# Results From The 2000 Transboundary Trawl Survey of the Eastern Strait of Juan De Fuca and Discovery Bay

by

Wayne A. Palsson, Paul Clarke, Suzanne Hoffmann, and James Beam
Washington Department of Fish and Wildlife
16018 Mill Creek Blvd.
Mill Creek, Washington 98012-1296

**November 2002**

## ABSTRACT

During May 2000, a synoptic survey of the eastern Strait of Juan de Fuca and Discovery Bay was conducted in the transboundary waters of Washington and British Columbia. The survey was designed to estimate the abundances and biomass of key benthic species, identify population trends, and quantify the impact of fisheries. The 2000 survey was also designed to describe the distribution of key commercial fishes that inhabit the Strait of Juan de Fuca and determine which are likely to move between both sides of the international boundary and which species are vulnerable to fisheries on either side of the border.

Standard trawl survey methodology was used to design the stratified systematic 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 approximately ten minutes. The survey was stratified by country and by four depth strata: 5-20 fathoms, 21-40 fm, 41-60 fm, and >60 fm stratum. There were 40 trawl samples collected in the 1,400 $km^2$ of the Washington Strait of Juan de Fuca, and 25 samples collected in the 463 $km^2$ of the B.C. Strait of Juan de Fuca. A special survey of Discovery Bay included 12 trawl samples within the 31 $km^2$ study area.

Seventy-two identifiable species of fish were collected during trawling exclusive of the Discovery Bay survey. Sixty-seven species of fish were collected in Washington, and 48 fishes were collected in B.C. An estimated 35,600 individual fish were caught during the trawl survey, and they weighed 7.9 mt. Thirty-three species of fish were collected during the twelve trawls conducted in Discovery Bay.

There was an estimated population of 132.2 million fish weighing 27,000 mt living in the eastern Strait of Juan de Fuca. Washington contained 112 million bottomfish while B.C. had 20 million. The B.C. bottomfish resource constituted an estimated 8,500 mt while the Washington resource weighed an estimated 19,000 mt. As expected, Discovery Bay had far fewer fish than either of the two larger survey areas. There was a fish population of 2.9 million fish weighing and estimated 90 mt in Discovery Bay.

Spotted ratfish comprised more than 75% of the fish populations in Washington and B.C. Flatfish as a group was the second most dominant species group in Washington while other species contributed together to form the second greatest proportion of any species group in B.C. Biomass and numerical abundance estimates and occurrence patterns were presented for key species including spiny dogfish, spotted ratfish, Pacific cod, walleye pollock, lingcod, English sole, rock sole, starry flounder, sand sole, Dover sole, Dungeness crab, and spotted prawn.

Overall, most populations were in less abundance than estimated during previous surveys of the Washington Strait of Juan de Fuca. Depressed species such Pacific cod and lingcod appear to be in continued low abundance despite fisheries that have been substantially reduced in recent years. Discovery Bay contains almost exclusively juvenile and small individuals of key species once harvested in commercial bottom trawl fisheries.

The geographic distribution and depth preferences of key species and invertebrates resulted in a complex pattern for transboundary management. The shallow banks and deep basins in the central Strait provides habitat for both deep and some shallow waters species resulting in a wide and continuous distribution spanning the international boundary. These continuous distributions require coordination between Washington and Canada if substantial fisheries re-develop in the area.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# INTRODUCTION

During the past 20 years, significant groundfish resources have declined in the eastern Strait of Juan de Fuca (ESJF) prompting reductions in fishing opportunities and prompting reviews for several fish species under the federal Endangered Species Act. The ESJF encompasses the international border between Canada and the United States (Figure 1) and includes Discovery Bay, one of several large embayments adjacent to the eastern Straits. The ESJF is surrounded by a variety of shorelines, marine riparian habitats, and urban and rural areas from metropolitan Victoria, British Columbia, to industrialized Port Angeles, and to undeveloped and residential shorelines common throughout the entire study area. The U.S. portions of the ESJF, especially Discovery Bay, once provided for thriving commercial fisheries for bottomfish but were closed in 1994 to most commercial fisheries targeting bottomfish. Recreational fisheries have also diminished in the eastern Strait of Juan de Fuca with substantial reductions in the harvest opportunities for rockfish, lingcod, and other groundfish species. 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 fisheries in British Columbia (B.C.) were more widespread in the Strait of Juan de Fuca than the fisheries are now.

To date, most marine resource management and assessments have occurred independently on either side of the border without much regard for the intermingling of resources between the countries. Bottom trawl surveys have been conducted in the U.S. Strait of Juan de Fuca in 1987 (Quinnell and Schmitt 1991), 1989, and 1991 (Palsson et al. 1997). These previous surveys included all of the Strait of Juan de Fuca east of Sekiu, but were seldom successful working west of Angeles Point.

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 which 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 B.C. and Washington. A trawl survey was conducted during the spring of 1997 in Washington and British Columbian waters of the southern Strait of Georgia (Palsson et al., unpublished report). 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, deepwater species such as Pacific cod, Dover 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. Similar transboundary surveys have never been conducted in the Strait of Juan de Fuca.

The WDFW conducted a bottom trawl survey in the eastern Strait during spring 2000 which included both Washington and British Columbian (Canadian) waters. 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. A special survey was conducted in Discovery Bay to test for the recovery of commercially targeted groundfish species following a decline in commercial catches and subsequent closure.

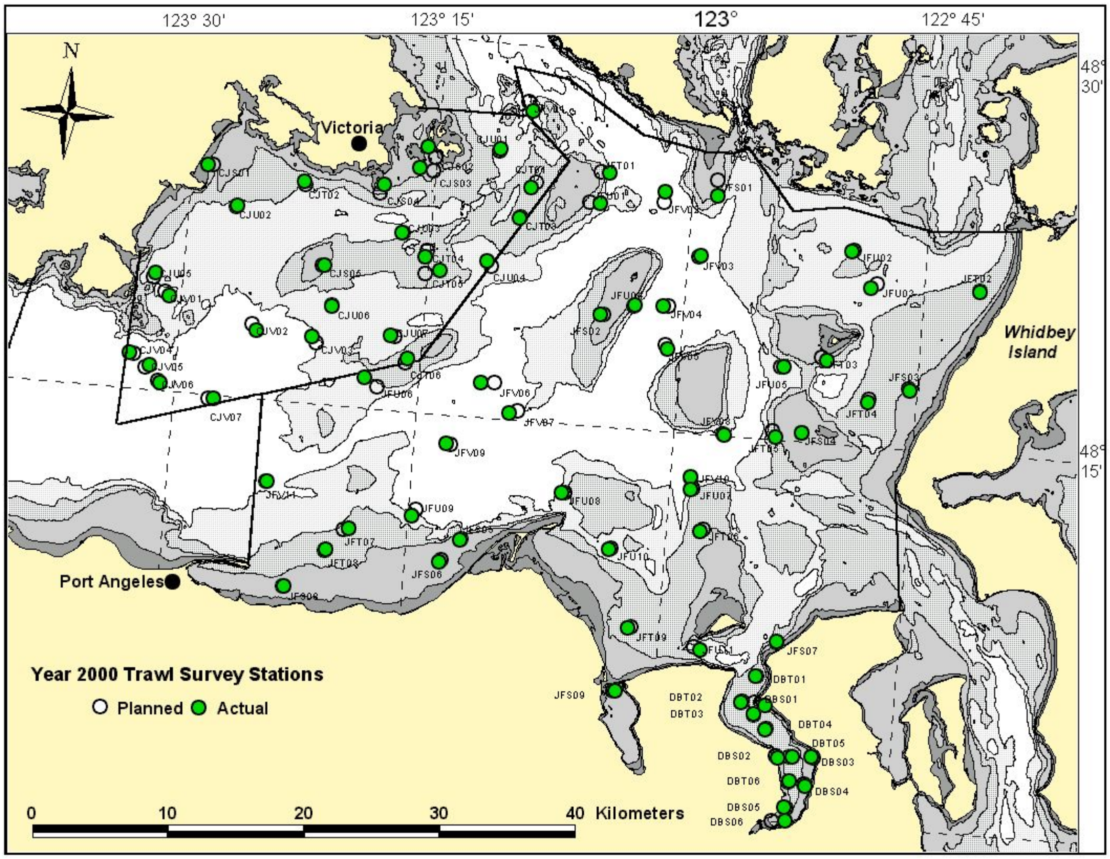


**Figure 1.** Planned and actual stations occupied during the 2000 Transboundary Trawl Survey of the Eastern Strait of Juan de Fuca and Discovery Bay.

# METHODS

## Survey Areas

The scope of the trawl survey included waters deeper than 5 fathoms (fms) in eastern Strait of Juan de Fuca (ESJF) and Discovery Bay. The Washington survey area of the ESJF consisted of those waters east of Ediz Hook to Whidbey Island, north to the San Juan Archipelago, and included Discovery Bay (Figure 1). The Washington survey area corresponded to WDFW Marine Fish Catch Areas 23A, 23B, 23D, 25A, and 25E. In addition, a separate survey area was developed for Discovery Bay (DB) which corresponded to WDFW Marine Fish Catch Area 25E and consisted of those waters of the bay deeper than 5 fms south of a line from Cape George to Diamond Point. The B.C. ESJF survey area included the waters from a straight line from Williamson Head through Race Rocks to the international border and the east to Haro Strait and the International Boundary north to a line due east from Cadboro Point. These areas corresponded to Canadian Department of Fisheries and Oceans (CDFO) Minor Statistical Areas 19-3 and 19-4. The Washington survey area was 1,401 $km^2$ and was three times the area of the B.C. region (463 $km^2$). The Discovery Bay region had an area of 31 $km^2$.

The EJF has a complex pattern of geology and bathymetry (Mosher and Johnson 2000). The deepest depths in the western end of the Washington and B.C. areas range from 70 fms to 100 fms. Just east of Port Angles and north to Victoria, a series of banks rise to depths less than 20 fms and form an irregular sill. Towards the east, the Washington survey area dives back to deeper depths between 70 fms and 80 fms and then deeper to depths of 150 fms in the southern part of Haro Strait. To the south and east, several other banks including Hein Bank, Middle Bank, Dallas Bank, McArthur Bank, Eastern Bank, Partridge Bank and Smith Island form a complex of shallow shelves and deep channels. To the east, Whidbey Island and the entrance to Admiralty Inlet form steep slopes in the nearshore zone. In B.C., the deep waters of the west give rise and are dominated by shallow banks and a shelf ranging in depth from 60 fms to less than 20 fms. Bottom substrate includes bedrock outcroppings from Race Rocks and east along the southeastern margin of Vancouver Island, glacial tills that comprise most of the banks, and marine sediments that overlay most of the subtidal features. Of note are large sand waves just south of Victoria which rise 25 m above the bottom with periods of 500 m which are among the largest of these subtidal features in the world (Mosher and Johnson 2000).

## 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 systematic survey design stratified first on survey area and then by four depth strata: 5-20 fms, 21-40 fms, 41-60 fms, and 60 fms or greater. The survey was planned for 40 trawl stations in the U.S. portion and 25 in the Canadian portion, and 12 in Discovery Bay. 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 Washington Strait of Juan de Fuca. The catch was processed 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 sub-samples were 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 used to estimate abundance and biomass 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 1). 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 when fished had previously been measured and was found to vary with both 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 scopes usually 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 systematic 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 computer 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. The number of 0.25 $nm^2$ cells for each stratum was determined by dividing 0.25 $nm^2$ into the cumulative area of the cells. The sampling intervals (k cells) was then obtained by dividing the total number of 0.25 $nm^2$ cells in a stratum by the number of samples to be taken in the stratum. A random starting point was selected within first series of k cells. Once a starting 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. Successive stations were selected by adding the sampling interval (every k-th cell) to the starting cell. If the station was not adequate for trawling, the next adjacent cell in the sequence was selected and evaluated in a similar manner as above until a suitable cell was found.

The occupation of stations 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 which was interfaced with a dGPS in the wheel house 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 systematically-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 station completion included vessel and worker safety, safe and legal navigation, and avoiding charted or known obstructions. Once a cell 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, 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 moving to an adjacent cell of higher sequential number that was within the same stratum. This provided for flexibility but maintained the systematic nature of the survey design.

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 from when the cable was paid out and vessel powered up to the time when net retrieval was begun was usually lasted ten 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 ten minutes, but a minimum fishing time of five minutes was usually required for a valid station. Occasionally, tow durations exceeded ten 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.

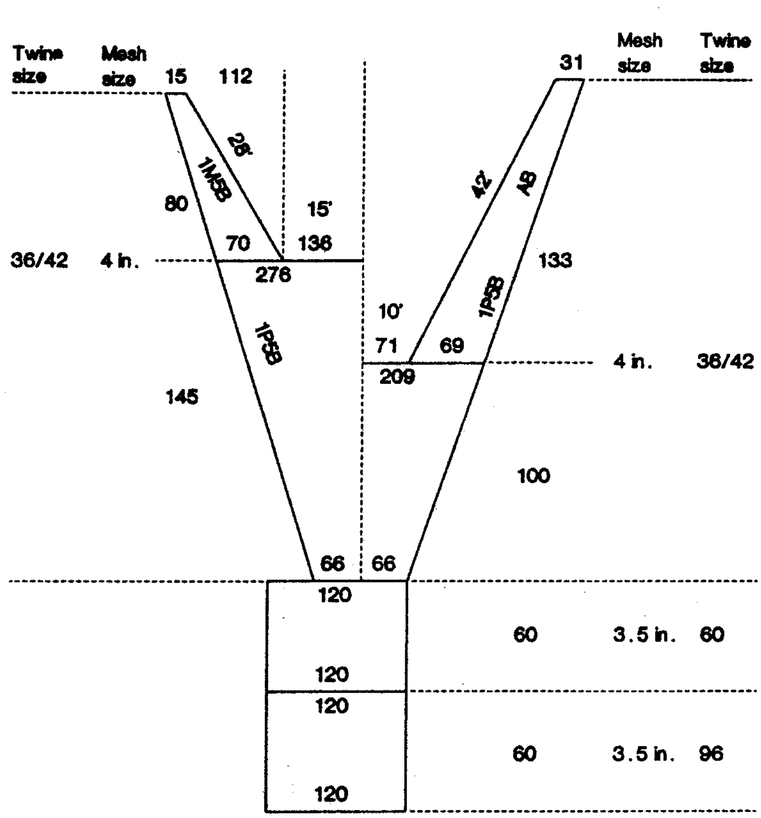


**Figure 2.** Schematic of the 400 mesh eastern bottom trawl used in the 2000 Transboundary Trawl Survey.

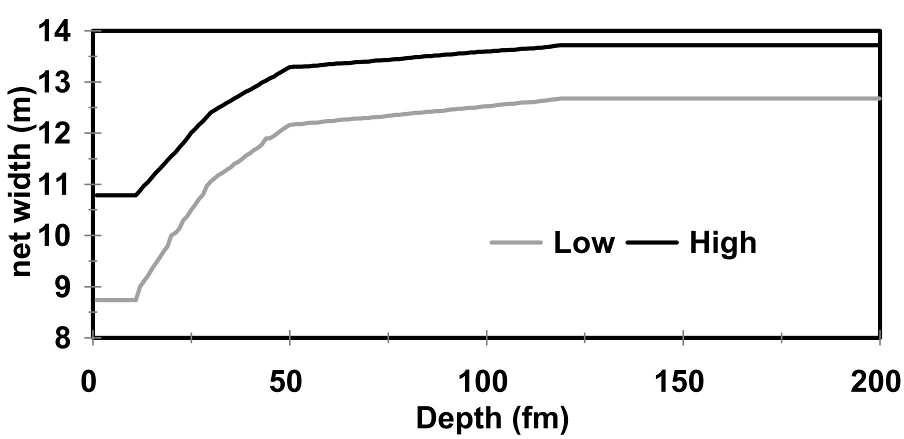


**Figure 3.** Net width as a function of low and high scope (wire out to depth ) and depth.

## 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 counted and weighed, specimens not retained for scientific purposes were discarded overboard.

Specimens were separated into their lowest identifiable taxonomic level 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 containers were 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 was discarded overboard.

## Sub-sampling

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 1.** Net specifications for the 400 mesh Nor'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 which 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, 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.

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 the distal portion of soft-rayed fins including the soft connective tissue from an individual fish. Fin clips were preserved in 95% percent ethanol in a labeled and covered vial.

## Data Management

Primary data consisted of station information, catch composition, and 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 which 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 systematic 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 mensuration 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 weight was 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 %C.V.s for significant taxonomic categories or key species into two databases.

# RESULTS

## Survey Frame and Area Sampled

The Transboundary Trawl Survey began on May 8th in the Washington Strait of Juan de Fuca and concluded on May 26th in B.C. (Table 2). There were 15 days of active sampling: seven days were spent in Washington Juan de Fuca waters, two days in Discovery Bay, five days in B.C., and one day was spent working on both sides of the border. The station selection process resulted in a systematic geographic pattern covering the ESJF and Discovery Bay (Figure 1, Table 2). In terms of area, the area of the survey totaled 186,500 ha of the ESJF (Table 3). The Washington component comprised 75% of the entire ESJF sampling frame. There was a marked difference in the proportions of depth strata between Washington and B.C. The Washington survey frame had greater amounts of habitat in the deepest and shallowest strata than the B.C. survey frame. The greatest areal proportion of any stratum in B.C. was in the 41-60 fm stratum. The area of Discovery Bay consisted only 2.2% of the Washington survey area, and most of the survey area in Discovery Bay was in the 21-40 fm stratum.

A total of 77 trawl stations were successfully trawled during the 2000 Transboundary Trawl Survey (Tables 2 and 3). Among these stations, the trawl swept over a total area of 63 ha which was 0.03% of the survey area in the ESJF. Forty stations were located in the Washington Strait of Juan de Fuca, twenty-five stations were conducted in the B.C. Strait, and an additional twelve stations were conducted in Discovery Bay. In Washington, eleven stations were conducted in each of the two deepest strata, and nine stations in each of the two shallowest strata. In B.C., seven stations were conducted in each of the two deepest strata, five in the shallowest, and six in the 21-40 fm stratum. Six stations were conducted in each of the two Discovery Bay depth strata. Most of the actual locations of the sampled stations were closely located to the pre-selected coordinates (Figure 1). During the entire survey, there were seven aborted samples because of fouled gear due to obstructions on the bottom. These stations, mostly in B.C., were either repeated until a successful tow was completed or relocated in the field to the next adjacent station in the chosen stratum.

## Fish Samples and Diversity

Seventy-two identifiable species of fish were collected during trawling in the ESJF exclusive of the Discovery Bay survey (Table 4). Sixty-seven species of fish were collected in the Washington ESJF, and 48 were collected in B.C. An estimated 35,600 individual fish were caught during the trawl survey, and they weighed 7.9 mt. The trawl survey in Washington resulted in 26,700 captured individuals that weighed 4.7 mt and in B.C. 9,000 individual fish were caught which weighed 3.2 mt.

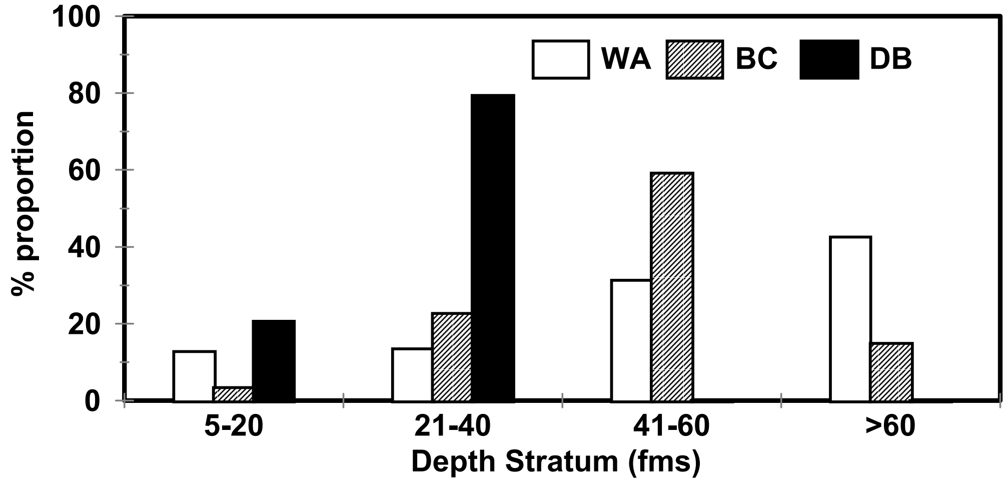


**Figure 4.** Depth distribution of the total fish populations of the eastern Strait of Juan de Fuca and Discovery Bay.

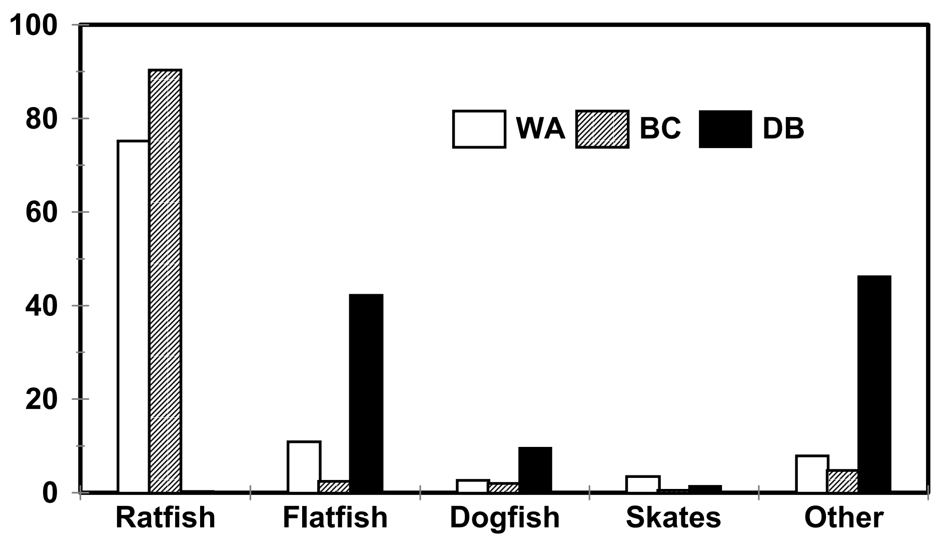


**Figure 5.** Species composition of fish populations surveyed by bottom trawl in the eastern Strait of Juan de Fuca and Discovery Bay.

