.8	81.06	73.09	3.18	46.72
Total sculpins	3419.9	43.83	895.38	64.98	81.06	73.09	3.18	46.72
Sturgeon poacher	491.89	46.34	10.75	37.11				
Other poacher	98.9	57.61	2.37	71.36	279.27	14.37	7.34	4.86
Total poachers	590.8	39.8	13.12	32.99	279.27	14.37	7.34	4.86
Snailfish	23.46	33.94	0.69	33.62	0.37	100	0.01	100
Shiner perch	53960.91	93.73	749.27	91.56				
Striped seaperch					1.75	100	0.09	100
Pile perch	18.41	47.09	0.95	41.8				
Total surfperch	53979.32	93.7	750.22	91.47	1.75	100	0.09	100
Prickleback	52.94	35.78	0.98	37.92				
Giant wrymouth	8.08	100	3.4	100				
Pacific sanddab	1158.57	32.86	188.93	31.09	19.02	45.74	4.18	47.6
Speckled sanddab	635.65	27.66	17.5	27.78				
Arrowtooth flounder	25.37	38.97	7.42	46.01	11.64	57.7	13.77	65.57
Petrale sole	2.47	100	0.35	100	2	100	0.24	100
Rex sole	358.92	31.18	17.21	27.01	17.3	45.66	1.51	46.06
Flathead sole	5204.87	59.1	522.96	56.48	48.81	66.71	8.7	74.82
Butter sole	1695.59	34.89	166.96	33.88				
Rock sole (unidentified)	41.73	68.3	12.97	74				
Northern rock sole	962.08	67.32	278.35	63.67				
Southern rock sole	1528.99	42.75	299.73	55.69	28.11	46.78	8.08	45.57
Total rock sole	2532.81	39.51	591.05	46.87	28.11	46.78	8.08	45.57
Slender sole	454.16	59.26	14.02	37.4	257.49	38.36	12.24	34.67
Dover sole	1393.73	19.74	156.88	13.85	633.72	16.94	116.96	18.64
English sole	24337.93	23.42	3339.58	22.37	2681.13	28.21	947.15	29.83

Table 7. Numerical and biomass abundance of fishes encountered during the 2001 trawl survey.

	Nos X 1000	%CV	mt	%CV	Nos X 1000	%CV	mt	%CV
Starry flounder	1762.49	34.73	805.54	36.37				
C-O sole	4.08	100	0.24	100				
Sand sole	688.91	27.27	179.14	27.35				
Total flatfish	40255.56	22.58	6007.79	18.72	3699.2	20.08	1112.83	24.12
Other nongame fish	11	44.69	0.48	53.47	9	69.42	0.27	78.64
Total Fish	159696.33	32.02	18370.51	21.36	23657.99	19.65	6972.26	17.8

Southern Areas	**WA San Juan Archipelago**				**BC Haro Strait & Boundary Pass**			
Spiny dogfish	1673.72	14.41	2370.52	13.58	99.89	30.97	209.5	23.81
Total sharks	1673.72	14.41	2370.52	13.58	99.89	30.97	209.5	23.81
Big skate	136.55	28.59	523.16	42.97	5.35	72.74	29.13	96.36
Longnose skate	37.96	26.52	31.93	45	2	100	5.39	100
Other skates & rays	6.98	52.42	5.27	69.32				
Total skates & rays	181.5	22.73	560.36	39.7	7.35	55.18	34.52	77.53
Spotted ratfish	14040.18	20.54	5808.31	24.6	2954.01	55.16	1237.61	53.18
Pacific herring	1195.08	45.1	33.85	40.81	12.82	53.04	0.47	61.76
Other clupeids	3.65	100	2.37	100				
Total clupeids	1198.73	44.96	36.22	38.4	12.82	53.04	0.47	61.76
Other smelt	132.15	32.01	3.51	32.41	8.75	58.17	0.3	57.92
Total smelts	132.15	32.01	3.51	32.41	8.75	58.17	0.3	57.92
Plainfin midshipman	27.08	81.78	1.19	83.36				
Pacific cod	290.32	19.5	184.13	34	113.51	31.61	43.86	31.46
Pacific tomcod	4336.31	37.96	279.49	37.96	12	40.81	1.39	51.17
Walleye pollock	21932.11	36.63	849.61	35.37	3181.73	62.99	167.63	59.4
Pacific whiting (hake)	23.03	40.79	4.81	39.13	3.99	100	1.16	100
Blackbelly eelpout	286.75	45.87	3.67	40.94				
Other eelpout	2.14	100	0.06	100	28.58	93.28	1.91	93.95
Total eelpouts	288.89	45.46	3.74	40.09	28.58	93.28	1.91	93.95
Puget Sound rockfish	741.21	54.78	22.75	57.45				
Quillback rockfish	11.98	100	6.65	100	7.75	60.64	6.14	67.76
Shortspine thornyhead					2.99	100	2.22	100
Total rockfish	753.2	54.57	29.4	58.24	10.74	58.49	8.35	74.9
Kelp greenling	28.08	67.12	9.53	65.51				
White-spotted greenling	1088.28	29.97	87.09	28.13				

Table 7. Numerical and biomass abundance of fishes encountered during the 2001 trawl survey.

	Nos X 1000	%CV	mt	%CV	Nos X 1000	%CV	mt	%CV
Total greenlings	1116.36	29.56	96.62	28.2				
Lingcod	48.72	41.56	35.97	65.95				
Sablefish	2.41	100	0.97	100				
Buffalo sculpin	86.98	43.53	17	51.14				
Red Irish lord	524.96	59.43	323.8	60.21				
Pacific staghorn sculpin	20.49	37.05	5.6	43.67				
Great sculpin	1376.45	32.79	555.17	35	17.92	100	12.51	100
Cabezon	11.93	64.55	17.53	64.7				
Roughback sculpin	72.85	55.47	2.4	55.39				
Other sculpin	2421.17	38.57	88.77	31.27	35.97	18.44	4	49.11
Total sculpins	4514.83	21.97	1010.28	31.02	53.89	42.76	16.51	86.86
Sturgeon poacher	46.07	39.31	1.71	35.77	86.18	94.64	2.7	96.54
Other poacher	410.53	27.27	11.3	27.52	60.01	61.23	1.54	91.34
Total poachers	456.6	26.14	13.01	25.62	146.19	30.73	4.24	28.54
Snailfish	84.38	40.7	2.39	50.75	4.79	72.91	0.14	72.91
Shiner perch	69.63	31.74	1.34	31.56				
Pile perch	1.82	100	0.05	100				
Total surfperch	71.45	31.13	1.38	30.9				
Prickleback	75.67	34.93	0.72	38.53	7.04	52.78	0.39	74.45
Gunnel	4.94	74.19	0.05	74.22				
Pacific sandlance	1.87	100	0.01	100				
Pacific sanddab	1035.67	38.32	162.01	37.47	10.47	50.27	2.32	41.68
Speckled sanddab	514	52.82	18.97	50.26				
Arrowtooth flounder	15.28	39.13	2.11	50.01	2.03	100	0.49	100
Petrale sole	2.8	100	0.34	100				
Rex sole	445.81	28.26	28.98	32.25	189.17	52.11	7.71	67.55
Flathead sole	135.65	45.72	5.57	42.47	78.1	100	11.48	100
Butter sole	315.84	71.19	34.78	71.94				
Northern rock sole	465.39	42.99	156.97	47.43				
Southern rock sole	1598.57	28.02	220.11	18.06	7.15	35.59	2.48	14.66
Total rock sole	2063.96	29.32	377.09	27.28	7.15	35.59	2.48	14.66
Slender sole	31.91	61.07	1.5	57.2				
Dover sole	2010.53	21.77	141.38	22.27	220.05	37.09	24.48	42.96
English sole	2329.62	32.97	221.66	29.69	278.06	70.34	61.79	64.16

Table 7. Numerical and biomass abundance of fishes encountered during the 2001 trawl survey.

	Nos X 1000	%CV	mt	%CV	Nos X 1000	%CV	mt	%CV
Starry flounder	35.9	59.1	27.17	64.86				
Sand sole	62.37	54.97	7.53	61.19				
Pacific halibut	2.63	100	19.19	100				
Total flatfish	9001.97	17.89	1048.28	15.64	785.03	48.33	110.75	52.94
Other nongame fish	250.89	40.35	12.36	42.41	7.17	100	0.32	100
Total Fish	60507.31	14.59	12353.32	11.77	7437.48	41.47	1839.06	38.97

Spiny Dogfish

Spiny dogfish constituted 6.7% of the biomass in the WASG, 10.8% in the BCSG, 19.2% in the WASJA, and 11.3% of the BCHB (Figures 5 and 6, Table 7). The numerical population of dogfish for the four study areas was estimated at 3.4 million (12.8% CV), a population that weighed 4571.0 mt (13.4% CV, Table 8). The WASJA had 2,371 mt (13.6% CV), the greatest biomass of dogfish for any region including the WASG that had 1,239 mt (18.1% CV). The plot of station densities for dogfish showed they were distributed throughout the survey regions but with greater concentrations in Bellingham Bay, northern Orcas Island, Cherry Point, and southern Rosario Strait (Figure 7). The greatest biomass of dogfish in the WASG was in the 5-20 fm stratum and was seconded by the 21-40 fm stratum (Figure 8). Dogfish were more uniformly distributed among the four depth strata in the WASJA, but almost 40% of the biomass was in the 41-60 fm stratum.

The size of dogfish encountered during the survey ranged from 30 cm to 110 cm in total length (Figures 9 and 10). Dogfish averaged 71.4 cm in total length in the BCSG and 77.7 cm in the BCHB (Table 5). These BC fish tended to be larger than those populations in the WASG where they averaged 61.7 cm and in the WASJA where they averaged 67.1 cm. Higher proportions of larger fish occurred in the southern survey regions with comparatively higher frequencies of 90 cm, 100 cm, and 110 cm individuals (Figure 10).

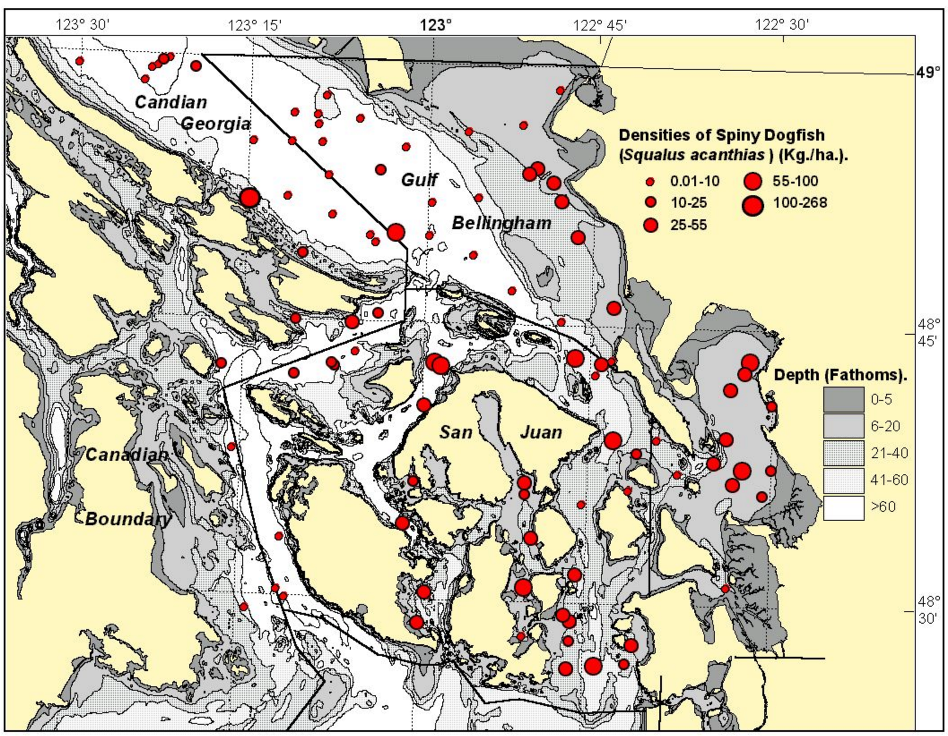

Figure 7. The distribution of spiny dogfish densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

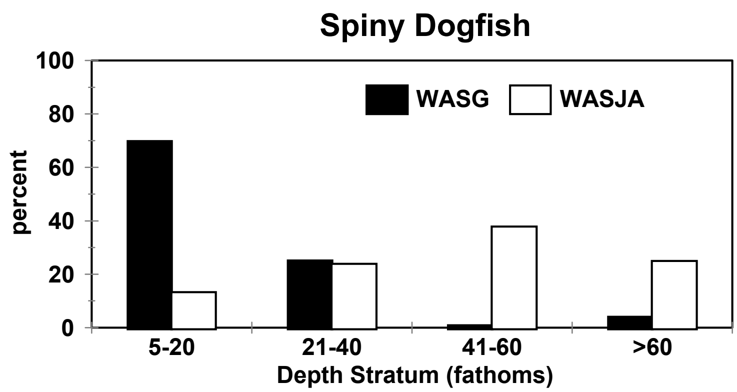

Figure 8. Depth distribution of spiny dogfish.

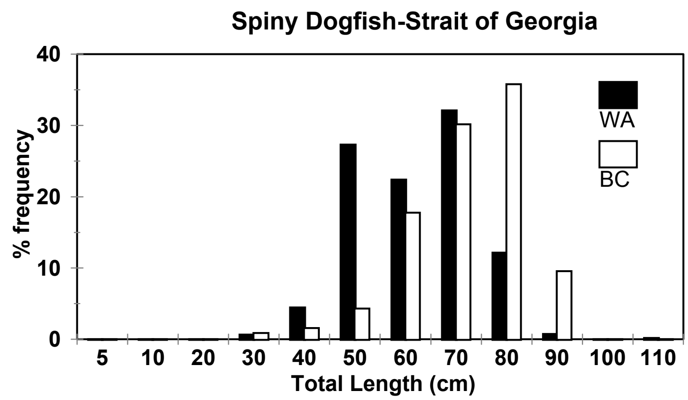

Figure 9. Length frequency distribution of spiny dogfish in the WA and BC Strait of Georgia.

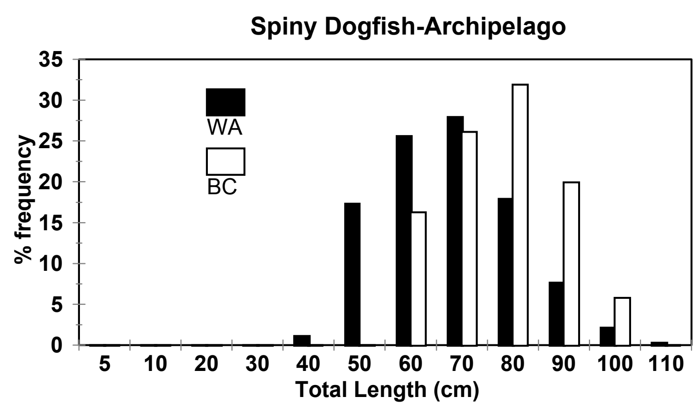

Figure 10. Length frequency distribution of spiny dogfish in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 8. Numerical (x1000) and biomass (mt) abundance of spiny dogfish in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	778.4	304.9	18.3	69.3		1171.0
(% CV)	23.5	34.0	61.5	26.6		18.1
Biomass (mt)	865.5	311.6	11.3	51.0		1239.3
(% CV)	22.4	36.0	62.6	36.5		18.1
British Columbia Strait of Georgia						
Abundance			311.1	138.2	14.2	463.4
(% CV)			92.5	44.6	26.2	63.5
Biomass (mt)			486.2	250.8	14.7	751.7
(% CV)			92.5	54.2	25.7	62.5
San Juan Archipelago						
Abundance	325.7	417.7	713.2	217.1		1,673.7
(% CV)	31.6	28.2	24.2	28.8		14.4
Biomass (mt)	315.3	567.2	897.1	591.0		2,370.5
(% CV)	28.6	25.5	21.3	33.1		13.6
British Columbia Haro Strait and Boundary Pass						
Abundance			30.3	69.6		99.9
(% CV)			64.5	34.5		31.0
Biomass (mt)			49.0	160.5		209.5
(% CV)			39.1	28.7		23.8

Spotted Ratfish

Spotted ratfish comprised 37% of the fish biomass in the WASG and 58% of the biomass in the limited survey of the BCSG (Table 7, Figure 5). They comprised 47% of the bottomfish biomass in the WASJA and 67.3% of the biomass of the BCHB (Table 7, Figure 6). There was an estimated 45.3 million ratfish (36.5% C.V.) in the entire study area accounting for a biomass of 17,900 mt (22.2% C.V., Table 9). There were 15.6 million ratfish (43.4% CV) in the WASG and these weighed 6,800 mt (52.1% CV). The BCSG had an estimated 12.7 million ratfish (18.4% CV) that weighed 4,000 mt (20.4 %CV). The WASJA had 14.0 million ratfish, and these had a biomass estimate of 5,800 mt (24.6% CV). The BCHB had the lowest estimate of ratfish that was 3.0 million individuals (55.2% CV) that weighed 1,200 mt (53.2% CV).

Ratfish were distributed continuously among the deep basins shared by BC and WA (Figure 11). The highest concentrations of dogfish were observed in the southern Strait of Georgia, followed by southern Haro Strait and then by Boundary Pass, President's Channel, and northern Rosario Strait. The ratfish population biomass was almost exclusively limited to the >60 fm stratum of the WASG (Figure 12) but in the WASJA the biomass was commonly distributed in the 41-60 fm and 21-40 fm strata. However, 60% of the ratfish still inhabited the >60 stratum in this region.

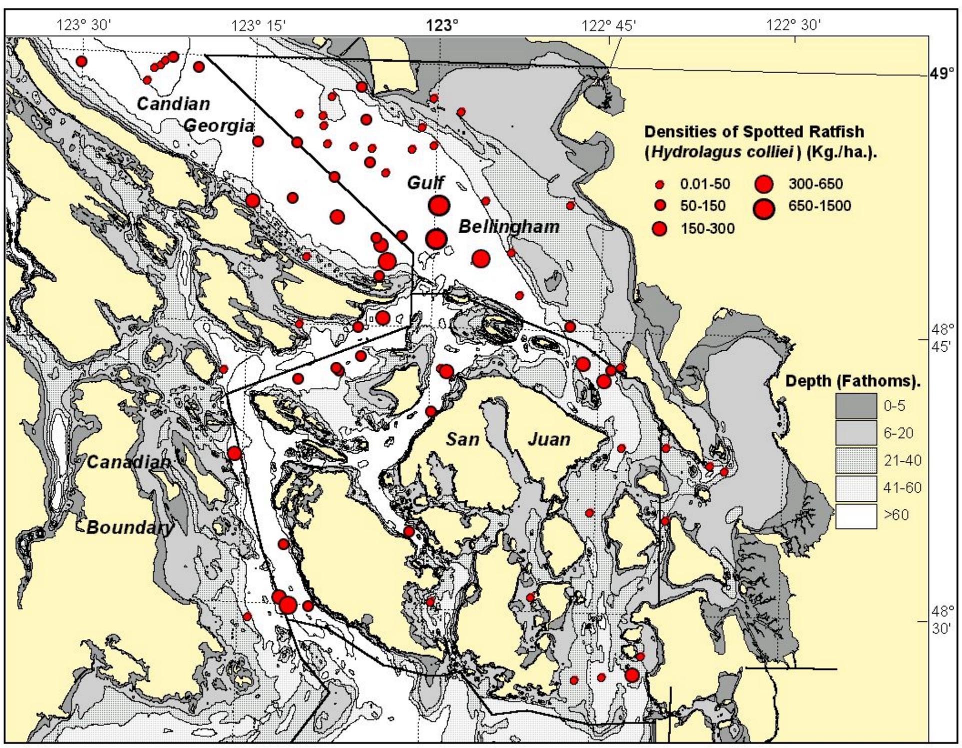

Figure 11. The distribution of spotted ratfish station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

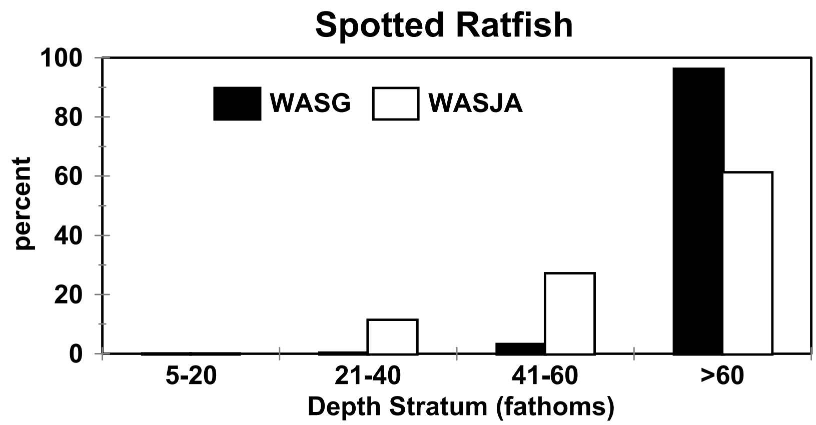

Figure 12. Depth distribution of spotted ratfish.

Table 9. Numerical (x1000) and biomass (mt) abundance of spotted ratfish in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	11.9	45.2	1,553.7	14,065.2		15,676.0
(% CV)	61.0	53.5	49.5	48.0		43.4
Biomass (mt)	5.0	25.1	221.1	6550.8		6802.0
(% CV)	68.1	54.6	42.3	54.1		52.1
British Columbia Strait of Georgia						
Abundance			2399.7	10199.1	85.4	12683.9
(% CV)			35.2	21.4	46.2	18.4
Biomass (mt)			541.7	3423.1	45.3	4010.1
(% CV)			60.7	21.9	55.4	20.4
San Juan Archipelago						
Abundance	14.8	1552.5	3895.1	8577.7		14040.2
(% CV)	78.6	95.6	45.2	20.3		20.5
Biomass (mt)	5.5	667.2	1578.3	3557.3		5808.3
(% CV)	85.2	94.3	43.4	30.5		24.6
British Columbia Haro Strait and Boundary Pass						
Abundance			32.0	2922.0		2954.0
(% CV)			79.2	55.8		55.2
Biomass (mt)			18.4	1219.2		1237.6
(% CV)			95.1	54.0		53.2

Skates

There were 636,700 skates (11.0% C.V., Table 10) in the study area, and they represented a biomass of 1,450 mt (21.4% C.V.). Big skate was a minor component of the bottomfish community in the Strait of Georgia were their biomass constituted 3.1% of total fish biomass in the WASG and 2.5% of the BCSG (Table 7). Skates comprised only 4.2% of the total fish biomass in the WASJA and only 1% of the fish biomass in the BCHB. Among the survey regions, the WASG had the greatest numerical abundance and biomass of skates with 328,800 individuals (15.8% CV) that weighed 636 mt (31.8% CV, Table 10). The WASJA had the second highest abundances with 181,500 individuals (22.7%) that weighed 560 mt (39.7% CV). Relatively high abundances of skates were observed in the BCSG where there were an estimated 119,000 skates (18.7% CV) that had an estimated weight of 223 mt (35.2% CV). The BCHB had low abundances of skates with only 7,000 individuals (55.2% CV) and 35.5 mt (77.5% CV). Big skate and longnose skates accounted for at least 85% of the numerical skate population and more than 90% of the population biomass (Table 7). Big skate dominated the skate biomass in all regions. In the WASG, big skates constituted 89% of the skate population biomass, in the BCSG they constituted 79%, in the WASJA they constituted 93% and in the BCHSBP they constituted 84% (Table 7). Longnose skates constituted 10% of the biomass in the WASG, 15% in the BCSG, 6% in the WASJA, and 15% in the BCHB. Sandpaper skate was the only other skate species encountered (Table 4) and accounted for the remainder of the skate population estimate.

Most big skate were aggregated in the deep waters of the southern Strait of Georgia and President's Channel, in the shallow waters of Bellingham Bay and north Lummi Island (Figure 13). They were sporadic in the WASJA and occurred at a few stations in Rosario Strait and East Sound. Big skates were not similarly distributed among the depth strata in the two fully-surveyed regions. In the WASG, the greatest biomass of big skate occurred in the 5-20 fm stratum (Figure 14) followed by the 21-40 fm stratum, >60 fm stratum, and the 41-60 fm stratum. In the WASJA, more than half of the biomass of big skate occurred in the 21-40 fm stratum with little biomass in the shallowest stratum.

The big skate populations estimated for the fully surveyed regions of Washington were smaller than the partially sampled BC regions. Big skate lengths ranged from 20 cm to 160 cm (Figures 15 and 16). In the WASG, most big skates measured between 20 cm and 40 cm but some measured 150 cm (Figure 15) and overall, the population averaged 43.1 cm (Table 5). In the WASJA, big skates averaged 54.0 cm in length (Figure 16) with the highest modes at 20 cm and 30 cm, but some of the population ranging above 100 cm in length. Big skate lengths in the BCSG were more clustered around the 60 cm average length with common modes at 60 cm to 80 cm. In the BCHB, big skate averaged 68.1 cm in length and had the highest frequency at 120 cm length.