**Table 2.** 2000 trawl survey station characteristics from the Eastern Strait of Juan de Fuca and Discovery Bay.

| Date | Station Identity | Latitude °' N | Longitude °' W | Duration (min) | Depth Stratum (fm) | Depth (m) | Width (m) | Length (km) |
|---|---|---|---|---|---|---|---|---|
| 08-May | 00JFS03 | 48 17.329 | 122 45.822 | 10 | 5-20 | 35 | 11.47 | 0.59 |
| 08-May | 00JFS04 | 48 15.357 | 122 52.010 | 4 | 5-20 | 22 | 10.88 | 0.46 |
| 08-May | 00JFT02 | 48 21.470 | 122 42.065 | 10 | 21-40 | 57 | 12.45 | 0.83 |
| 08-May | 00JFT04 | 48 16.759 | 122 48.238 | 10 | 21-40 | 60 | 11.23 | 0.63 |
| 08-May | 00JFU03 | 48 21.303 | 122 48.533 | 10 | 41-60 | 99 | 12.19 | 0.74 |
| 09-May | 00JFS08 | 48 7.665 | 123 21.899 | 10 | 5-20 | 20 | 8.74 | 0.89 |
| 09-May | 00JFT05 | 48 15.101 | 122 53.563 | 10 | 21-40 | 42 | 11.81 | 0.63 |
| 09-May | 00JFT07 | 48 10.154 | 123 18.337 | 12 | 21-40 | 60 | 11.23 | 0.65 |
| 09-May | 00JFV06 | 48 16.367 | 123 11.211 | 11 | >60 | 126 | 13.40 | 0.52 |
| 09-May | 00JFV07 | 48 15.229 | 123 9.396 | 10 | >60 | 128 | 13.40 | 0.54 |
| 10-May | 00JFS05 | 48 10.082 | 123 11.739 | 11 | 5-20 | 15 | 10.79 | 0.72 |
| 10-May | 00JFS06 | 48 9.152 | 123 12.832 | 11 | 5-20 | 16 | 10.79 | 0.67 |
| 10-May | 00JFT08 | 48 9.270 | 123 19.613 | 10 | 21-40 | 53 | 10.97 | 0.74 |
| 10-May | 00JFU08 | 48 12.265 | 123 5.902 | 11 | 41-60 | 99 | 13.31 | 0.61 |
| 10-May | 00JFU09 | 48 10.852 | 123 14.693 | 11 | 41-60 | 99 | 13.31 | 0.74 |
| 10-May | 00JFV11 | 48 11.765 | 123 23.379 | 12 | >60 | 137 | 13.43 | 0.7 |
| 11-May | 00DBS04 | 48 1.410 | 122 50.220 | 9 | 5-20 | 31 | 9.57 | 0.5 |
| 11-May | 00DBS05 | 48 0.504 | 122 51.339 | 10 | 5-20 | 24 | 10.97 | 0.8 |
| 11-May | 00DBS06 | 47 59.968 | 122 51.219 | 10 | 5-20 | 16 | 10.79 | 0.78 |
| 11-May | 00DBT01 | 48 5.606 | 122 53.599 | 10 | 21-40 | 53 | 12.32 | 0.72 |
| 11-May | 00DBT02 | 48 4.514 | 122 54.359 | 12 | 21-40 | 53 | 12.32 | 0.85 |
| 11-May | 00DBT06 | 48 1.560 | 122 51.182 | 11 | 21-40 | 42 | 11.81 | 0.72 |
| 12-May | 00JFS01 | 48 24.461 | 122 58.062 | 7 | 5-20 | 22 | 9.00 | 0.52 |
| 12-May | 00JFU02 | 48 22.668 | 122 49.824 | 10 | 41-60 | 77 | 11.72 | 0.65 |
| 12-May | 00JFV03 | 48 22.065 | 122 58.780 | 10 | >60 | 137 | 13.43 | 0.82 |
| 12-May | 00JFV08 | 48 15.063 | 122 56.600 | 10 | >60 | 119 | 13.37 | 0.63 |
| 15-May | 00JFT03 | 48 18.290 | 122 50.840 | 10 | 21-40 | 46 | 12.00 | 0.59 |
| 15-May | 00JFT06 | 48 11.157 | 122 57.603 | 10 | 21-40 | 42 | 11.81 | 0.63 |
| 15-May | 00JFU05 | 48 17.939 | 122 53.333 | 10 | 41-60 | 93 | 12.17 | 0.59 |
| 15-May | 00JFU07 | 48 12.766 | 122 58.335 | 9 | 41-60 | 99 | 13.31 | 0.59 |
| 15-May | 00JFV05 | 48 18.253 | 123 0.364 | 14 | >60 | 154 | 13.50 | 0.65 |
| 16-May | 00JFS07 | 48 7.024 | 122 52.559 | 10 | 5-20 | 20 | 10.79 | 0.72 |
| 16-May | 00JFS09 | 48 4.598 | 123 1.875 | 10 | 5-20 | 20 | 8.74 | 0.7 |
| 16-May | 00JFT09 | 48 7.135 | 123 1.388 | 10 | 21-40 | 42 | 11.81 | 0.78 |
| 16-May | 00JFU10 | 48 10.151 | 123 2.875 | 12 | 41-60 | 99 | 13.31 | 0.63 |
| 16-May | 00JFU11 | 48 6.481 | 122 57.049 | 11 | 41-60 | 93 | 13.30 | 0.57 |
| 16-May | 00JFV10 | 48 13.280 | 122 58.359 | 11 | >60 | 117 | 13.37 | 0.69 |
| 17-May | 00JFS02 | 48 19.424 | 123 4.483 | 12 | 5-20 | 31 | 11.30 | 0.54 |
| 17-May | 00JFT01 | 48 25.064 | 123 4.585 | 9 | 21-40 | 49 | 12.16 | 0.61 |
| 17-May | 00JFU01 | 48 23.798 | 123 5.020 | 9 | 41-60 | 93 | 13.30 | 1 |
| 17-May | 00JFU04 | 48 19.922 | 123 2.492 | 14 | 41-60 | 91 | 13.29 | 0.95 |
| 17-May | 00JFV02 | 48 24.491 | 123 1.210 | 14 | >60 | 166 | 13.54 | 0.89 |
| 17-May | 00JFV04 | 48 19.938 | 123 0.807 | 12 | >60 | 159 | 13.52 | 0.85 |
| 18-May | 00CJT05 | 48 20.661 | 123 14.198 | 10 | 21-40 | 59 | 11.18 | 0.46 |
| 18-May | 00CJT06 | 48 17.076 | 123 15.698 | 9 | 21-40 | 64 | 11.33 | 0.5 |
| 18-May | 00CJU07 | 48 17.915 | 123 16.826 | 15 | 41-60 | 91 | 13.29 | 0.95 |
| 18-May | 00CJV03 | 48 17.634 | 123 21.426 | 12 | >60 | 113 | 13.36 | 0.78 |

**Table 2.** (cont'd.) 2000 trawl survey station characteristics from the Eastern Strait of Juan de Fuca and Discovery Bay.

| Date | Station Identity | Latitude °' N | Longitude °' W | Duration (min) | Depth Stratum (fm) | Depth (m) | Width (m) | Length (km) |
|---|---|---|---|---|---|---|---|---|
| 18-May | 00JFV09 | 48 13.826 | 123 12.956 | 14 | >60 | 150 | 13.49 | 0.76 |
| 19-May | 00DBS01 | 48 4.477 | 122 52.940 | 10 | 5-20 | 27 | 11.13 | 0.69 |
| 19-May | 00DBS02 | 48 2.445 | 122 51.969 | 10 | 5-20 | 29 | 11.22 | 0.78 |
| 19-May | 00DBS03 | 48 2.571 | 122 49.967 | 7 | 5-20 | 26 | 11.05 | 0.37 |
| 19-May | 00DBT03 | 48 4.097 | 122 53.606 | 13 | 21-40 | 49 | 12.16 | 0.93 |
| 19-May | 00DBT04 | 48 3.541 | 122 52.814 | 11 | 21-40 | 46 | 12.00 | 0.87 |
| 19-May | 00DBT05 | 48 2.514 | 122 51.109 | 7 | 21-40 | 42 | 11.81 | 0.39 |
| 22-May | 00CJU02 | 48 22.563 | 123 26.508 | 10 | 41-60 | 79 | 12.99 | 0.85 |
| 22-May | 00CJU05 | 48 19.651 | 123 30.997 | 9 | 41-60 | 101 | 12.20 | 0.7 |
| 22-May | 00CJU06 | 48 18.878 | 123 20.425 | 10 | 41-60 | 95 | 13.30 | 0.52 |
| 22-May | 00CJV02 | 48 17.698 | 123 24.738 | 10 | >60 | 124 | 13.39 | 1 |
| 22-May | 00CJV07 | 48 14.849 | 123 26.962 | 11 | >60 | 155 | 13.51 | 1.11 |
| 23-May | 00CJS05 | 48 20.485 | 123 21.029 | 4 | 5-20 | 33 | 11.38 | 0.19 |
| 23-May | 00CJV01 | 48 18.771 | 123 30.113 | 13 | >60 | 113 | 13.36 | 0.8 |
| 23-May | 00CJV04 | 48 16.385 | 123 32.179 | 6 | >60 | 205 | 13.66 | 0.3 |
| 23-May | 00CJV05 | 48 15.992 | 123 30.899 | 10 | >60 | 177 | 13.58 | 0.65 |
| 23-May | 00CJV06 | 48 15.293 | 123 30.192 | 10 | >60 | 165 | 13.54 | 0.87 |
| 23-May | 00JFU06 | 48 16.172 | 123 18.154 | 11 | 41-60 | 80 | 13.03 | 0.52 |
| 24-May | 00CJT03 | 48 22.993 | 123 9.718 | 9 | 21-40 | 51 | 12.24 | 0.48 |
| 24-May | 00CJT04 | 48 21.135 | 123 15.116 | 10 | 21-40 | 68 | 12.72 | 0.48 |
| 24-May | 00CJU03 | 48 22.014 | 123 16.640 | 11 | 41-60 | 88 | 13.20 | 0.52 |
| 24-May | 00CJU04 | 48 21.160 | 123 11.426 | 11 | 41-60 | 93 | 13.30 | 0.67 |
| 24-May | 00JFV01 | 48 27.262 | 123 9.457 | 12 | >60 | 143 | 13.45 | 0.76 |
| 25-May | 00CJS02 | 48 25.499 | 123 15.450 | 10 | 5-20 | 33 | 11.38 | 0.59 |
| 25-May | 00CJS03 | 48 24.644 | 123 15.891 | 10 | 5-20 | 26 | 11.05 | 0.67 |
| 25-May | 00CJS04 | 48 23.895 | 123 17.883 | 10 | 5-20 | 27 | 11.13 | 0.57 |
| 25-May | 00CJT01 | 48 24.232 | 123 9.199 | 6 | 21-40 | 57 | 11.12 | 0.28 |
| 25-May | 00CJU01 | 48 25.666 | 123 11.151 | 6 | 41-60 | 82 | 11.90 | 0.32 |
| 26-May | 00CJS01 | 48 24.086 | 123 28.450 | 10 | 5-20 | 33 | 11.38 | 0.78 |
| 26-May | 00CJT02 | 48 23.723 | 123 22.625 | 11 | 21-40 | 69 | 12.77 | 0.74 |

**Table 3.** Stratum characteristics for the 2000 Transboundary Trawl Survey of the Eastern Strait of Juan de Fuca and Discovery Bay.

| **Stratum** | **1** | **2** | **3** | **4** | **Total** |
|---|---|---|---|---|---|
| **Depth Range (fms)** | **5 - 20** | **21 - 40** | **41-60** | **>60** | |
| **Washington** | | | | | |
| Area (ha) | 23,271.7 | 35,474.8 | 38,617.0 | 42,800.0 | 140,163.4 |
| Number of Stations | 9 | 9 | 11 | 11 | 40 |
| Area Sampled (ha) | 5.93 | 7.15 | 9.84 | 10.50 | 33.42 |
| **British Columbia** | | | | | |
| Area (ha) | 4,645.7 | 12,180.6 | 19,824.6 | 9,646.4 | 46,297.3 |
| Number of Stations | 5 | 6 | 7 | 7 | 25 |
| Area Sampled (ha) | 3.15 | 3.54 | 5.86 | 7.41 | 19.96 |
| **Discovery Bay** | | | | | |
| Area (ha) | 1,025.7 | 2,093.3 | | | 3,119.0 |
| Number of Stations | 6 | 6 | | | 12 |
| Area Sampled (ha) | 4.24 | 5.43 | | | 9.67 |

In the ESJF, spotted ratfish was by far the most common fish sampled in terms of both numbers and biomass in both Washington and B.C. (Table 4). This species alone, accounted for 89% and 78% of the sampled weight in B.C. and Washington, respectively. After ratfish, the four most common fishes captured in Washington in terms of weight were walleye pollock, Pacific sanddab, English sole, and spiny dogfish, while in terms of number walleye pollock, Pacific sanddab, Pacific tomcod, and shiner perch were most encountered. In. B.C., the four most common fishes in terms of weight after spotted ratfish were spiny dogfish, walleye pollock, southern rock sole, and kelp greenling (Table 4). By number, the four most dominant fishes after ratfish in B.C. were walleye pollock, Pacific sanddab, southern rock sole, and ribbed sculpin. Almost all of the species captured in the B.C. Strait of Juan de Fuca were also captured in Washington. The only exceptions were quillback and vermillion rockfishes which were captured in B.C. and not in Washington. In general, rocky habitat species such as kelp greenling, lingcod, rockfishes, and sculpins were relatively more frequent on the B.C. side of the Strait. Rockfishes were very uncommon throughout the survey areas (Table 5).

Thirty-three species of fish were collected during the twelve trawls conducted in Discovery Bay (Table 5). The species sampled in Discovery Bay were more reflective of the shallow species collected in the Washington Strait of Juan de Fuca. All but one species, the longfin smelt, were collected at other eastern Strait of Juan de Fuca stations. In contrast to the main body the Strait, Discovery Bay catches were dominated in terms of biomass by starry flounder, then Pacific tomcod, spiny dogfish, English sole, and shiner perch. In terms of number, tomcod were most numerous, then followed by Pacific herring, shiner perch, English sole, and Pacific sanddab.

Almost 3,771 individual fish and forty species of fish and invertebrates were measured for length. In Washington, 2199 length samples were collected from 35 species. In British Columbia, 805 lengths were obtained from 29 species. In Discovery Bay, 805 individuals were measured among 15 species. Selected average lengths and number of specimens measured are presented in Table 6.

## Fish Abundance and Distribution

### Total Fish and Species Composition

There were an estimated 132.3 million fish weighing 27,000 mt living in near bottom habitats in the ESJF (Table 7). These numerical and biomass population estimates had a coefficient of variation (C.V.) of 13% and 10%, respectively. The Washington ESJF contained 112 million bottomfish while B.C. had 20 million. The B.C. bottomfish resource constituted an estimated 8,100 mt while the Washington resource weighed an estimated 19,000 mt. C.V.s for the regional abundance and biomass estimates ranged from 12% to 16%. As expected, Discovery Bay had far fewer fish than either of the two larger survey areas. There was a fish population of 2.9 million fish (30% C.V.) weighing an estimated 90 mt (21% C.V.) in Discovery Bay.

In the main basins of the eastern Strait of Juan de Fuca, the two deeper depth strata contained greater proportions of the estimated populations in terms of both numerical and biomass abundance than the shallow depth strata (Table 7, Figure 4). The >60 fm depth strata had the greatest fish population of any Washington Juan de Fuca stratum, however, the 41-60 fm stratum of B.C. contained the greatest population of any stratum north of the international border. Of the two Discovery Bay strata, the deeper 21-40 fm stratum had the greatest population abundance.

The species compositions of the estimated populations were consistent, in general, with the amounts and proportions of fishes sampled (Figure 5, Table 8). Spotted ratfish comprised more than 75% of the fish populations in Washington and B.C. Flatfish as a group was the second most dominant species group in Washington while other species contributed together to form the second greatest proportion of any species group in B.C. Among the flatfish populations, Pacific sanddab and southern rock sole were dominant in terms of both numbers and biomass in B.C. In Washington, Pacific sanddab and English sole dominated flatfish populations. Spiny dogfish constituted less than 5% of the population abundance in the main basins of Washington and B.C. but comprised 10% of the Discovery Bay fish populations. In terms of numerical abundance, the Other Species category was dominated by walleye pollock in Washington and B.C. basins, but in terms of weight, kelp greenling, walleye pollock, and sculpins were dominant in B.C. and pollock, skates, and sculpins were dominant in Washington. The Other Species category dominated the populations of Discovery Bay bottomfish, followed closely by flatfish. More specifically, Pacific tomcod, Pacific herring, shiner perch, English sole, and flathead sole were the most dominant species in terms of numerical abundance while starry flounder, Pacific tomcod, spiny dogfish, great sculpin, and shiner perch were in greatest estimated tonnage (Table 9).

**Table 4.** Sampled fish numbers and weights encountered in the Eastern Strait of Juan de Fuca Trawl Survey.

| Common Name | Scientific Name | British Columbia Number | British Columbia Biomass (kg) | Washington Number | Washington Biomass (kg) |
|---|---|---|---|---|---|
| Spiny dogfish | Squalus acanthias | 53 | 66.44 | 132 | 116.76 |
| Big skate | Raja binoculata | 1 | 0.88 | 11 | 41.37 |
| Sandpaper skate | Raja kincaidi | 1 | 0.29 | 12 | 10.76 |
| Longnose skate | Raja rhina | 6 | 12.55 | 48 | 53.74 |
| Spotted ratfish | Hydrolagus colliei | 5645 | 2828.84 | 9674 | 3668.64 |
| Pacific herring | Clupea pallasi | 121 | 6.73 | 334 | 14.24 |
| Chinook salmon | Oncorhynchus tshawytscha | | | 1 | 0.58 |
| Eulachon | Thaleichthys pacificus | 1 | 0.03 | 11 | 0.78 |
| Plainfin midshipman | Porichthys notatus | 1 | 0.07 | 12 | 0.96 |
| Pacific cod | Gadus macrocephalus | 52 | 17.18 | 53 | 19.16 |
| Pacific tomcod | Microgadus proximus | 24 | 0.82 | 1339 | 30 |
| Walleye pollock | Theregra chalcogramma | 1628 | 38.96 | 8182 | 192.79 |
| Pacific whiting (hake) | Merluccius productus | 1 | 0.11 | 1 | 0.03 |
| Black eelpout | Lycodes diapterus | | | 1 | 0.02 |
| Wattled eelpout | Lycodes palearis | | | 5 | 0.16 |
| Blackbelly eelpout | Lycodopsis pacifica | | | 3 | 0.07 |
| Copper rockfish | Sebastes caurinus | 2 | 1.88 | 2 | 1.11 |
| Puget Sound rockfish | Sebastes emphaeus | 7 | 0.22 | 8 | 0.18 |
| Quillback rockfish | Sebastes maliger | 10 | 13.43 | 9 | 7.87 |
| Vermillion rockfish | Sebastes miniatus | 1 | 0.07 | | |
| Redstriped rockfish | Sebastes proriger | 1 | 0.24 | | |
| Kelp greenling | Hexagrammos decagrammus | 62 | 35.83 | 1 | 0.53 |
| Whitespotted greenling | Hexagrammos stelleri | 3 | 0.36 | 25 | 2.66 |
| Lingcod | Ophiodon elongates | 39 | 7.06 | 16 | 3.54 |
| Sablefish | Anoplopoma fimbria | 2 | 1.02 | | |
| Longspined combfish | Zaniolepis latipinnis | | | 1 | 0.03 |
| Padded sclupin | Artedius fenestralis | | | 24 | 0.35 |
| Silverspotted sculpin | Nautichthys oculofasciatus | | | 1 | 0.03 |
| Spinyhead sculpin | Dasycottus setiger | 2 | 0.07 | 8 | 0.38 |
| Buffalo sculpin | Enophrys bison | 15 | 2.24 | 51 | 7.24 |
| Red Irish lord | Hemilepidotus hemilepidotus | 3 | 2.34 | | |
| Northern sculpin | Icelinus borealis | 2 | 0.02 | 31 | 0.25 |
| Pacific staghorn sculpin | Leptocottus armatus | | | 7 | 1.61 |
| Great sculpin | Myoxocephalus polyacanthocephalus | 46 | 19.3 | 97 | 50.57 |
| Sailfin sculpin | Nautichthys oculofasciatus | 2 | 0.05 | 1 | 0.02 |
| Slim sculpin | Radulinus asprellus | | | 5 | 0.04 |
| Grunt sculpin | Rhamphocottus richardsoni | 1 | 0.01 | 6 | 0.06 |
| Cabezon | Scorpaenichthys marmoratus | 3 | 6.81 | | |
| Ribbed sculpin | Triglops pingeli | 169 | 5.36 | 86 | 2.09 |
| Roughback sculpin | Chitonotus pugetensis | 18 | 0.53 | 55 | 1.35 |
| Poacher unidentified | Agonidae spp. | 1 | 0.02 | | |
| Northern spearnose poacher | Agonopsis emmelane | 11 | 0.26 | 5 | 0.28 |
| Smooth alligatorfish | Anoplagonus inermis | | | 3 | 0.04 |
| Gray starsnout poacher | Asterotheca alascana | | | 1 | 0.02 |
| Bigeye starsnout poacher | Bathyagonus pentacanthus | | | 1 | 0.01 |