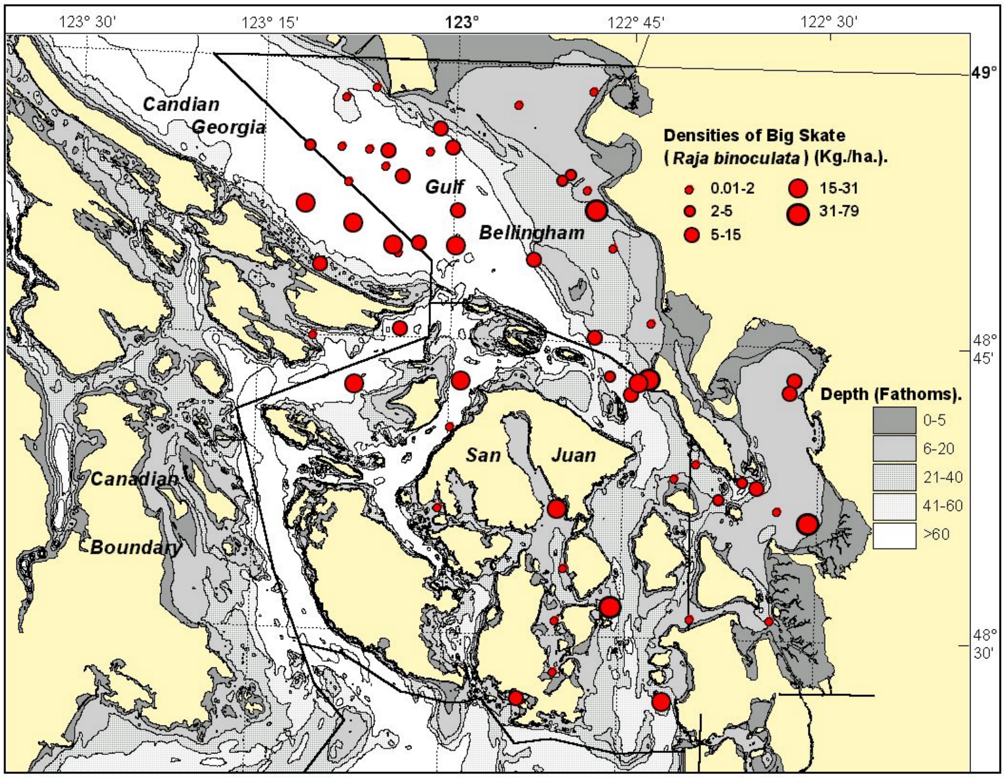

Figure 13. The distribution of big skate station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

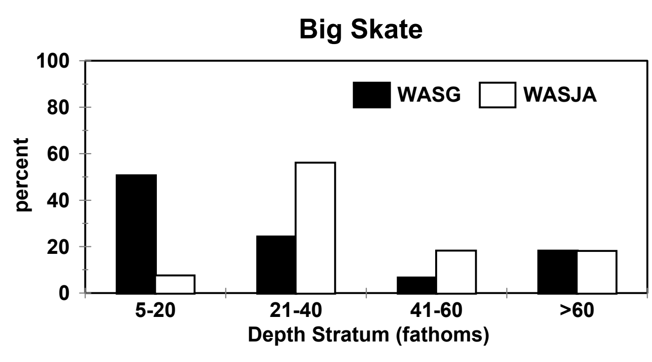

Figure 14. Depth distribution of big skate.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	88.3	103.9	43.5	93.1		328.8
(% CV)	27.3	38.9	28.1	19.2		15.8
Biomass (mt)	293.4	152.7	49.4	140.6		636.1
(% CV)	55.1	72.9	28.5	33.3		31.8
British Columbia Strait of Georgia						
Abundance			5.3	109.2	4.6	119.0
(% CV)			100.0	19.8	26.3	18.7
Biomass (mt)			18.4	202.1	3.2	223.7
(% CV)			100.0	37.9	26.8	35.2
San Juan Archipelago						
Abundance	65.1	48.7	27.1	40.6		181.5
(% CV)	36.8	61.7	29.7	31.2		22.7
Biomass (mt)	39.7	304.2	105.4	111.1		560.4
(% CV)	65.9	66.4	59.3	57.4		39.7
British Columbia Haro Strait and Boundary Pass						
Abundance			3.3	4.0		7.4
(% CV)			100.0	57.7		55.2
Biomass (mt)			1.1	33.4		34.5
(% CV)			100.0	80.0		77.5

Table 10. Numerical (x1000) and biomass (mt) abundance of skates in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

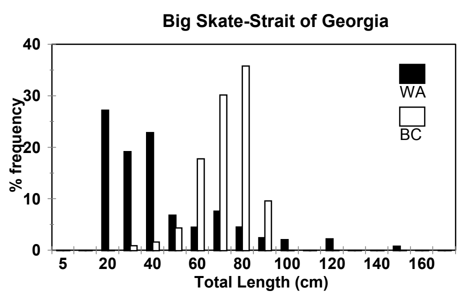

Figure 15. Length frequency distribution of big skate in the WA and BC Strait of Georgia.

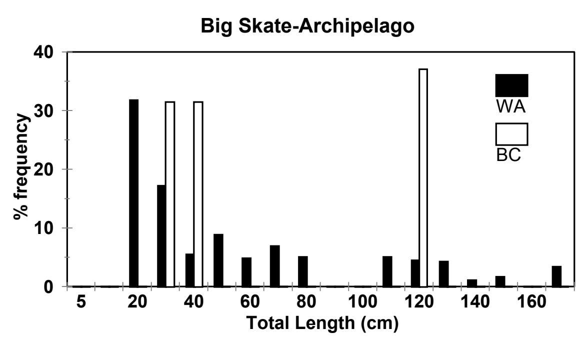

Figure 16. Length frequency distribution of big skate in the WA San Juan Archipelago and the BC Haro Strait and Boundary Pass.

Longnose skate was more restricted to the deeper depths than big skate (Figures 17 and 18). Longnose skate was infrequent in the WASJA and BCHB, and more frequently occurred in the central, deep portions of the WASG and BCSG. This skate species constituted 10% of the skate biomass in the WASG, 15% in the BCSG, 6% in the WASJA, and 15% in the BCHB (Table 7). Half of the longnose skate population occurred in the >60 fm depth stratum in the WASG (Figure 18), and only 10% of the biomass occurred in the 5-20 fm stratum. Longnose skate were the most prevalent in the >60 fm stratum in the WASJA, but the remaining were evenly distributed among the 21-40 fm stratum and the 41-60 fm stratum with virtually none occurring in the shallowest depth stratum.

The longnose skate population measured between 20 cm and 80 cm in total length (Figures 19 and 20), and the length distribution was clustered around 40 cm and 50 cm in the SG (Figure 19). The population length averaged 46.5 cm in the WASG and 43.0 cm in the BCSG (Table 5). The population length distribution was more even in the WASJA where longnose skate averaged 40.2 cm in length (Figure 20). In the BSHB, large longnose skates was the only skate encountered, and they averaged 76 cm in length.

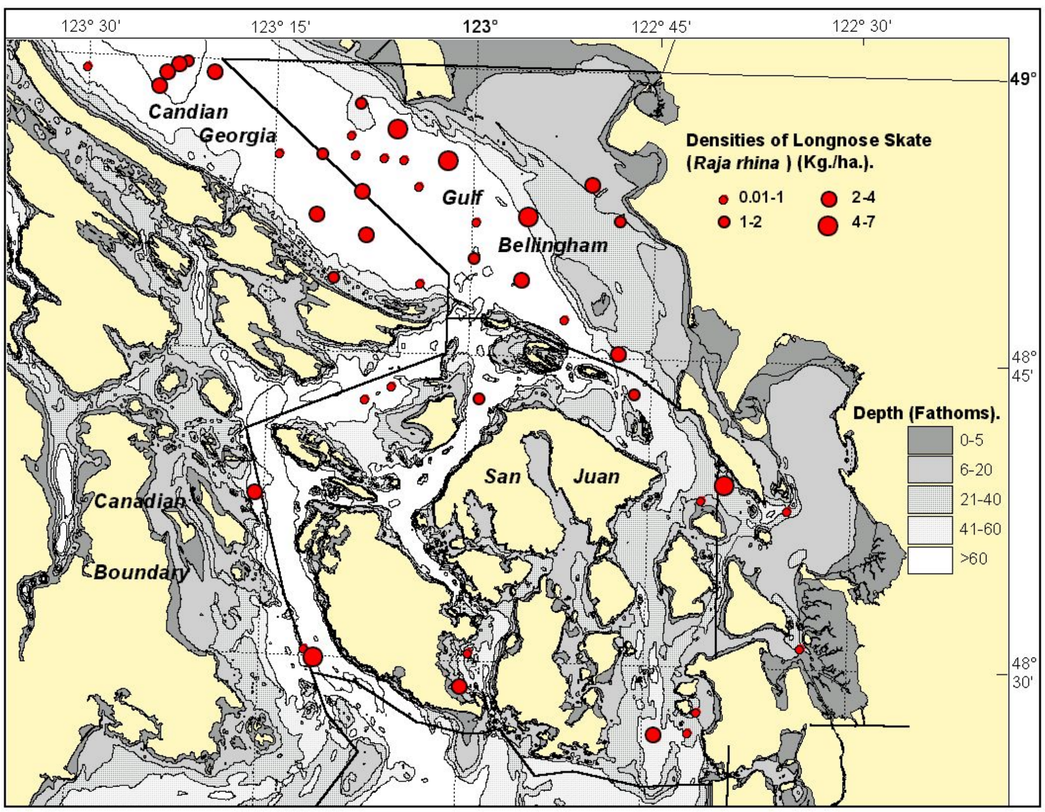

Figure 17. The distribution of longnose skate station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

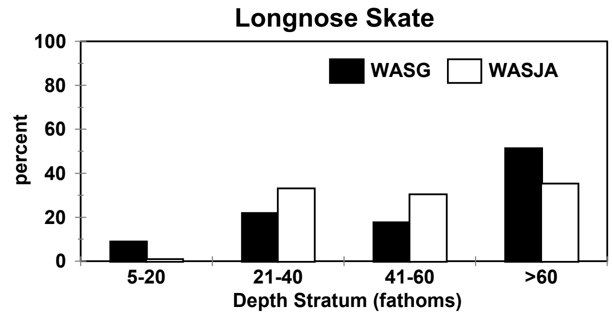

Figure 18. Depth distribution of longnose skate.

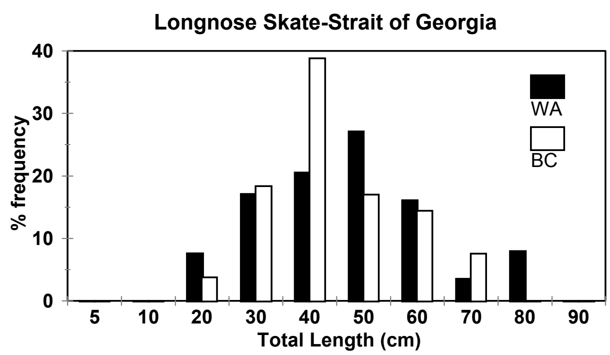

Figure 19. Length frequency distribution of longnose skate in the WA and BC Strait of Georgia.

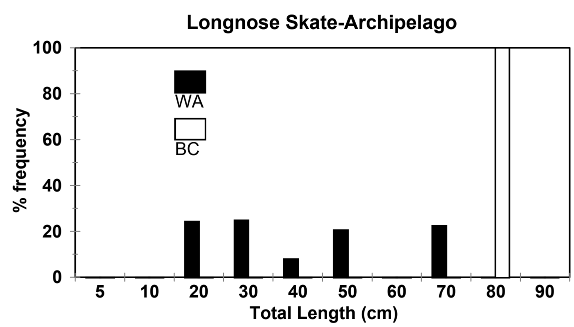

Figure 20. Length frequency distribution of longnose skate in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Pacific Cod

Pacific cod was a minor component of the catch and comprised less than 3% of the total fish biomass (Table 7). Only 0.8% of the fish biomass was Pacific cod in the WASG, 2.2% in the BCSG, 1.5% in the WASJA, and 2.3% in the BCHB. For all survey regions combined, there were 665,700 individuals (13.5% CV, Table 11) that weighed 519 mt (17.4% CV). The WASJA had the greatest population and biomass of cod with 122,500 individuals (19.5%) and a biomass of 184 mt (34.0% CV). The BCSG had the second greatest biomass with 152.6 mt (32.4% CV) and 122,500 individuals (25.4% CV). The WASG had a population estimate of 139,400 individuals (36.8% CV) that weighed 138.4 mt (28.6%). The BCHB had 113,000 individuals (31.6% CV) weighing 43.9 mt (31.5%). Pacific cod is primarily a deepwater species that inhabits the deep basins of the WA and BC Strait of Georgia (Figure 21), Boundary Pass, Haro Strait, and President's Channel. Pacific cod were also present at many Rosario Strait stations. Cod were almost exclusively distributed in the >60 fm depth stratum (Figure 22) where 70% or more of the population was distributed. The 41-60 fm stratum contained between 7% and 19% of the population biomass and less than 5% of the biomass occurred in the remaining shallow strata.

The length frequency distribution of the Pacific cod population ranged from 10 cm to 90 cm (Figures 23 and 24). The Pacific cod population averaged 41.6 cm in length (Table 5) in the WASG where the modal frequency was 30 cm but high frequencies at 40 cm, 50 cm, and 60 cm were also observed (Figure 23). A small proportion of the BCSG population was 90 cm in length, but overall the population averaged 45.7 cm in length. Cod were not as large in the southern survey regions were 30 cm was the modal size for both the WASJA and the BCHB (Figure 24). The cod population averaged 31.9 cm and 33.2 cm in length in these regions, respectively (Table 5).

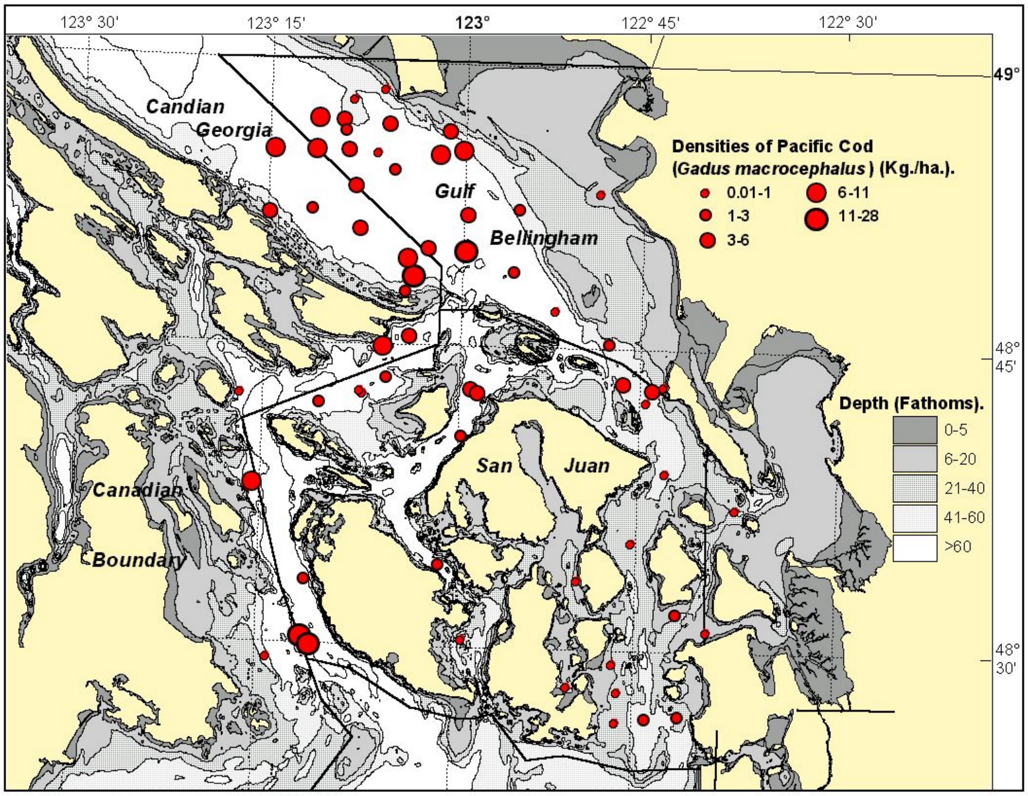

Figure 21. The distribution of Pacific cod station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

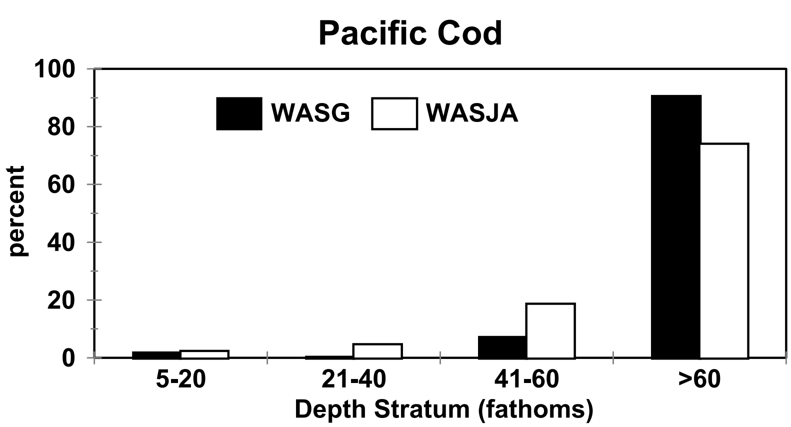

Figure 22. Depth distribution of Pacific cod.

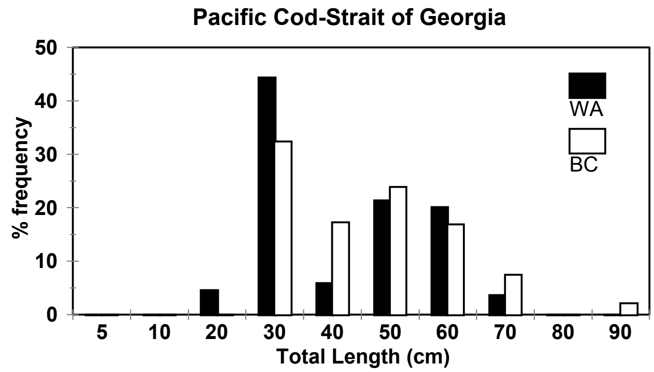

Figure 23. Length frequency distribution of Pacific cod in the WA and BC Strait of Georgia.

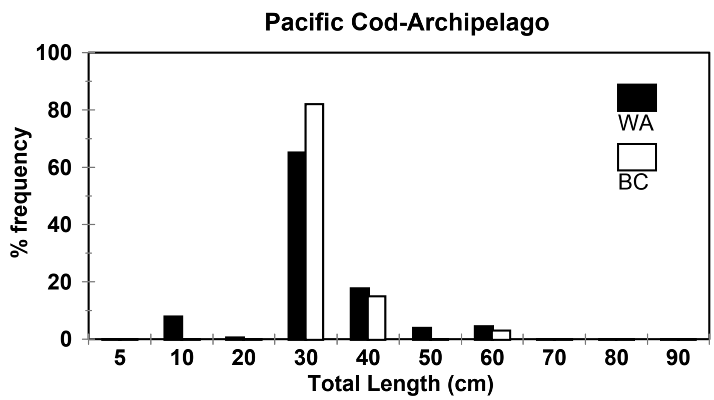

Figure 24. Length frequency distribution of Pacific cod in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 11. Numerical (x1000) and biomass (mt) abundance of Pacific cod in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	16.3	2.0	9.7	11.3		139.4
(% CV)	63.7	100.0	41.0	44.9		36.8
Biomass (mt)	2.6	0.5	9.9	125.3		138.4
(% CV)	64.0	100.0	41.0	31.4		28.6
British Columbia Strait of Georgia						
Abundance			25.3	97.2		122.5
(% CV)			53.2	28.8		25.4
Biomass (mt)			11.4	141.3		152.7
(% CV)			60.2	34.7		32.4
San Juan Archipelago						
Abundance	40.0	28.4	67.8	155.2		290.3
(% CV)	60.1	38.9	23.1	30.7		19.5
Biomass (mt)	4.5	8.7	34.5	136.5		184.1
(% CV)	76.9	42.1	38.3	44.7		34.0
British Columbia Haro Strait and Boundary Pass						
Abundance			3.6	109.8		113.5
(% CV)			100.0	32.5		31.6
Biomass (mt)			0.9	42.9		43.9
(% CV)			100.0	32.1		31.5

Walleye Pollock

Walleye pollock was present throughout the areas surveyed and encountered at most of the deeper stations (Figure 25). Their biomass contributed less than 10% to the total fish biomass, but their numbers often ranked them as one of the top five numerous species (Table 7). There were 43.2 million (23.3% CV) walleye pollock among all the surveyed areas and these fish had a biomass of 20,400 mt (20.8%, Table 12). Pollock comprised 3.8% of the total fish biomass in the WASG, 4.7% of the BCSG biomass, 6.9% of the WASJA biomass, and 9.1% of the BCHB biomass. The greatest numerical and biomass abundance was in the WASJA where there were 21.9 million individuals (36.6% CV) that weighed 849.6 mt (35.4% CV). The WASG had the second greatest abundance with 13.0 million individuals (36.5% CV) and a biomass of 691.8 mt (29.8% CV). The BCSG had 5.0 million pollock (63.1% CV) that weighed 328 mt (58.7% CV), and the BCHB population was composed of 3.2 million individuals (63.0% CV) that had a biomass of 168 mt (59.4% CV). The highest station densities of pollock were found in the deep portions of the Strait of Georgia, northern Rosario Strait, and Boundary Pass (Figure 25). Pollock were present in low concentrations throughout southern Rosario Strait, San Juan Channel, and Haro Strait. For the WASG and WASJA, the pollock biomass was highest in the 41-60 fm depth stratum (Figure 26), and second highest in the >60 fm stratum. Together, these two strata accounted for 80% or more of the biomass. Less than 3% of the biomass was in the shallowest stratum.

The length distribution of the walleye pollock populations was consistent among the surveyed regions. Over 85% of the populations were in the 20 cm length category (Figures 27 and 29) with very low frequencies in the 10 cm, 30 cm, and 40 cm length categories. Pollock averaged between 17.5 cm and 19.3 cm among the four regions (Table 5).

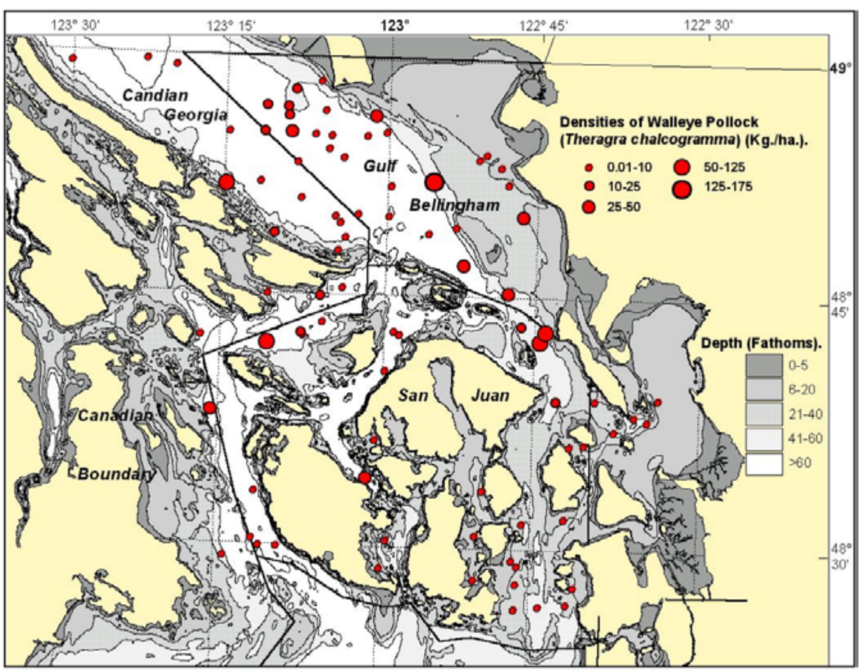

Figure 25. The distribution of walleye pollock station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

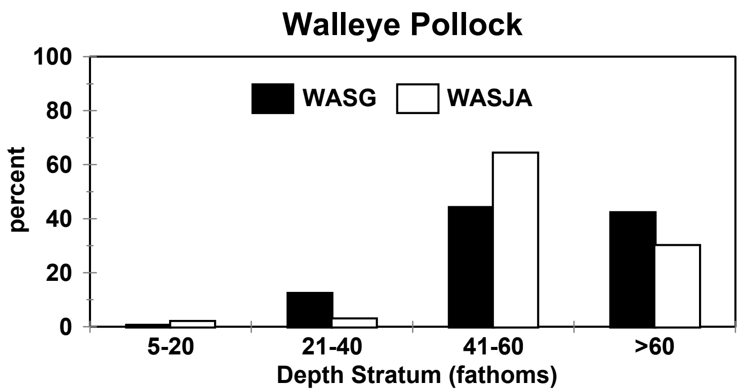

Figure 26. Depth distribution of walleye pollock.

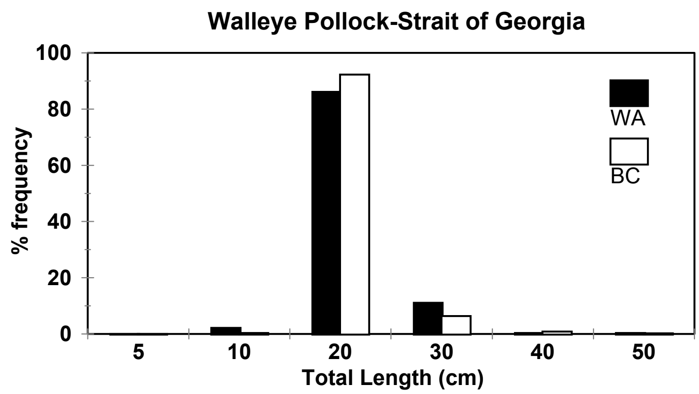

Figure 27. Length frequency distribution of walleye pollock in the WA and BC Strait of Georgia.

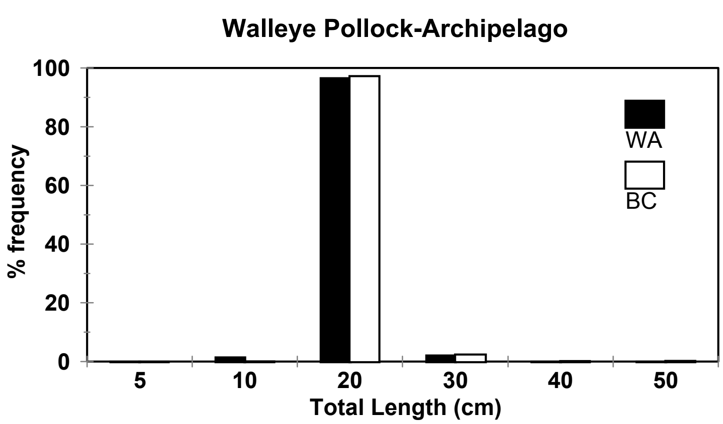

Figure 28. Length frequency distribution of walleye pollock in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 12. Numerical (x1000) and biomass (mt) abundance of walleye pollock in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	137.6	2476.8	7263.9	3166.8		13045.0
(% CV)	67.6	67.1	59.9	31.3		36.5
Biomass (mt)	5.0	86.7	306.4	293.7		691.8
(% CV)	67.4	68.1	59.9	25.0		29.8
British Columbia Strait of Georgia						
Abundance			4615.1	448.7	0.7	5064.5
(% CV)			69.1	45.0	100.0	63.1
Biomass (mt)			241.7	86.3	0.1	328.1
(% CV)			77.9	46.0	100.0	58.7
San Juan Archipelago						
Abundance	452.3	571.1	13293.7	7615.0		21932.1
(% CV)	57.5	58.9	53.8	47.4		36.6
Biomass (mt)	18.3	26.1	547.9	257.3		849.6
(% CV)	59.4	51.7	51.3	41.0		35.4
British Columbia Haro Strait and Boundary Pass						
Abundance			27.5	3154.2		3181.7
(% CV)			8.8	63.5		63.0
Biomass (mt)			1.0	166.6		167.6
(% CV)			6.3	59.8		59.4

Pacific Whiting (Hake)

Pacific whiting was almost exclusively limited to the deep waters of the WA and BC Strait of Georgia (Figure 29). Their biomass constitutes less than 5% of any regional fish biomass (Table 7). There were 1 million whiting (16.4% CV) among the four regions, and these fish had a population biomass of 446 mt (23.8% CV). The greatest abundance was observed in the BCSG where there were 654,000 whiting (21.8% CV) that weighed 312 mt (27.2% CV). The WASG had the second greatest abundance with 308,000 individuals (24.8% CV) that weighed 127.9 mt (50% CV). Whiting were rare in the WASJA and BCHB where their biomasses were less than 5 mt in each region. The highest station densities of whiting were observed throughout the central portions of the BCSG and along the international border of the WASG (Figure 29). Whiting were present, but in low densities in Haro Strait and President's Channel. Whiting were almost exclusively found in the deepest stratum of the WASG and WASJA (Figure 30) where over 90% of the population biomasses were located.

The length composition of the whiting population was similar between the WA and BC Strait of Georgia (Figure 31). The greatest frequencies of length were for the 40 cm length interval but whiting lengths also ranged from 20 cm to 70 cm. Whiting averaged 38.2 cm and 40.0 cm in length for the WASG and BCSG, respectively (Table 5). Whiting averaged 31.7 cm in length in the WASJA and 35.5 cm in the BCHP region.

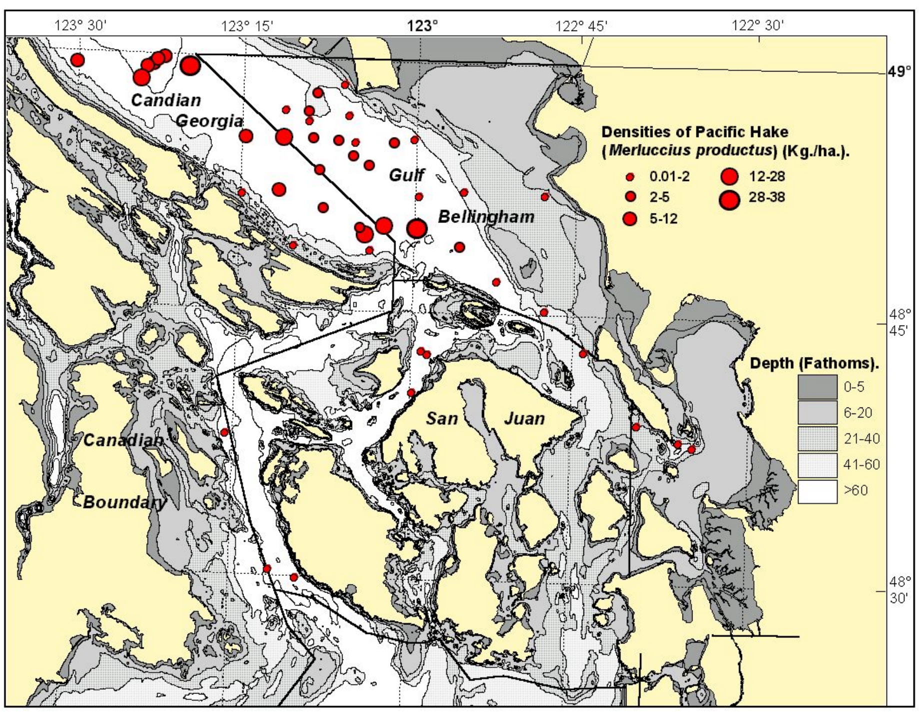

Figure 29. The distribution of Pacific whiting (hake) station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

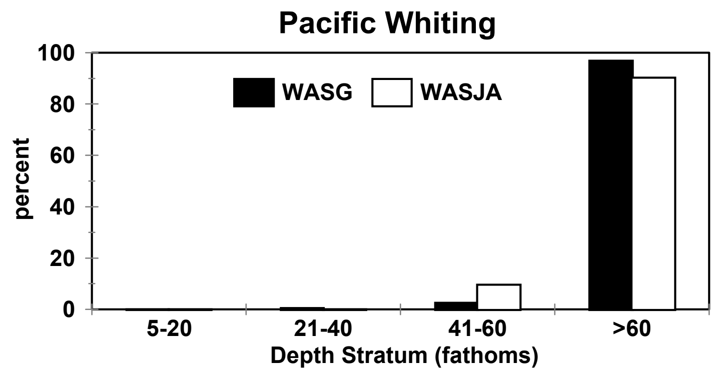

Figure 30. Depth distribution of Pacific whiting (hake).

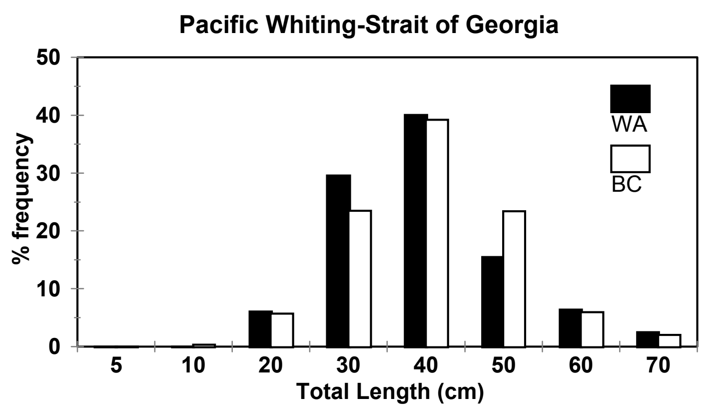

Figure 31. Length frequency distribution of Pacific whiting (hake) in the WA and BC Strait of Georgia.

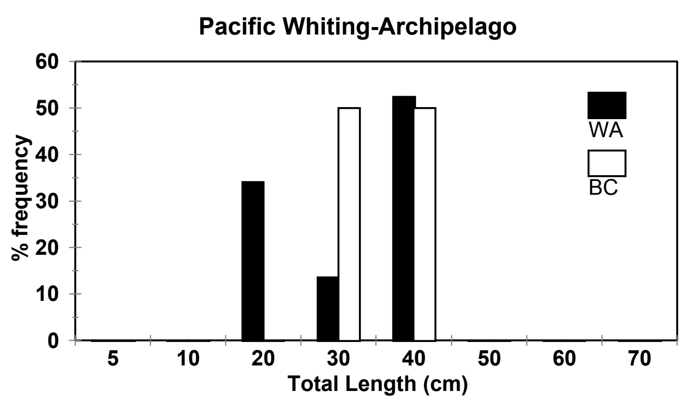

Figure 32. Length frequency distribution of Pacific whiting (hake) in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 13. Numerical (x1000) and biomass (mt) abundance of Pacific whiting (hake) in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	0	7.1	16.4	284.9		308.4
(% CV)		49.2	38.3	26.7		24.8
Biomass (mt)	0	0.7	3.3	123.9		127.9
(% CV)		80.2	85.2	51.5		50.0
British Columbia Strait of Georgia						
Abundance			12.3	609.7	32.4	654.3
(% CV)			62.3	23.3	28.7	21.8
Biomass (mt)			5.8	286.7	19.3	311.8
(% CV)			50.2	29.5	30.5	27.2
San Juan Archipelago						
Abundance	0	0	3.1	20.0		23.0
(% CV)			100.0	44.5		40.8
Biomass (mt)	0	0	0.5	4.3		4.8
(% CV)			100.0	42.0		39.1
British Columbia Haro Strait and Boundary Pass						
Abundance				4.0		4.0
(% CV)				100.0		100.0
Biomass (mt)				1.2		1.2
(% CV)				100.0		100.0

Lingcod

The lingcod population biomass estimated from the bottom trawl survey was less that a tenth of a percent of the total fish biomass (Table 7). Overall, all surveyed areas resulted in estimates of 103,000 individual lingcod (29.9% CV) and 52.8 mt (46.2% CV, Table 14). The survey in the WASJA resulted in the highest regional estimates of lingcod with 48,700 individuals (41.6%) and 36.0 mt (66.0% CV). There was a population of 36,200 lingcod (55.9% CV) in the WASG that had a biomass of 10.9 mt (41.6% CV). The BCSG survey resulted in estimates of 18,300 lingcod (62.3% CV) and 5.9 mt (52.3% CV). There were not any lingcod encountered in the BCHB. The plot of station densities found most observations of lingcod close to shore or in association with offshore banks (Figure 33). Lingcod were found near Point Robert's Reef, Saturna Island, Alden Bank, north Orcas Island, Lummi Island, Allen Island, Middle Bank, and between Decatur Island and Bird Rocks. Several lingcod were also found in the deep basin of the WASG. More than 50% of the lingcod biomass was distributed in the deepest depth stratum in both the WASG and WASJA (Figure 34). From 20% to 25% of the lingcod biomass was distributed in each of the 5-20 fm and 41-60 fm strata in the WASG, but the lingcod biomass was more evenly distributed among the three shallowest depth strata in the WASJA.

Most lingcod captured by the bottom trawl were 30 cm in length (Figures 35 and 36). However, a small proportion of the estimated population measured in the 20 cm, 50 cm, and 60 cm in the WA SG, BCSG, and WASJA. Lingcod averaged 30.6 cm in length in the WASG, 32.3 cm in the BCSG, and 36.3 cm in the WASJA (Table 5).

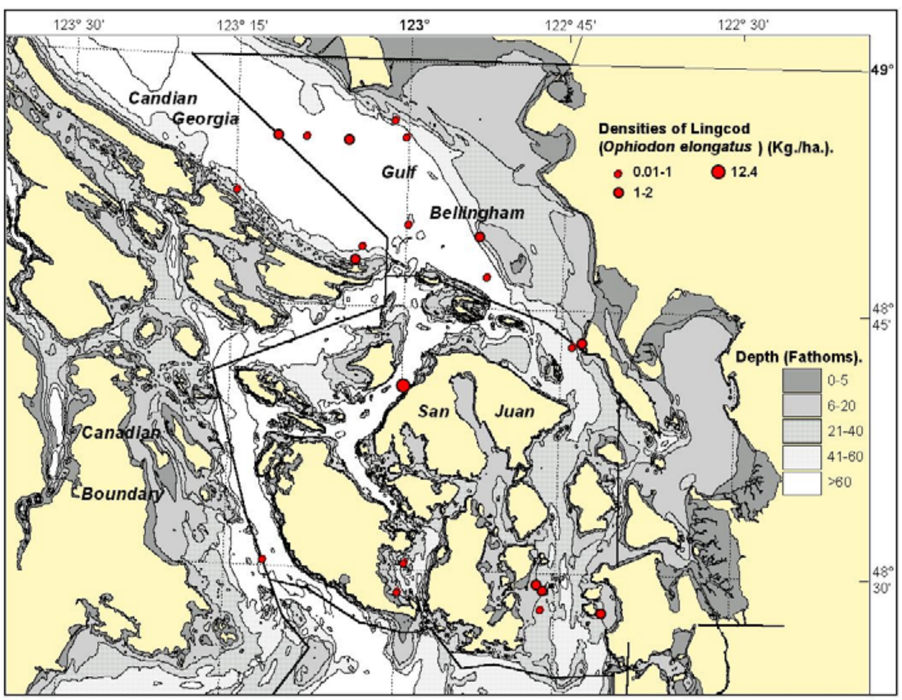

Figure 33. The distribution of lingcod station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

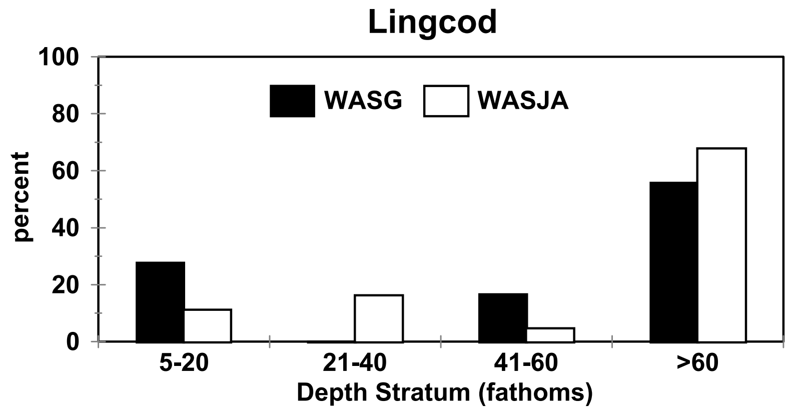

Figure 34. Depth distribution of lingcod.

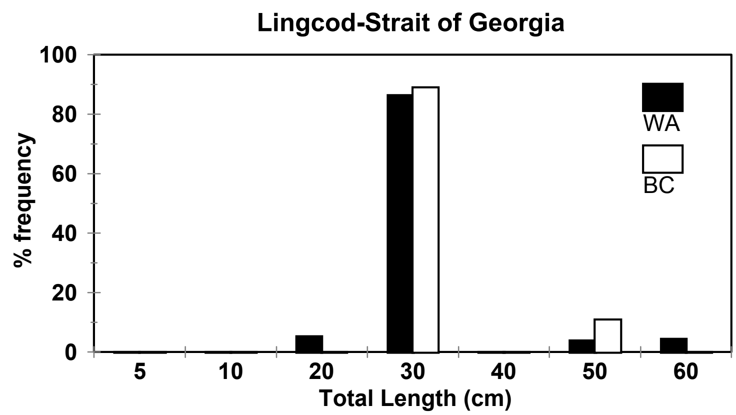

Figure 35. Length frequency distribution of lingcod in the WA and BC Strait of Georgia.

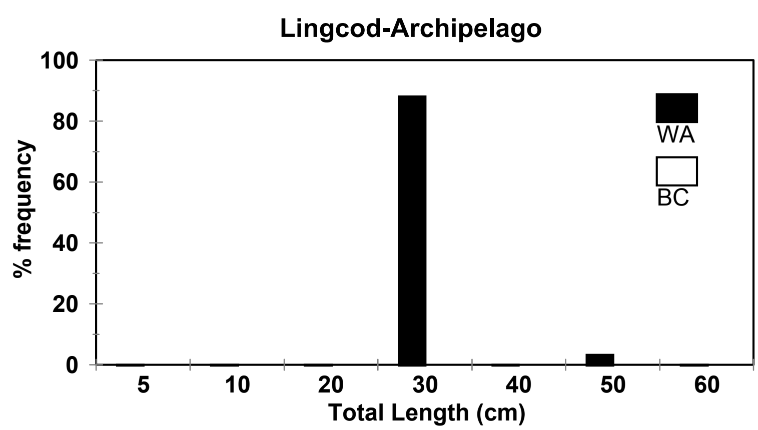

Figure 36. Length frequency distribution of lingcod in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 14. Numerical (x1000) and biomass (mt) abundance of lingcod in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	19.2	0	6.9	10.0		36.2
(% CV)	100.0		69.8	39.2		55.9
Biomass (mt)	3.0	0	1.8	6.1		10.9
(% CV)	100.0		72.5	51.4		41.6
British Columbia Strait of Georgia						
Abundance			14.2	4.1	0	18.3
(% CV)			78.0	67.1		62.3
Biomass (mt)			3.1	2.7	0	5.9
(% CV)			66.9	82.1		52.3
San Juan Archipelago						
Abundance	11.0	27.3	6.2	4.2		48.7
(% CV)	85.4	63.3	63.3	68.6		41.6
Biomass (mt)	4.0	5.8	1.7	24.4		36.0
(% CV)	69.0	69.2	64.0	94.4		66.0
British Columbia Haro Strait and Boundary Pass						
Abundance			0	0		0
(% CV)						
Biomass (mt)			0	0		0
(% CV)						

English Sole

English sole was an important member of the benthic fish community in the Strait of Georgia where it constituted 18.2% of the fish biomass in the WASG and 13.4% of the biomass in the BCSG (Table 7). In the southern regions, however, English sole only constituted 1.8% of the WASJA fish biomass and 3.3% of the BCHB fish biomass. There were 29.6 million individuals (19.9% CV, Table 15) among the survey areas, and these fish had a biomass of 4,600 mt (17.6% CV). By far, English sole were the most abundant in the WASG where there were 24.3 million fish (23.4% CV) with a biomass of 3,400 mt (22.4% CV). The BCSG survey resulted in a numerical abundance estimate of 2.7 million fish (28.2% CV) with a corresponding biomass estimate of 947 mt (29.8% CV). The WASJA also had a numerical abundance exceeding 2 million fish (2.3 million, 33.0% CV) but the biomass was only 221 mt (29.7% CV) compared to the BCSG. English sole were not abundant in the deeper waters of the BCHB where there were only 0.3 million fish (70.3% CV) with a biomass of 61.8 mt (64.2% CV).

English sole occurred the most consistently and in the highest densities through the Strait of Georgia and Bellingham Bay (Figure 37). English sole densities were comparatively low in the WASJA and BCHB, primarily occurring in the southern Rosario Strait, Lopez and East Sound, and Boundary Pass. English sole were distributed somewhat evenly among the four depth strata of the WASG and WASJA (Figure 38), but the least biomass was observed in the 41-60 depth stratum.

The English sole population ranged in length from 10 cm to 50 cm (Figures 39 and 40). Most English sole occurred as 20 cm and 30 cm fish in the WASG where they averaged 24.0 cm in length (Figure 39, Table 5). This length distribution contrasted with that of the BCSG where most English sole measured 30 cm to 40 cm and averaged 33.0 cm. Most of the English sole population measured between 10 and 30 cm in the WASJA and averaged 20.4 cm in length. The BCHB had English sole populations that measured 30 cm as the modal frequency and averaged 27.7 cm.

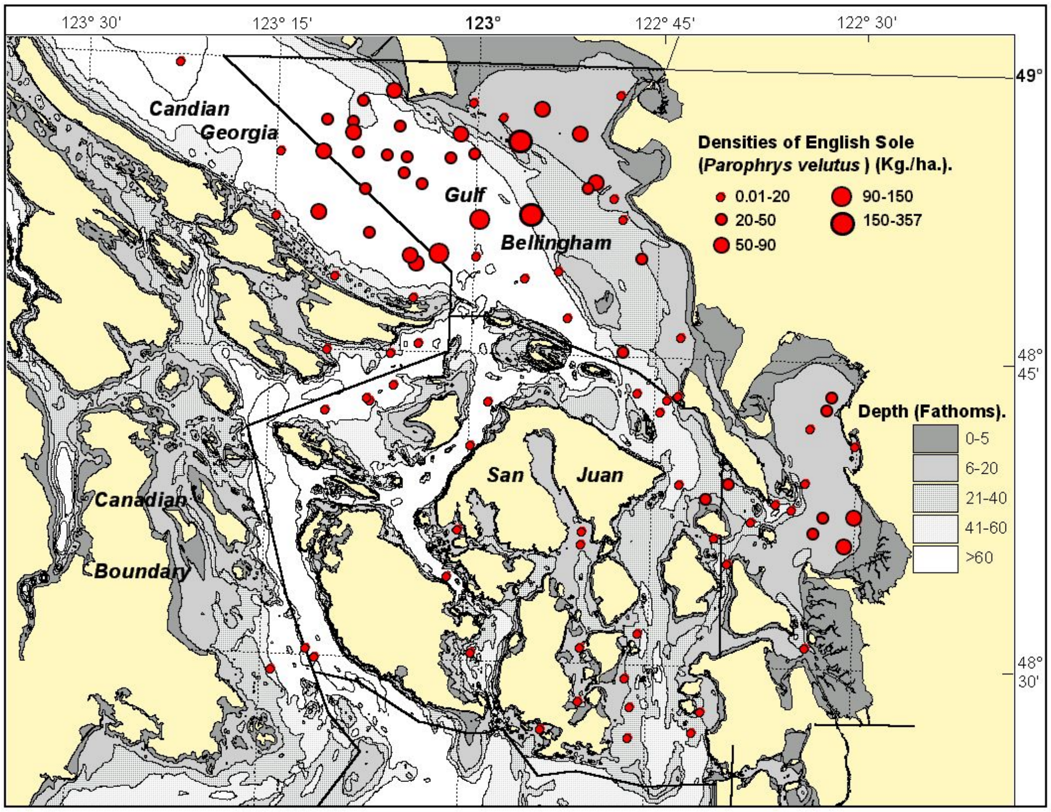

Figure 37. The distribution of English sole station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

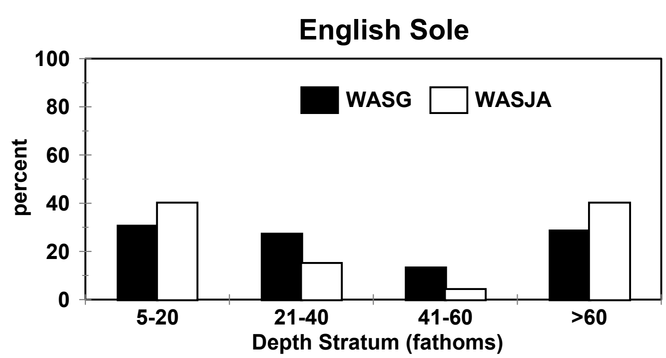

Figure 38. Depth distribution of English sole.

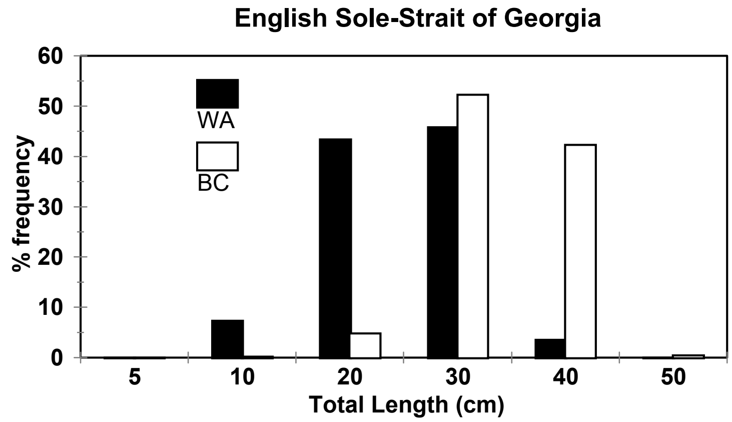

Figure 39. Length frequency distribution of English sole in the WA and BC Strait of Georgia.

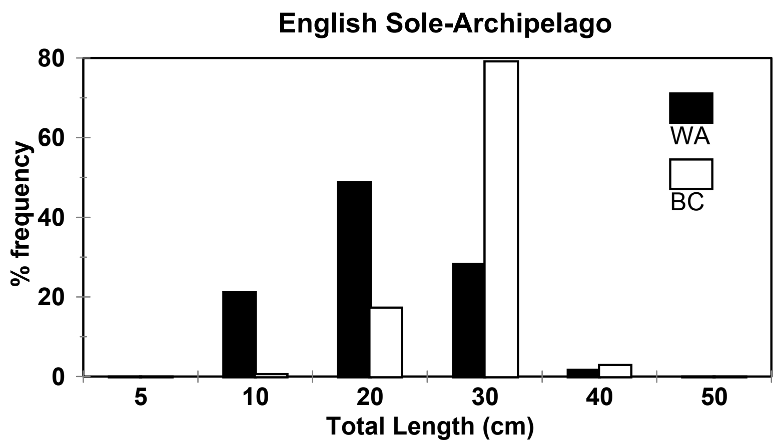

Figure 40. Length frequency distribution of English sole in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 15. Numerical (x1000) and biomass (mt) abundance of English sole in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	10072.9	6291.7	3947.3	4026.1		24337.9
(% CV)	24.8	74.9	47.6	18.1		23.4
Biomass (mt)	1023.4	914.2	44.5	957.4		3339.6
(% CV)	24.0	71.7	35.1	21.9		22.4
British Columbia Strait of Georgia						
Abundance			37.6	2643.2	0.4	2681.1
(% CV)			61.6	28.6	100.0	28.2
Biomass (mt)			4.5	942.4	0.2	947.2
(% CV)			55.9	30.0	100.0	29.8
San Juan Archipelago						
Abundance	1401.5	321.4	90.7	516.0		2329.6
(% CV)	47.2	92.2	54.0	48.0		33.0
Biomass (mt)	89.1	33.7	9.6	89.2		221.7
(% CV)	49.7	88.2	48.1	42.9		29.7
British Columbia Haro Strait and Boundary Pass						
Abundance			88.3	189.7		278.1
(% CV)			91.9	93.8		70.3
Biomass (mt)			20.6	41.2		61.8
(% CV)			30.6	95.1		64.2

Sand Sole

Sand sole was a minor component of the fish population in the WASG and WASJA where it comprised 1% and 0.06% of the total fish biomass for each respective region (Table 7). Sand sole were not observed in the BC survey areas. There were 151,000 sand sole (25.4% CV) between the two WA survey areas, and these fish had a biomass of 187 mt (26.4% CV). Most of the sand sole were in the WASG where there were 688, 000 (27.3% CV) that had a biomass of 179 mt (27.4% CV). The population estimates were an order of magnitude less in the WASJA where 62,000 individuals (55.0% CV) had a biomass of 7.5 mt (61.2 % CV).

Sand sole were primarily found in the shallow waters east of a line from Point Roberts to Point Whitehorn (Figure 41). Sand sole also occurred in high densities in Bellingham Bay. In the WASJA, sand sole were primarily found in the shallow waters of East and Lopez Sounds. For both Washington regions, ninety percent or more of the sand sole biomass was estimated for the 5-20 fm stratum with the remainder in the 21-40 fm stratum (Figure 42).