**Table 4.** (cont'd.) Sampled fish numbers and weights encountered in the Eastern Strait of Juan de Fuca Trawl Survey.

| Common Name | Scientific Name | British Columbia Number | British Columbia Biomass (kg) | Washington Number | Washington Biomass (kg) |
|---|---|---|---|---|---|
| Blacktip poacher | Xeneretmus latifrons | | | 1 | 0.01 |
| Sturgeon poacher | Agonus acipenserinus | 25 | 0.42 | 126 | 4.3 |
| Pacific spiny lumpsucker | Eumicrotremus orbis | 1 | 0.01 | 6 | 0.06 |
| Marbled snailfish | Liparis dennyi | | | 6 | 0.11 |
| Slimy snailfish | Liparis mucosus | | | 1 | 0.03 |
| Showy snailfish | Liparis pulchellus | | | 4 | 0.16 |
| Shiner perch | Cymatogaster aggregate | 1 | 0.01 | 1128 | 16.64 |
| Pile perch | Rhacochilus vacca | 1 | 0.04 | 1 | 0.01 |
| Northern ronquil | Ronquilus jordani | 3 | 0.09 | 6 | 0.19 |
| Snake prickleback | Lumpenus sagitta | | | 9 | 0.14 |
| Red gunnel | Pholis schultzi | | | 3 | 0.01 |
| Pacific sandlance | Ammodytes hexapterus | 1 | 0.01 | 5 | 0.23 |
| Pacific sanddab | Citharichthys sordidus | 370 | 34.88 | 1871 | 130.6 |
| Speckled sanddab | Citharichthys stigmaeus | 60 | 1.29 | 154 | 4.93 |
| Arrowtooth flounder | Atheresthes stomias | 2 | 0.18 | 54 | 1.33 |
| Petrale sole | Eopsetta jordani | | | 4 | 0.5 |
| Slender sole | Lyopsetta exilis | 9 | 0.2 | 6 | 0.19 |
| Flathead sole | Hippoglossoides elassodon | 6 | 0.35 | 114 | 6.87 |
| Rock sole unidentified | Lepidopsetta spp. | | | 287 | 20.66 |
| Northern rock sole | Lepidopsetta polyxystra | | | 4 | 1.34 |
| Southern rock sole | Lepidopsetta bilineata | 276 | 38.21 | 382 | 55.92 |
| Dover sole | Microstomus pacificus | 129 | 10.99 | 399 | 25.11 |
| Starry flounder | Platichthys stellatus | | | 25 | 36.34 |
| Butter sole | Isopsetta isolepis | | | 14 | 1.75 |
| English sole | Parophrys vetulus | 120 | 8.27 | 1600 | 121.31 |
| Curlfin sole | Pleuronichthys decurrnes | | | 1 | 0.13 |
| Sand sole | Psettichthys melanostictus | | | 7 | 1.34 |
| Pacific halibut | Hippoglossus stenolepis | | | 2 | 45.55 |
| Rex sole | Glyptocephalus zachirus | 21 | 0.98 | 172 | 7.63 |
| Number of Species- 77 | 77 | 72 | | 67 | |
| Total | | 8959 | 3165.95 | 26655 | 4713.71 |

**Table 5.** Species collected in Discovery Bay during the 2000 trawl survey.

| Common Name | Scientific Name | Number | Biomass (kg) |
|---|---|---|---|
| **INVERTEBRATES** | | | |
| Seawhip unidentified | Virgularia spp. | 3 | 0.35 |
| Gigantic anemone | Metridium giganteum | 2778 | 1304.58 |
| *Cerebratulus californiensis* | Cerebratulus californiensis | 1 | 0.01 |
| *Nereis* unidentified | Nereis spp. | 2 | 0.1 |
| Moon snail | Polinices lewisii | 3 | 0.46 |
| Common spotted nudibranch | Triopha catalinae | 1 | 0.02 |
| California arminid | Armina californica | 1 | 0.02 |
| Crisscross yoldia | Yoldia seminude | 1 | 0.01 |
| Axe yoldia | Yoldia thraciaeformis | 2 | 0.02 |
| Weathervane scallop | Patinopecten caurinus | 1 | 0.74 |
| Basket cockel | Clinocardium nuttallii | 1 | 0.19 |
| Bent-nose macoma | Macoma nasuta | 3 | 0.18 |
| Butter clam | Saxidomus giganteus | 50 | 2.48 |
| California market squid | Loligo opalescens | 388 | 6.46 |
| Giant octopus | Octopus dofleini | 1 | 0.02 |
| Alaskan pink shrimp | Pandalus eous | 70242 | 159.26 |
| Humpy shr imp | Pandalus goniurus | 3373 | 8.46 |
| Spotted prawn | Pandalus platyceros | 40 | 1.12 |
| Coonstriped shrimp | Pandalus hypsinotus | 5536 | 35.15 |
| Dock shrimp | Pandalus danae | 4021 | 18.09 |
| Crangonid shrimp unidentified | Crangonidae spp. | 60 | 0.32 |
| Bay ghost shrimp | Neotrypea californiensis | 3 | 0.1 |
| Hermit crab unidentified | Paguridae spp. | 1 | 0.02 |
| Graceful decorator crab | Oregonia gracilis | 12 | 0.14 |
| North Pacific toad crab | Hyas lyratus | 3 | 0.02 |
| Broad snow crab (female) | Chionoecetes bairdi | 1 | 0.01 |
| Cryptic kelp crab | Pugettia richii | 11 | 0.07 |
| Graceful kelp crab | Pugettia gracilis | 5 | 0.05 |
| Longhorned decorator crab | Chorilia longipes | 1 | 0.01 |
| Red rock crab (male) | Cancer productus | 35 | 11.76 |
| Red rock crab (female) | Cancer productus | 43 | 9.73 |
| Dungeness crab (male) | Cancer magister | 178 | 139.27 |
| Dungeness crab (female) | Cancer magister | 164 | 74.49 |
| Graceful crab (male) | Cancer gracilis | 312 | 34.89 |
| Graceful crab (female) | Cancer gracilis | 32 | 2.51 |
| Banana starfish | Luidia foliate | 29 | 5.7 |
| Rose sea star | Crossaster papposus | 4 | 0.08 |
| False ochre star | Evasterias troschelii | 13 | 1.36 |
| Pink short spined seastar | Pisaster brevispinus | 40 | 30.11 |
| Long-armed spiny seastar | Orthasterias koehleri | 1 | 0.21 |
| Sunflower star | Pycnopodia helianthoides | 166 | 105.24 |
| Basket star | Gorgonocephalus caryi | 4 | 0.08 |
| Pentamera populifera | Pentamera populifera | 5 | 0.06 |
| Red sea cucumber | Parastichopus californicus | 6 | 5.78 |
| **FISHES** | | | |
| Spiny dogfish | Squalus acanthias | 84 | 27.08 |

**Table 5.** (cont'd.) Species collected in Discovery Bay during the 2000 trawl survey.

| Common Name | Scientific Name | | Number | Biomass (kg) |
|---|---|---|---|---|
| Big skate | Raja binoculata | | 4 | 4.01 |
| Spotted ratfish | Hydrolagus colliei | | 2 | 1.14 |
| Pacific herring | Clupea harengus pallasi | | 1834 | 15.26 |
| Longfin smelt | Spirinchus thaleichthys | | 4 | 0.14 |
| Eulachon | Thaleichthys pacificus | | 1 | 0.01 |
| Plainfin midshipman | Porichthys notatus | | 15 | 0.61 |
| Pacific tomcod | Microgadus proximus | | 2195 | 47.08 |
| Walleye pollock | Theregra chalcogramma | | 24 | 0.5 |
| Blackbelly eelpout | Lycodopsis pacifica | | 92 | 1.07 |
| Kelp greenling | Hexagrammos decagrammus | | 4 | 0.57 |
| Longspine combfish | Zaniolepis latipinnis | | 64 | 1.48 |
| Spinyhead sculpin | Dasycottus setiger | | 12 | 0.35 |
| Pacific staghorn sculpin | Leptocottus armatus | | 3 | 0.16 |
| Great sculpin | Myoxocephalus polyacanthocephalus | | 51 | 21.42 |
| Slim sculpin | Radulinus asprellus | | 4 | 0.02 |
| Roughback sculpin | Chitonotus pugetensis | | 50 | 0.84 |
| Gray starsnout poacher | Asterotheca alascana | | 2 | 0.02 |
| Sturgeon poacher | Agonus acipenserinus | | 34 | 0.36 |
| Shiner perch | Cymatogaster aggregata | | 1589 | 22.42 |
| Pile perch | Rhacochilus vacca | | 66 | 1.79 |
| Snake prickleback | Lumpenus sagitta | | 77 | 0.55 |
| Pacific sanddab | Citharichthys sordidus | | 345 | 18.28 |
| Speckled sanddab | Citharichthys stigmaeus | | 310 | 7.58 |
| Arrowtooth flounder | Atheresthes stomias | | 34 | 0.62 |
| Flathead sole | Hippoglossoides elassodon | | 332 | 7.42 |
| Southern rock sole | Lepidopsetta bilineata | | 9 | 1.1 |
| Dover sole | Microstomus pacificus | | 9 | 0.22 |
| Starry flounder | Platichthys stellatus | | 109 | 61.63 |
| Butter sole | Isopsetta isolepis | | 9 | 0.28 |
| English sole | Parophrys vetulus | | 872 | 24.97 |
| Sand sole | Psettichthys melanostictus | | 7 | 1.28 |
| Rex sole | Glyptocephalus zachirus | | 2 | 0.04 |
| Number of Invertebrate Species | | 41 | 87577 | 1959.73 |
| Number of Fish Species | | 33 | 8249 | 270.3 |

**Table 6.** Number of length samples and average population lengths or widths of selected species collected during the trawl survey of the Eastern Strait of Juan de Fuca and Discovery Bay (all fish measured as total length in centimeters).

| **Species** | **British Columbia** | | **Washington** | | **Discovery Bay** | |
|---|---|---|---|---|---|---|
| | **Ave.** | **No.** | **Ave.** | **No.** | **Ave.** | **No.** |
| Spotted prawn (carapace length-mm) | 32.6 | 45 | 36.2 | 112 | 37.7 | 9 |
| Male Dungeness crabs (carapace width-mm) | 164.4 | 28 | 158.5 | 235 | 166.6 | 177 |
| Female Dungeness crabs (carapace width-mm) | 139.1 | 43 | 138.5 | 284 | 136.9 | 167 |
| Spiny dogfish | 67.6 | 53 | 57.0 | 132 | 40.6 | 84 |
| Big skate | | | 47.7 | 23 | 19.5 | 3 |
| Longnose skate | 63.7 | 6 | 46.3 | 36 | | |
| Pacific cod | 29.1 | 51 | 31.2 | 51 | | |
| Walleye pollock | 14.7 | 645 | 14.7 | 2618 | 14.0 | 24 |
| Pacific whiting | 25.0 | 1 | | | | |
| Copper rockfish | 42.0 | 1 | 31.5 | 2 | | |
| Quillback rockfish | 40.0 | 10 | 34.2 | 9 | | |
| Redstriped rockfish | 28.0 | 1 | | | | |
| Kelp greenling | 29.1 | 6 | 34.0 | 1 | | |
| Whitespotted greenling | 21.7 | 3 | 19.4 | 11 | | |
| Lingcod | 29.0 | 39 | 30.3 | 15 | | |
| Sablefish | 33.0 | 1 | | | | |
| Buffalo sculpin | 18.2 | 15 | 16.5 | 40 | | |
| Red Irish lord | 35.7 | 3 | | | | |
| Great sculpin | 28.7 | 46 | 31.0 | 91 | 26.1 | 49 |
| Cabezon | 48.6 | 3 | | | | |
| Pile perch | 13.0 | 1 | | | | |
| Pacific sanddab | 20.9 | 225 | 17.0 | 605 | 17.0 | 180 |
| Northern rock sole | | | 25.7 | 2 | | |
| Southern rock sole | 22.7 | 272 | 19.8 | 393 | 19.4 | 17 |
| Dover sole | 20.9 | 128 | 18.7 | 396 | 11.0 | 9 |
| Starry flounder | | | 44.0 | 24 | 31.9 | 109 |
| English sole | 19.4 | 121 | 19.8 | 1179 | 13.6 | 854 |
| Sand sole | | | 23.7 | 6 | 24.0 | 7 |
| Pacific halibut | | | 124.3 | 2 | | |

**Table 7.** Numerical (x 1000) and biomass (mt) abundance of all fishes in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 13,472.8 | 23,503.2 | 35,904.2 | 39,268.0 | 112,147.1 |
| (% CV) | 68.4 | 17.0 | 34.9 | 14.9 | 15.3 |
| Biomass (mt) | 2,417.6 | 2,543.3 | 5,928.4 | 8,062.9 | 18,952.3 |
| (% CV) | 59.0 | 24.9 | 25.0 | 11.5 | 12.4 |
| **British Columbia** | | | | | |
| Abundance | 1,145.1 | 3,845.6 | 11,416.8 | 3,740.1 | 20,147.6 |
| (% CV) | 25.8 | 33.7 | 19.9 | 38.7 | 14.9 |
| Biomass (mt) | 273.3 | 1,825.2 | 4,768.4 | 1,196.5 | 8,063.4 |
| (% CV) | 36.9 | 31.7 | 24.3 | 21.5 | 16.4 |
| **Discovery Bay** | | | | | |
| Abundance | 348.1 | 2,524.7 | | | 2,872.9 |
| (% CV) | 16.2 | 33.5 | | | 29.5 |
| Biomass (mt) | 18.5 | 71.5 | | | 90.1 |
| (% CV) | 16.2 | 26.3 | | | 21.2 |

**Table 8.** Numerical abundance and biomass population estimates for fishes in the Eastern Strait of Juan de Fuca.

| | British Columbia | | | | Washington | | | |
|---|---|---|---|---|---|---|---|---|
| | Abundance | | Biomass | | Abundance | | Biomass | |
| Species | No. (x1000) | % CV | Mt | % CV | No. (x1000) | % CV | Mt | % CV |
| Spiny dogfish | 125.75 | 22.46 | 159.29 | 23.82 | 573.62 | 17.53 | 502.2 | 14.22 |
| Other skates & rays | 1.17 | 100 | 0.34 | 100 | 52.87 | 42.56 | 48.09 | 45.89 |
| Big skate | 1.29 | 100 | 1.14 | 100 | 52.81 | 33.07 | 371.56 | 65.36 |
| Longnose skate | 17.58 | 48.11 | 38.39 | 50.41 | 173.11 | 37.58 | 230.42 | 36.34 |
| Total skates & rays | 20.05 | 42.12 | 39.87 | 48.51 | 278.79 | 27.91 | 650.07 | 39.18 |
| Spotted ratfish | 14218.28 | 19.37 | 7285.92 | 18.37 | 38142.78 | 15.02 | 14244.37 | 16.47 |
| Other nongame fish | 9.06 | 46.6 | 0.27 | 49.67 | 24.19 | 53.28 | 0.79 | 55.28 |
| Pacific herring | 177.86 | 34.53 | 9.74 | 34.62 | 1454.63 | 29.52 | 62.97 | 26.22 |
| Chinook salmon | 0 | 0 | 0 | 0 | 3.38 | 100 | 1.96 | 100 |
| Total smelts | 2.26 | 100 | 0.07 | 100 | 44.97 | 51.05 | 2.93 | 73.69 |
| Plainfin midshipman | 1.05 | 100 | 0.07 | 100 | 52.59 | 59.4 | 4.22 | 49.51 |
| Pacific cod | 105.56 | 21.43 | 30.54 | 22.52 | 211.63 | 34.85 | 73.73 | 36.57 |
| Pacific tomcod | 55.65 | 62.8 | 1.92 | 64.02 | 5481.69 | 41.58 | 121.34 | 41.45 |
| Walleye Pollock | 2681.1 | 40.22 | 63.01 | 37.62 | 35771.98 | 26.73 | 830.16 | 25.02 |
| Pacific whiting (hake) | 1.17 | 100 | 0.13 | 100 | 3.56 | 100 | 0.11 | 100 |
| Blackbelly eelpout | 0 | 0 | 0 | 0 | 14.33 | 56.74 | 0.33 | 56.02 |
| Other eelpout | 0 | 0 | 0 | 0 | 31.05 | 74.29 | 0.96 | 87.34 |
| Total eelpouts | 0 | 0 | 0 | 0 | 45.38 | 66.72 | 1.29 | 75.74 |
| Copper rockfish | 7.72 | 71.45 | 7.78 | 82.5 | 5.28 | 100 | 2.93 | 100 |
| Puget Sound rockfish | 24.45 | 55.21 | 0.76 | 59.36 | 30.35 | 58.42 | 0.66 | 58.58 |
| Quillback rockfish | 36.78 | 50.67 | 48.96 | 55.43 | 31.83 | 51.52 | 27.6 | 53.37 |
| Redstriped rockfish | 3.59 | 100 | 0.86 | 100 | 0 | 0 | 0 | 0 |
| Other rockfish | 1.05 | 100 | 0.07 | 100 | 0 | 0 | 0 | 0 |
| Total rockfish | 73.59 | 37.79 | 58.44 | 48.58 | 67.46 | 39.71 | 31.19 | 51.7 |
| Kelp greenling | 243.12 | 98.31 | 140.56 | 98.65 | 3.33 | 100 | 1.76 | 100 |
| White-spotted greenling | 4.18 | 68.74 | 0.5 | 63.99 | 90.33 | 44.91 | 9.57 | 50.91 |

**Table 8.** (cont'd.) Numerical abundance and biomass population estimates for fishes in the Eastern Strait of Juan de Fuca.

| | British Columbia | | | | Washington | | | |
|---|---|---|---|---|---|---|---|---|
| | Abundance | | Biomass | | Abundance | | Biomass | |
| Species | No. (x1000) | % CV | Mt | % CV | No. (x1000) | %CV | Mt | %CV |
| Total greenlings | 247.3 | 96.65 | 141.06 | 98.3 | 93.65 | 46.36 | 11.33 | 57.6 |
| Lingcod | 84.36 | 33.99 | 15.37 | 34.18 | 68.14 | 37.75 | 14.19 | 40.15 |
| Sablefish | 3.48 | 78.21 | 2.12 | 87.98 | 0 | 0 | 0 | 0 |
| Longspine combfish | 0 | 0 | 0 | 0 | 4.29 | 100 | 0.13 | 100 |
| Buffalo sculpin | 20.54 | 76.65 | 3.09 | 93.95 | 203.27 | 46.7 | 30.1 | 50.27 |
| Red Irish lord | 4.37 | 100 | 3.41 | 100 | 0 | 0 | 0 | 0 |
| Pacific staghorn sculpin | 0 | 0 | 0 | 0 | 36.48 | 47.72 | 8.25 | 43.75 |
| Great sculpin | 65.79 | 31.36 | 29.74 | 41.17 | 374.78 | 51.05 | 190.26 | 45.67 |
| Cabezon | 4.18 | 68.74 | 9.76 | 87.49 | 0 | 0 | 0 | 0 |
| Roughback sculpin | 19.14 | 91.97 | 0.56 | 91.83 | 278.96 | 49.05 | 7.09 | 58.2 |
| Other sculpin | 358.55 | 36.3 | 12.11 | 38.16 | 764.09 | 34.64 | 15.67 | 35.57 |
| Total sculpins | 472.58 | 29.73 | 58.68 | 25.53 | 1657.58 | 30 | 251.37 | 39.37 |
| Sturgeon poacher | 44.63 | 64.57 | 0.84 | 61.71 | 565.66 | 40.07 | 19.42 | 42.96 |
| Other poacher | 27.58 | 84.07 | 0.64 | 86.07 | 48.94 | 47.82 | 1.64 | 75.19 |
| Total poachers | 72.21 | 53.03 | 1.47 | 53.17 | 614.6 | 36.68 | 21.05 | 39.34 |
| Snailfish | 1.26 | 100 | 0.01 | 100 | 69.33 | 26.68 | 1.54 | 44.75 |
| Shiner perch | 2.56 | 100 | 0.03 | 100 | 4369.61 | 87.89 | 64.56 | 86.31 |
| Pile perch | 6.58 | 100 | 0.26 | 100 | 5.54 | 100 | 0.06 | 100 |
| Total surfperch | 9.14 | 77.25 | 0.29 | 91.6 | 4375.15 | 87.77 | 64.62 | 86.24 |
| Prickleback | 0 | 0 | 0 | 0 | 34.6 | 78.37 | 0.54 | 85.63 |
| Gunnel | 0 | 0 | 0 | 0 | 10.78 | 100 | 0.02 | 100 |
| Pacific sandlance | 3.59 | 100 | 0.04 | 100 | 25.25 | 67.87 | 1.25 | 88.23 |
| Pacific sanddab | 670.32 | 49.8 | 71.7 | 52.16 | 8774.13 | 31.17 | 600.22 | 29.65 |
| Speckled sanddab | 63.94 | 90.44 | 1.4 | 79.37 | 621.24 | 45.27 | 21.28 | 46.06 |
| Arrowtooth flounder | 4.82 | 64.73 | 0.45 | 79.04 | 238.68 | 46.63 | 5.69 | 41.51 |
| Petrale sole | 0 | 0 | 0 | 0 | 14.37 | 63.83 | 1.94 | 75.41 |
| Slender sole | 23.16 | 64.36 | 0.53 | 48.36 | 27.51 | 51.5 | 0.79 | 50.85 |