Sand sole in the WASG averaged 26.7 cm in length (Table 5), and ranged in size from 10 cm to 50 cm (Figure 43). The highest sizes frequencies occurred in the 20 cm and 30 cm length categories. Most of the sand sole population in the WASJA was small with almost 60% as 10 cm individuals (Figure 44). Sand sole did range to 40 cm, but the average size of the population was 17.3 cm (Table 5).

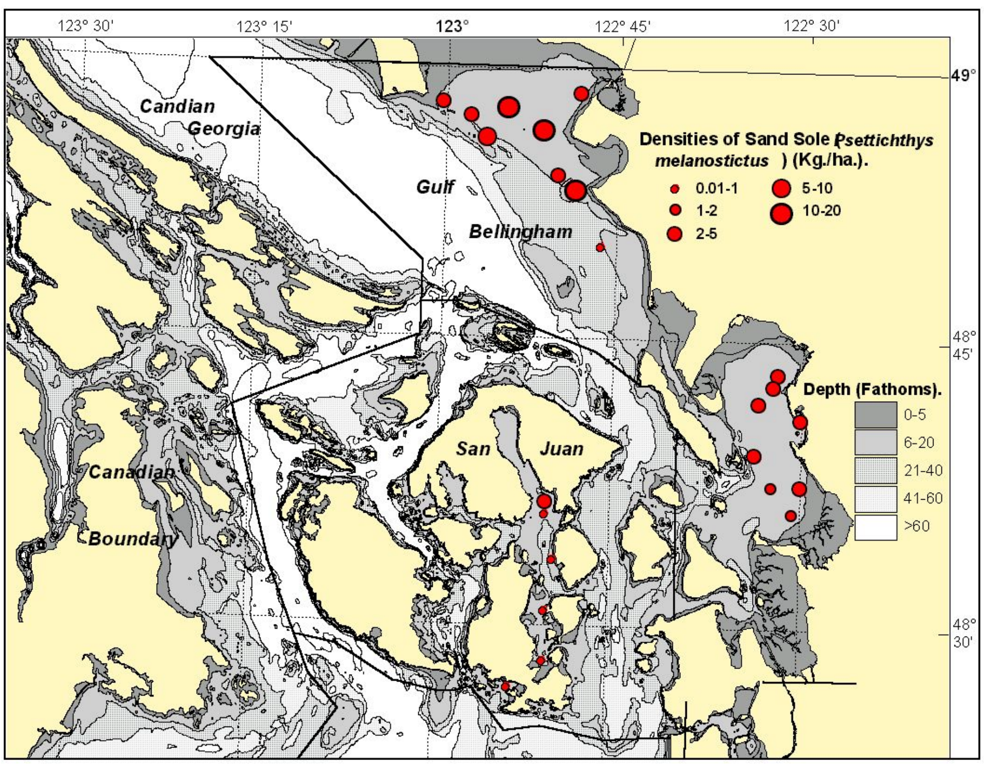

Figure 41. The distribution of sand sole station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

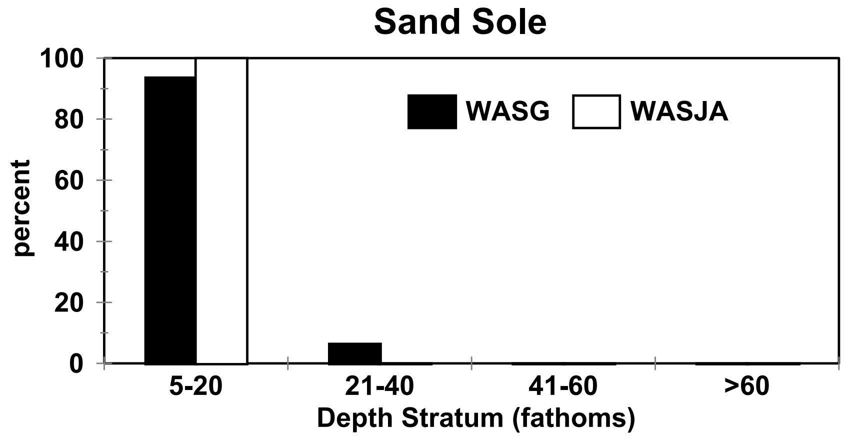

Figure 42. Depth distribution of sand sole.

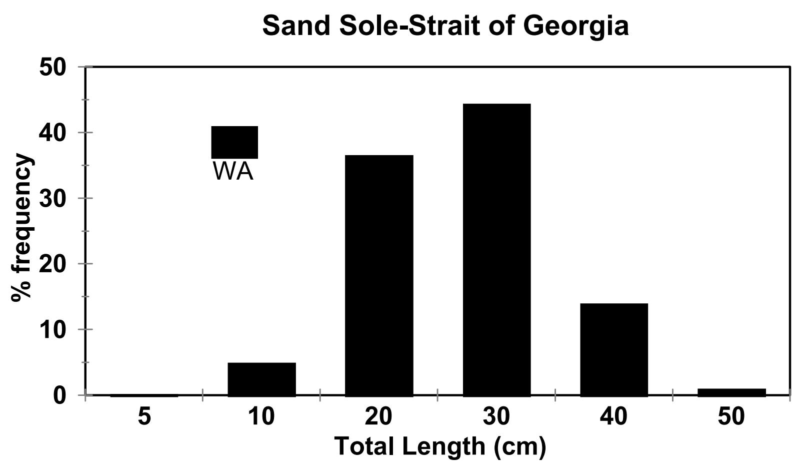

Figure 43. Length frequency distribution of sand sole in the WA Strait of Georgia.

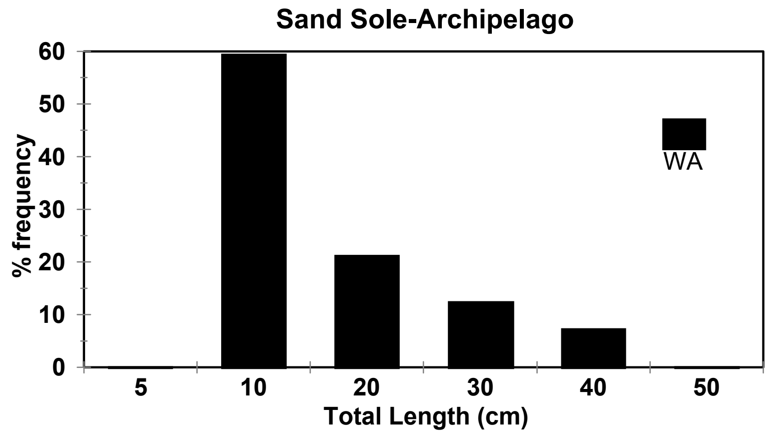

Figure 44. Length frequency distribution of sand sole in the WA San Juan Archipelago.

Table 16. Numerical (x1000) and biomass (mt) abundance of sand sole in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	622.5	66.4	0	0		688.9
(% CV)	28.4	97.0				27.3
Biomass (mt)	167.7	11.5	0	0		179.1
(% CV)	28.6	84.6				27.4
British Columbia Strait of Georgia						
Abundance			0	0	0	0
(% CV)						
Biomass (mt)			0	0	0	0
(% CV)						
San Juan Archipelago						
Abundance	62.4	0	0	0		62.4
(% CV)	55.0					55.0
Biomass (mt)	7.5	0	0	0		7.5
(% CV)	61.2					61.2
British Columbia Haro Strait and Boundary Pass						
Abundance			0	0		0
(% CV)						
Biomass (mt)			0	0		0
(% CV)						

Starry Flounder

Starry flounder was a minor species of the fish community in the SG and neighboring waters and the biomass only accounted for 4.3% of the total fish biomass in the WASG and 0.2% of the biomass in the WASJA (Table 7). Like sand sole, starry flounder was not encountered in the BC survey areas. There were 1.8 million starry flounder (34.0% CV, Table 17) in the WA survey areas, and these fish had an estimated biomass of 832.7 mt (35.3% CV). The WASG had the larger component of the surveyed population with 1.8 million individuals (34.7% CV) and 806 mt (36.4% CV). The WASJA only had an estimated population of 36,000 individuals (59.1% CV) and 27.2 mt (64.9% CV). Similar to sand sole, the trawl station densities revealed starry flounder was distributed in shallow waters (Figure 45). The highest concentrations were near the Nooksack River in northern Bellingham Bay and near the entrance to Drayton Harbor in Semiamhoo Bay (Figure 45). Starry flounder were also present at stations near Point Roberts, Point Whitehorn, in Lopez and East Sounds, and at one station in Rosario Strait and in the deep basin of the WASG. Virtually the entire population of starry flounder resided in the 5-20 fm depth stratum (Figure 46).

Starry flounder lengths ranged from 20 cm to 50 cm (Figures 47 and 48), and the starry flounder was slightly larger in the WASJA than the WASG. Starry flounder averaged 32.2 cm in length in the WASG and 37.0 cm in the WASJA (Table 5). In both the WASG and WASJA, most starry flounder were in the 30 cm or 40 cm length categories.

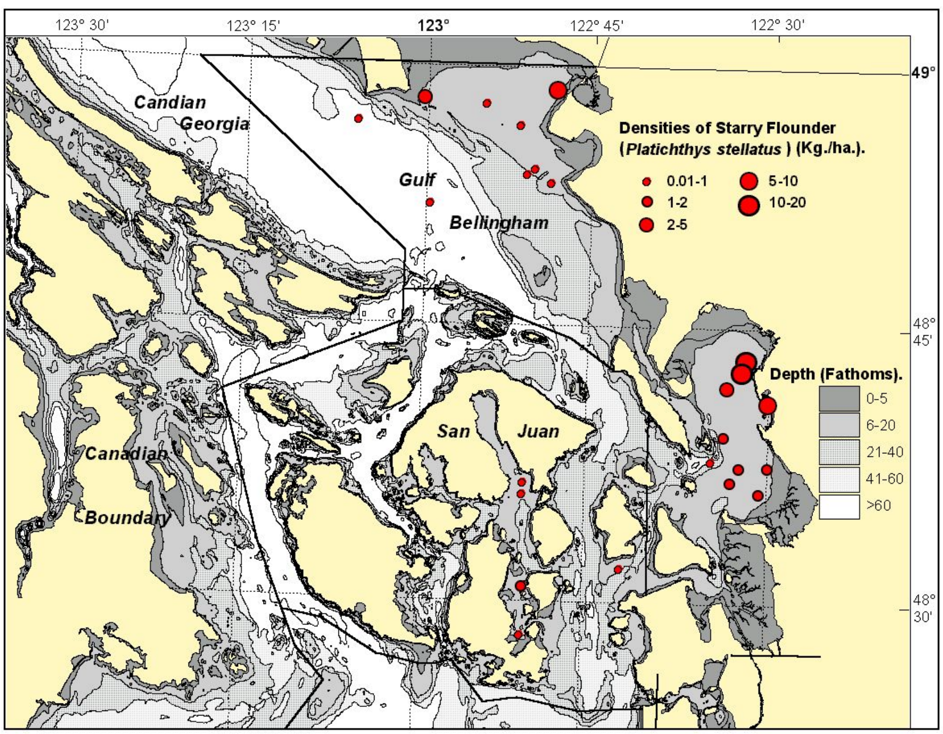

Figure 45. The distribution of starry flounder station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

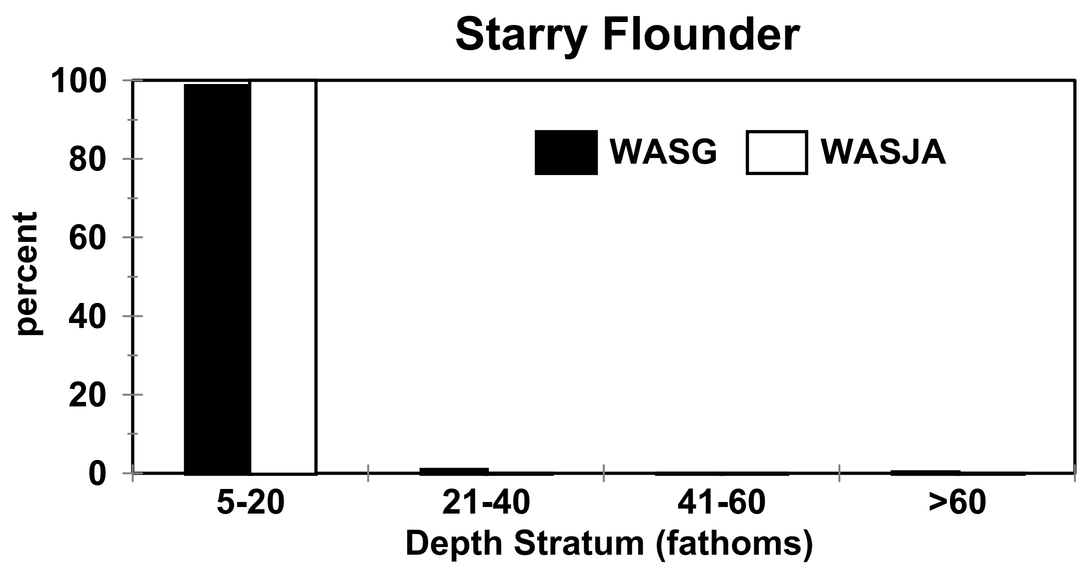

Figure 46. Depth distribution of starry flounder.

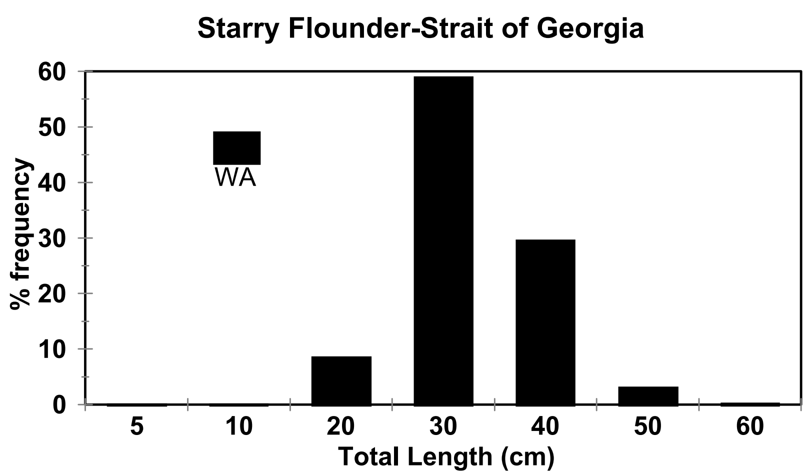

Figure 47. Length frequency distribution of starry flounder in the WA Strait of Georgia.

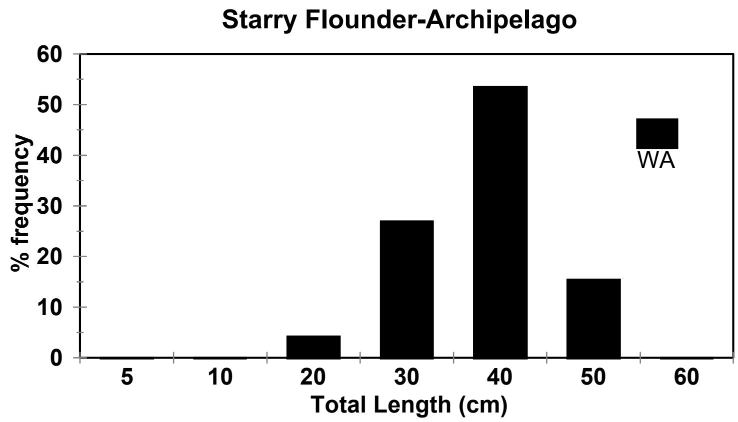

Figure 48. Length frequency distribution of starry flounder in the WA San Juan Archipelago.

Table 17. Numerical (x1000) and biomass (mt) abundance of starry flounder in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	1738.7	20.1	0	3.7		1762.5
(% CV)	35.2	79.4		68.25		34.7
Biomass (mt)	794.8	8.1	0	2.7		805.5
(% CV)	36.9	74.2	0	80.9		36.4
British Columbia Strait of Georgia						
Abundance			0	0	0	0
(% CV)						
Biomass (mt)			0	0	0	0
(% CV)						
San Juan Archipelago						
Abundance	35.9	0	0	0		35.9
(% CV)	59.1					59.1
Biomass (mt)	27.2	0	0	0		27.2
(% CV)	64.9					64.9
British Columbia Haro Strait and Boundary Pass						
Abundance			0	0		0
(% CV)						
Biomass (mt)			0	0		0
(% CV)						

Pacific Sanddab

Pacific sanddab comprised less than 1% of any regional biomass (Table 7). There were 2.2 million individuals (24.7% CV, Table 18) among the survey areas, and these had an estimated biomass of 357.4 mt (23.7% CV). They occurred in all the regions surveyed with the WASG and WASJA having the greatest and approximately equal biomasses. There were 1.2 million individuals in the WASG with a biomass of 189 mt (31.1% CV), and there were 1.0 million individuals (38.3% CV) in the WASJA with a biomass of 162.0 mt (37.5% CV). There were less than 20,000 individuals in either of the BC survey areas (CVs 46% to 50%) and biomasses were less than 4 mt (CVs 42% to 48%). Pacific sanddabs were primarily found in shallow and intermediate depth waters throughout the Strait of Georgia and the surrounding waters (Figure 49). The highest concentrations were along the interface between the two shallow strata between Cherry Point and Point Roberts and in the southern portions of San Juan Channel and Rosario Strait. The Pacific sanddab biomass was almost equally distributed between the 5-20 fm and 21-40 fm depth strata (Figure 50) and less than 10% was in the 41-60 fm stratum.

Most Pacific sanddab were either 20 cm or 30 cm in length in each of the survey regions (Figure 51 and 52). In the WASG, the individuals were equally distributed between these length categories (Figure 51), but were more frequent as 30 cm fish in the BCSG. Most sanddab in the WASJA were in the 30 cm category (Figure 52) but were more common as 20 cm fish in the BCHB (Figure 52). Pacific sanddab averaged between 24 cm and 28 cm in length among the four survey regions (Table 5).

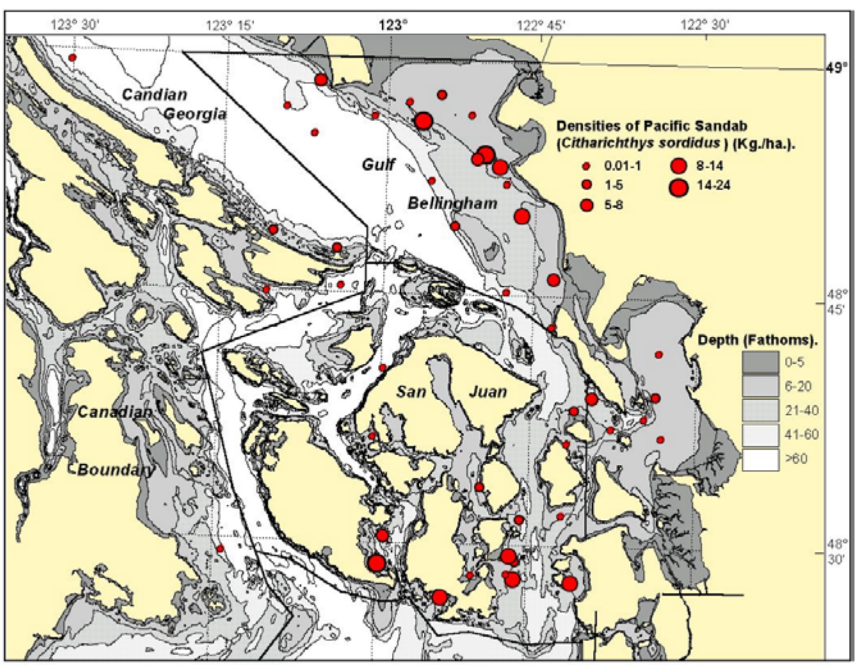

Figure 49. The distribution of Pacific sanddab station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

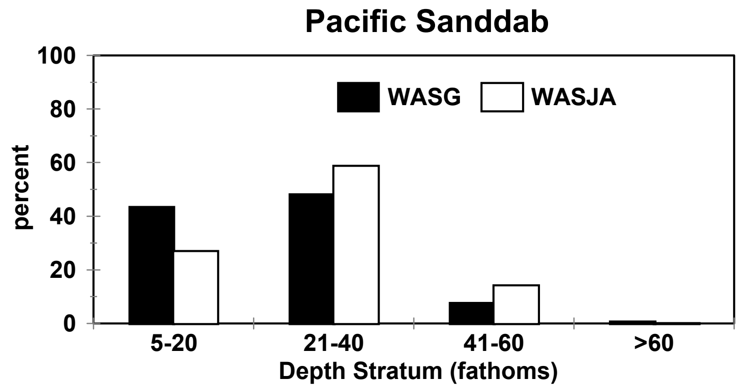

Figure 50. Depth distribution of Pacific sanddab.

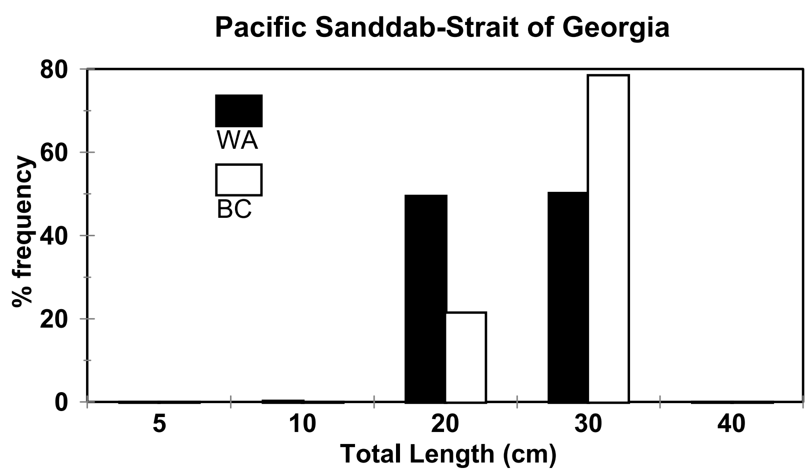

Figure 51. Length frequency distribution of Pacific sanddab in the WA and BC Strait of Georgia.

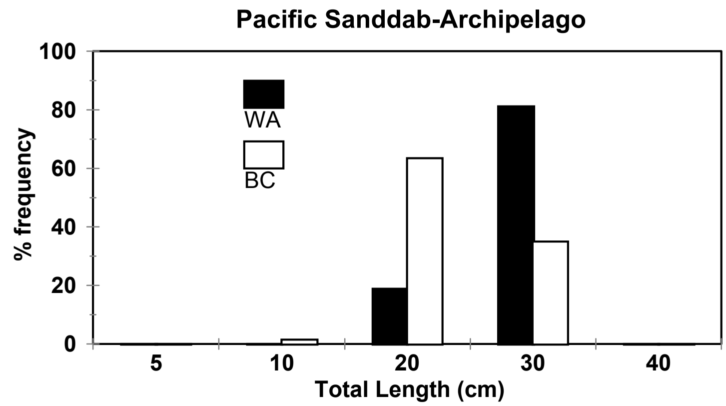

Figure 52. Length frequency distribution of Pacific sanddab in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 18. Numerical (x1000) and biomass (mt) abundance of pacific sanddab in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	545.9	537.3	68.4	7.0		1158.6
(% CV)	47.1	51.7	61.1	69.2		32.9
Biomass (mt)	82.1	91.0	14.5	1.3		188.9
(% CV)	46.3	48.4	54.0	68.3		31.1
British Columbia Strait of Georgia						
Abundance			16.7	2.3		19.0
(% CV)			50.2	100.0		45.7
Biomass (mt)			3.9	0.3		4.2
(% CV)			50.2	100.0		47.6
San Juan Archipelago						
Abundance	334.5	552.3	146.4	2.5		1035.7
(% CV)	42.4	61.7	100.0	100.0		38.3
Biomass (mt)	43.7	95.2	23.0	0.2		162.0
(% CV)	40.8	56.0	100.0	100.0		37.5
British Columbia Haro Strait and Boundary Pass						
Abundance			8.4	2.0		10.5
(% CV)			57.5	100.0		50.3
Biomass (mt)			2.0	0.3		2.3
(% CV)			45.4	100.0		41.7

Rock Soles

Rock soles comprised 3% or less of the total fish biomass in the WASG and WASJA, and they comprised less than 0.1% in the BC survey areas (Table 7). There were 4.6 million (25.2% CV, Table 19) rock soles in the four survey areas, and these had a biomass of 979 mt (30.2% CV). The WASG had the highest abundance of rock soles with 2.5 million individuals (39.5% CV) and 591 mt (46.9% CV). The WASJA had the second highest population estimates with 2.1 million fish (29.3% CV) and 377 mt (27.3% CV). Rock soles were not abundant in the deep-water surveys of BC, and 30,000 or less individuals were estimated in these regions with 8 mt or less as biomass.

Two species of rock sole occurred in the survey areas. Roughly equal proportions of biomass occurred between the southern rock sole (*Lepidopsetta bilineata*) and northern rock sole (*Lepidopsetta polyxystra*) in the WASG (Table 7). Southern rock sole comprised 51% of the total rock sole biomass in this region, and northern rock sole comprised 47%. Southern rock sole was slightly more dominant in biomass terms in the WASJA where they constituted 58% of the biomass compared to 42% for northern rock sole. Only southern rock sole were identified in the two deep-water BC areas. Northern and southern rock sole co-occurred at almost every station (Figures 53 and 54). Rock soles were primarily distributed in the shallow or intermediate waters from Point Roberts to Point Whitehorn, in outer Bellingham Bay, in southern Rosario Strait, Lopez and East Sounds, southern San Juan Channel, and around Saturna Island. Both species primarily occurred in the 5-20 fm and 21-40 fm depth zones (Figures 55 and 56). However, 75% or more of the southern rock sole biomass occurred in the shallowest depth zone with a minor proportion occurring in progressively less amounts in the three deepest depth zones. Northern rock sole were more evenly distributed between the two shallowest depth zones and in the WASG, 60% of the biomass of northern rock sole was distributed in the 21-40 fm depth zone.

Southern rock sole ranged in size from 10 cm to 40 cm in the WA survey areas and from 20 cm to 40 cm in the deeper BC survey areas (Figures 57 and 58). The modal size category for southern rock sole in the WA survey areas and the BCSG was 20 cm but was 30 cm in the BCHB. Southern rock sole averaged 22.9 cm in the WASG, 28.1 cm in the BCSG, 20.0 cm in the WASJA, and 29.7 cm in the BCHB (Table 5). Northern rock sole also ranged in length from 10 cm to 40 cm in the WA survey areas (Figures 59 and 60), and the modal frequency was the 30 cm category in both areas. Average lengths for northern rock sole were 27.4 cm in the WASG and 25.0 cm in the WASJA (Table 5).

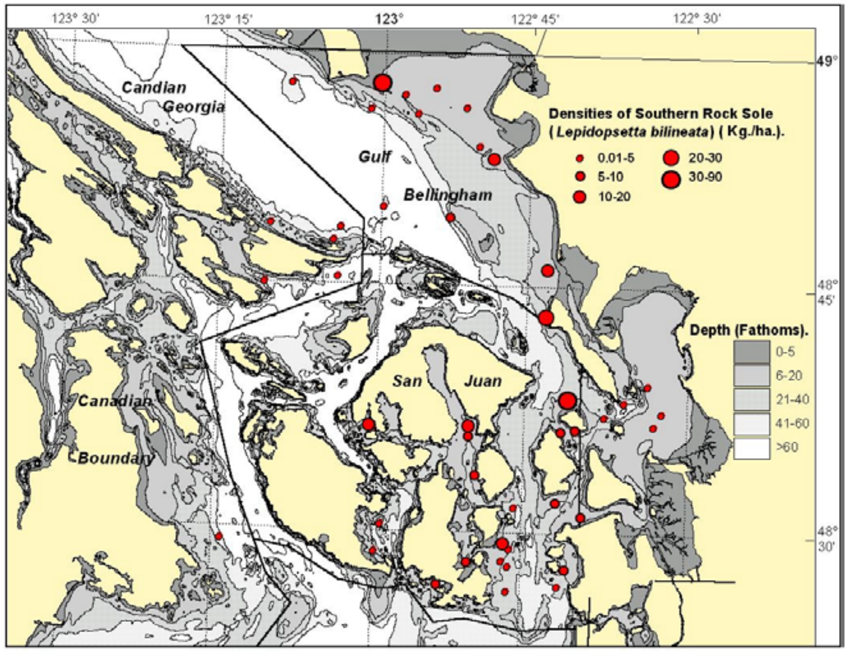

Figure 53. The distribution of southern rock sole station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

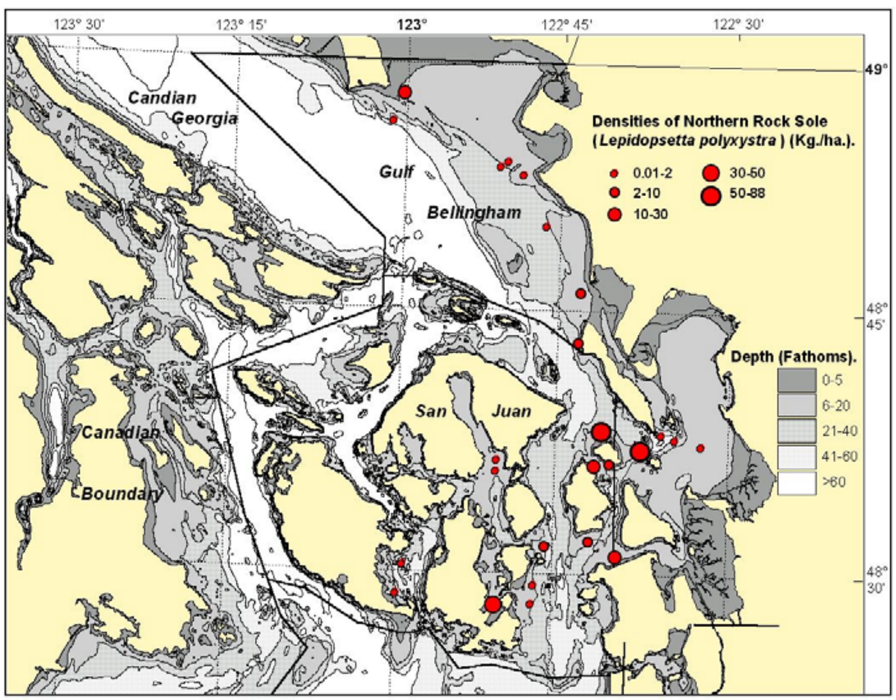

Figure 54. The distribution of northern rock sole station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

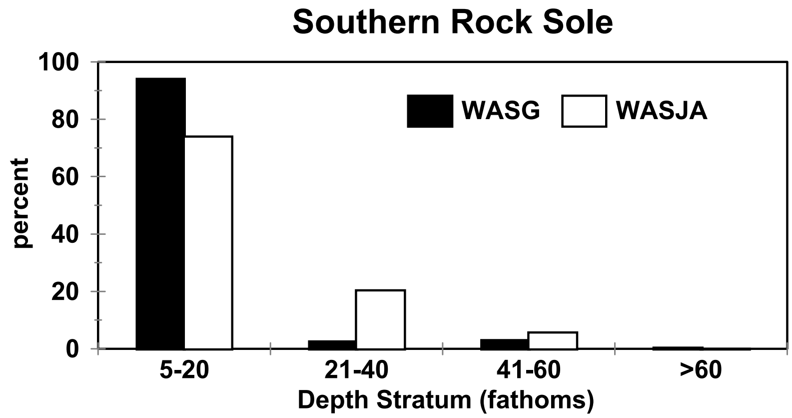

Figure 55. Depth distribution of southern rock sole.

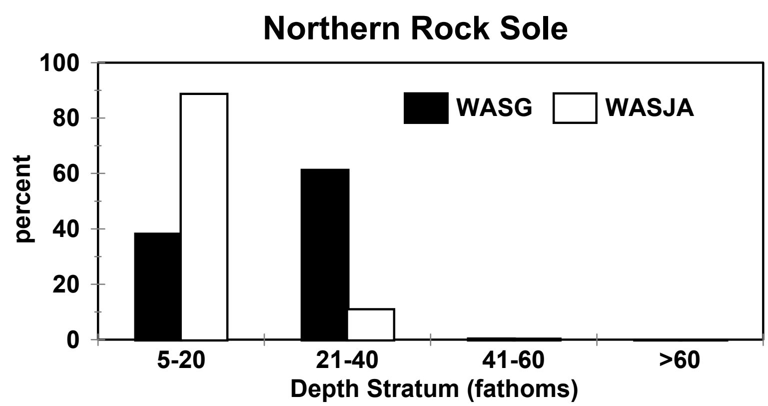

Figure 56. Depth distribution of northern rock sole.

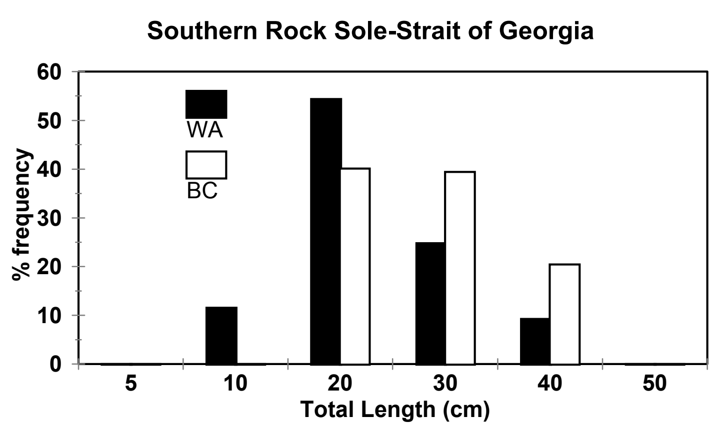

Figure 57. Length frequency distribution of southern rock sole in the WA and BC Strait of Georgia.

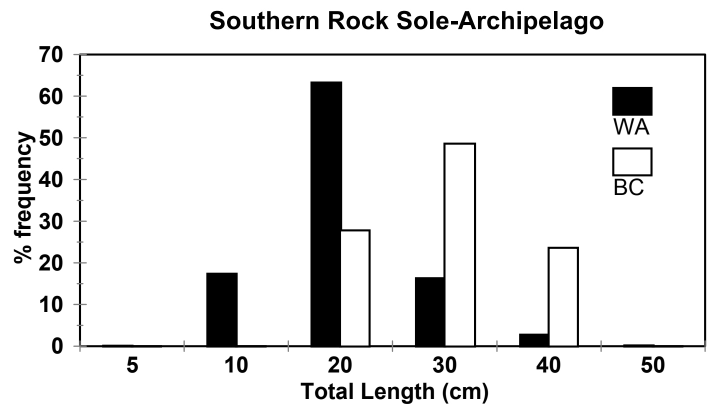

Figure 58. Length frequency distribution of southern rock sole in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

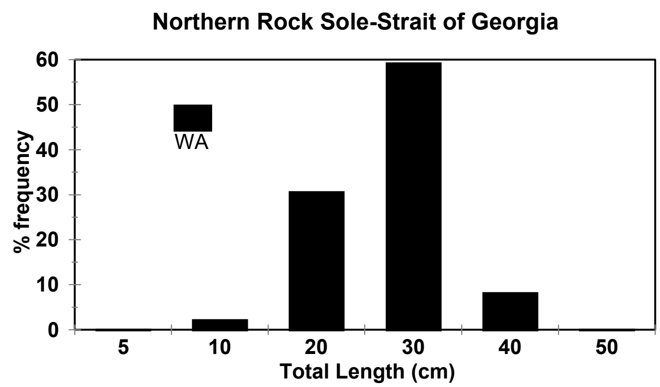

Figure 59. Length frequency distribution of northern rock sole in the WA and BC Strait of Georgia.

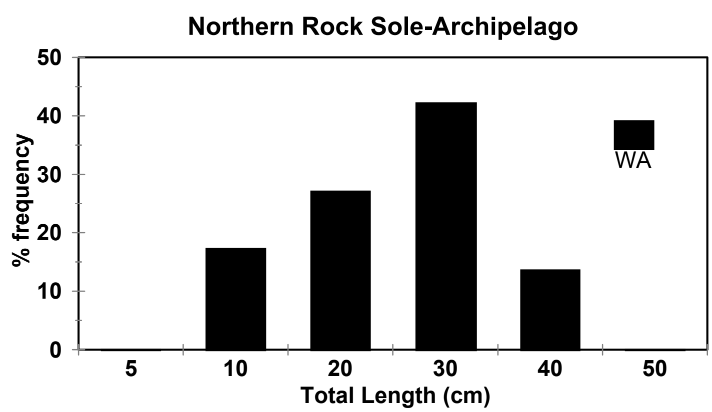

Figure 60. Length frequency distribution of northern rock sole in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 19. Numerical (x1000) and biomass (mt) abundance of rock soles in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	1781.9	721.2	27.8	1.9		2532.8
(% CV)	43.3	88.5	45.7	100.0		39.5
Biomass (mt)	389.0	190.6	10.3	1.2		591.1
(% CV)	56.3	88.9	53.3	100.0		46.9
British Columbia Strait of Georgia						
Abundance			24.0	4.1	0	28.1
(% CV)			52.1	100.0		46.8
Biomass (mt)			7.0	1.1	0	8.1
(% CV)			50.3	100.		45.6
San Juan Archipelago						
Abundance	1735.7	238.0	90.3	0		2064.0
(% CV)	34.2	30.5	100.0			29.3
Biomass (mt)	302.1	62.0	13.0	0		377.1
(% CV)	33.1	33.1	100.0	0		27.3
British Columbia Haro Strait and Boundary Pass						
Abundance			5.1	2.0		7.2
(% CV)			29.9	100.0		35.6
Biomass (mt)			2.2	0.3		2.5
(% CV)			10.4	100.0		14.7

Dover Sole

Dover sole was a minor component of the total fish biomass, accounting for less than 2% of the total fish biomass in any region (Table 7). The Dover sole biomass constituted 2.6% of the flatfish biomass in the WASG, 10.5% in the BCSG, 13.5% in the WASJA, and 22% in the BCHB. The numerical abundance of Dover sole was 4.3 million individuals (12.6% CV, Table 20) that had a biomass of 440 mt (10.3% CV). The WASG had the greatest biomass of Dover sole with 157 mt (13.9% CV). The numerical abundance of 1.4 million individuals (19.7% CV) was second to the WASJA that had 2.0 individuals (21.8% CV) and a second greatest biomass of 141 mt (22.3% CV) of any surveyed region. The BCSG had the third greatest population with 0.6 million fish (16.9% CV) and 117 mt (18.6% CV). There were only 0.2 million individuals (37.1% CV) in the BCHB, and these had a biomass of 24.5 mt (43.0% CV). Dover sole were distributed throughout the deeper waters of the four study areas (Figure 61). Their highest concentrations were observed in the central WASG and BCSG including the >120 fm depth stratum in the BCSG. Dove sole also occurred in high concentrations in President's Channel, Boundary Pass, Haro Strait, and southern Rosario Strait. Dover sole were also present at shallower stations in Semiamhoo Bay, Bellingham Bay, East Sound, and San Juan Channel. More than two-thirds of the Dover Sole biomass was in the >60 fm depth stratum of the WA survey areas (Figure 62). Dover sole was present in other depth strata, but usually as small specimens.

Dover sole lengths ranged from 5 cm to 50 cm (Figures 63 and 64). The modal frequencies were either 20 cm or 30 cm in most survey areas. Dover sole averaged 22.2 cm in length in the WASG, 26.2 cm in the BCSG, 18.5 cm in the WASJA, and 22.8 cm in the BCHP (Table 5).

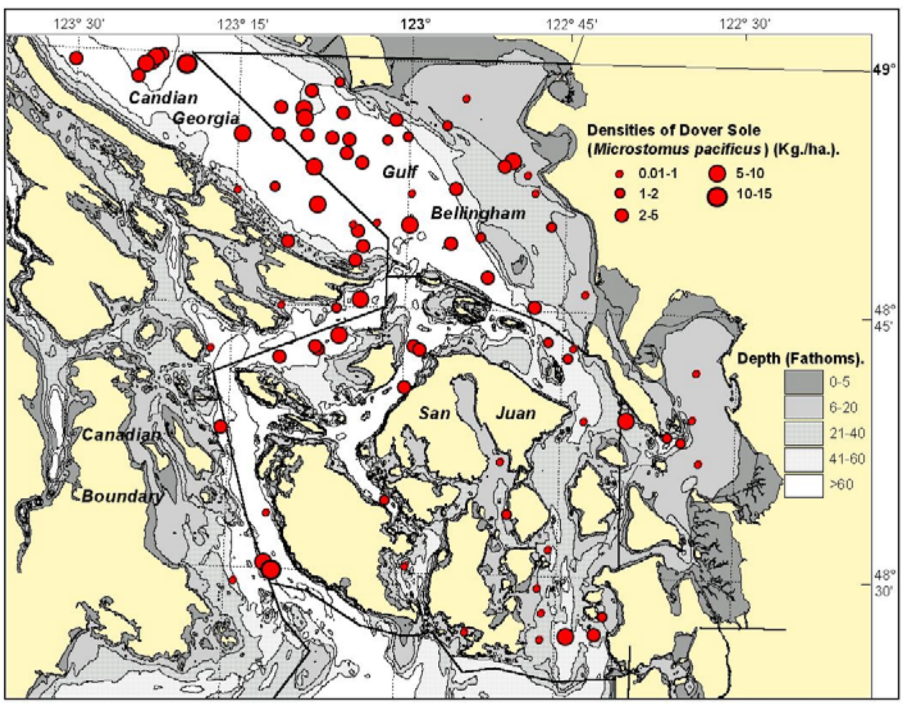

Figure 61. The distribution of Dover sole station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

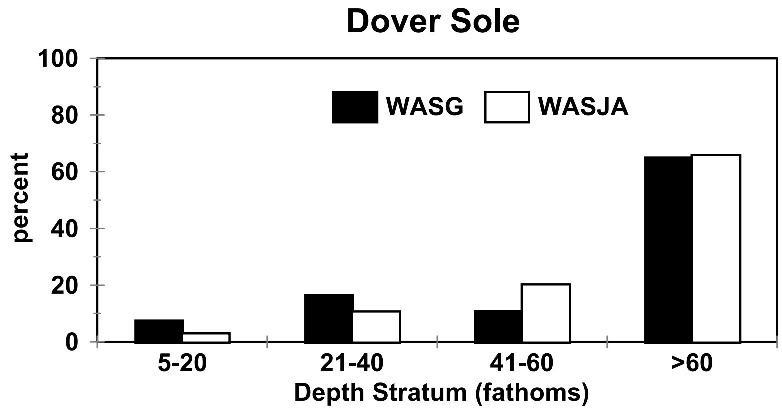

Figure 62. Depth distribution of Dover Sole.

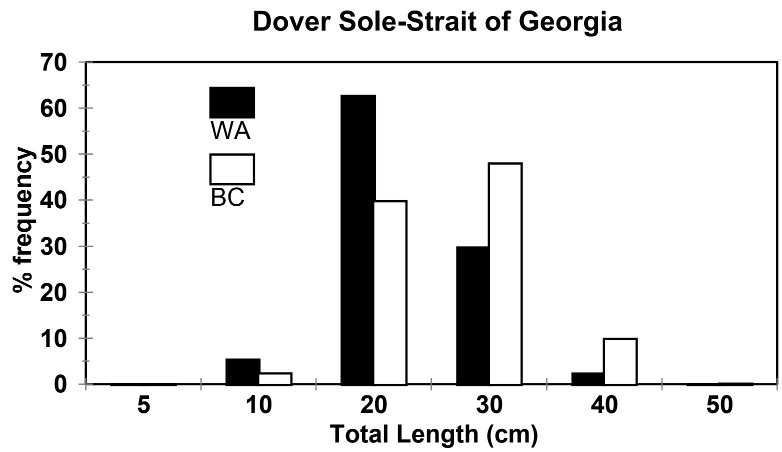

Figure 63. Length frequency distribution of Dover sole in the WA and BC Strait of Georgia.

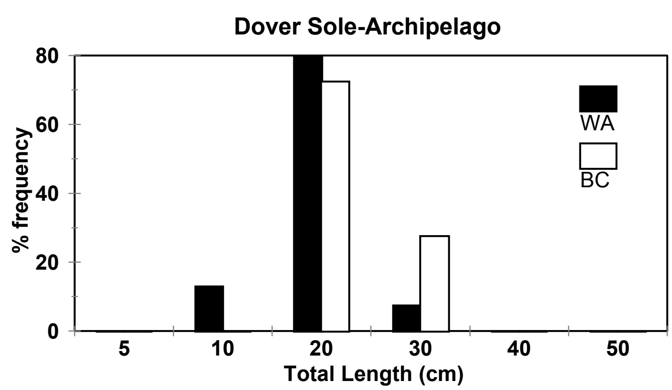

Figure 64. Length frequency distribution of Dover sole in the WA San Juan Archipelago and the BC Haro Strait and Boundary Pass.

Table 20. Numerical (x1000) and biomass (mt) abundance of Dover sole in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	184.1	395.6	202.3	611.7		1393.7
(% CV)	78.9	46.7	12.6	23.0		19.7
Biomass (mt)	11.9	25.9	17.1	102.2		156.9
(% CV)	79.1	39.4	13.2	16.3		13.9
British Columbia Strait of Georgia						
Abundance			148.5	458.4	26.9	633.7
(% CV)			43.4	18.7	20.8	16.9
Biomass (mt)			8.6	97.3	11.1	117.0
(% CV)			39.4	22.0	19.0	18.6
San Juan Archipelago						
Abundance	130.3	414.4	573.3	892.6		2010.5
(% CV)	57.2	68.4	42.9	23.8		21.8
Biomass (mt)	4.3	15.3	28.6	93.2		141.4
(% CV)	53.5	68.8	50.9	27.7		22.3
British Columbia Haro Strait and Boundary Pass						
Abundance			26.0	194.1		220.1
(% CV)			10.4	42.0		37.1
Biomass (mt)			1.9	22.6		24.5
(% CV)			15.4	46.6		43.0

Invertebrate Diversity and Abundance

Sampled Diversity and Species Composition

One hundred seventeen taxa of invertebrates were captured and categorized among the four survey regions (Table 21). In all, 8 species of gastropods were collected, 13 species of bivalves, 9 species of nudibranchs, 14 species of shrimp, 18 species of crabs, 14 species of sea stars, 3 species of sea urchins, and 5 species of sea cucumbers. The WASJA had the greatest species richness with 81, the WASG area had 75 species, the BCSG had 53 species, and the BCHB had 38 species of invertebrates. Fifty-three species were only collected in one survey region, and most of these unique species occurred in the WASG (22 species). The WASJA had 16 unique species, the BCSG had 9, and the BCBP had 6 species. Twenty-one species were found in all of the four regions, and 18 species were collected only in the two Washington survey areas. There were at least 107,000 individuals captured, and they had a mass of 4.8 mt among the three survey areas.

Population Abundance

The estimated population of invertebrates was 225.5 million individuals (32.2% C.V.) among the four surveyed areas (Tables 22 and 23). The invertebrates had a biomass of 10,700 mt (11.2%). The WASJA had the greatest abundance of invertebrates in terms of numerical abundance (168.7 million individuals, 41.9% CV), but the WASG had the greatest population biomass of any region (6,107 mt, 16.1% CV, Table 23). The BC survey areas contained from 4.8 to 6.1 million individuals with biomasses ranging from 265 mt to 352 mt. The fully surveyed WA regions demonstrated that over 60% of the invertebrate biomass resided in the 5-20 fm stratum (Table 23). The deepest strata contained less than 8% of the population biomass.

Overall, pandalid shrimp dominated most areas in terms of numerical abundance (Tables 22) and for most regions ranked either highest as a group or highest in numerical abundance as individual species. These species included Alaskan pink shrimp, humpy shrimp, dock shrimp, and spotted prawn (Tables 21 and 22). In terms of biomass, however, Dungeness crab accounted for the greatest biomass of any invertebrate species in each of the four survey areas (Table 22). Other important invertebrate populations included several species of seastars and anemones in the WASG, red sea urchins, pink scallops, and Oregon hairy tritons in the BCSG, seastars, barnacles, shrimps and red sea urchins in the WASJA, and shrimps, red sea urchins, clams, and barnacles in the BCHB.

Table 21. Sampled invertebrates numbers and weights encountered during the 2001 trawl survey.

Common Name	Scientific Name	WA Strait of Georgia Nos	WA Strait of Georgia Kg	BC Strait of Georgia Nos	BC Strait of Georgia Kg	San Juan Archipelago Nos	San Juan Archipelago Kg	BC Haro Strait & Boundary Pass Nos	BC Haro Strait & Boundary Pass Kg
Sponge uniden.	Phylum Porifera spp.			1	0.02	10	0.31		
Cloud sponge	*Aphrocallistes vastus*			3	5.80				
Lion's mane jelly	*Cyanea capillata*			2	0.93	1	0.56		
Sea pansy	*Renilla koellikeri*	1	0.02						
Orange sea pen	*Ptilosarcus gurneyi*	4	0.19			1	0.04		
Sea anemone uniden.	Order Actiniaria spp.			1	0.01	1	0.21		
Sand rose anemone	*Urticina columbiana*			3	1.08				
Mottled olive green anemone	*Urticina crassicornius*	3	0.17	4	0.10	2	0.28		
Scarlet anemone	*Urticina lofotensis*	1	0.04			1	0.06		
Metridium uniden.	*Metridium spp.*	117	52.00			1	0.32		
Gigantic anemone	*Metridium giganteum*	37	15.79	4	1.10	49	22.68		
Polychaete worm uniden.	Class Polychaeta spp.	2	0.01						
Sea mouse uniden.	Aphroditidae spp.			2	0.27				
Scale worm	*Halosydna brevisetosa*							1	0.00
Nereis uniden.	*Neris spp.*			1	0.02				
Lugworm uniden.	Arenicolidae spp.	1	0.01						
Snail uniden.	Class Gastropoda spp.	5	0.08	4	0.06	9	0.02		
Variable topsnail	*Calliostoma variegatum*					1	0.01		
Slippersnail uniden.	*Crepidula spp.*					1	0.05		
Moon snail	*Polinices lewisii*			1	0.12				
Oregon hairy triton	*Fusitriton oregonensis*	1	0.05	134	10.15	14	1.62	7	0.40
Leafy hornmouth	*Ceratostoma foliatum*	3	0.11			3	0.11		
Fringed dogwinkle	*Nucella lamellosa*					1	0.01		
Lyre or sinuous whelk	*Buccinum plectrum*			3	0.08				
Ridged whelk	*Neptunea lyrata*					5	0.40		
Nudibranch uniden.	Order Nudibranchia spp.	1	0.01	1	0.02				
Ringed dorid (San Diego dorid)	*Diaulula sandiegensis*							1	0.00
Common or spot nudibranch	*Triopha catalinae*			1	0.01	1	0.05		
Rosy tritonia	*Tritonia diomedea*	39	2.39						
Tritonia festiva	*Tritonia festiva*							1	0.02
Tochuina tetraquetra	*Tochuina tetraquetra*	1	0.03						
Rainbow nudibranch	*Dendronotus irus*	16	0.41						

Table 21. Sampled invertebrates numbers and weights encountered during the 2001 trawl survey.