**Table 8.** (cont'd.) Numerical abundance and biomass population estimates for fishes in the Eastern Strait of Juan de Fuca.

| | British Columbia | | | | Washington | | | |
|---|---|---|---|---|---|---|---|---|
| | Abundance | | Biomass | | Abundance | | Biomass | |
| Species | No. (x1000) | % CV | Mt | % CV | No. (x1000) | %CV | Mt | %CV |
| Flathead sole | 11.33 | 70.13 | 0.65 | 64.29 | 538.7 | 52.62 | 31.28 | 43.4 |
| Rock sole (unidentified) | 0 | 0 | 0 | 0 | 1521.22 | 100 | 109.51 | 100 |
| Northern rock sole | 0 | 0 | 0 | 0 | 17.18 | 60.66 | 6.03 | 69.43 |
| Total rock sole | 490.89 | 30.85 | 82.05 | 26.39 | 3400.37 | 42.72 | 360.87 | 30.7 |
| Southern rock sole | 490.89 | 30.85 | 82.05 | 26.39 | 1861.98 | 32.29 | 245.33 | 26.02 |
| Dover sole | 199.25 | 25.6 | 16.58 | 29.54 | 1511.63 | 23.82 | 91.82 | 24.88 |
| Starry flounder | 0 | 0 | 0 | 0 | 124.3 | 55.42 | 190.14 | 63.5 |
| Butter sole | 0 | 0 | 0 | 0 | 70.86 | 60.46 | 8.92 | 61.92 |
| English sole | 266.79 | 78.55 | 19.49 | 76.85 | 6965.7 | 31.09 | 525.57 | 29.48 |
| Curlfin sole | 0 | 0 | 0 | 0 | 3.32 | 100 | 0.43 | 100 |
| Sand sole | 0 | 0 | 0 | 0 | 27.43 | 72.23 | 5.12 | 94.59 |
| Pacific halibut | 0 | 0 | 0 | 0 | 8.13 | 70.85 | 183.71 | 70.82 |
| Rex sole | 51.71 | 72.36 | 2.22 | 64.62 | 710.72 | 30.8 | 31.16 | 27.39 |
| Total flatfish | 1782.22 | 35.64 | 195.06 | 31 | 23037.09 | 21.76 | 2058.94 | 18.06 |
| Total Fish | 20147.52 | 14.92 | 8063.35 | 16.43 | 112147.12 | 15.25 | 18952.29 | 12.37 |

**Table 9.** Numerical abundance and biomass for invertebrate and fish populations in Discovery Bay.

| | Abundance | | Biomass | |
|---|---|---|---|---|
| **Species** | **No. (x1000)** | **% CV** | **mt** | **% CV** |
| **Invertebrates** | | | | |
| Smooth sea whip | 0.93 | 100.00 | 0.11 | 100.00 |
| Giant sea anemone | 689.7 | 29.85 | 300.5 | 33.93 |
| Total sea anemones | 689.7 | 29.85 | 300.5 | 33.93 |
| Misc. nongame invertebrate | 0.20 | 100.00 | 0.00 | 100.00 |
| Other polychaete | 0.61 | 69.17 | 0.04 | 81.57 |
| Total polychaetes | 0.61 | 69.17 | 0.04 | 81.57 |
| Moon snail | 0.61 | 100.00 | 0.09 | 100.00 |
| Total snails | 0.61 | 100 .00 | 0.09 | 100.00 |
| Other nudibranch | 0.53 | 73.07 | 0.01 | 73.06 |
| Total nudibranchs | 0.53 | 73.07 | 0.01 | 73.06 |
| Weathervane scallop | 0.20 | 100.00 | 0.15 | 100.00 |
| Other clam | 36.66 | 81.79 | 1.73 | 71.74 |
| Total clams | 36.86 | 81.33 | 1.89 | 66.20 |
| Total squids | 110.63 | 46.68 | 1.82 | 50.75 |
| California market squid | 110.63 | 46.68 | 1.82 | 50.75 |
| Total octopi | 0.20 | 100.00 | 0.00 | 100.00 |
| Giant octopus | 0.20 | 100.00 | 0.00 | 100 .00 |
| Spotted prawn | 12.84 | 50.46 | 0.36 | 47.3 |
| Other pandalid shrimp | 30340.58 | 42.51 | 80.18 | 28.32 |
| Other shrimp | 23.74 | 45.05 | 0.15 | 55.77 |
| Total shrimps | 30377.16 | 42.44 | 80.69 | 28.11 |
| Hermit crab | 0.33 | 100.00 | 0.01 | 100 .00 |
| Broad snow crab | 0.41 | 100.00 | 0.00 | 100.00 |
| Red rock crab | 17.72 | 34.44 | 4.94 | 34.43 |
| Female Dungeness crabs | 113.27 | 14.38 | 23.75 | 18.21 |
| Male Dungeness crabs | 51.26 | 18.38 | 48.91 | 23.41 |
| Total Dungeness crab | 62.00 | 19.28 | 72.66 | 18.90 |
| Graceful crab | 119.78 | 45.04 | 12.28 | 36.30 |
| Other crab | 10.42 | 38.18 | 0.13 | 45.79 |
| Total crabs | 261.93 | 18.89 | 90.02 | 15.05 |
| Banana seastar | 9.21 | 52.83 | 2.13 | 65.30 |
| Sunflower seastar | 47.64 | 25.95 | 33.36 | 39.55 |
| Other seastar | 16.70 | 33.75 | 9.13 | 51.11 |
| Total seastars | 73.54 | 20.06 | 44.62 | 38.21 |
| Red sea cucumber | 1.57 | 62.26 | 1.48 | 70.29 |
| Other sea cucumber | 3.80 | 100 | 0.05 | 100 |
| Total sea cucumbers | 5.37 | 70.20 | 1.52 | 67.85 |
| Total invertebrates | 31558.28 | 40.64 | 521.30 | 20.45 |

**Table 9.** (cont'd.) Numerical Abundance and Biomass for Invertebrate and Fish Populations in Discovery Bay.

| | Abundance | | Biomass | |
|---|---|---|---|---|
| **Species** | **No. (x1000)** | **% CV** | **Species** | **No. (x1000)** |
| **Fishes** | | | | |
| Spiny dogfish | 28.38 | 33.88 | 8.64 | 32.44 |
| Big skate | 1.15 | 46.20 | 1.33 | 95.24 |
| Total skates & rays | 1.15 | 46.20 | 1.33 | 95.24 |
| Spotted ratfish | 0.55 | 67.17 | 0.36 | 80.73 |
| Pacific herring | 622.04 | 70.92 | 5.20 | 54.61 |
| Total smelts | 1.58 | 48.48 | 0.05 | 70.26 |
| Plainfin midshipman | 5.08 | 29.33 | 0.19 | 36.24 |
| Pacific tomcod | 836.05 | 49.13 | 17.71 | 41.7 |
| Walleye Pollock | 8.40 | 68.70 | 0.18 | 67.02 |
| Blackbelly eelpout | 35.63 | 16.9 | 0.41 | 13.37 |
| Kelp greenling | 0.90 | 100 | 0.13 | 100 .00 |
| Longspine combfish | 20.76 | 25.05 | 0.46 | 24.93 |
| Pacific staghorn sculpin | 1.53 | 56.67 | 0.08 | 56.46 |
| Great sculpin | 18.95 | 76.73 | 7.99 | 73.00 |
| Roughback sculpin | 11.73 | 33.77 | 0.20 | 29.73 |
| Other sculpin | 6.31 | 85.39 | 0.15 | 96.67 |
| Total sculpins | 38.51 | 52.11 | 8.41 | 70.77 |
| Sturgeon poacher | 11.28 | 43.44 | 0.12 | 40.94 |
| Other poacher | 0.72 | 63.57 | 0.01 | 63.56 |
| Total poachers | 12.00 | 39.71 | 0.13 | 37.8 |
| Shiner perch | 565.43 | 44.4 | 7.84 | 48.09 |
| Pile perch | 26.75 | 89.33 | 0.72 | 94.86 |
| Total surfperch | 592.17 | 46.08 | 8.56 | 51.62 |
| Prickleback | 26.76 | 29.24 | 0.20 | 32.63 |
| Pacific sanddab | 114.98 | 32.47 | 6.22 | 37.58 |
| Speckled sanddab | 70.85 | 20.62 | 1.77 | 19.20 |
| Arrowtooth flounder | 12.68 | 71.23 | 0.23 | 71.29 |
| Flathead sole | 118.76 | 22.4 | 2.71 | 19.47 |
| Southern rock sole | 1.98 | 66.16 | 0.28 | 60.87 |
| Dover sole | 2.99 | 44.11 | 0.08 | 51.85 |
| Starry flounder | 36.96 | 21.87 | 18.74 | 19.35 |
| Butter sole | 4.15 | 47.94 | 0.12 | 52.83 |
| English sole | 276.56 | 18.33 | 7.48 | 25.14 |
| Sand sole | 2.25 | 58.84 | 0.43 | 49.68 |
| Rex sole | 0.72 | 63.57 | 0.01 | 63.56 |
| Total flatfish | 642.89 | 14.04 | 38.08 | 17.44 |
| Total Fish | 2872.86 | 29.51 | 90.05 | 21.17 |

## Spiny Dogfish

Spiny dogfish constituted 2.6% of the biomass in Washington waters while dogfish comprised 2.0% of the population biomass in B.C. (Figure 4). The numerical population of dogfish in the eastern Strait of Juan was estimated at 699,400 (14.9% C.V.) which weighed 661.5 mt (12.2% CV, Table 10). Three-quarters of the dogfish population were in the Washington portion of the Strait, but the plot of station densities for dogfish showed they were distributed somewhat evenly throughout the deeper waters of the eastern Strait (Figure 6). Virtually all of the dogfish were encountered in waters greater than 20 fms, and in Washington, dogfish were most abundant in the deepest depth stratum (Figure 7). In B.C., the population was evenly distributed throughout the three deepest depth strata (Figure 6).

Although spiny dogfish comprised 10% of the fish population in Discovery Bay, the population of 8.6 mt constituted only 1% of the dogfish population of the Washington Strait of Juan de Fuca (Table 10). The pattern of depth distribution showed that the bulk of the population was in the deeper of the two sampled depth strata. However, dogfish were encountered in almost all parts of the bay (Figure 7).

The dogfish population in B.C. consisted of fish that were slightly larger than those from Washington (Figure 8). Dogfish in B.C. averaged 67 cm in total length compared to 57 cm in Washington (Table 6). B.C. had more individuals measuring greater than 80 cm than Washington. Dogfish were smaller in Discovery Bay, averaging 41 cm, and 40 cm fish made up almost 90% of the population (Figure 8).

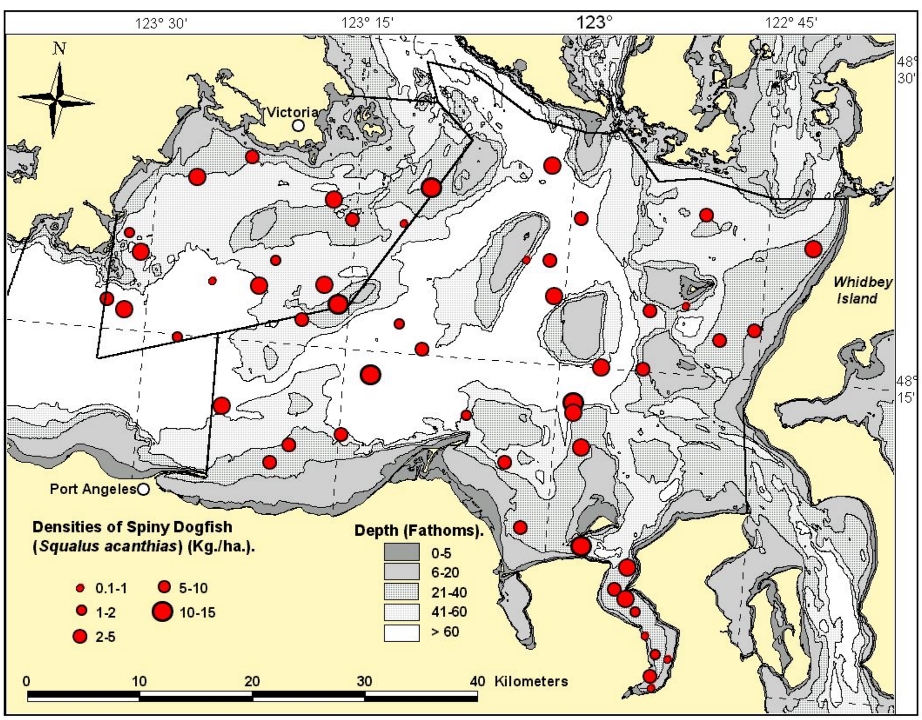


**Figure 6.** The distribution of spiny dogfish station densities (kg/ha) in the Eastern Strait of Juan de Fuca.

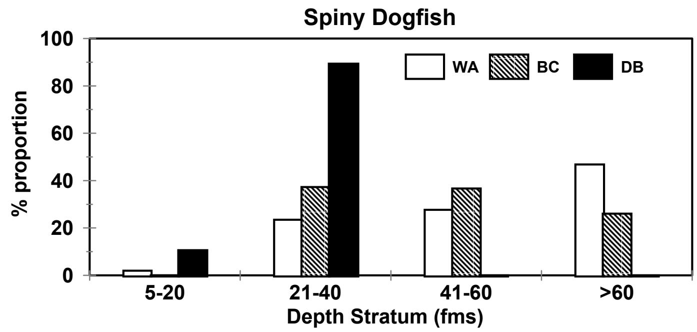


**Figure 7.** Depth distribution of spiny dogfish.

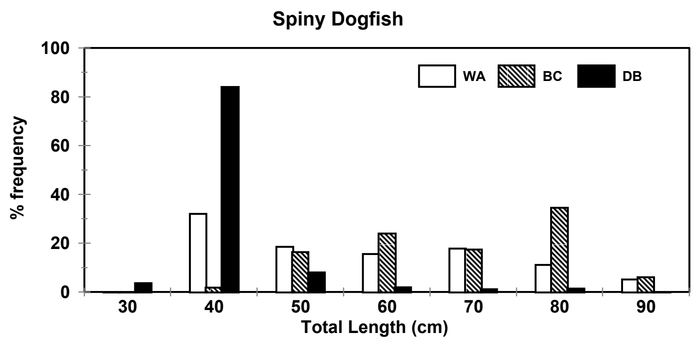


**Figure 8.** Length frequency distribution of spiny dogfish.

**Table 10.** Numerical (x1000) and biomass (mt) abundance of spiny dogfish in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | 61-120 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 19.0 | 150.0 | 165.7 | 238.9 | 573.6 |
| (% CV) | 100.0 | 35.7 | 37.5 | 23.0 | 17.5 |
| Biomass (mt) | 10.1 | 118.0 | 139.3 | 234.8 | 502.2 |
| (% CV) | 100.0 | 23.8 | 31.9 | 20.1 | 14.2 |
| **British Columbia** | | | | | |
| Abundance | 0.0 | 42.8 | 51.0 | 32.0 | 125.8 |
| (% CV) | | 46.3 | 32.1 | 36.5 | 22.5 |
| Biomass (mt) | 0.0 | 59.4 | 58.4 | 41.5 | 159.3 |
| (% CV) | | 48.0 | 36.2 | 32.4 | 23.8 |
| **Discovery Bay** | | | | | |
| Abundance | 1.2 | 27.2 | | | 28.4 |
| (% CV) | 35.8 | 35.3 | | | 33.9 |
| Biomass (mt) | 0.9 | 7.7 | | | 8.6 |

| | | | | |
|---|---|---|---|---|
| (% CV) | 67.1 | 35.4 | | 32.4 |

## Spotted Ratfish

More than three-quarters of the fish population in the ESJF consisted of spotted ratfish. They made up 90% of the B.C. fish population biomass in B.C. and 75% of the fish population in Washington (Figure 5). They were virtually absent in Discovery Bay. There was an estimated 52 million ratfish (12.1% C.V.) in the ESJF accounting for a biomass of 21,500 mt (12.7% C.V., Table 11). Three quarters of the ratfish in the Strait were from Washington. The Discovery Bay ratfish biomass of 0.4 mt was far less than 1% of the Washington population of 14,200 mt (16.7% C.V.). High and low station densities of ratfish were observed throughout the central and northern straits (Figure 9), and tended to be the highest in the central ESJF and in association with the offshore banks. In Discovery Bay, the few ratfish captured were in the 5-20 fm depth stratum and none were in the deeper stratum (Figures 9 and 10). In the main basin, more than 80% of the ratfish population was at depths greater than 40 fm. Most of the ratfish population was in the 41-60 fm depth strata in B.C., while in Washington, most of the ratfish population was in depths greater than 60 fms.

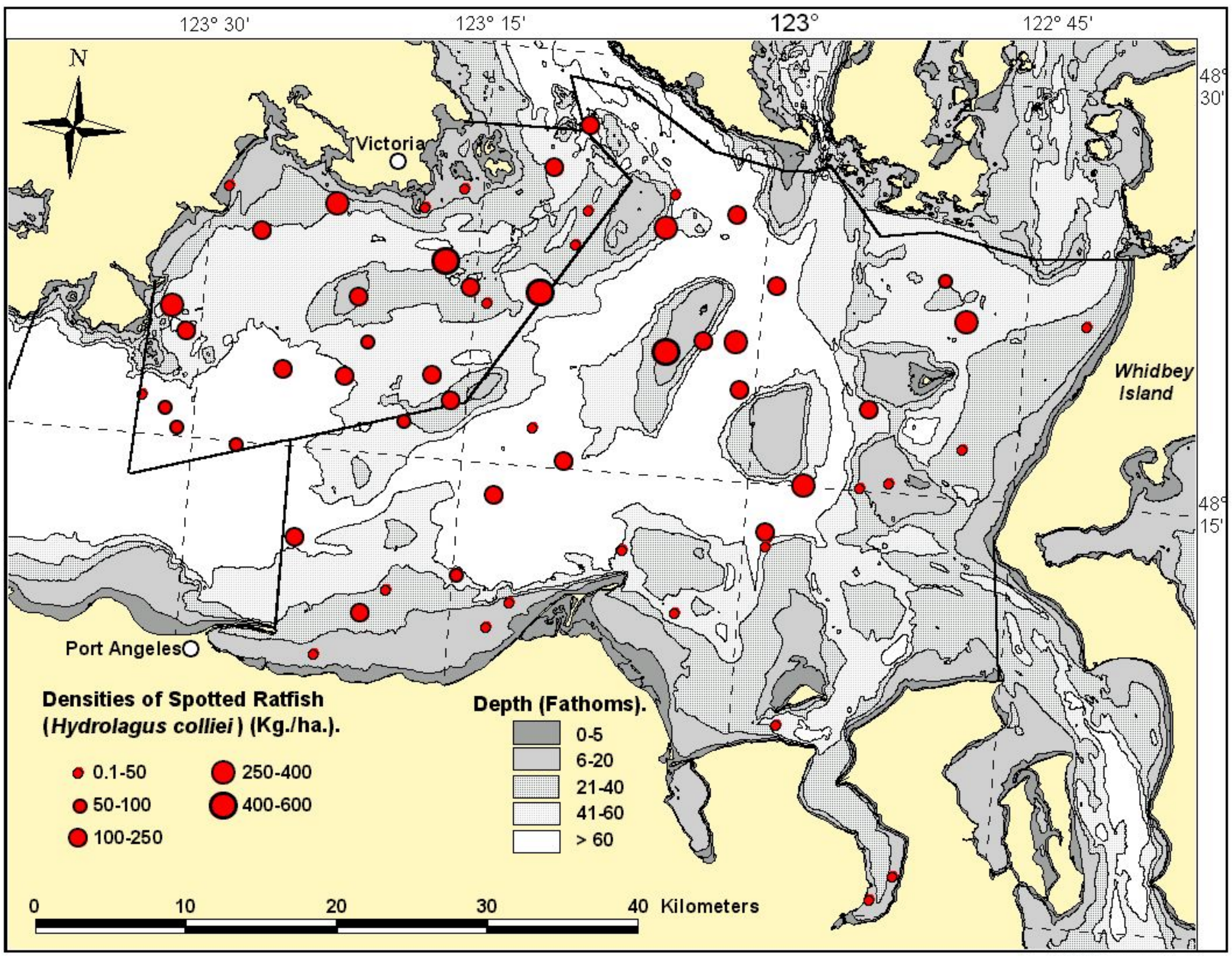


**Figure 9.** The distribution of spotted ratfish station densities (kg/ha) in the Eastern Strait of Juan de Fuca.

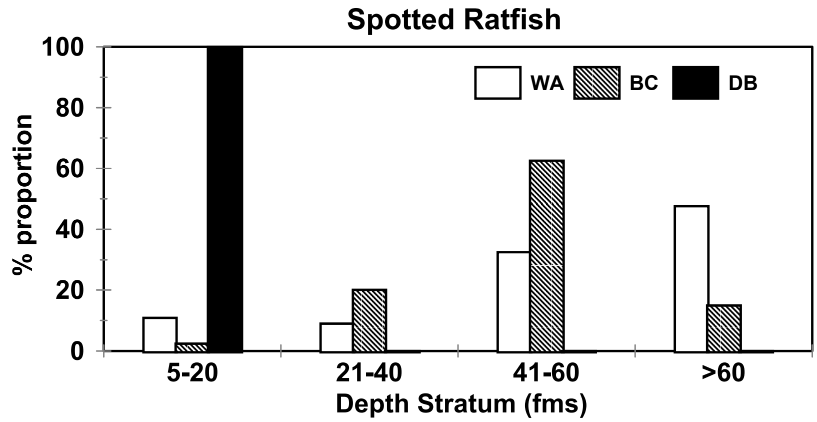


**Figure 10.** Depth distribution of spotted ratfish.

**Table 11.** Numerical (x1000) and biomass (mt) abundance of spotted ratfish in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | > 60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 2,589.1 | 3,439.7 | 13,432.0 | 18,682.0 | 38,142.8 |
| (% CV) | 92.4 | 48.8 | 31.2 | 13.9 | 15.0 |
| Biomass (mt) | 1,620.2 | 1,360.1 | 4,360.1 | 6,780.0 | 14,244.4 |
| (% CV) | 92.7 | 53.6 | 30.7 | 14.3 | 16.7 |
| **British Columbia** | | | | | |
| Abundance | 283.1 | 2,738.5 | 9,070.9 | 2,125.8 | 14,218.3 |
| (% CV) | 54.4 | 44.1 | 26.6 | 25.7 | 19.4 |
| Biomass (mt) | 177.2 | 1,463.3 | 4,557.6 | 1,087.8 | 7,285.9 |
| (% CV) | 63.2 | 41.3 | 25.5 | 22.7 | 18.4 |
| **Discovery Bay** | | | | | |
| Abundance | 0.6 | 0.0 | | | 0.6 |
| (% CV) | 67.2 | | | | 67.2 |
| Biomass (mt) | 0.4 | 0.0 | | | 0.4 |
| (% CV) | 80.7 | | | | 80.7 |

## Skates

There were 298,800 skates (26.2% C.V., Table 12) in the ESJF which accounted for a biomass of 690 mt (37.0% C.V.). Big skate and longnose skates accounted for at least 80% of the numerical skate population and more than 90% of the population biomass (Table 8). Sandpaper skate accounted for the remainder of the skate population estimates. More than 90% of the skate population resided in Washington (Table 12). The pattern of the numerical and biomass population estimates differed among the depth strata between B.C. and Washington: very few skates occurred in the shallowest stratum but these were large individuals that contributed to 28% of the Washington biomass (Table 12). This difference may relate to the species distribution. Station density plots revealed that big skates were almost exclusively caught in two shallowest depth strata in the U.S. and were not captured in B.C. (Figures 11 and 12). Most longnose skate were caught in the two deepest strata in both B.C. and Washington (Figures 14 and 15). One thousand skates were in Discovery Bay, and these accounted for a metric ton of biomass (Table 12). Big skate was the only skate species captured in Discovery Bay (Table 9, Figure 11)

Most of the big skate population was less than 40 cm total length (Figure 13), but a small proportion was in excess of 180 cm. Longnose skate were larger in B.C. averaging 64 cm in total length and were only an average 46 cm in length in Washington (Figure 16, Table 6).

**Table 12.** Numerical (x1000) and biomass (mt) abundance of skates in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | > 60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 3.8 | 36.2 | 120.6 | 118.2 | 278.8 |
| (% CV) | 100.0 | 57.4 | 51.7 | 35.0 | 27.9 |
| Biomass (mt) | 180.4 | 50.4 | 260.5 | 158.8 | 650.1 |
| (% CV) | 100.0 | 71.8 | 63.6 | 37.5 | 39.2 |
| **British Columbia** | | | | | |
| Abundance | 0.0 | 0.0 | 14.2 | 5.9 | 20.0 |
| (% CV) | | | 54.6 | 57.4 | 42.1 |
| Biomass (mt) | 0.0 | 0.0 | 38.9 | 5.0 | 39.9 |
| (% CV) | | | 54.5 | 68.9 | 48.5 |
| **Discovery Bay** | | | | | |
| Abundance | 0.8 | 0.3 | | | 1.1 |
| (% CV) | 50.7 | 100.0 | | | 46.2 |
| Biomass (mt) | 0.06 | 1.3 | | | 1.3 |
| (% CV) | 68.7 | 100.0 | | | 95.2 |

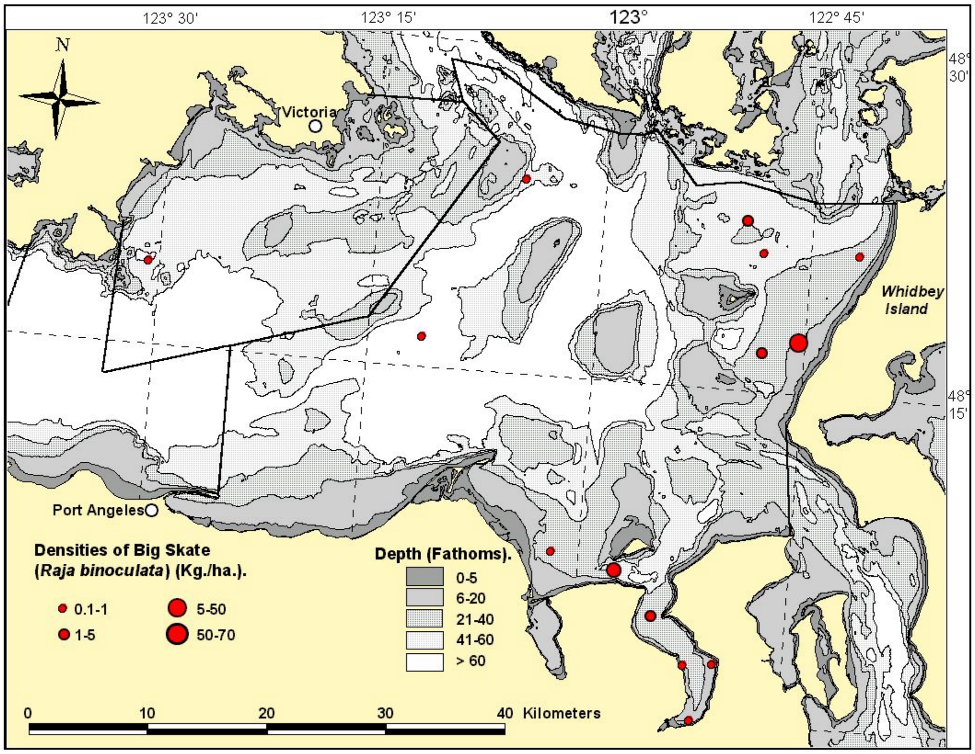


**Figure 11.** The distribution of big skate station densities (kg/ha) in the Eastern Strait of Juan de Fuca.

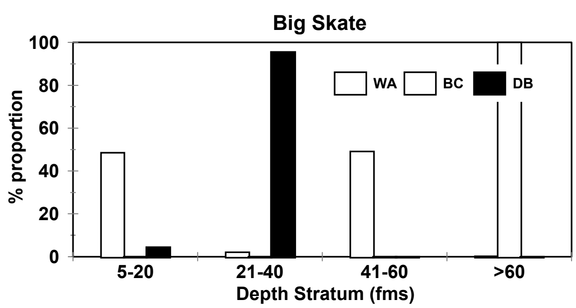


**Figure 12.** Depth distribution of big skate.

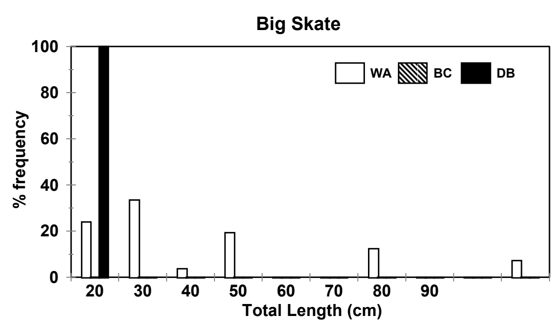


**Figure 13.** Length frequency distribution of big skate.

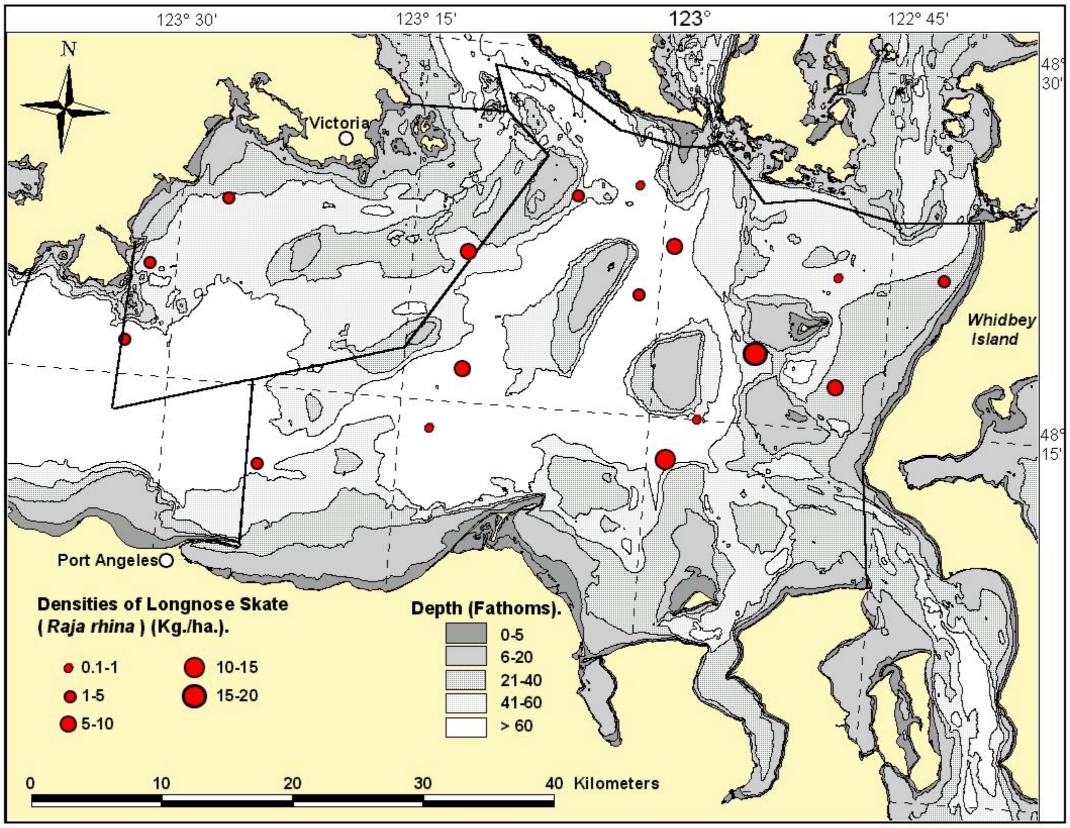


**Figure 14.** The distribution of longnose skate station densities (kg/ha) in the Eastern Strait of Juan de Fuca.

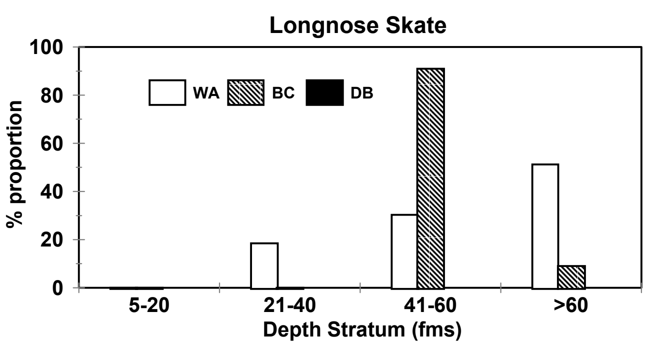


**Figure 15.** Depth distribution of longnose skate.

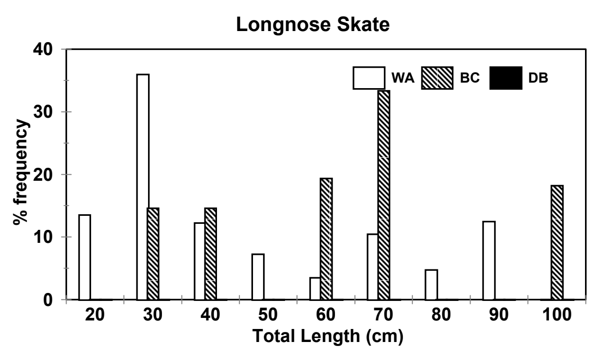


**Figure 16.** Length frequency distribution of longnose skate.

## Pacific Cod

Pacific cod constituted 0.4% of the biomass in Washington and B.C. ESJF (Table 8). The numerical population of cod in the eastern Strait of Juan was estimated at 317,200 (24.3% C.V.) which weighed 104.2 mt (26.7% C.V., Table 13). Two-thirds of the cod population was in the Washington portion of the Strait, but the plot of station densities for cod showed they were mostly distributed in the central Washington Strait and throughout shallow and deep waters of B.C. including the central banks, near Race Rocks, and along the southeastern shore of Vancouver Island (Figure 17). Over 90% of the Washington cod population was in the deepest two depth strata, and of those, most cod were found in waters greater than 60 fms (Figure 18). In B.C., the cod population was primarily in the 21-40 fm stratum or in the >60 fm stratum. Cod were not present in Discovery Bay.

The size frequency distributions of Pacific cod populations were identical between the Washington and B.C. survey areas (Figure 19). Eighty percent of the populations were 30 cm in length category with the remainder of the populations at 20 cm or 40 cm. Few cod were in the 50 cm or 60 cm length category. Average cod lengths were 29 cm and 31 cm in B.C. and Washington, respectively (Table 6).

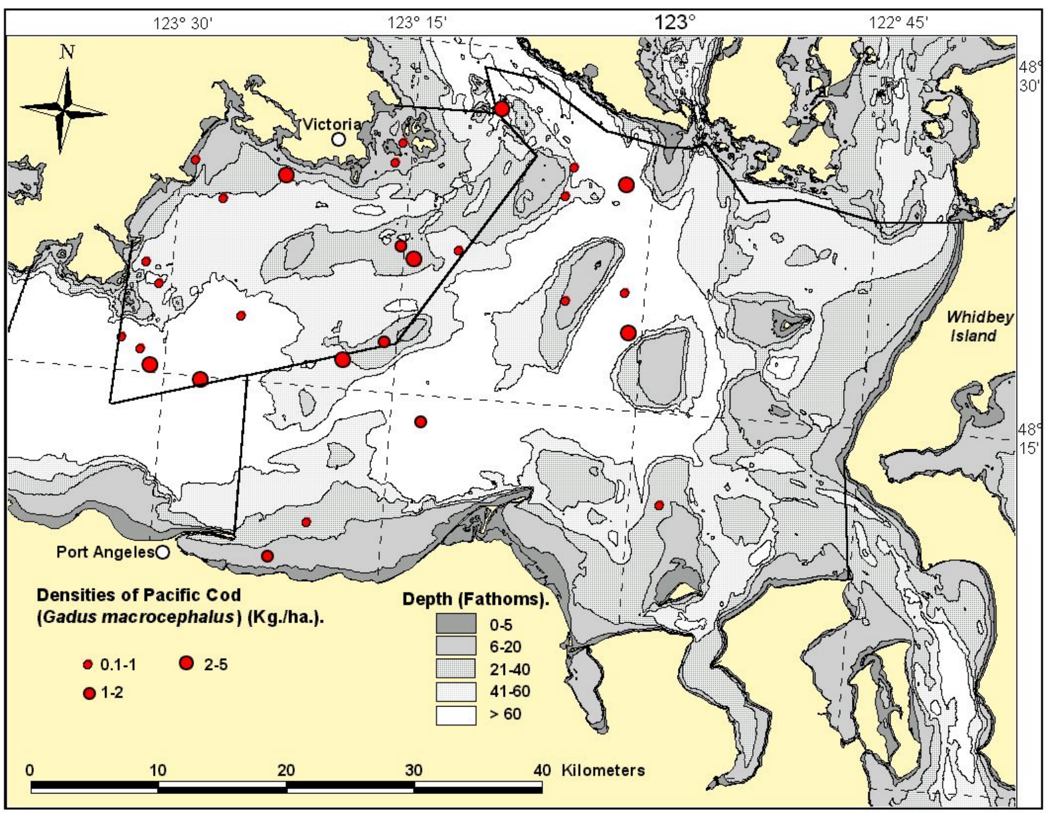


**Figure 17.** The distribution of Pacific cod station densities (kg/ha) in the eastern Strait of Juan de Fuca.

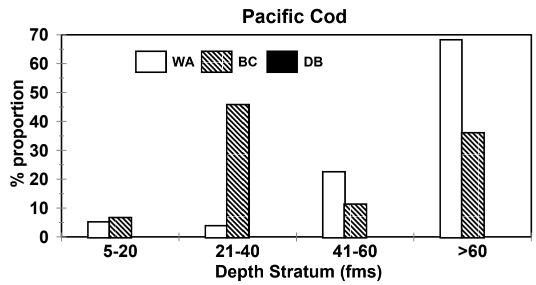


**Figure 18.** Depth distribution of Pacific cod.

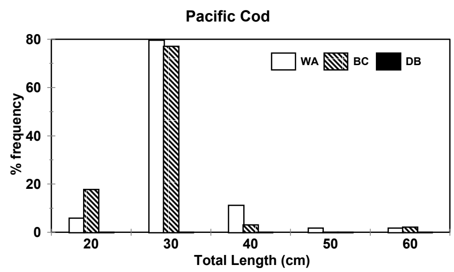


**Figure 19.** Length frequency distribution of Pacific cod.

**Table 13.** Numerical (x 1,000) and biomass (mt) abundance of Pacific Cod in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 14.2 | 15.5 | 54.7 | 127.3 | 211.6 |
| (% CV) | 72.7 | 50.1 | 85.3 | 43.7 | 34.9 |
| Biomass (mt) | 3.9 | 2.9 | 16.6 | 50.3 | 73.7 |
| (% CV) | 72.1 | 52.2 | 85.6 | 45.1 | 36.6 |
| **British Columbia** | | | | | |
| Abundance | 14.9 | 55.5 | 15.6 | 19.7 | 105.6 |
| (% CV) | 47.7 | 34.6 | 52.2 | 26.9 | 21.4 |
| Biomass (mt) | 2.0 | 14.0 | 3.5 | 11.0 | 30.5 |
| (% CV) | 42.4 | 34.5 | 48.4 | 41.0 | 22.5 |
| **Discovery Bay** | | | | | |
| Abundance | 0.0 | 0.0 | | | 0.0 |
| (% CV) | | | | | |
| Biomass | 0.0 | 0.0 | | | 0.0 |
| (%CV) | | | | | |

## Walleye Pollock

The biomass population estimate of walleye pollock comprised 4.4% of the fish in Washington's ESJF, and comprised only 0.8% of the fish population in B.C. (Table 8). Numerically, however, pollock in Washington accounted for 32% of the fish population and 15% of B.C.'s fish population (Table 14). The pollock population estimate combined over the two main basins was 38.4 million fish (25.0% C.V.) and was a biomass of 893.2 mt (23.4% C.V.). There were eleven times more pollock in the Washington Strait than in B.C., but there was less than a ton of pollock in Discovery Bay. The distribution of walleye pollock was primarily offshore in both B.C. and in Washington (Figure 20), and the highest station densities were observed in the central Strait. Moderate station densities were observed on the shallow banks in both countries and pollock were present in nearshore stations in low densities. The depth distribution of the population was almost identical between the two countries (Figure 21). The pollock population was distributed equally between the 41-60 fms and >60 fms depth strata. In Discovery Bay, all pollock were in the deepest stratum of 21-40 fms.

In all surveyed areas, walleye pollock populations were in the 10 cm or 20 cm total length categories (Figure 22), and demonstrated a similar pattern of proportions among the three study areas averaging from 14 cm to 15 cm in length (Table 6).