Common Name	Scientific Name	WA Strait of Georgia Nos	WA Strait of Georgia Kg	BC Strait of Georgia Nos	BC Strait of Georgia Kg	San Juan Archipelago Nos	San Juan Archipelago Kg	BC Haro Strait & Boundary Pass Nos	BC Haro Strait & Boundary Pass Kg
Dall's dendronotid	*Dendronotus dalli*							2	0.02
California arminid	*Armina californica*	12	0.21						
Shag-rug aeolis	*Aeolidia papillosa*	1	0.01						
Gumboot chiton	*Cryptochiton stelleri*					1	0.50		
Clam uniden.	Class Bivalvia spp.			4	0.04				
Divaricate nut clam	*Acila castrensis*	27	0.04						
Yoldia uniden.	*Yoldia spp.*	4	0.03						
Crisscross yoldia	*Yoldia seminuda*	3	0.01						
Axe yoldia	*Yoldia thraciaeformis*	1	0.02						
Mussel uniden.	Mytilidae spp.	5	0.24			1	0.01		
Northern horse mussel	*Modiolus modiolus*	231	8.15	136	3.91	468	21.34	110	3.92
Pink scallop uniden.	*Chlamys spp.*	118	2.65						
Pink scallop (deep ribs)	*Chlamys hastata*	6	0.16	5	0.05	154	4.83	30	0.90
Pink scallop (smooth)	*Chlamys rubida*	3	0.07	306	4.71	658	17.34	69	1.65
Weathervane scallop	*Patinopecten caurinus*	5	2.16						
Giant rock scallop	*Crassedoma giganteum*	1	0.46						
Basket cockel	*Clinocardium nuttallii*	1	0.18			1	0.04		
Bent-nose macoma	*Macoma nasuta*	1	0.02						
Butter clam	*Saxidomus giganteus*	5	0.36			5	0.36		
Ugly clam	*Entodesma saxicolum*							1	0.07
Stubby squid	*Rossia pacifica*	3	0.19	11	0.53	13	0.77	1	0.06
California market squid	*Loligo opalescens*	8	0.21			5	0.10		
Big red squid	*Berryteuthis magister*	7	0.75	17	7.43	8	0.95		
Giant octopus	*Octopus dofleini*							1	7.08
Octopus leioderma	*Octopus leioderma*			1	0.07				
Barnacle uniden.	Subclass Cirripedia spp.					397	30.89	59	0.68
Balanus nubilis	*Balanus nubilis*	4	0.64			164	12.84		
Krill uniden.	Order Euphausiacea spp.			128	0.13				
Grass shrimp	*Hippolyte clarki*					1	0.01		
Dana's deep bladed shrimp	*Spirontocaris lamellicornis*	8	0.02			15	0.06		
Spiny lebbeid	*Lebbeus groenlandicus*			1	0.00	434	1.75	16	0.04
Shortscale eualid	*Eualus suckleyi*	19	0.03			295	0.38		
Alaskan pink shrimp	*Pandalus borealis*	2564	12.33	604	3.03	2719	12.11	1066	4.43

Table 21. Sampled invertebrates numbers and weights encountered during the 2001 trawl survey.

		WA Strait of Georgia		BC Strait of Georgia		San Juan Archipelago		BC Haro Strait & Boundary Pass	
Common Name	**Scientific Name**	**Nos**	**Kg**	**Nos**	**Kg**	**Nos**	**Kg**	**Nos**	**Kg**
Humpy shrimp	*Pandalus goniurus*	4896	10.97			52861	198.97	2	0.01
Ocean pink shrimp	*Pandalus jordani*	23	0.11						
Spotted prawn	*Pandalus platyceros*	20	0.54	51	1.12	2713	85.78	37	1.24
Coonstriped shrimp	*Pandalus hypsinotus*	622	5.96			687	5.43		
Dock shrimp	*Pandalus danae*	769	6.52	9	0.05	13295	90.18	1232	9.76
Rough patch shrimp	*Pandalus stenolepis*					12	0.06		
Sidestriped shrimp	*Pandalus dispar*	2058	18.60	417	3.64	356	4.19	15	0.25
Crangonid shrimp uniden.	Crangonidae spp.	253	0.73	1	0.00	1919	2.62	23	0.04
Horned shrimp	*Paracrangon echinata*	2	0.02			118	0.41	1	0.00
Hermit crabs uniden.	Paguridae spp.	8	0.28	259	4.71	14	0.75	1	0.01
Alaskan hermit crab	*Pagurus ochotensis*	3	0.19	12	0.47	2	0.04		
Widehand hermit crab	*Elassochirus tenuimanus*	1	0.01			7	0.21		
Hair crab alternate	*Hapalogaster mertensii*					3	0.06		
Brown box crab	*Lopholithodes foraminatus*			5	4.32				
Squat lobster	*Mundia quadrispina*	1	0.02	59	0.40	55	0.83	35	0.27
Paguristes turgidus	*Paguristes turgidus*	6	0.35						
Decorator or spider crab uniden.	Majidae spp.			1	0.00	13	0.13	2	0.07
Graceful decorator crab	*Oregonia gracilis*	5	0.04			25	0.20	3	0.04
North Pacific toad crab	*Hyas lyratus*	13	0.23	2	0.07	27	0.49	2	0.11
Broad snow crab (female)	*Chionoecetes bairdi*	77	6.28	5	0.65	17	1.86	18	2.33
Broad snow crab (male)	*Chionoecetes bairdi*	100	13.40	8	2.49	45	9.72	45	10.98
Broad snow crab (mixed)	*Chionoecetes bairdi*							2	0.31
Cryptic kelp crab	*Pugettia richii*					14	0.06		
Sharpnose crab	*Scyra acutifrons*					2	0.02		
Longhorned decorator crab	*Chorilia longipes*	7	0.03			25	0.14		
Helmet crab	*Telmessus cheiragonus*					4	0.13		
Red rock crab (female)	*Cancer productus*	5	1.00	1	0.31	52	10.01		
Red rock crab (male)	*Cancer productus*	14	3.53			82	30.34	1	0.54
Red rock crab (mixed)	*Cancer productus*							1	0.18
Dungeness crab (female)	*Cancer magister*	1920	719.94	54	19.84	1103	400.24	121	65.06
Dungeness crab (male)	*Cancer magister*	4776	1592.30	6	4.20	1390	576.64	12	11.51
Graceful crab (female)	*Cancer gracilis*	3	0.08			15	1.16		

Table 21. Sampled invertebrates numbers and weights encountered during the 2001 trawl survey.

Common Name	Scientific Name	WA Strait of Georgia Nos	WA Strait of Georgia Kg	BC Strait of Georgia Nos	BC Strait of Georgia Kg	San Juan Archipelago Nos	San Juan Archipelago Kg	BC Haro Strait & Boundary Pass Nos	BC Haro Strait & Boundary Pass Kg
Graceful crab (male)	*Cancer gracilis*	4	0.05			25	4.23		
Graceful crab (mixed)	*Cancer gracilis*	18	0.21			2	0.01		
Pygmy rock crab	*Cancer oregonensis*	1	0.00			26	0.12		
Lampshell brachiopod	*Terabratalia transversa*			2	0.01	9	0.12	20	0.10
Banana starfish	*Luidia foliata*	548	56.69	18	7.24	6	0.47	4	0.21
Vermillion starfish	*Mediaster aequalis*	2	0.06						
Rose sea star	*Crossaster papposus*			3	0.48	1	0.17		
Stimpson's sun starfish	*Solaster stimpsoni*	3	0.38						
Slime star	*Pteraster tesselatus*	7	2.29	2	0.10	38	15.57	2	0.61
Leather star	*Dermasterias imbricata*					1	0.88		
Blood star	*Henricia leviuscula*			1	0.01	5	0.06	2	0.02
False ochre star	*Evasterias troschelii*	7	3.09			10	6.61		
Pink short spined seastar	*Pisaster brevispinus*	70	51.79	1	1.55	4	6.83		
Long armed spiny seastar	*Orthasterias koehleri*					4	1.14		
Sunflower star	*Pycnopodia helianthoides*	56	47.73	3	7.98	74	99.33	12	8.67
Brittle star uniden.	Ophiuroidae spp.	4	0.02	23	0.03	2	0.00		
Basket star	*Gorgonocephalus caryi*	15	1.42	29	3.66	33	5.03	9	1.70
Ophiura sarsi	*Ophiura sarsi*	67	0.06						
Green sea urchin	*Strongylocentrotus droebachiensis*	18	1.94	85	7.40	677	60.67	37	2.58
Red sea urchin	*Strongylocentrotus franciscanus*	3	3.44	86	64.07	67	63.50		
Pallid sea urchin	*Stronglyocentrotus pallidus*	14	0.62	5	1.11	2	0.05		
White sea cucumber	*Eupentacta quinquesemita*					6	0.04		
Orange sea cucumber	*Cucumaria miniata*					3	0.33		
Salt and pepper cucumber	*Cucumaria piperata*	1	0.00			2	0.03		
Red sea cucumber	*Parastichopus californicus*	23	14.09	2	0.34	80	47.77	6	2.05
Sweet potato sea cucumber	*Molpadia intermedia*	3	0.37	1	0.03	1	0.03		
Tunicate uniden.	Class Ascidiacea spp.	15	0.05			25	0.24		
Warty sea squirt	*Pyura haustor*					147	1.14		
Total		19730	2665.64	2529	175.92	81546	1865.95	3010	137.92
Number of Taxa		81	81	54	54	85	85	40	40

Table 22. Numerical and biomass abundance of invertebrates encountered during the 2001 trawl survey.

	Nos x 1000	%CV	Mt	%CV	Nos X 1000	%CV	Mt	%CV
Northern Regions	**WA Strait of Georgia**				**BC Strait of Georgia**			
Sponge					6.18	45.58	10.31	83.46
Jellyfish					4.47	70.73	2.04	98.88
Orange sea pen	8.66	77.5	0.4	82				
Giant sea anemone	61.93	39.52	32.87	48.18	8.64	58.72	2.3	73.3
Other sea anemone	288.63	41.2	125.11	37.47	12.77	91.64	0.66	72.46
Total sea anemones	350.56	33.87	157.97	29.99	21.4	57.56	2.96	58.85
Other Coelenterates	2.54	100	0.05	100				
Sea mouse					4.66	100	0.63	100
Other polychaete	6.81	73.93	0.04	68.89	0.37	100	0.01	100
Total polychaetes	6.81	73.93	0.04	68.89	5.03	92.87	0.64	98.83
Moon snail					2.33	100	0.28	100
Oregon hairy triton	1.57	100	0.08	100	306.03	98.95	23.36	99.42
Other snail	15.27	49.87	0.34	60.46	13.9	56.41	0.26	71.31
Total snails	16.84	45.73	0.42	51.48	322.26	96.66	23.9	99.1
Rosy tritonia	89.1	71.55	5.41	66.88				
Other nudibranch	78.14	54.81	1.65	62.39	2.37	85.69	0.03	77.69
Total nudibranchs	167.24	45.8	7.06	53.42	2.37	85.69	0.03	77.69
Northern horse mussel	435.75	100	15.37	100	312.69	78.49	9	76.26
Other scallop	154.46	72.04	3.46	72.27				
Pink scallop (deep ribs)	6.75	100	0.18	100	10.3	100	0.1	100
Pink scallop (smooth)	11.36	83.94	0.29	96.56	623.75	80.58	9.78	70.49
Weathervane scallop	10.28	58.86	4.47	57.77				
Other clam	220.72	72.93	3.25	38.48	1.5	100	0.01	100
Total clams	839.32	56.65	27.03	58.24	948.23	62.22	18.89	59.36
Stubby squid	11.66	82.36	0.72	80.53	19.69	83.89	0.95	80.25
California market squid	19.58	65.45	0.52	69.87				
Other squid	12.58	36.71	1.42	57.39	13.58	40.72	3.82	38.92
Total squids	32.16	42.36	1.94	46.04	13.58	40.72	3.82	38.92
Total octopi					2.49	100	0.17	100
Barnacle	7.99	100	1.28	100				
Spotted prawn	78.42	88.75	2.28	93.83	89.57	97.73	1.95	99.48
Sidestriped shrimp	3352.76	45.98	30.71	38.4	732.59	53.6	6.38	50.42
Other pandalid shrimp	20909.61	63.15	83.97	46.8	1093.14	83.42	5.48	82.24
Other shrimp	743.7	36.59	2.18	31	68.36	29.51	0.06	22.65

Table 22. Numerical and biomass abundance of invertebrates encountered during the 2001 trawl survey.

	Nos x 1000	**%CV**	**Mt**	**%CV**	**Nos X 1000**	**%CV**	**Mt**	**%CV**
Total shrimps	25084.49	53.59	119.14	36	1983.65	69.56	13.88	69.09
Hermit crab	19.43	44.75	0.7	49.02	626.18	94.38	11.83	87.43
Brown box crab					9.44	33.52	8.44	3.5
Broad snow crab	383.55	32.81	40.76	35.18	23.28	90.73	5.6	92.58
Red rock crab	53.93	47.99	13.04	41.51	1.75	100	0.54	100
Male Dungeness crabs	11160.04	21.73	3557.92	16.98	12.69	80.82	8.9	80.16
Female Dungeness crabs	5307.7	28.37	1704.66	27.56	113.61	81.89	42.04	78.02
Dungeness crab	16467.74	22.23	5262.57	18.41	126.3	81.49	50.93	77.74
Graceful crab	62.65	40.11	0.84	34.95				
Other crab	75.5	28.82	1.34	41	108.91	98.05	0.82	98.71
Total crabs	17062.79	21.55	5319.26	18.24	895.86	67.35	78.16	51.63
Banana seastar	1569.65	25.2	144.85	26.47	43.75	51.85	17.61	67.24
Sunflower seastar	140.12	23.26	111.32	25.06	6.99	100	18.59	100
Other seastar	380.27	24.49	162.32	57.07	131.54	42.39	12.17	45.14
Total seastars	2090.04	20.57	418.48	26.19	182.28	36.58	48.37	42.81
Green sea urchin	33.32	85.61	3.49	77.8	195.22	88.4	16.96	85.99
Red sea urchin	9.61	100	11.02	100	171.75	100	127.96	100
Other sea urchin	24.5	84.9	1.1	71.95	10.53	79.07	2.5	82.76
Total sea urchins	67.43	56.83	15.61	73.35	377.5	66.31	147.41	88.03
Red sea cucumber	57.95	38.2	36.9	39.2	4.54	67.11	0.77	67.93
Other sea cucumber	9.36	60.14	0.92	68.3	0.37	100	0.01	100
Total sea cucumbers	67.32	34.59	37.82	38.15	4.91	62.47	0.78	67.13
Tunicate/sea squirt	30.69	100	0.1	100				
Misc. nongame invertebrate					4.59	100	0.02	100
Total invertebrates	45846.54	34.28	6107.34	16.11	4794.49	36.03	352.33	41.98

Southern Regions		**San Juan Archipelago**				**BC Haro Strait and Boundary Pass**		
Sponge	31.13	50.9	0.83	42.15				
Jellyfish	4.15	100	2.32	100				
Orange sea pen	1.79	100	0.07	100				
Giant sea anemone	82.38	71.55	37.81	71.77				
Other sea anemone	11.93	45.53	1.73	45.03				
Total sea anemones	94.31	62.77	39.54	68.72				
Total polychaetes					4.76	100	0.01	100
Oregon hairy triton	41.54	77.92	4.83	78.73	15.18	76.01	0.87	75.05

Table 22. Numerical and biomass abundance of invertebrates encountered during the 2001 trawl survey.

	Nos x 1000	%CV	Mt	%CV	Nos X 1000	%CV	Mt	%CV
Other snail	65.31	55.97	1.7	58.25				
Total snails	106.85	41.86	6.53	60.45	15.18	76.01	0.87	75.05
Total nudibranchs	1.79	100	0.09	100	14.3	63.97	0.18	77.02
Gumboot chiton	1.48	100	0.74	100				
Northern horse mussel	1161.04	33.1	54.2	34.41	328.98	60.69	10.84	56.46
Pink scallop (deep ribs)	493.08	35.19	16.08	40.11	128.08	92.47	3.81	92.24
Pink scallop (smooth)	1885.19	37.37	49.98	34.41	269.29	86.86	6.41	86.49
Other clam	15.4	35.93	0.82	39.68	4.76	100	0.33	100
Total clams	3554.71	27.33	121.07	23.82	731.12	74.86	21.39	69.99
Stubby squid	53.35	83.07	3.23	82.8	1.66	100	0.1	100
California market squid	11.15	49.31	0.25	61.68				
Other squid	24.39	45.34	2.45	82.7				
Total squids	35.54	34.75	2.7	75.24				
Giant octopus					2.03	100	14.38	100
Total octopi					2.03	100	14.38	100
Barnacle	2400.74	55.63	201.78	58.53	258.49	91.95	3.01	93.07
Spotted prawn	9736.55	47.18	297.91	45.13	171.43	96.13	5.75	96.77
Sidestriped shrimp	925.39	51.95	11.07	50.52	26.59	82.01	0.42	91.8
Other pandalid shrimp	136428.81	50.31	635.94	42.74	4136.11	83.96	25.48	86.72
Other shrimp	5995.02	29.62	13.09	24.99	76.51	45.74	0.16	47.04
Total shrimps	153085.78	45.72	958	33.26	4410.65	79.09	31.81	70.86
Hermit crab	76.78	38.4	3.46	51.63	1.66	100	0.02	100
Broad snow crab	97.2	47.62	18.09	52.43	114.2	92.05	23.59	93.96
Red rock crab	257	25.63	82.46	27.49	3.32	100	1.2	100
Male Dungeness crabs	2559.17	30.83	1000.81	25.71	19.94	100	19.13	100
Female Dungeness crabs	2546.35	26.77	834.4	26.33	201.07	100	108.11	100
Dungeness crab	5105.52	27.04	1835.21	23.28	221.01	100	127.24	100
Graceful crab	126.43	55.94	17.13	57.68				
Other crab	544.7	25.27	6.42	38.09	80.9	77.94	0.96	65.71
Total crabs	6207.64	23.95	1962.77	22.63	421.1	63.67	153.01	98.02
Banana seastar	10.97	61.08	1.42	87.02	6.65	100	0.35	100
Sunflower seastar	145.57	26.29	218.58	24.29	23.74	65.12	17.01	51.72
Other seastar	253.68	14.74	87.62	21.76	47.76	74.54	8.5	71.37
Total seastars	410.22	13.06	307.62	18.44	78.14	58.32	25.87	43.49
Green sea urchin	1533.75	41.52	150.12	44.66	92.59	28.06	6.46	34.17

Table 22. Numerical and biomass abundance of invertebrates encountered during the 2001 trawl survey.

	Nos x 1000	%CV	Mt	%CV	Nos X 1000	%CV	Mt	%CV
Red sea urchin	134.04	63.25	126.24	69.31				
Other sea urchin	4.53	100	0.11	100				
Total sea urchins	1672.33	38.76	276.47	40.88	92.59	28.06	6.46	34.17
Red sea cucumber	207.94	27.62	117.97	31.51	22.61	85.63	7.47	83.59
Other sea cucumber	27.76	39.77	1.22	58.77				
Total sea cucumbers	235.7	25.02	119.19	31.1	22.61	85.63	7.47	83.59
Tunicate/sea squirt	811.25	75.24	5.99	61.23				
Misc. nongame invertebrate	29.98	62.16	0.36	67.64	67.51	66.69	0.42	87.8
Total invertebrates	168738.73	41.92	4009.29	16.25	6120.13	57	264.97	51.46

Table 23. Numerical (x1000) and biomass (mt) abundance of invertebrates in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	27601.7	11910.6	4365.0	1969.3		45846.5
(% CV)	53.5	42.8	37.4	32.9		34.3
Biomass (mt)	3808.6	1748.2	305.5	245.0		6107.3
(% CV)	23.8	21.0	23.1	26.9		16.11
British Columbia Strait of Georgia						
Abundance			2539.1	2187.9	67.5	4794.5
(% CV)			51.7	51.3	22.3	36.0
Biomass (mt)			186.5	162.8	3.1	352.3
(% CV)			68.1	46.6	45.8	42.0
San Juan Archipelago						
Abundance	118756.7	13964.1	27875.3	8142.7		168738.7
(% CV)	58.6	51.4	37.8	32.6		41.9
Biomass (mt)	2686.8	504.8	511.1	306.6		4009.3
(% CV)	21.7	40.8	36.6	28.3		16.3
British Columbia Haro Strait and Boundary Pass						
Abundance			4685.7	1434.5		6120.1
(% CV)			70.6	76.8		57.0
Biomass (mt)			191.3	73.7		265.0
(% CV)			68.4	51.8		51.5

Dungeness Crab

Dungeness crab was a dominant invertebrate species within each of the four study areas. There were 21.9 million crabs (13.9% CV) among the four survey regions (Tables 22, 24, and 25), and these had a biomass of 7,300 mt (11.6% CV). Overall, male Dungeness crabs constituted approximately 62% of the numerical and biomass population estimates. The WASG had the greatest population of male and female crabs but the greatest difference in the sex ratio of any surveyed region. Two-thirds of the population was male crabs consisting of 11.1 million males (21.7% CV) and a biomass of 3,600 mt (17.0% CV). The remaining population consisted of 5.3 million females (28.4% CV) that had a biomass of 1,700 mt (27.6% CV). The WASJA had the second greatest abundance of crabs but relatively equal sex ratios consisting of 2.6 million male crabs (30.8% CV) with a biomass of 1,000 mt (25.7% CV) and 2.5 million females (26.8% CV) that had a biomass of 830 mt (26.3% CV). Crab population in the deep BC survey areas primarily consisted of females but abundances were less than 0.2 million individuals in each of regions with biomasses of approximately 130 mt. Coefficients of variation exceeded 75% for these estimates.

Dungeness crabs occurred in the highest concentrations in the shallow bays and sounds of the survey areas (Figures 65 and 66). Males generally co-occurred with females. The areas of greatest station densities included Bellingham Bay, south of Lummi Island, off Cherry Point, Point Roberts Reef, and Birch Bay, Padilla Bay, and East and Lopez Sounds. Crabs were also found in lesser concentrations in the central Strait of Georgia, southern San Juan Channel, and Fisherman's Bay which is east of Rosario Strait. More than half of the male and female Dungeness crab biomasses were distributed in the shallowest depth stratum (Figures 67 and 68). There were subtle differences in the depth distribution of the crabs. In the WASG, 77% of the female crabs biomass was in the 5-20 fm stratum while only 55% of the male crab biomass was distributed in this depth zone. Thirty-eight percent of the male biomass was also found in the 21-40 fm depth stratum while only 14% of the female crab was found in the second deepest zone. The depth distribution of crabs in the WASJA was more similar between the sexes with over 90% of the male and female biomass occurring in the shallowest stratum. Females were the dominant sex found in the deep depths of both BC survey areas.

The carapace width frequency distributions of the Dungeness crab numerical populations revealed a wide diversity of sizes, often with several modal frequencies (Figures 69 to 72). Carapace widths ranged from 30 mm to 210 mm. In the WASG, male carapace widths ranged from 70 mm to 200 mm with modes at 110 mm and 150 mm and a low proportion measuring greater than 160 mm in width. The average size of males was 119.5 mm and 101.6 mm for females (Table 5). Male crabs were much larger in the BCSG where they averaged 161.3 mm and had a modal width frequency at 170 mm (Figure 69). There was a wide range of sizes for male crabs in the WASJA where they averaged 127.7 mm in width and had modes at 50 mm, 120 mm, and 180 mm (Figure 70). Male crabs in the deep waters of the BCHB averaged 178.9 mm and only ranged in size from 150 mm to 200 mm (Figure 70) with a modal size at 180 mm. Female crabs were smaller than males in each region. In the WASG, females averaged 101.6 mm in width and ranged in size from 80 mm to 150 mm with a modal size at 130 mm (Figure 71). Female crabs were larger in the BCSG where they averaged 131.0 mm in width and had a modal size of 130 mm. In the WASJA, female crabs ranged from 40 mm to 160 mm and were larger than female crab in the WASG with an average of 121.7 mm (Figure 72). Modal lengths in the WASJA female population were at 60 mm, and 130 mm. In the BSHB, female crabs were the largest of any region, averaging 147.0 mm in width and having a modal frequency at 150 mm.

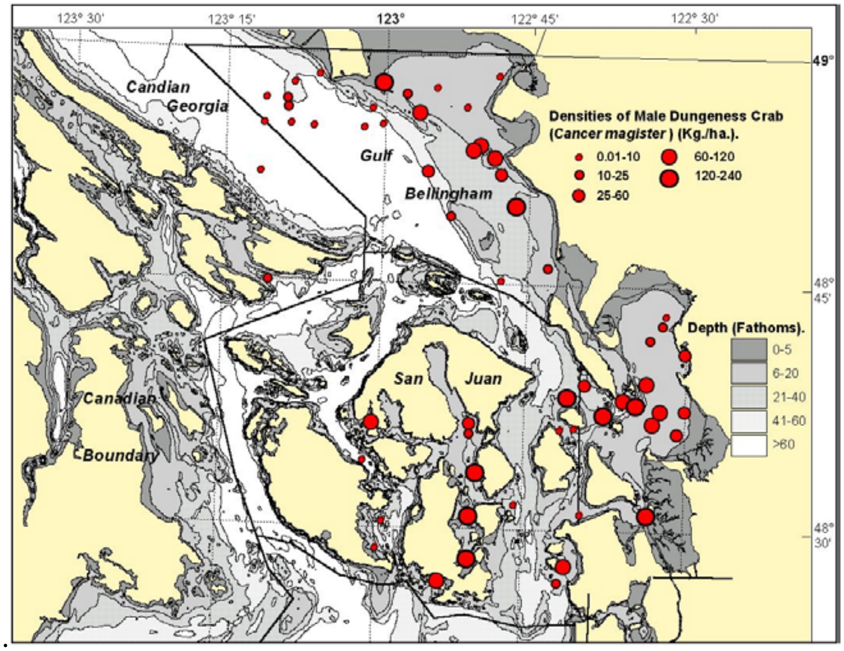

Figure 65. The distribution of male Dungeness crab station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

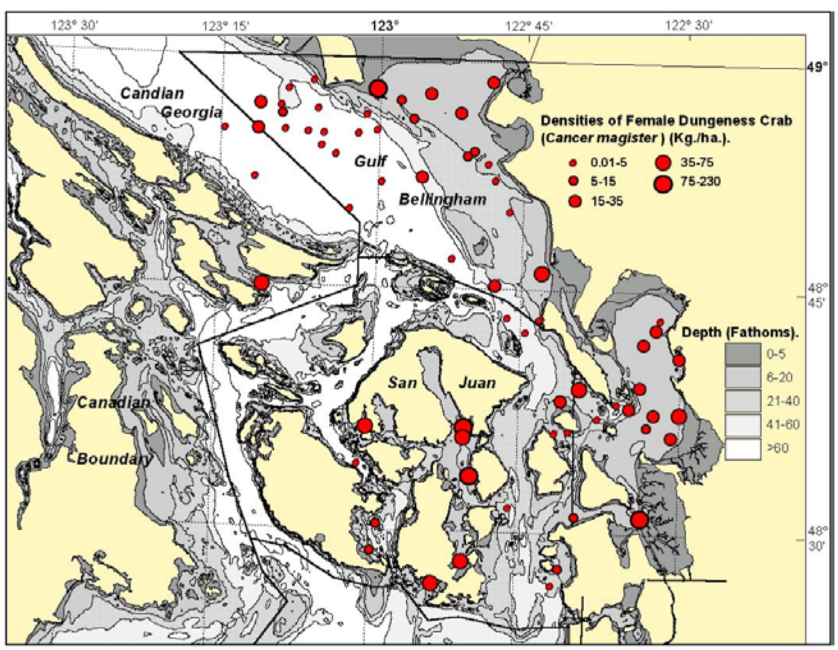

Figure 66. The distribution of female Dungeness crab station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

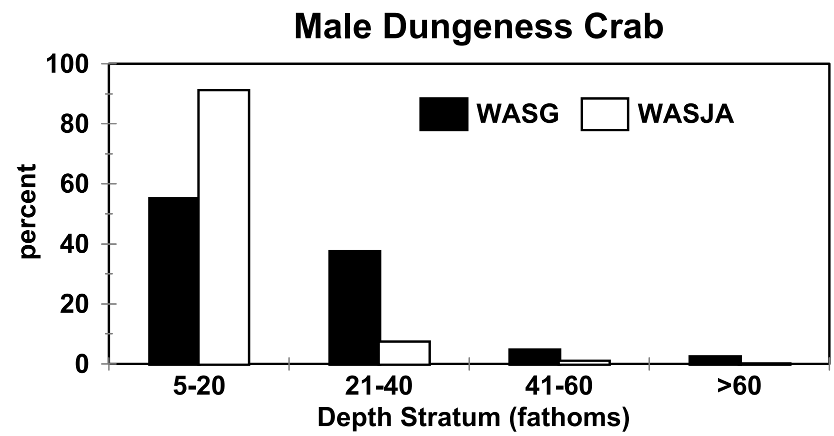

Figure 67. Depth distribution of male Dungeness crab.