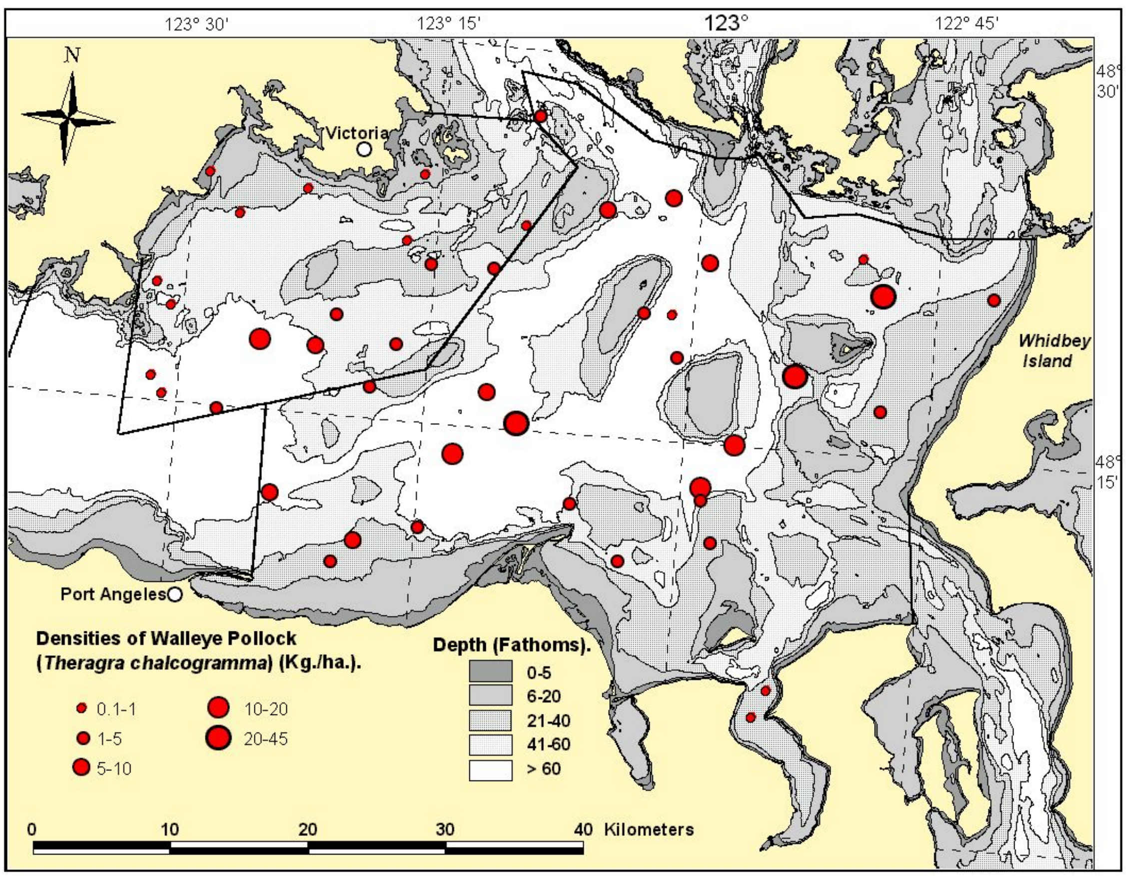


**Figure 20.** The distribution of walleye pollock station densities (kg/ha) in the eastern Strait of Juan de Fuca.

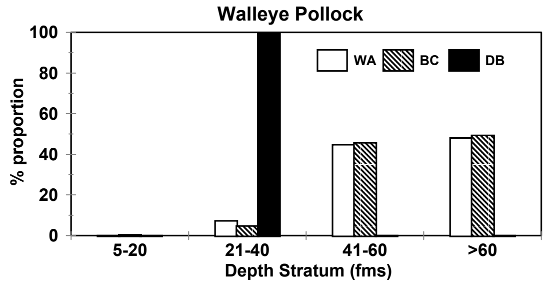


**Figure 21.** Depth distribution of walleye pollock.

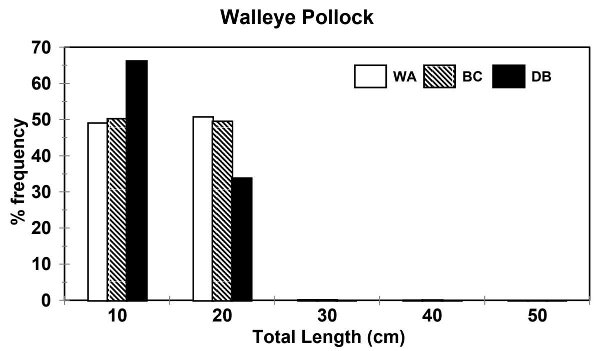


**Figure 22.** Length frequency distribution of walleye pollock.

**Table 14.** Numerical (x1000) and biomass (mt) abundance of walleye pollock in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | 61-120 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 0 | 3,238.7 | 16,606.6 | 15,926.7 | 35,772.0 |
| (% CV) | | 48.9 | 50.0 | 28.1 | 26.7 |
| Biomass (mt) | 0 | 60.6 | 371.3 | 398.3 | 830.2 |
| (% CV) | | 43.9 | 49.7 | 23.1 | 25.0 |
| **British Columbia** | | | | | |
| Abundance | 6.5 | 102.3 | 1,271.5 | 1,300.8 | 2,681.1 |
| (% CV) | 78.1 | 82.3 | 44.6 | 70.2 | 40.2 |
| Biomass (mt) | 0.2 | 3.0 | 28.6 | 31.1 | 63.0 |
| (% CV) | 78.1 | 72.1 | 41.7 | 65.5 | 37.6 |
| **Discovery Bay** | | | | | |
| Abundance | 0 | 8.4 | | | 8.4 |
| (% CV) | | 68.7 | | | 68.7 |
| Biomass (mt) | 0 | 0.2 | | | 0.2 |
| (% CV) | | 67.0 | | | 67.0 |

## Lingcod

The numerical and biomass population estimates of lingcod comprised far less than 1% of the fish in either the Washington or B.C. Strait of Juan de Fuca (Table 8). Combined over the eastern Strait, the lingcod population estimate was 152,500 fish (25.3% C.V., Table 15) and had a mass of 29.6 mt (26.2% C.V.). The numerical and biomass populations were roughly equal between the two portions of the main basin. Lingcod were not captured in Discovery Bay. Lingcod were more frequent in higher densities among the few trawl stations in B.C. and relatively uncommon on the Washington side of the Strait (Figure 23). Lingcod tended to occur either in nearshore waters or on the shallow banks of the central Strait. The lingcod population was primarily in the two shallowest depth strata, but significant amounts of the population occurred in the two deeper strata (Figure 24).

Almost all of the lingcod population was in the 30 cm length category in both Washington and B.C. (Figure 25), and were on average 30 cm and 29 cm in average total length, respectively (Table 6).

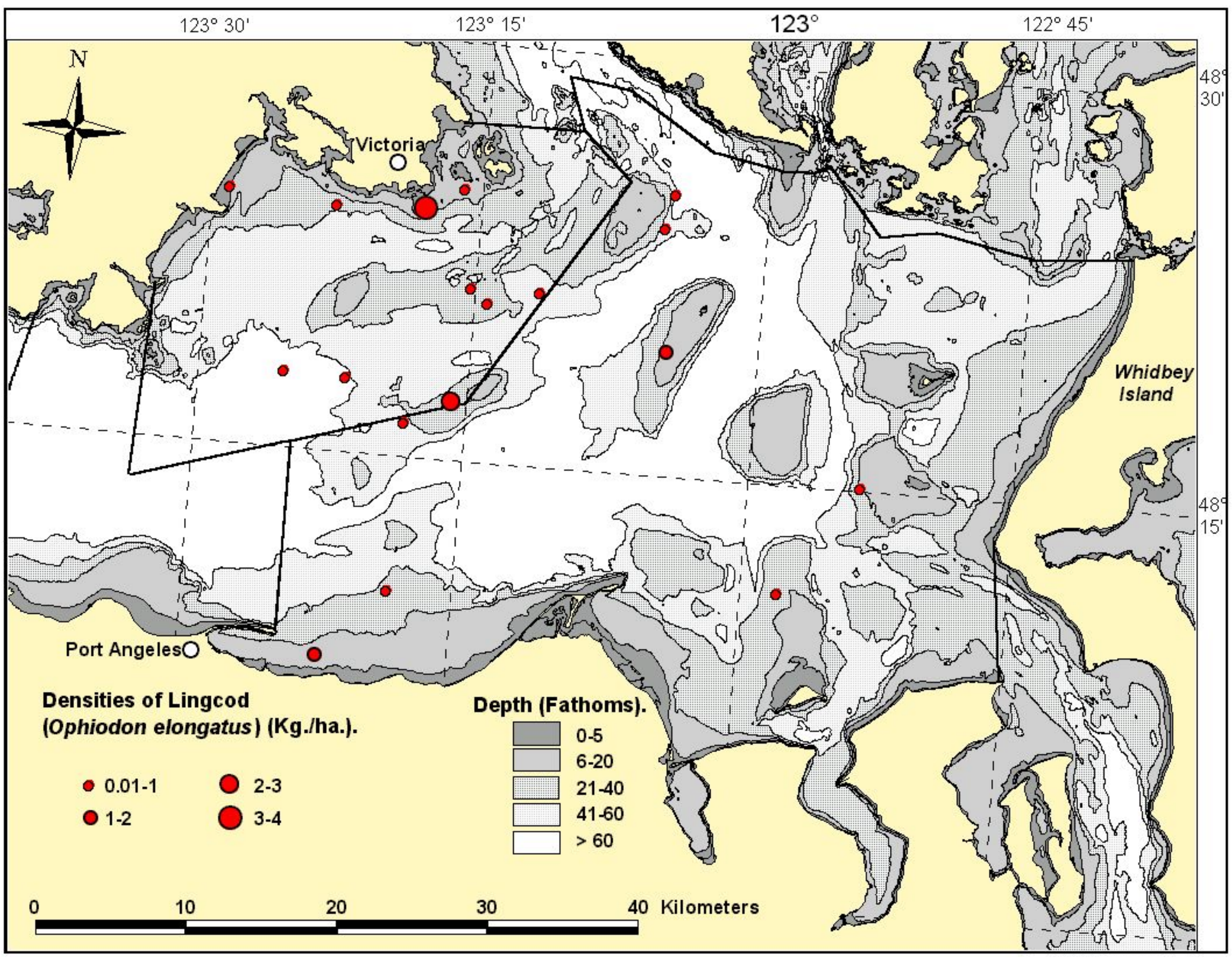


**Figure 23.** The distribution of lingcod station densities (kg/ha) in the eastern Strait of Juan de Fuca.

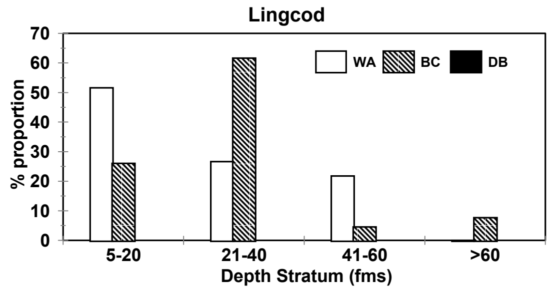


**Figure 24.** Depth distribution of lingcod.

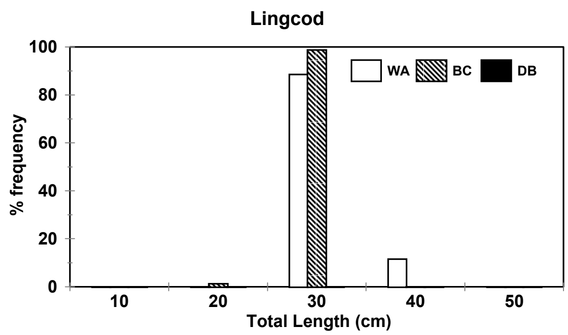


**Figure 25** Length frequency distribution of lingcod.

**Table 15.** Numerical (x 1,000) and biomass (mt) abundance of lingcod in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 33.7 | 26.6 | 7.8 | 0 | 68.1 |
| (% CV) | 66.2 | 43.5 | 71.3 | | 37.8 |
| Biomass (mt) | 7.3 | 3.8 | 3.1 | 0 | 14.2 |
| (% CV) | 68.7 | 44.0 | 68.1 | | 40.2 |
| **British Columbia** | | | | | |
| Abundance | 24.0 | 52.2 | 3.2 | 5.0 | 84.4 |
| (% CV) | 69.0 | 43.8 | 100.0 | 78.7 | 34.0 |
| Biomass (mt) | 4.0 | 9.5 | 0.7 | 1.2 | 15.4 |
| (% CV) | 70.6 | 45.1 | 100.0 | 76.9 | 34.2 |
| **Discovery Bay** | | | | | |
| Abundance | 0 | 0 | | | 0 |
| (% CV) | | | | | |
| Biomass (mt) | 0 | 0 | | | 0 |
| (% CV) | | | | | |

## English Sole

English sole was a common flatfish in the Washington ESJF where it accounted for 3% of the total fish population biomass and 26% of the flatfish biomass (Table 8). In B.C. ESJF, English sole only accounted for less that 1% of the total fish biomass and 10% of the flatfish biomass. The numerical population of English sole in the ESJF was estimated at 7.2 million fish (30.3% C.V., Table 16) which had a population biomass of 545.1 mt (28.8% CV). There was 26 times more biomass of English sole in the Washington ESJF than in the B.C. ESJF. English sole were distributed throughout the central and eastern portions of the Washington ESJF (Figure 26) and were especially dense on in the eastern waters near Whidbey Island and south of Lopez Island. English sole were in low density in the B.C. region and were encountered primarily at nearshore stations or on the offshore banks. The population distributions among the depth strata differed between the two main basin regions: in B.C. the great majority of the sole population was in the 41-60 fm stratum (Figure 27), but in Washington, the biomass was the greatest either in the 21-40 fm stratum or the >60 fm stratum.

English sole were present and common at all stations in Discovery Bay (Figure 26). There were 276,500 (18.3% C.V.) English sole in Discovery Bay, which had a mass of 7.5 mt (25.1% C.V. Table 17). English sole were slightly more abundant in the deeper stratum in Discovery Bay (Figure 27).

The occurrence of English sole populations by size category was similar between B.C. and Washington (Figure 28). More than 80% of the numerical population was in the 20 cm category and only a small proportion was at 30 cm, the minimum allowable commercial size. Smaller fish were present in Discovery Bay where almost 70% of the population was comprised by fish that were in the 10 cm category. There were no English sole in Discovery Bay of commercial size. English sole averaged 19 cm in total length in B.C., 20 cm in Washington, and only 14 cm in Discovery Bay (Table 6).

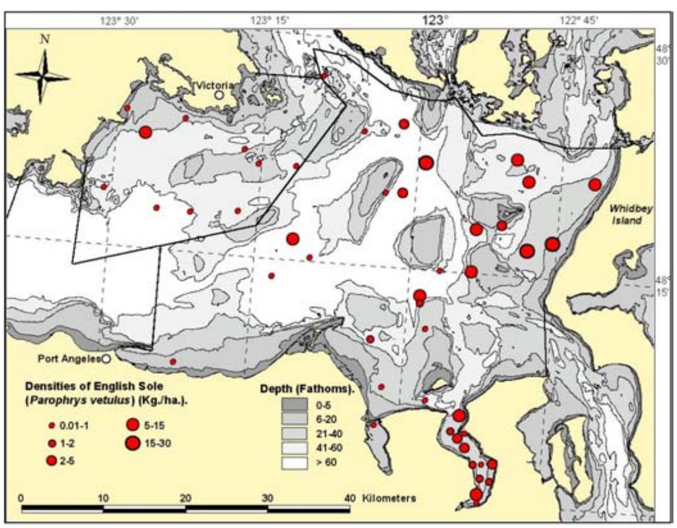


**Figure 26.** The distribution of English sole station densities (kg/ha) in the Eastern Strait of Juan de Fuca.

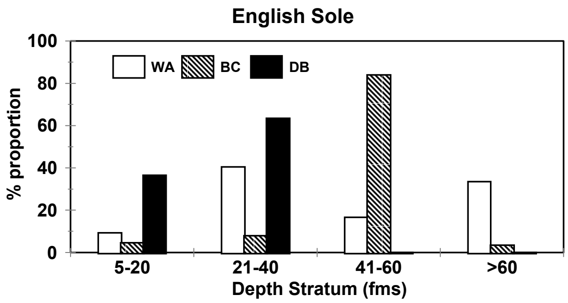


Figure 27. Depth distribution of English sole.

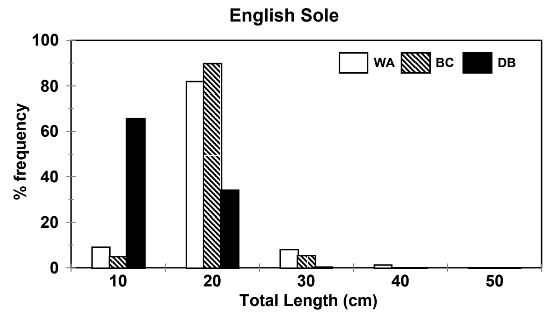


**Figure 28.** Length frequency distribution of English sole.

**Table 16.** Numerical (x 1,000) and biomass (mt) abundance of English sole in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 1,081.2 | 2,994.2 | 1,142.7 | 1,748.3 | 6,965.7 |
| (% CV) | 94.1 | 49.8 | 36.7 | 64.0 | 31.1 |
| Biomass (mt) | 49.1 | 212.8 | 87.8 | 175.9 | 525.6 |
| (% CV) | 98.5 | 53.6 | 40.6 | 48.8 | 29.7 |
| **British Columbia** | | | | | |
| Abundance | 24.2 | 10.9 | 222.8 | 8.9 | 266.9 |
| (% CV) | 100.0 | 65.4 | 93.4 | 59.4 | 78.6 |
| Biomass (mt) | 0.9 | 1.6 | 16.4 | 0.7 | 19.5 |
| (% CV) | 100.0 | 63.3 | 91.2 | 54.5 | 76.9 |
| **Discovery Bay** | | | | | |
| Abundance | 106.4 | 170.1 | | | 276.5 |
| (% CV) | 28.1 | 24.1 | | | 18.3 |
| Biomass (mt) | 2.7 | 4.8 | | | 7.5 |
| (% CV) | 45.4 | 29.8 | | | 25.1 |

## Sand Sole

Sand sole was a minor component of the fish population in the ESJF accounting for far less than 1% of the total fish or flatfish population in Washington (Table 8). Sand sole was not detected in the B.C. portion of the ESJF (Table 17). There were only 27,400 sand sole (72.2% C.V.) weighing 5.1 mt (94.6% C.V.) in the Washington ESJF, and they were only found at nearshore stations in Sequim Bay, off Whidbey Island and in Discovery Bay were they were encountered at four of the twelve survey stations (Figure 29). In Discovery Bay, there was an estimated population of 1,400 fish (58.8% C.V.) which weighed a third of a metric ton (49.7 % C.V., Table 17). The entire sand sole population was in the 5-20 fm depth stratum (Figure 30). Most of the sand sole population was in the 30 cm length category in the main basin with much of the population at 10 cm and 20 cm (Figure 31). Small sand sole were not observed in Discovery Bay where the sand sole population was distributed evenly between the 20 cm and 30 cm length categories. Sand sole averaged 24 cm in total length in Washington and 27 cm in Discovery Bay (Table 6).

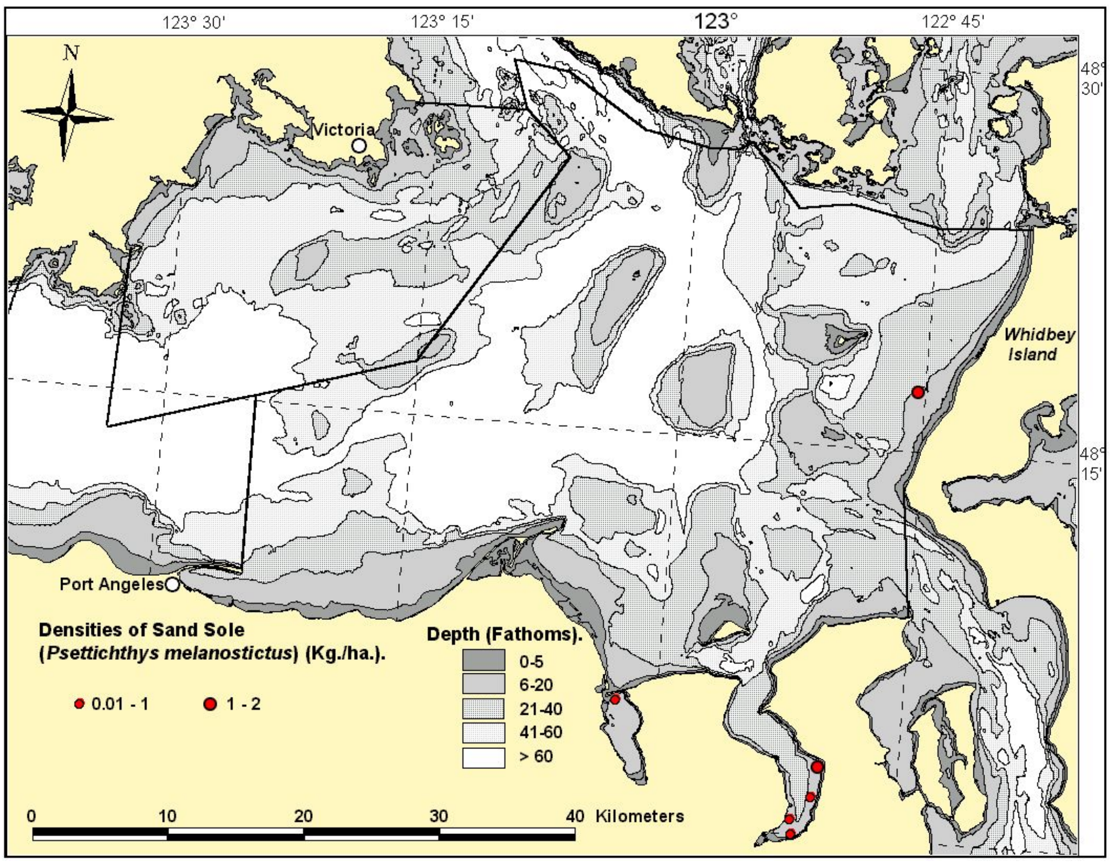


**Figure 29.** The distribution of sand sole station densities (kg/ha) in the eastern Strait of Juan de Fuca..

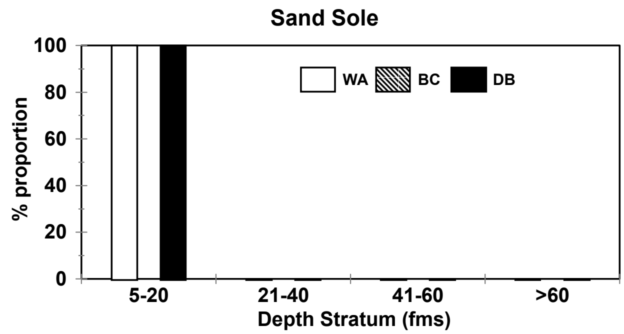


**Figure 30.** Depth distribution of sand sole.

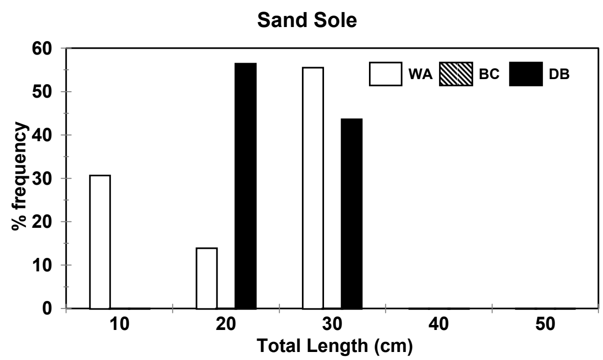


**Figure 31.** Length frequency distribution of sand sole.

**Table 17.** Numerical (x 1,000) and biomass (mt) abundance of sand sole in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 27.4 | 0.0 | 0.0 | 0.0 | 27.4 |
| (% CV) | 72.2 | | | | 72.2 |
| Biomass (mt) | 5.1 | 0.0 | 0.0 | 0.0 | 5.1 |
| (% CV) | 94.6 | | | | 94.6 |
| | | | | | |
| **British Columbia** | | | | | |
| Abundance | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| (% CV) | | | | | |
| Biomass (mt) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| (% CV) | | | | | |
| | | | | | |
| **Discovery Bay** | | | | | |
| Abundance | 2.3 | 0.0 | | | 2.3 |
| (% CV) | 58.8 | | | | 58.8 |
| Biomass (mt) | 0.4 | 0.0 | | | 0.4 |
| (% CV) | 49.7 | | | | 49.7 |

## Starry Flounder

In terms of numbers, starry flounder accounted for less than a percent of the total fish and flatfish population in the Washington ESJF (Table 8). In terms of weight, however, they accounted for 1% of the total fish biomass and 9% of the flatfish biomass in Washington. They were not encountered in the B.C. region (Table 18, Figure 32). There was a population of 124,300 fish (55.4% C.V.) in Washington, which represented a biomass of 190.1 mt (63.3% C.V.). There were 37,000 starry flounder in Discovery Bay (21.9% C.V.) where this population had a mass of 18.7 mt (19.4% C.V.). Starry flounder were encountered frequently in Discovery Bay at 11 of 12 stations and were only observed at six stations in the main Washington region (Figure 32). Half of these occurrences were on Eastern Bank in the eastern part of the study area and the remaining occurrences were in inshore or shallow stations. All of the starry flounder population was either in the 5-20 fm or 21-40 fm depth strata with a slight tendency for a greater proportion to be in the shallowest stratum in the Washington region than in Discovery Bay (Figure 33).

Most of the starry flounder population measured between 40 cm and 60 cm in the main Washington basin, where they averaged 44 cm (Figure 34, Table 6). Five percent of the population measured 70 cm while 10% measured 10 cm. Starry flounder averaged 32 cm in Discovery Bay, and the majority of the population measured in the 20 cm to 50 cm length categories with fewer large fish than in the main basin.

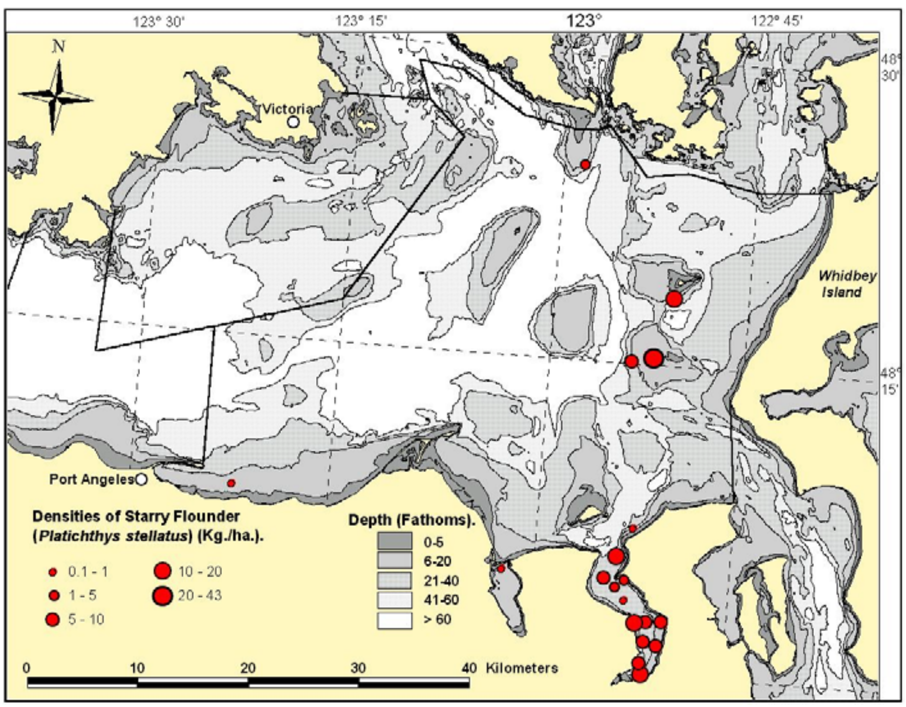


**Figure 32.** The distribution of starry flounder station densities (kg/ha) in the eastern Strait of Juan de Fuca.

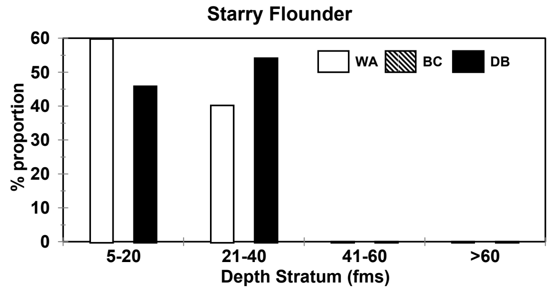


**Figure 33.** Depth distribution of starry flounder.

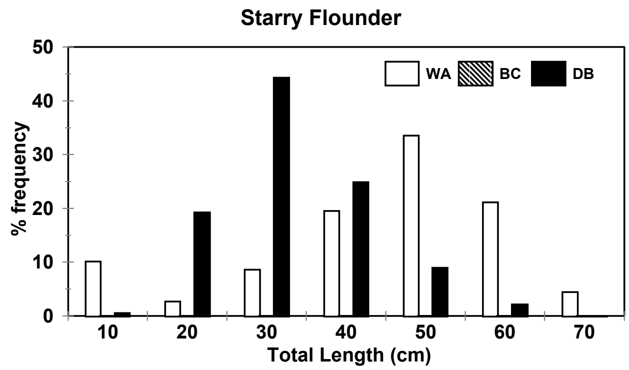


**Figure 34.** Length frequency distribution of starry flounder.

**Table 18.** Numeric (x 1,000) and biomass (mt) abundance of starry flounder in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 91.5 | 32.8 | 0.0 | 0.0 | 124.3 |
| (% CV) | 70.8 | 71.3 | | | 55.4 |
| Biomass (mt) | 113.7 | 76.4 | 0.0 | 0.0 | 190.1 |
| (% CV) | 95.3 | 69.6 | | | 63.3 |
| **British Columbia** | | | | | |
| Abundance | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| (% CV) | | | | | |
| Biomass (mt) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| (% CV) | | | | | |
| **Discovery Bay** | | | | | |
| Abundance | 16.4 | 20.5 | | | 37.0 |
| (% CV) | 28.0 | 32.3 | | | 21.9 |
| Biomass (mt) | 8.6 | 10.2 | | | 18.7 |
| (% CV) | 21.6 | 30.7 | | | 19.4 |

## Rock Sole

Northern and southern rock soles occurred in the ESFJ. Rock sole populations in the Washington ESJF accounted for 2% of the total fish biomass and 15% of the flatfish biomass (Table 8). In B.C., the rock sole populations only accounted for 1% of the total fish population in terms of biomass, and rock soles constituted 42% of the flatfish biomass. There were 3.9 million (37.5% C.V., Table 19) rock sole in the ESJF which accounted for a mass of 443.0 mt (25.6% C.V.). There was almost seven times the rock sole biomass in Washington than in B.C. Southern rock sole was by far the predominant species (Table 8). Only 2% of the identified rock sole were northern rock sole in Washington, and northern rock sole were not encountered in B.C. Southern rock sole were distributed in shallower waters around the periphery of the Washington and B.C. survey areas (Figure 35). Rock sole were infrequent in Discovery Bay where only 2,000 individuals (66.% C.V.) were estimated which had a mass of 0.3 mt (60.9% C.V., Table 19). Northern rock sole occurred two nearshore, shallow stations where they co-occurred with southern rock sole. One station on the top of Eastern Bank had northern rock sole in the absence of southern rock sole. Most of the southern rock sole population was in either of the two shallowest depth strata in B.C. and Washington (Figure 36). Southern rock sole was exclusively in the shallowest stratum in Discovery Bay.

The proportions of population at length for southern rock sole were similar among the three survey areas, and most of the population measured between 10 cm and 30 cm (Figure 37). Average lengths of southern rock sole ranged from 19 cm to 23 cm among the three study areas (Table 6).

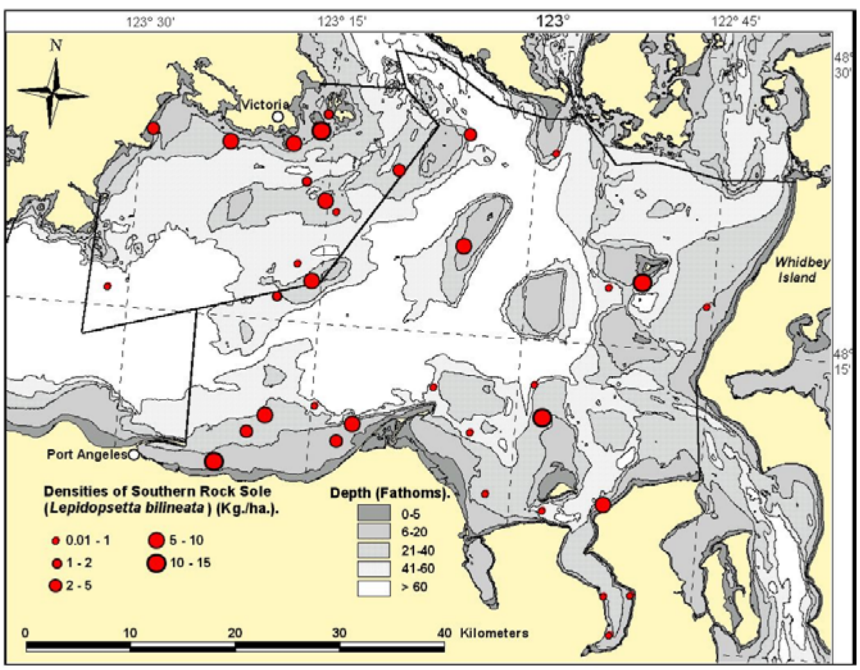


**Figure 35.** The distribution of southern rock sole station densities (kg/ha) in the eastern Strait of Juan de Fuca.

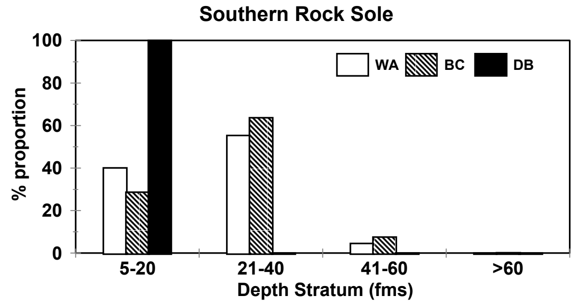


**Figure 36.** Depth distribution of southern rock sole.

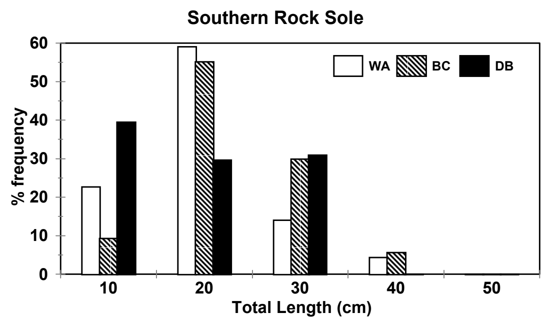


**Figure 127.** Length frequency distribution of southern rock sole.

**Table 19.** Numerical (x 1,000) and biomass (mt) abundance of rock sole in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 321.8 | 3,006.6 | 72.0 | 0.0 | 3,400.4 |
| (% CV) | 34.7 | 48.2 | 55.1 | | 42.7 |
| Biomass (mt) | 104.3 | 245.4 | 11.2 | 0.0 | 360.9 |
| (% CV) | 33.3 | 42.8 | 46.7 | | 30.8 |
| **British Columbia** | | | | | |
| Abundance | 250.3 | 203.3 | 35.7 | 1.6 | 490.9 |
| (% CV) | 47.8 | 43.4 | 80.1 | 100.0 | 30.9 |
| Biomass (mt) | 23.6 | 52.2 | 6.2 | 0.1 | 82.1 |
| (% CV) | 46.9 | 34.9 | 64.8 | 100.0 | 26.4 |
| **Discovery Bay** | | | | | |
| Abundance | 2.0 | 0.0 | | | 2.0 |
| (% CV) | 66.2 | | | | 66.2 |
| Biomass (mt) | 0.3 | 0.0 | | | 0.3 |
| (% CV) | 60.9 | | | | 60.9 |

## Dover Sole

Dover sole constituted one percent or less of the total fish population in either Washington or B.C. ESJF (Table 8). Among flatfish, however, Dover sole accounted for 8% of the B.C. biomass and 7% of the Washington biomass. There was a population of 1.7 million Dover sole (21.2%) in the ESJF (Table 20) and the population biomass was 108.4 mt (21.6% C.V.). The biomass of 87.1 mt in Washington was over five times the biomass of B.C. Low densities of Dover sole were observed in Discovery Bay (Figure 38) where the population estimate was 3,000 fish (44.1% C.V.) which had a biomass of 0.1 mt (51.9% C.V., Table 20). Otherwise, the highest densities of Dover sole occurred in the central and deep portions of the B.C. and Washington survey areas (Figure 38). Low densities of Dover sole were, however, observed in shallower, nearshore stations. Sixty percent or more of the Dover sole population biomass occurred in the deepest stratum (Figure 39). Thirty percent of the biomass occurred in the 41-60 fm stratum.

Seventy percent or more of the Dover sole population measured 20 cm in length category in the Washington and B.C. survey areas (Figure 40), and their average lengths were 19 cm and 21 cm, respectively (Table 6). Discovery Bay Dover sole were substantially smaller, averaging 11 cm and the entire population was in the 10 cm length interval (Figure 40).

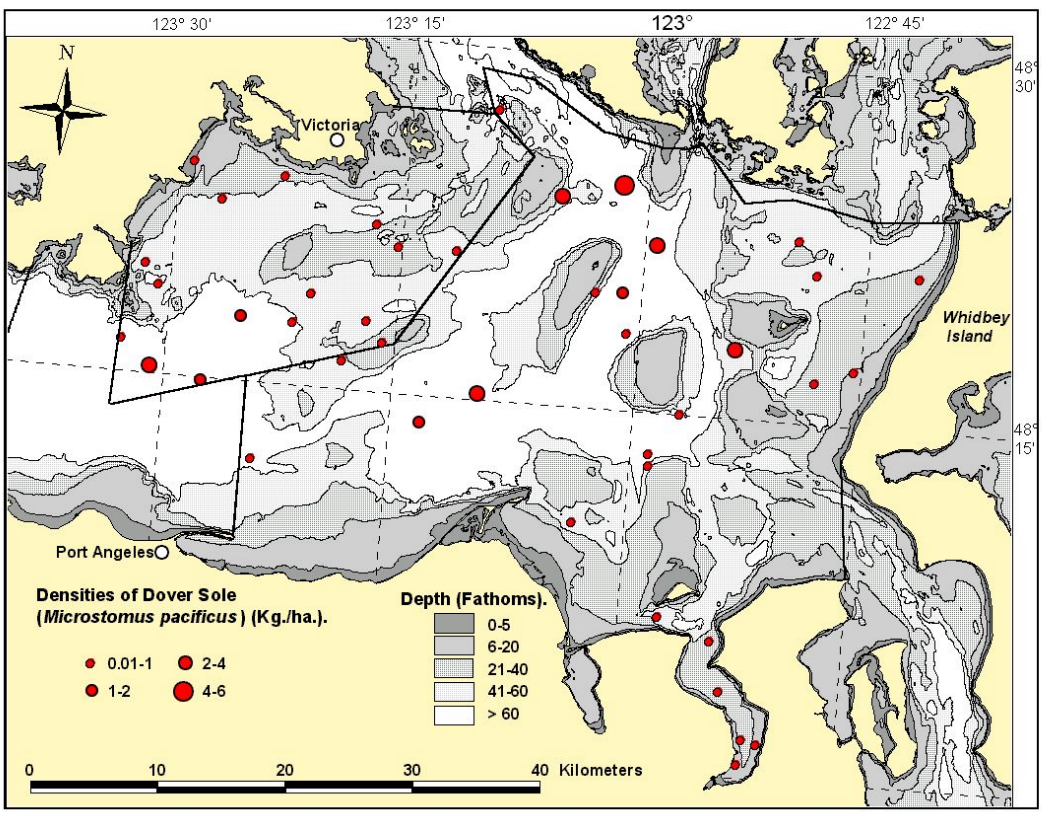


**Figure 38.** The distribution of Dover sole station densities (kg/ha) in the eastern Strait of Juan de Fuca.

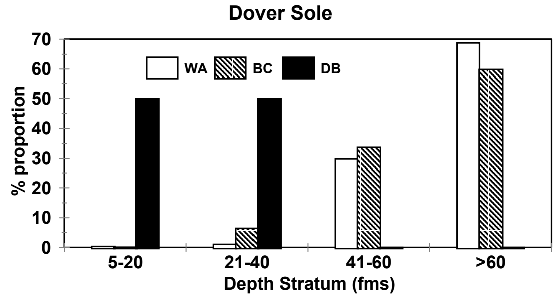


**Figure 39.** Depth distribution of Dover Sole.

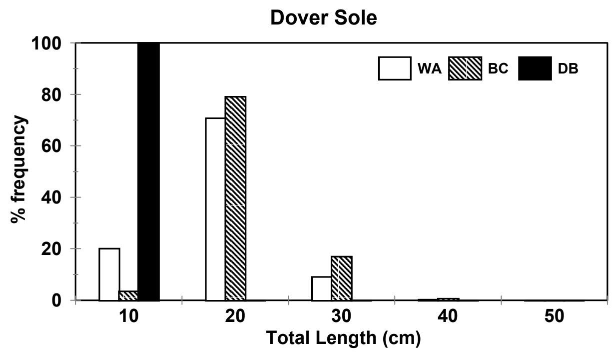


**Figure 40.** Length frequency distribution of Dover sole.

**Table 20.** Numerical (x 1,000) and biomass (mt) abundance of Dover sole in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 7.6 | 22.5 | 641.1 | 840.3 | 1,511.6 |
| (% CV) | 100.0 | 66.2 | 43.4 | 27.1 | 23.8 |
| Biomass (mt) | 0.3 | 0.9 | 27.4 | 63.2 | 91.8 |
| (% CV) | 100.0 | 81.7 | 44.5 | 30.6 | 24.9 |
| **British Columbia** | | | | | |
| Abundance | 1.1 | 12.4 | 74.2 | 111.7 | 199.3 |
| (% CV) | 100.0 | 53.1 | 32.5 | 39.8 | 25.6 |
| Biomass (mt) | 0.01 | 1.1 | 5.6 | 9.9 | 16.6 |
| (% CV) | 100.0 | 61.1 | 32.3 | 45.4 | 29.5 |
| **Discovery Bay** | | | | | |
| Abundance | 1.5 | 1.5 | | | 3.0 |
| (% CV) | 72.8 | 51.0 | | | 44.1 |
| Biomass (mt) | 0.04 | 0.04 | | | 0.1 |
| (% CV) | 88.6 | 51.3 | | | 51.9 |

## Invertebrate Diversity and Abundance

### Sampled Diversity and Species Composition

One hundred taxa of invertebrates were captured and identified among the three survey regions (Tables 5 and 21). There were at least 115 thousand individuals captured and they had a mass of 3.8 mt among the three survey areas. In all, 7 species of gastropods, 11 species of bivalves, 3 species of nudibranchs, 12 species of shrimp, 15 species of crabs, 16 species of sea stars, 4 species of sea urchins, and 4 species of sea cucumbers were collected. The Washington ESJF had the greatest species richness with 80, the B.C. area had 53 species, and Discovery Bay had 41 species of invertebrates. Thirty-five species were only collected in Washington and not in B.C., 8 species were found in B.C. and not in Washington, and 10 species in Discovery Bay and no where else.

### Population Abundance

The estimated population of invertebrates was 108.9 million individuals (23.8% C.V.) in the eastern Strait of Juan de Fuca (Tables 22 and 23). Invertebrates had a biomass of 6,309.8 mt (17.1%). There were 14 times more individuals in the Washington survey area than in the B.C. survey area, and there was almost 6 times the biomass on the Washington side than on the B.C. side. In Washington, the greatest numerical abundance was in the 41-60 fm stratum, however, in terms of biomass, the 5-20 fm stratum had the greatest population biomass with a decreasing pattern in biomass with depth. In B.C., the shallowest stratum had both the greatest numerical and biomass population abundance. Discovery Bay had a greater population estimate of individual invertebrates than the B.C. basin (Tables 23), and this bay had almost half of the biomass as B.C. Most of the individual abundance in Discovery Bay was in the deeper stratum, but in terms of population biomass, most was in the shallower stratum.