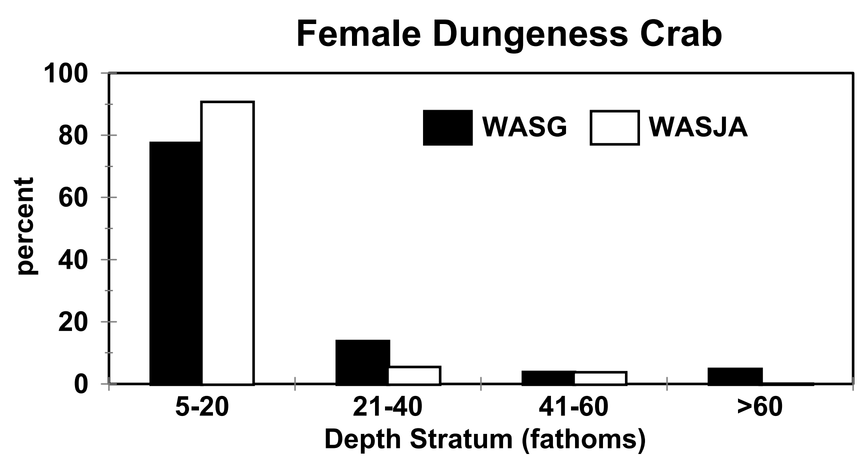

Figure 68. Depth distribution of female Dungeness crab.

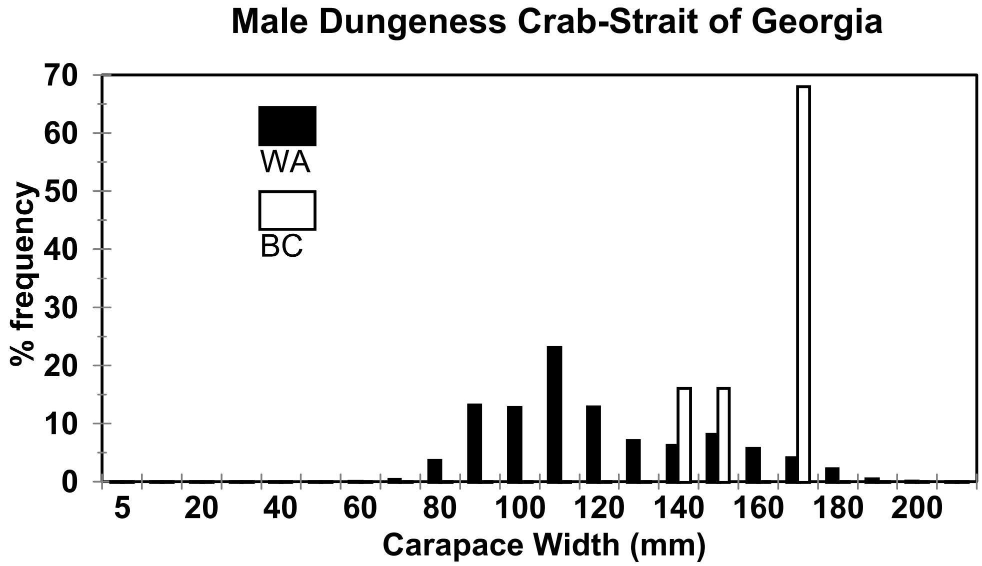

Figure 69. Carapace width frequency distribution of male Dungeness crab in the WA and BC Strait of Georgia.

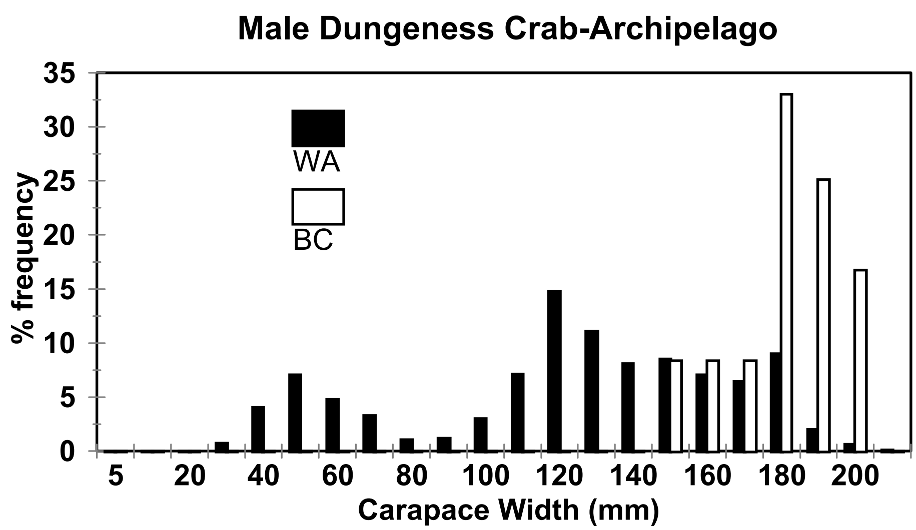

Figure 70. Carapace width frequency distribution of male Dungeness crab in the WA San Juan Archipelago and the BC Haro Strait and Boundary Pass.

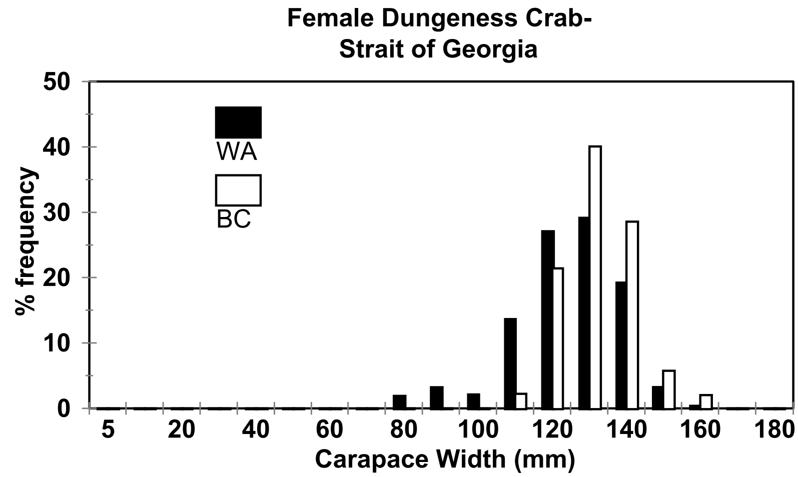

Figure 71. Carapace width frequency distribution of female Dungeness crab in the WA and BC Strait of Georgia.

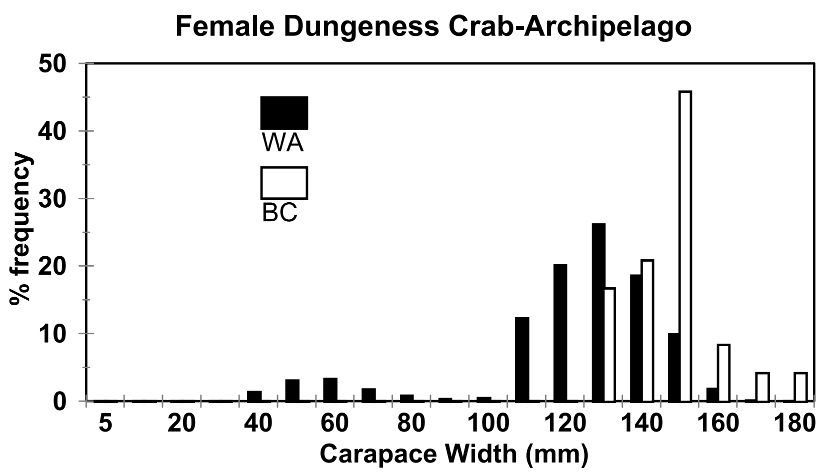

Figure 72. Carapace width frequency distribution of male Dungeness crab in the WA San Juan Archipelago and the BC Haro Strait and Boundary Pass.

Table 24. Numerical (x1000) and biomass (mt) abundance of male Dungeness crab in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	6415.8	4266.2	334.7	143.3		11160.0
(% CV)	33.1	27.2	43.9	47.1		21.7
Biomass (mt)	1964.3	1337.0	169.2	87.4		3557.9
(% CV)	25.3	35.0	43.1	42.9		17.0
British Columbia Strait of Georgia						
Abundance				12.7		12.7
(% CV)				80.8		80.8
Biomass (mt)				8.9		8.9
(% CV)				80.2		80.2
San Juan Archipelago						
Abundance	2463.4	78.1	15.5	2.2		2559.2
(% CV)	32.0	57.2	78.6	100.0		30.8
Biomass (mt)	913.2	74.7	10.9	2.0		1000.8
(% CV)	27.8	58.6	77.3	100.0		25.7
British Columbia Haro Strait and Boundary Pass						
Abundance			19.9			19.9
(% CV)			100.0			100.0
Biomass (mt)			19.1			19.1
(% CV)			100.0			100.0

Table 25. Numerical (x1000) and biomass (mt) abundance of female Dungeness crabs in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance	4266.5	642.8	175.6	225.9		5307.7
(% CV)	34.3	51.8	38.9	38.3		28.4
Biomass (mt)	1321.8	235.2	65.2	82.5		1704.7
(% CV)	34.1	54.6	43.2	36.0		27.6
British Columbia Strait of Georgia						
Abundance				113.6		113.6
(% CV)				82.0		82.0
Biomass (mt)				42.0		42.0
(% CV)				78.0		78.0
San Juan Archipelago						
Abundance	2382.9	97.8	63.5	2.2		2546.4
(% CV)	28.5	47.6	80.4	100.0		26.8
Biomass (mt)	757.4	45.1	31.1	0.9		834.4
(% CV)	28.7	48.7	83.5	100.0		26.3
British Columbia Haro Strait and Boundary Pass						
Abundance			201.1			201.1
(% CV)			100.0			100.0
Biomass (mt)			108.1			108.1
(% CV)			100.0			100.0

Spotted Prawn

Spotted prawn was primarily encountered in the deep waters of the WASJA, BCSG, and BCHB. There were 10.1 million prawns (45.7% CV, Table 26) estimated for the entire survey area and these animals had a biomass of 308 mt (42.7% CV). The WASJA had the greatest population with 9.7 million individuals (47.2% CV) that had a biomass of 300 mt (45.1% CV). The three remaining regions had between 0.08 million and 0.2 million individuals and biomasses ranging between 2 mt and 6 mt (CVs in excess of 89%). Spotted prawn occurred at the highest densities near sheer drop offs and shelves in northern Rosario Strait, Boundary Pass, the western portion of San Juan Channel, and the Gulf Islands in the SG (Figure 73). Spot prawns were also present in lesser densities in the southeast SG, southern Rosario Strait, and western Haro Strait. The greatest biomass of spotted prawn was primarily encountered in the 41-60 fm depth stratum in the WA survey areas (Figure 74) with over 95% occurring in that stratum in the WASG and almost 50% occurring in the WASJA. In the WASJA, spotted prawn biomass also occurred in significant amounts in the 21-40 fm (36%) and in the >60 fm stratum (16%).

The carapace lengths of spotted prawn ranged from 20 mm to 50 mm in most of the survey regions (Figures 75 and 76). The average lengths were 32.3 mm in the WASG and 33.0 in the BCSG (Table 5) and were slightly larger at 36.4 mm in the WASJA and 36.5 mm in the BCHB. Modal frequencies were 30 mm in the BCSG, 40 mm in the WASG, WASJA and BCHB regions (Figures 75 and 76).

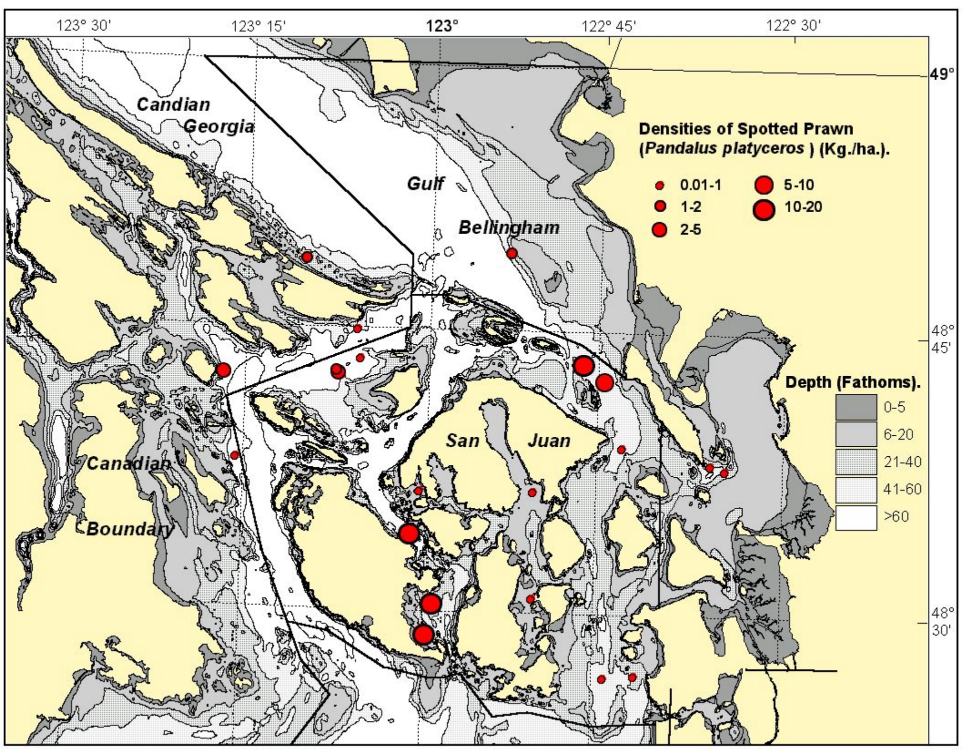

Figure 73. The distribution of spotted prawn station densities (kg/ha) in the Strait of Georgia, San Juan Archipelago, and adjacent waters.

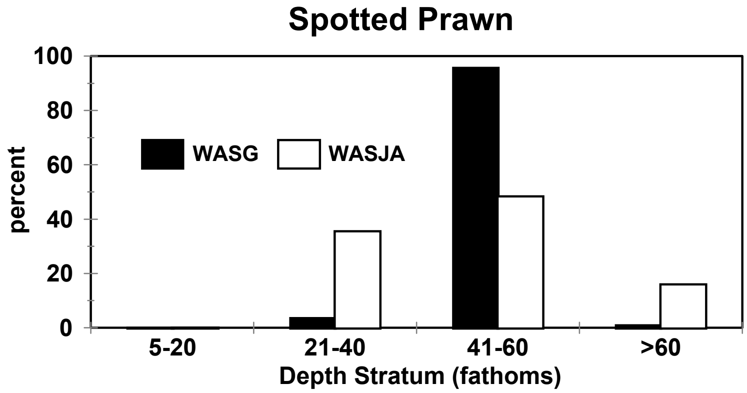

Figure 74. Depth distribution of spotted prawn.

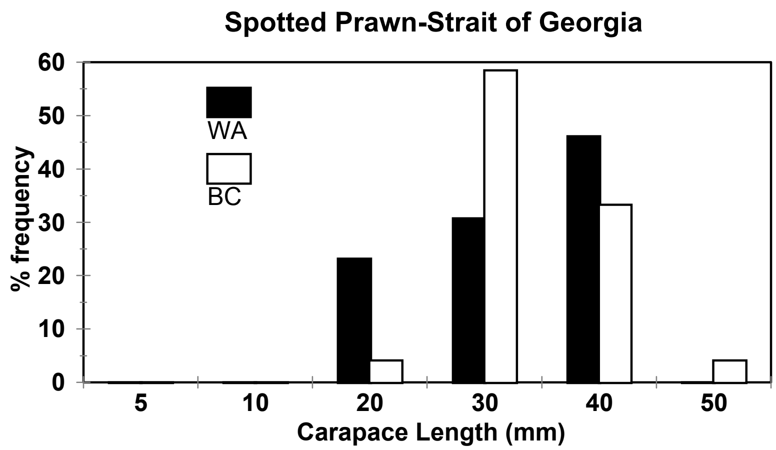

Figure 75. Carapace length frequency distribution of spotted prawn in the WA and BC Strait of Georgia.

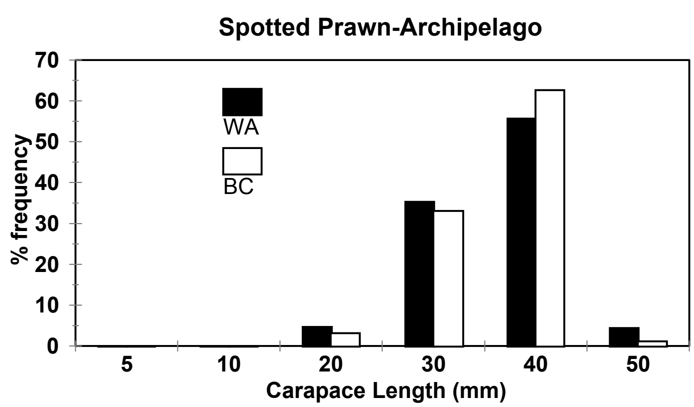

Figure 76. Carapace length frequency distribution of spotted prawn in the WA San Juan Archipelago and BC Haro Strait and Boundary Pass.

Table 26. Numerical (x1000) and biomass (mt) abundance of spotted prawn in the Southern Strait of Georgia, San Juan Archipelago, and adjacent waters.

Stratum	5-20 fm	21-40 fm	41-60 fm	>60 fm or 60-120 fm	>120 fm	Total
Washington Strait of Georgia						
Abundance		4.1	72.4	1.9		78.4
(% CV)		100.0	95.9	100.0		88.8
Biomass (mt)		0.1	2.2	0.0		2.3
(% CV)		100.0	97.9	100.0		93.8
British Columbia Strait of Georgia						
Abundance			87.5	2.1	0	89.6
(% CV)			100.0	100.0		97.7
Biomass (mt)			1.9	0.0	0	1.9
(% CV)			100.0	100.0		99.5
San Juan Archipelago						
Abundance	12.1	3806.9	4706.6	1212.9		9736.6
(% CV)	73.7	98.5	52.4	80.7		47.2
Biomass (mt)	0.1	105.8	144.3	47.7		297.9
(% CV)	67.1	97.8	53.1	81.4		45.1
British Columbia Haro Strait and Boundary Pass						
Abundance				171.4		171.4
(% CV)				96.1		96.1
Biomass (mt)				5.8		5.8
(% CV)				96.8		96.8

Benthic Marine Debris

Almost 240 mt (26.3% CV) of human-generated marine debris was estimated from the benthos among the four study areas (Table 27). The bulk of the material was found in the WASJA (148 mt, 34.3% CV) seconded by the WASG where there was 83 mt (43.6% CV). The BCSG, in contrast only contained 8 mt (95.5% CV) in the deep waters that were surveyed. The BCHB only had trace amount of debris. Fifty-four percent of the debris consisted of derelict fishing gear primarily in the form of crab and shrimp pots. Glass constituted 20% of the debris, plastic was 13%, aluminum was 0.2% and other material was 12.5% of the total debris material by weight. Most of the debris in the WASG and WASJA consisted of fishing gear. Glass was the second greatest amount of debris in the WASG followed by plastic. In the WASJA, plastic and glass occurred in equal amounts but other debris was the second greatest category of debris. Plastic was the primary material in the BC study areas.

Table 27. Marine debris estimates (metric tons) from the Strait of Georgia, San Juan Archipelago, and Haro Strait.

	WA SOG		BC SOG		SJA		BC HS & BP	
Category	**mt**	**% C.V.**	**mt**	**% C.V.**	**mt**	**% C.V.**	**mt**	**% C.V.**
Plastic	9.2	68.6	7.8	99.6	13.9	86.1	0.04	100.0
Glass	33.5	36.7	0		13.9	63.4	0	
Aluminum	0.5	72.4	0		0.01	100.0	0	
Fishing gear	35.6	87.7	0.04	100.0	93.9	49.9	0	
Other man-made debris	3.7	57.1	0.3	100.0	25.8	87.1	0	
Total	82.5	43.6	8.1	95.2	147.5	34.3	0.04	100.0

DISCUSSION

The successful completion of the 2001 trawl survey in the WA and BC Strait of Georgia repeats, in part, a survey conducted in the transboundary waters in 1997. For the San Juan Archipelago and BC Haro Strait and Boundary Pass, the survey accomplished the first regional survey of benthic fishes and large invertebrates in these waters shared by British Columbia and Washington. The data and estimates that resulted from the survey will be valuable for determining fishery potential and impact, planning for conservation, and achieving an understanding of the factors controlling fish and invertebrate distributions. The information also serves as an environmental baseline for evaluating changes in the transboundary waters due to management actions, catastrophic damage, or natural changes.

The survey failed, however, to adequately sample the 5-20 fm and 21-40 fm depth strata in the two BC survey areas. For the BCSG, rocky habitat and steep walls were the primary habitats in the shallow strata and prevented successful trawling at the randomly selected stations. During the earlier survey in 1997 (Palsson et al., unpublished manuscript), the larger scope of the survey provided greater opportunities to sample shallow substrates with unconsolidated sediments and less vertical relief in areas to the north of the 49^{th} parallel, the northern boundary of the 2001 survey. The BCBP shallow strata were not adequately sampled because of the limited time available to complete the survey. The deeper strata in this region were sampled but only 2 stations were occupied in the 41-60 fm stratum and 4 stations in the >60 fm stratum. Of minor note, the stratum areas of the 2001 WASG survey were greater (87.6 thousand hectares) than those reported in 1997 (84.7 thousand hectares) because newer bathymetric data were used to define the areas and because the Washington State Plane datum was used instead of a standard Mercator projection. All comparisons between affected 1997 and 2001 estimates will be made with the newer area values.

The survey found that benthic fishes were relatively diverse in the area, and that the two WA survey areas had approximately the same species richness. Species richness was less in the BC survey areas most likely due to the restricted nature of the surveys in the two regions. Species richness in the WASG was greater in the 2001 survey with 67 species compared to 63 species observed in the 1997 survey of the same region. Species richness in the 2001 BCSG survey was 43, much less than the 76 observed during the more expansive 1997 survey. For the Strait of Georgia survey in 2001, spotted ratfish was the dominant fish species, and flatfish, other species, and dogfish were the less dominant biomasses. The 1997 and 2001 species compositions were similar in terms of biomass: Spotted ratfish also dominated in 1997 the species followed by other species, English sole, and dogfish. Dungeness crabs and pandalid shrimps dominated the invertebrate species surveyed during 2001. Fish species richness in the WASJA was comparable to the WASG with 64 species that were collected among 40 stations, ten fewer than the WASG. Only 30 fish species were encountered in the BCHB at the six sampled stations. The WASJA had the greatest species richness of invertebrates with 81 species compared to 75 species in the WASG, 53 species in the BCSG, and 38 species in the BCHB.

The 2001 survey in the WASG was the sixth in a series of bottom trawl surveys and provides the basis to evaluate trends in population abundance from 1987 to 2001. Total fish biomass estimated from the 2001 results was the highest point estimate for the WASG ever recorded (Figure 77). However, wide 95% confidence limits encompassed the point estimates of the 1987, 1994, and 1997 surveys indicating stability among recent survey estimates comparable to the first survey estimate. The 2001 confidence limits for total fish biomass did not overlap the point estimates of the 1989 and 1991 surveys indicating they were significantly lower than the 2001 biomass estimate. Not all individual fish species mimicked this pattern (Table 28). Spiny dogfish biomass was slightly greater in 2001 than the biomass estimated in 1997 but their overlapping confidence limits do not suggest biomass has changed. However, the biomass estimates are significantly lower by more than a factor of two than any previous survey estimates indicating a substantial population decline since 1987. Ratfish biomass is four to six times greater during the most recent three surveys but whereas the 1994 and 1997 values are significantly different than earlier surveys, the 2001 estimates are not distinguishable from other previous surveys because of imprecision. Total skate biomass has trended lower in during the last two surveys, but the biomass estimates are not significantly different than any other survey estimate. For Pacific cod, 1991 was the least biomass ever estimated and was significantly different from all other surveys. The 2001 cod biomass was the second lowest ever estimated and the 95% confidence limits from the 1997 and 2001 survey biomasses did not overlap indicating a recent decline. The walleye pollock biomass was the second highest ever estimated and was similar to the 1987 biomass. The recent estimate was significantly higher than the biomasses estimated between 1989 and 1997 indicating a recent population increase. Lingcod were not detected in the WASG trawl survey until 1997 when a biomass of 0.3 mt was estimated. Lingcod biomass was significantly greater in 2001 with 11 mt. The sablefish population biomass has fluctuated over the period of the trawl surveys but the 2001 estimate is significantly lower than the 1987 and 1991 estimates. Sablefish were not observed in the 1997 WASG survey. For sculpins as a complex of species, biomass has fluctuated among the survey years and was the highest ever estimated during 2001. However, wide confidence limits did not detect any significant trend. Pacific sanddab were not detected during the 1987 survey and biomasses were extremely low in 1989 and 1991. Biomasses were significantly higher for Pacific sanddab during the three subsequent surveys but these estimates were not different from one another. Arrowtooth flounder biomasses have trended from high and variable populations during the first two trawl surveys to very low biomasses during recent surveys. Population biomasses since 1994 have been significantly lower than the 1987 biomass. Rex sole biomass has fluctuated with no significant trend as has flathead sole biomass. Butter sole biomass has been variable with the 2001 biomass significantly greater than the biomasses estimated during the 1989 to 1994 period. The 2001 biomass was similar to the 1997 biomass estimate. The point estimates for total rock sole biomass has varied from highs in 1989 and 2001 to almost undetectable populations in 1987 and 1991. The most recent estimate is significantly higher than these estimates from nadir years. Dover sole biomasses have been consistently similar during the last three surveys that were also similar to the 1987 estimate. The 1996, 1997, and 2001 estimates were significantly greater than the 1989 and 1991 biomass estimates for Dover sole. English sole biomass was low from 1987 to the 1994 survey and then increased in 1997 and 2001. The 2001 biomass was significantly greater than the biomass estimates from the first four surveys. Starry flounder biomass trends are similar to the trend for English sole. Biomass was low during the first four surveys and then increased in 1997 and then again in 2001. The recent biomass estimate was significantly greater than the first for survey biomass estimates. Sand sole biomass has been similar between 1991 and 2001 but all but one of these estimates were greater than the biomass estimates from the

1987 and 1989 surveys. The 2001 estimate of total flatfish biomass is three times greater than the biomasses estimated during the first four bottom trawl surveys. Biomass has increased since 1997 and the 2001 estimate is significantly greater than those estimates from the 1987-1994 period.

The series of six survey also provides the basis to compare the trend in Dungeness crab biomass. Total Dungeness crab biomass in 2001 was similar to the1997 biomass but both are twice as high compared to previous survey estimates. The confidence limits of the latest two surveys do not overlap those prior to 1994 indicating true population increases that are coincidentally reflected in more successful crab fisheries during the past five years.

For all fish sampled among the four regions, the sampling intensity during the survey achieved an 11% coefficient of variation for biomass and 21% CV for abundance. However, the goal of the survey was to estimate biomasses for total fishes and key species with a precision of a 30% CV or less in individual regions. For the species highlighted in this report, the precision goal was reached in slightly less than half of the occurrences in the fully surveyed regions, and only met the goal in one fourth of the cases in the BC regions. However, not all of the species presented were expected to have precise population estimates especially for semi-pelagic species such as Pacific whiting and walleye pollock and species that typically inhabit rocky habitats such as lingcod and spotted prawn. The 30% CV goal was met in the WASG for spiny dogfish, total skates, Pacific whiting, English sole, sand sole, Dover sole, and both female and male Dungeness crabs. The goal was met in the WASJA for spiny dogfish, total skates, English sole, total rock sole, Dover sole, and both female and male Dungeness crab. In the BCSG, the goal was met for spotted ratfish, Pacific whiting, English sole, and Dover sole. In the BCHB, the goal was met only for spiny dogfish and total rock sole. One notable exception for not meeting the goal was for spotted ratfish in the WASG. Since this was the dominant species, the poor precision of this estimate contributed to a higher than expected 21% CV for the total fish biomass which usually approaches 10% for other surveys. Another exception to the precision goal was for starry flounder, a shallow water species that despite sampling 20 stations in the 5-20 fm depth stratum for the WASG, had a poor CV of 36%. To improve precision, future survey designs should be considered with fewer strata to decrease survey complexity and increase sample sizes. Most of the species presented had either a shallow or deep depth distribution pattern generally separated at the 40 fm isobath suggesting that the survey regions should only consist of two depth strata.

The precision goals were generally achieved for key benthic species, but the potential bias of the trawl survey could not be evaluated. The abundance and biomass estimates resulting from a trawl survey are dependent on a number of assumptions, the foremost of which is that all of the fish and invertebrates are captured in the path of the trawl (Gunderson 1993). We defined the net width as the distance between the wings of the net, but more recent definitions consider the net width as the width between the otter doors. Therefore, the catch process is composed of the fish that are herded by the bridles into the path of the net and the fish that enter into the net. Both of these components have a potential for fish to escape past the bridles or over or under the net (Somerton et al. 1999). The catching process potentially suffers from three sources of bias: vertical herding, horizontal herding, and escapement. These assumptions have seldom been verified, but recent work has evaluated herding and net efficiency for a larger version of the research trawl used in the transboundary survey. For rock sole, English sole, Pacific sanddab, rex sole, flathead sole and Dover sole, the horizontal herding by the bridle gear was found to be significant and resulted in bridle efficiencies of 0.07 to 0.4 ratios (Somerton and Munro 2001). For Pacific sanddab and English sole, bridle efficiency was dependent upon the length of the fish with larger fish not being as efficiently herded by the bridle. While 48% of the rock sole caught in the net resulted from herding, the net escapement was not examined and may have compensated for the bias due to the bridle herding. Net escapement has been examined for snow and Tanner crabs using the same net and net efficiencies ranged from 81% to 82% for male Tanner crabs and to 47% for mature female Tanner crab (Somerton and Otto 1999). Net efficiency decreased as carapaces widths approached 50 mm but then increased asymptotically with length. How the smaller Eastern Trawl used in this survey performed in terms of bridle and net efficiency are unknown. Studies similar to those conducted with the survey nets used by the National Marine Fisheries Service are suggested for the Eastern to in order to understand the potential for fishing bias. Other comparisons to known population sizes such as those estimated through virtual population analyses, tagging studies, or other comprehensive survey techniques (Somerton et al. 1999) can be used to examine the catchability of trawls. The population estimates presented have the underlying assumption that the bias due to herding into the path of the net equals the bias of fish that escape over or under the net and that the net width serves as the most likely width swept. The WDFW trawl survey may be an effective population estimation tool to manage commercial and recreational groundfish and crab fisheries if experimental studies are conducted to estimate net efficiency and confirm this assumption.

Other factors may influence whether the trawl survey estimates reflect the true population of fishes and large invertebrates. Because the survey net and vessel could not sample effectively in waters less than 5 fm in depth, segments of the fish population were certainly missed. Shallow water groundfish species and juvenile stages, especially starry flounder which can occur in high abundance in the estuarine portions of Puget Sound rivers (McCain et al. 1982), most likely were underestimated during our survey. Future surveys might consider employing a smaller vessel and net to sample shallow waters as a complimentary survey to the deeper water survey. Migrations of species or stocks within the study area may also affect the conclusions derived for fishery and ecosystem management. If substantial numbers of English sole or other species migrate into or out of the area during the year (Ketchen et al. 1983), then the survey may either overestimate or underestimate the population exposed to fisheries or other ecosystem stressors. Our trawl survey results also underestimated groundfish species that spend substantial time in the midwater. Pacific whiting and walleye pollock are primarily pelagic species and were most likely underestimated.

The total survey area encompassed 2,108 km^2 of benthic habitats between the depths of 5 fms and over 100 fms. The WASG represented about 42% of the surveyed area, the WASJA 38%, the BCSG 16%, and the BCHB was 6% of the surveyed area. Species abundance in terms of numbers and biomass was not uniformly distributed over these two survey areas. Sixty-four percent of the numerical abundance of fishes occurred in the WASG, while only 24% of the numerical abundance occurred in the WASJA. Biomass was approximately distributed proportionately to area among the four survey areas with 46% occurring in the WASG, 18% in the BCSG, 31% in the WASJA, and 5% in the BCHB. Biomass was not distributed in proportion to regional areas for individual species. Deep-water species occurred in higher proportions in the BCSG that had 23% of the ratfish biomass for its 16% of the survey area.

Thirty percent of the cod biomass occurred there, 70% of the whiting biomass, and 27% of the Dover sole. The WASG had higher proportions of the shallow water species than would be predicted from the 42% of the survey area. Almost three quarters of the English sole biomass occurred in the WASG, 96% of the sand sole biomass, 97% of the starry flounder biomass, 53% of the Pacific sanddab biomass, and 60% of the rock sole biomass. The WASJA had higher proportions of walleye Pollock biomass (42%), spiny dogfish biomass (52%), and lingcod biomass (68%) than the 38% area would predict.

The differences among the geographical distributions of key species and among the nature of the bathymetry and habitat have important implications for the management of marine resources in transboundary waters. The extensive transboundary trawl survey of 1997 revealed distinct patterns in depth distributions in the Strait of Georgia that were confirmed during the 2001 survey. The 1997 Transboundary Trawl Survey in the Strait of Georgia found that only deep water species such as Pacific cod, Pacific hake (whiting), walleye pollock, English sole, and Dover sole were candidates for transboundary management because the deep Malaspina Trough aggregated these species in the area around the international border. Shallow-water species such as the rock and sand soles and starry flounder in the Strait of Georgia were more restricted to the perimeter of the basin and were less likely candidates in their adult stages for two independent fisheries targeting a common stock. The complex distribution of depths, sediment characteristics, current patterns and patterns of exploitation likely play a great role in determining the species distribution patterns, but until detailed bottom substrate information is obtained, understanding the nature of species distributions to their habitats will remain unclear.

Transboundary intermingling patterns have been documented by Ketchen et al. (1983) and Westrheim and Pedersen (1986). Review of tagging data identified Pacific cod is a transboundary species in the Strait of Georgia with spawning grounds in Nanoose Bay but were often recovered by fisheries in the Washington Strait of Georgia (see also Palsson 1990). Tagging data also revealed that spiny dogfish from the east coast of Vancouver Island showed considerable wandering across the deep water of the across the Strait of Georgia (Ketchen et al. 1983), and recent studies of spiny dogfish in BC found substantial movements between the Strait of Georgia and the coast (McFarlane and King 2003). Rock sole was identified as a shallow-water and less mobile species probably existing as numerous populations around the periphery of the Georgia Strait, and starry flounder was probably restricted in a similar manner (Ketchen et al. 1983).

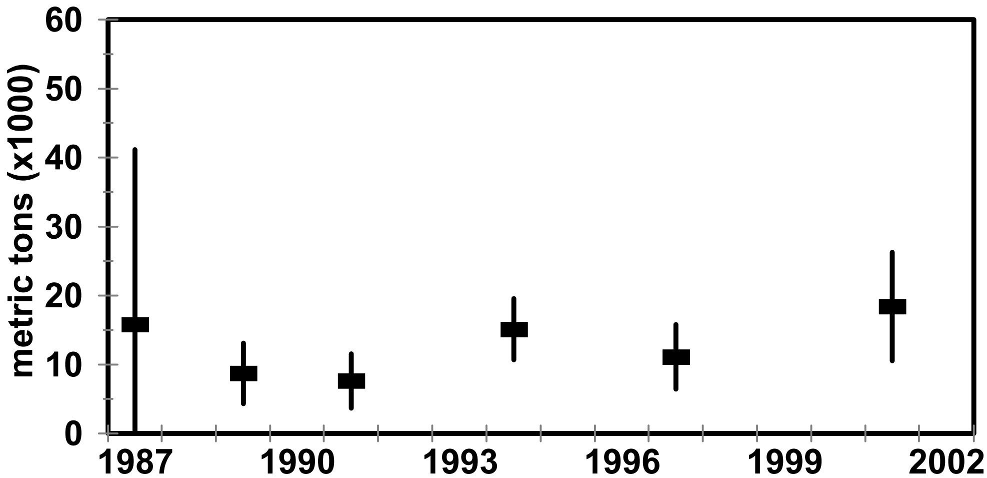

Figure 77. Total fish abundance (mt) and 95% confidence limits estimated during bottom trawl surveys in the Washington Strait of Georgia.

Commercial bottom trawl and other bottomfish fisheries targeting flatfishes such as English sole are active in the WASG. Recent annual harvests of English sole range from 136 mt to 360 mt and for dogfish range from 45 mt to 450 mt. Pacific cod has been harvested in excess of 560 mt per year, but recent quotas of 27 mt have limited this harvest in the Strait of Georgia.

The estimates from the 2001 bottom trawl survey can be compared to the commercial catches of key species during the subsequentf twelve-month period to the spring survey and a robust measure of the annual exploitation rate can be estimated. The WA harvest of English sole in between the WASG and WASJA was 376 mt and compared to the biomass estimate of 3,561 mt, an approximate annual exploitation rate is 10.6% (Table 29). This was the highest harvest of any species in the WASG and had the second highest exploitation rate. The halibut exploitation rate was the highest in WA at 14.6% of the 19 mt estimated in the entire study region. Most of the harvest rates ranged from 3% to 6% for key species including skates, Pacific cod, starry flounder and sand sole. The exploitation rate for dogfish was 1.1%, a rate that is likely commensurate for this late-maturing and long-lived species. Other species such as spotted ratfish, lingcod, walleye pollock, and Dover sole had exploitation rates in the Washington study areas of less than 1% due to restricted or non-existent fisheries. In the BC study areas, little commercial fishing apparently occurred during the 12 month period subsequent to the trawl survey: The entire catch of key species weighed less than one metric ton. BC exploitation rates based upon the limited survey areas were far less than one percent.

This survey was financially supported by the Groundfish Unit of the Washington State Department of Fish and Wildlife, by the Fish Task of the Puget Sound Ambient Monitoring Program, and by the Puget Sound Water Quality Action Team. These entities are participants in

the Transboundary Process established by the Environmental Cooperative Agreement in 1992. Along with providing fisheries managers and scientists with stock assessment information for management in shared waters, the survey serves the Agreement goals of identifying shared marine resources of a significant portion of the ecosystem. These survey data including population estimates, distributions, and community attributes may be used as a baseline for future comparisons and evaluations of changes in the marine environment as a result of natural and human-induced stressors. All future surveys conducted in the shared and transboundary waters in the Puget Sound/Georgia Basin need to encompass all significant oceanographic units regardless of political boundaries and need to consider the impacts of resource management on commonly shared populations.

Table 28. Biomass estimates (mt) and coefficients of variation from the 2001 trawl survey.

	1987		1989		1991		1994		1997		2001	
Species	**mt**	**%CV**	**mt**	**%CV**	**mt**	**%CV**	**mt**	**%CV**	**mt**	**%CV**	**mt**	**%CV**
Dungeness crab	1261.4	67.4	1995.8	38.8	1079.3	35.6	1101.3	19.8	4405.7	27.2	5262.6	18.4
Male Dungeness crabs									3443.4	35.6	3557.9	17.0
Female Dungeness crabs							3.6	79.1	962.3	21.6	1704.7	27.6
Spiny dogfish	4932.3	97.3	4071.2	39.9	4057.2	40.4	3534.5	22.9	779.9	18.6	1239.3	18.1
Spotted ratfish	739.2	41.0	779.8	36.5	352.0	43.7	6314.9	27.8	3930.4	34.1	6802.0	52.1
Big skate	604.1	92.4	885.3	51.1	684.2	47.9	177.5	41.6	456.4	34.4	567.2	35.6
Longnose skate	29.2	100.0	335.5	64.3	235.8	66.7	837.1	28.4	107.3	30.2	65.9	29.7
Total skates & rays	775.3	72.3	1350.1	37.3	929.8	34.7	1051.6	21.7	628.7	24.8	636.1	31.8
Plainfin midshipman	2.7	62.9	218.3	84.7	134.1	51.1	218.9	40.9	188.4	34.8	251.1	49.8
Pacific cod	145.0	30.2	145.7	32.3	19.3	55.2	203.7	25.6	264.8	21.7	138.4	28.6
Walleye pollock	859.9	41.8	232.7	25.4	102.0	38.0	109.5	23.2	175.6	20.5	691.8	29.8
Pacific whiting (hake)	105.4	35.3	183.7	44.4	77.2	45.6	424.5	31.8	351.2	18.6	127.9	50.0
Total eelpouts	3.0	51.4	17.1	59.9	14.9	50.5	8.4	43.1	12.4	40.6	21.5	41.2
Copper rockfish							32.1	100.0	6.0	100.0		
Quillback rockfish			8.4	100.0			24.3	92.8	50.5	59.4	1.4	100.0
Total rockfish	1.0	66.0	8.4	100.0	0.2	100.0	56.8	96.3	64.5	58.3	3.5	54.2
White-spotted greenling			4.2	51.9	6.4	53.2	18.7	30.4	1.7	41.1	35.2	42.8
Lingcod									0.3	100.0	10.9	41.6
Sablefish	18.2	42.5	3.2	100.0	20.5	45.8	0.3	100.0			1.2	71.2
Buffalo sculpin			32.8	86.2	3.7	100.0	7.5	78.9	3.5	46.1	214.3	54.7
Pacific staghorn sculpin	0.5	100.0	1.1	54.8	15.4	87.9	29.0	57.9	30.8	25.5	48.6	36.7
Great sculpin			19.5	71.7	30.6	86.2	86.6	50.7	28.9	63.4	611.2	77.9
Cabezon			22.0	100.0			11.5	100.0	4.4	100.0		
Roughback sculpin							2.7	57.2	4.8	71.6	1.9	52.0
Total sculpins	138.1	99.6	78.1	82.0	52.5	61.0	142.9	36.4	77.2	25.4	895.4	65.0
Sturgeon poacher	1.2	88.6	2.1	43.6	6.6	74.7	5.4	30.1	19.2	72.5	10.8	37.1
Shiner perch	2153.7	100.0	81.1	87.7	6.9	62.8	7.7	46.8	102.7	44.6	749.3	91.6
Pacific sanddab			7.2	30.6	23.5	73.1	420.2	37.8	257.8	34.2	188.9	31.1
Speckled sanddab			10.9	81.0	7.2	45.6	41.9	36.5	21.0	29.3	17.5	27.8
Arrowtooth flounder	108.8	34.7	104.3	65.9	33.0	17.5	15.3	26.3	5.8	63.0	7.4	46.0
Rex sole	76.2	47.6	24.2	47.7	28.1	28.9	57.7	38.5	27.3	28.2	17.2	27.0
Flathead sole	293.8	88.1	81.8	54.2	178.0	49.2	152.3	49.9	198.6	33.3	523.0	56.5

Table 28. Biomass estimates (mt) and coefficients of variation from the 2001 trawl survey.

	1987		1989		1991		1994		1997		2001	
Species	**mt**	**%CV**	**mt**	**%CV**	**mt**	**%CV**	**mt**	**%CV**	**mt**	**%CV**	**mt**	**%CV**
Butter sole	172.1	100.0	16.6	83.8	7.2	74.0	22.3	60.8	185.4	43.8	167.0	33.9
Total rock sole	13.2	83.6	437.0	92.5	36.5	61.3	312.2	40.9	152.6	34.9	591.1	46.9
Slender sole	6.1	64.3	1.3	82.5	1.9	73.9	10.1	62.7	7.3	51.6	14.0	37.4
Dover sole	155.7	34.3	58.0	51.5	36.1	15.3	143.5	23.6	137.6	13.7	156.9	13.9
English sole	1324.6	45.7	412.6	41.2	514.1	49.4	1072.2	33.1	2779.5	66.9	3339.6	22.4
Starry flounder	61.1	100.0	50.3	50.8	68.9	66.0	144.1	41.3	324.0	39.8	805.5	36.4
Sand sole	1.6	100.0	41.6	24.5	128.6	51.7	122.7	28.8	140.5	24.5	179.1	27.4
Total flatfish	2268.9	51.9	1245.8	38.6	1062.9	39.2	2515.3	22.7	4242.4	44.5	6007.8	18.7
Total Fish	15849.3	80.3	8681.8	25.3	7618.7	25.9	15090.2	14.7	11056.7	21.2	18370.5	21.4

Table 29. Biomass and commercial catch comparison for principal species estimated from the 2001 trawl survey.

Species	WA Biomass (mt)	2001 Washington Catch (mt)	WA Exploitation Rate (%)	B.C. Biomass (mt)	2001 B.C. Catch (mt)	B.C. Exploitation Rate (%)	Southern SG Exploitation Rate (%)
Spiny dogfish	3609.8	39.6	1.1	961.2			0.4
Skates	1196.5	35.0	2.9	258.2			
Spotted ratfish	12610.3	0	0	5247.7			
Pacific cod	322.5	17.6	5.5	196.6	0.18	0.6	0.2
Walleye pollock	1541.4	0	0	226.3			
Lingcod	46.9	0.2	0.4	5.9	0.01	0.1	0.03
English sole	3561.2	376.3	10.6	1009.0	0.02	0.1	0.003
Rock sole	968.1	1.4	0.1	10.6	0.06	0.1	0.01
Starry flounder	832.7	29.9	3.6	0			
Sand sole	186.6	5.6	3.0	0			
Dover sole	298.3	0	0	141.5	0.03	0.2	0.03
Pacific halibut	19.2	2.7	14.6	0			0.8

LITERATURE CITED

Gunderson, D.R. 1993. Surveys of Fisheries Resources. John Wiley & Sons, New York, 248 pages.

Gustavson, R.G., W.H. Lenarz, B.B. McCain, C.C. Schmitt, W.S. Grant, T.L. Builder, and R.D. Methot. 2000. Status review of Pacific hake, Pacific cod, and walleye pollock from Puget Sound, Washington. NOAA Technical Memorandum NWFS-NWFC-44, 275 p.

Ketchen, K.S, N. Bourne, and T.H. Butler. 1983. History and present status of fisheries for marine fishes and invertebrates in the Strait of Georgia, British Columbia. Can. J. Fish. Aquat. Sci. 40:1095-1119.

McCain, B.B., M.S. Myers, U. Varanasi, D.W. Brown, L.D. Rhodes, W.D. Gronlund, D.G. Elliott, W.A. Palsson, H.O. Hodgins, and D.C. Malins. 1982. Pathology of two species of flatfish from urban estuaries in Puget Sound.

McFarlane, G.A., and J.R. King. 2003. Migration patterns of spiny dogfish (*Squalus acanthias*) in the North Pacific Ocean. Fishery Bulletin 101:35-367.

Mosher, D.C. and Johnson, S.Y. (eds.), Rathwell, G.J., Kung, R.B., and Rhea, S.B. (compilers), 2000. Neotectonics of the eastern Juan de Fuca Strait; a digital geological and geophysical atlas. Geological Survey of Canada Open File Report 3931.

Quinnell, S. and C. Schmitt. 1991. Abundance of Puget Sound demersal fishes: 1987 research trawl survey results. Wash. Dept. Fish. Prog. Rep. No. 286. 267 p.

Palsson, W.A. 1990. Pacific cod (*Gadus macrocephalus*) in Puget Sound and adjacent waters: Biology and stock assessment. Wash. Dept. Fish. Prog. Rep. No. 112, 137 p.

Palsson, W.A., J. C. Hoeman, G.G. Bargmann, and D.E. Day. 1996. 1995 status of Puget Sound bottomfish stocks. Wash. Dept. Fish and Wildlife, Olympia, 99 p.

Reeves, J.E., and G.S. DiDonato. 1972. Effects of trawling in Discovery Bay, Washington. Washington Department of Fisheries Technical Report No. 8, 45 p.

Saunders, M.W. 1990. Dogfish. pp. 173-183. *In:* Tyler, A.V. and J. Fargo (ed.). Groundfish stock assessments for the west coast of Canada in 1989 and recommend yield options for 1990. Can. Tech. Rep. Fish. Aquat. Sci. 1732:343 p.

Scheaffer, R.L., W. Mendenhall, and L. Ott. 1979. Elementary Survey Sampling, Second Edition. Duxbury Press, North Sictuate, Mass. 278 pages.

Schmitt, C., J. Schweigert, and T.P. Quinn. 1994. Anthropogenic influences on fish populations of the Georgia Basin. pp. 218-252. *In:* Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait. Can. Tech. Rep. Fish. Aquat. Sci. 1948:390.

Somerton, D.A., and P. Munro. 2001. Bridle efficiency of a survey trawl for flatfish. Fishery Bulletin 99:641-652.

Somerton, D.A., and R.S. Otto. 1999. Net efficiency of a survey trawl for snow crab, *Chioneocetes opilio*, and tanner crab, *C. bairdi*. Fishery Bulletin 97:617-625.

Somerton, D., J. Ianelli, S. Walsh, S. Smith, O.R. Godo, and D. Ramm. Incorporating experimentally derived estimates of survey trawl efficiency into the stock assessment process: a discussion. ICES Journal of Marine Science 56:299-302.

Stout, H.A., R.G. Gustavson, W.H. Lenarz, B.B. McCain, D.M. VanDoornik, T.L. Builder, and R.D. Methot. 2001a. Status review of Pacific herring (Clupea pallasi) in Puget Sound, Washington. NOAA Technical Memorandum NMFS-NWFSC-45, 175 p.

Stout, H.A., B.B. McCain, R.D. Vetter, T.L. Builder, W.H. Lenarz, L.L. Johnson, and R.D. Methot. 2001b. Status review of copper rockfish (Sebastes caurinus), quillback rockfish (S. maliger), and brown rockfish (S. auriculatus) in Puget Sound, Washington. NOAA Technical Memorandum NMFS-NWFSC-46, 158 p.

Washington Department of Fish and Wildlife. 1996. Puget Sound/Georgia Basin 1995 transboundary survey: analytical results for Georgia Basin bottomfish survey, Final Report. Wash. Dept. Fish and Wildlife, Olympia, Washington, 23 p + append.

Westrheim, S.J., and M.G. Pedersen. 1986. An anomalous Pacific cod fishery in Juan de Fuca Strait. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1891,55 p.