Overall, pandalid shrimp dominated most areas in terms of numerical abundance (Tables 22). In the B.C. survey area, other pandalid shrimp was in greatest numerical abundance followed in rank by barnacles, smooth pink scallops, red sea urchins, and green sea urchins. In Washington, other pandalid shrimp dominated invertebrate populations: there were 65 million of these shrimps. Numerical abundance then was dominated by northern horse mussel, sidestriped shrimp, smooth pink scallops, and spotted prawn. In terms of biomass abundance, red sea urchins dominated invertebrates in the B.C. survey area followed in rank by Dungeness crab, sunflower seastar, other seastars, and barnacles. In the Washington ESJF, the population biomass was dominated by Dungeness crab, red sea urchins, sunflower seastar, other seastar, and other pandalid shrimps. The invertebrate population in Discovery Bay was dominated by other pandalid shrimp, giant sea anemone, graceful crab, Dungeness crab, and California market squid in terms of numerical abundance; and by giant sea anemone, other pandalid shrimp, Dungeness crab, sunflower seastar, and graceful crab in terms of biomass abundance (Table 9).

**Table 21.** Invertebrates captured in the Washington Eastern Strait of Juan de Fuca during the 2000 trawl survey.

| Common Name | Scientific Name | British Columbia Number | British Columbia Biomass (kg) | Washington Number | Washington Biomass (kg) |
|---|---|---|---|---|---|
| Sponge unidentified | Phylum Porifera spp. | 15 | 4.78 | 10 | 2.41 |
| Cloud sponge | *Aphrocallistes vastus* | 5 | 1.65 | | |
| Vase sponge | *Stylissa stipitata* | 1 | 0.04 | 2 | 0.03 |
| Ostrich plume hydroid | *Aglaophenia struthionides* | | | 1 | 0.03 |
| Jellyfish unidentified | Order Scyphozoa spp. | 1 | 0.5 | 4 | 0.83 |
| Mottled green anemone | *Urticina crassicornius* | 1 | 0.08 | | |
| *Metridium* unidentified | *Metridium* spp. | | | 11 | 1.48 |
| Gigantic anemone | *Metridium giganteum* | 16 | 3.66 | 313 | 87.41 |
| *Cerebratulus* unidentified | *Cerebratulus* spp. | 1 | 0.03 | | |
| *Nereis* unidentified | *Nereis* spp. | | | 1 | 0.01 |
| Chaetopterid unidentified | *Chaetopteridae* spp. | | | 0 | 2.64 |
| Snail unidentified | Class Gastropoda spp. | 1 | 0.01 | 3 | 0.22 |
| Whitecap limpet | *Acmaea mitra* | 1 | 0.01 | | |
| Blue topsnail | *Calliostoma ligatum* | | | 1 | 0.01 |
| Variable topsnail | *Calliostoma variegatum* | | | 1 | 0.01 |
| Moon snail | *Polinices lewisii* | | | 4 | 0.81 |
| Oregon hairy triton | *Fusitriton oregonensis* | 6 | 0.57 | 23 | 2.24 |
| Leafy hornmouth | *Ceratostoma foliatum* | 1 | 0.03 | 3 | 0.09 |
| Tabled whelk | *Neptunea tabulata* | | | 1 | 0.01 |
| Speckled sea lemon | *Anidodoris nobilis* | 1 | 0.02 | | |
| Common spotted nudibranch | *Triopha catalinae* | 1 | 0.01 | | |
| Dall’s dendronotid | *Dendronotus dalli* | 1 | 0.01 | | |
| Gumboot chiton | *Cryptochiton stelleri* | | | 18 | 12.12 |
| Bay mussel | *Mytilus edulis* | | | 1 | 0.02 |
| Northern horse mussel | *Modiolus modiolus* | 3 | 0.14 | 2631 | 68.35 |
| Pink scallop unidentified | *Chlamys* spp. | | | 12 | 0.27 |
| Deep ribbed pink scallop | *Chlamys hastata* | 61 | 1.6 | 271 | 4.8 |
| Smooth pink scallop | *Chlamys rubida* | 202 | 4.35 | 766 | 17.83 |
| Rock jingle | *Pododesmus cepio* | | | 1 | 0.08 |
| Butter clam | *Saxidomus giganteus* | 1 | 0.13 | 6 | 0.27 |
| Stubby squid | *Rossia pacifica* | 4 | 0.21 | 4 | 0.16 |
| California market squid | *Loligo opalescens* | | | 14 | 0.25 |
| Giant Barnacle | *Balanus nubilis* | 237 | 18.21 | 302 | 40.59 |
| Spiny lebbeid | *Lebbeus groenlandicus* | 1 | 0.01 | 168 | 0.62 |
| Shortscale eualid | *Eualus suckleyi* | | | 3 | 0.01 |
| Alaskan pink shrimp | *Pandalus eous* | 139 | 0.48 | 7879 | 62.84 |
| Humpy shrimp | *Pandalus goniurus* | 4 | 0.02 | 30 | 0.13 |
| Pink shrimp | *Pandalus jordani* | | | 3791 | 14.32 |
| Spotted prawn | *Pandalus platyceros* | 55 | 1.15 | 635 | 21.24 |
| Coonstriped shrimp | *Pandalus hypsinotus* | 2 | 0.01 | 107 | 0.43 |
| Dock shrimp | *Pandalus danae* | 2235 | 11.42 | 2723 | 15.87 |
| Rough patch shrimp | *Pandalus stenolepis* | | | 18 | 0.25 |
| Sidestriped shrimp | *Pandalus dispar* | 173 | 2.35 | 1743 | 19.38 |
| Crangonid shrimp unidentified | Crangonidae spp. | 21 | 0.04 | 25 | 0.12 |
| Horned shrimp | *Paracrangon echinata* | 15 | 0.07 | 36 | 0.12 |
| Coastal spinyhead | *Metacrangon munita* | | | 1 | 0.01 |
| Hermit crabs unidentified | Paguridae spp. | 4 | 0.19 | 20 | 2.05 |
| Squat lobster | *Mundia quadrispina* | | | 12 | 0.05 |
| Porcelain crab unidentified | Porcellanidae spp. | | | 2 | 0.01 |

**Table 21.** Invertebrates captured in the Washington Eastern Strait of Juan de Fuca during the 2000 trawl survey.

| | | | | | |
|---|---|---|---|---|---|
| Flattop crab | *Petrolisthes eriomerus* | | | 1 | 0.01 |
| Graceful decorator crab | *Oregonia gracilis* | | | 45 | 0.27 |
| North Pacific toad crab | *Hyas lyratus* | 2 | 0.26 | 14 | 0.52 |
| Broad snow crab (female) | *Chionoecetes bairdi* | | | 17 | 2.32 |
| Broad snow crab (male) | *Chionoecetes bairdi* | | | 5 | 1.08 |
| Broad snow crab (unsexed) | *Chionoecetes bairdi* | | | 1 | 0.01 |
| Cryptic kelp crab | *Pugettia richii* | | | 5 | 0.02 |
| Graceful kelp crab | *Pugettia gracilis* | | | 6 | 0.03 |
| Sharpnose crab | *Scyra acutifrons* | | | 8 | 0.34 |
| Longhorned decorator crab | *Chorilia longipes* | 4 | 0.03 | 9 | 0.07 |
| Red rock crab (unsexed) | *Cancer productus* | | | 21 | 5.57 |
| Red rock crab (male) | *Cancer productus* | 4 | 1.71 | 64 | 21.24 |
| Red rock crab (female) | *Cancer productus* | 4 | 0.87 | 22 | 4.26 |
| Dungeness crab (male) | *Cancer magister* | 28 | 21.28 | 262 | 176.90 |
| Dungeness crab (female) | *Cancer magister* | 188 | 74.38 | 280 | 123.09 |
| Graceful crab (female) | *Cancer gracilis* | | | 7 | 0.28 |
| Graceful crab (male) | *Cancer gracilis* | | | 11 | 0.64 |
| Graceful crab (unsexed) | *Cancer gracilis* | 4 | 0.03 | 4 | 0.51 |
| Pygmy rock crab | *Cancer oregonensis* | | | 13 | 0.1 |
| Lampshell brachiopod | *Terabratalia transversa* | 1 | 0.01 | 8 | 0.14 |
| Banana starfish | *Luidia foliata* | 27 | 8.65 | 76 | 22.39 |
| Gephyreaster swifti | *Gephyreaster swifti* | | | 1 | 0.32 |
| Spiny vermillion star | *Hippasteria spinosa* | 5 | 0.41 | 4 | 0.54 |
| Vermillion starfish | *Mediaster aequalis* | 3 | 0.05 | 20 | 0.68 |
| Rose sea star | *Crossaster papposus* | | | 4 | 1.02 |
| Morning sun star | *Solaster dawsoni* | 3 | 1.25 | 11 | 1.84 |
| Stimpson's sun starfish | *Solaster stimpsoni* | 2 | 0.29 | 4 | 0.29 |
| Slime star | *Pteraster tesselatus* | 11 | 3.86 | 20 | 12.39 |
| Blood star | *Henricia leviuscula* | 5 | 0.08 | 10 | 0.1 |
| False ochre star | *Evasterias troschelii* | 13 | 13.18 | 20 | 8.32 |
| Pink short spined seastar | *Pisaster brevispinus* | 5 | 8.63 | 31 | 32.58 |
| Long armed spiny seastar | *Orthasterias koehleri* | 28 | 11.66 | 77 | 35 |
| Sunflower star | *Pycnopodia helianthoides* | 33 | 69.51 | 120 | 109.54 |
| Brittle star unidentified | Ophiuroidae spp. | 3 | 0.03 | 1 | 0.01 |
| Basket star | *Gorgonocephalus caryi* | | | 40 | 8.56 |
| Green sea urchin | *S. droebachiensis* | 216 | 24.07 | 346 | 36.51 |
| Red sea urchin | *Strongylocentrotus franciscanus* | 260 | 249.48 | 208 | 184.95 |
| Pallid sea urchin | *Stronglyocentrotus pallidus* | | | 2 | 0.35 |
| Purple sea urchin | *Strongylocentrotus purpuratus* | | | 8 | 6.18 |
| White sea cucumber | *Eupentacta quinquesemita* | | | 1 | 0.08 |
| Orange sea cucumber | *Cucumaria miniata* | | | 1 | 0.1 |
| Red sea cucumber | *Parastichopus californicus* | 14 | 7.31 | 92 | 99.15 |
| Sweet potato sea cucumber | *Molpadia intermedia* | | | 1 | 0.01 |
| Tunicate unidentified | Class Ascidiacea spp. | | | 32 | 0.48 |
| Warty sea squirt | Class Ascidiacea spp. | 48 | 1.15 | | |
| Glassy sea squirt | *Ascida paratropa* | 3 | 0.15 | 2 | 0.07 |
| Total | | 4123 | 550.11 | 23532 | 1279.28 |
| Number of species | 100 | 53 | | 80 | |

**Table 23.** Numerical (x 1,000) and biomass (mt) abundance of all invertebrates in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 7,444.7 | 9,591.6 | 74,051.7 | 10,712.2 | 101,800.2 |
| (% CV) | 32.8 | 29.9 | 34.3 | 26.4 | 25.4 |
| Biomass (mt) | 2,107.9 | 1,535.0 | 1,208.3 | 538.3 | 5,389.4 |
| (% CV) | 32.8 | 27.9 | 41.8 | 52.5 | 18.3 |
| **British Columbia** | | | | | |
| Abundance | 3,578.6 | 1,515.9 | 1,546.0 | 442.0 | 7,082.5 |
| (% CV) | 49.5 | 28.4 | 25.6 | 33.2 | 26.4 |
| Biomass (mt) | 634.4 | 78.3 | 191.1 | 16.6 | 920.4 |
| (% CV) | 67.8 | 35.8 | 51.9 | 37.9 | 48.1 |
| **Discovery Bay** | | | | | |
| Abundance | 2,130.9 | 29,427.4 | | | 31,558.3 |
| (% CV) | 31.5 | 43.5 | | | 40.6 |
| Biomass (mt) | 292.1 | 229.2 | | | 521.3 |
| (% CV) | 33.4 | 18.8 | | | 20.5 |

## Dungeness Crab

Dungeness crab was among the dominant invertebrate species in all survey areas (Tables 9 and 22). In the B.C. ESJF, the Dungeness crab population accounted for 17% of the biomass of all invertebrates. The population of Dungeness crabs was far greater in Washington than in B.C. In Washington, Dungeness crab represented 25% of the biomass of all invertebrates (Table 22). In the entire ESJF, there were 2.7 million crabs (28.0% C.V., Tables 22, 24, and 25) which weighed 1,500 mt (29.3% C.V.). Of these crabs, 1.3 million were males (43.6% C.V.) which had a mass of 892.6 mt (43.3% C.V.). In the ESJF, there was a population of 1.4 million female crabs (36.0% C.V.) weighing 629.5 mt (35.5% C.V.). There were 1.2 million males and 1.1 million females in Washington compared to only 29 thousand males and 317 thousand females in B.C. Discovery Bay had a population of 113 thousand crabs, of which 55% were males. The biomass of male crabs in Discovery Bay was 49 mt and was 24 mt for females. Male and female Dungeness crabs were distributed in mostly shallow areas along the periphery of the Strait and high densities were observed in Sequim and Discovery Bays and near the entrance to Port Angeles Harbor and near Esquimalt Harbor (Figures 41 and 42). Moderate densities of crabs were also observed near the banks and shallow areas of the eastern Washington Strait. Male crabs exclusively co-occurred with females, but females were encountered by themselves, and more frequently at deeper depths. In the Washington and Discovery Bay survey areas, most of the male crab population biomass was in the 21-40 fm depth stratum (Figure 43). In B.C., the entire male population biomass was in the shallowest stratum. In both the Washington and B.C. crab populations, female crab biomass tended to be deeper than males (Figure 44). While more than half of the Washington females were in the 5-20 fm stratum, 20% of the population biomass was in the 41-60 fm stratum. In B.C., most of the female population was in the third deepest stratum.

The bulk of the population biomass of male Dungeness crabs had carapace widths greater than 16 cm, the minimum legal landing size (Figure 45). Male crabs ranged to 22 cm, over 8.5 inches. The sampled population included small males as little as 4 cm width. The distribution of male carapace widths was similar among the three study areas, although smaller crabs were common in Discovery Bay. Male crab widths averaged between 15.8 and 16.6 cm (Table 6). Female crabs were smaller than male crabs, and female crab widths were similar among all the three study areas (Figure 46). Female carapace widths averaged between 13.7 cm and 13.9 cm (Table 6).

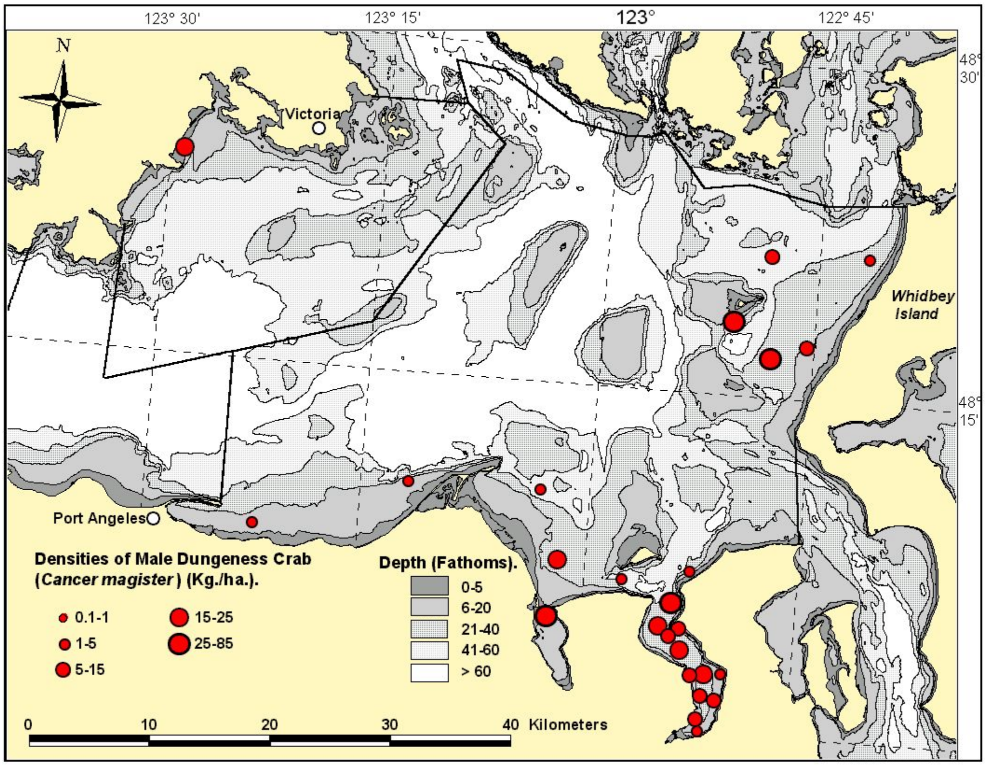


**Figure 41.** The distribution of male Dungeness crab station densities (kg/ha) in the eastern Strait of Juan de Fuca.

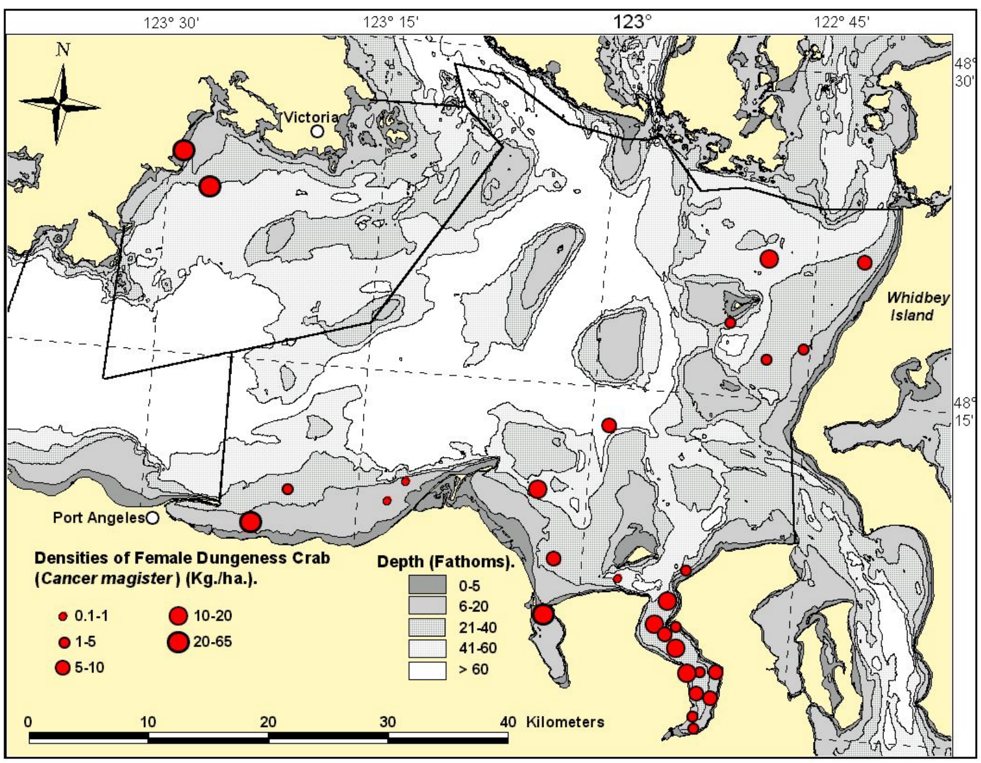


**Figure 42.** The distribution of female Dungeness crab station densities (kg/ha) in the eastern Strait of Juan de Fuca.

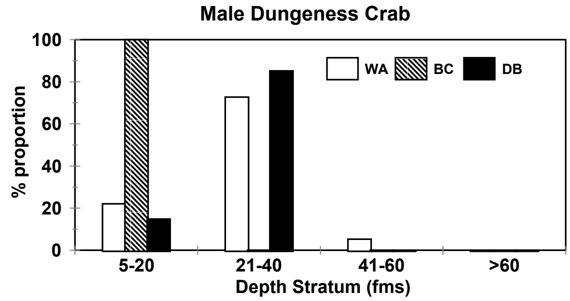


**Figure 43.** Depth distribution of male Dungeness crab.

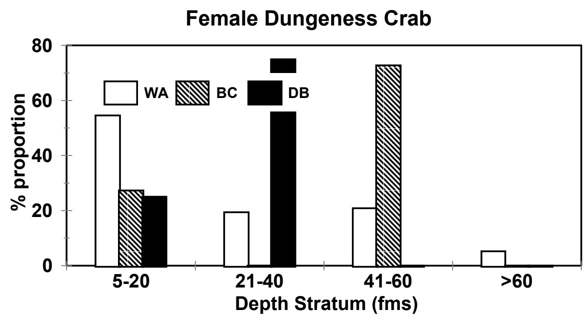


**Figure 44.** Depth distribution of female Dungeness crab.

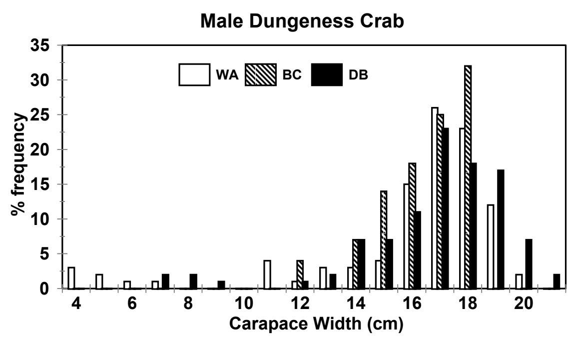


**Figure 45.** Carapace width frequency distribution of male Dungeness crab.

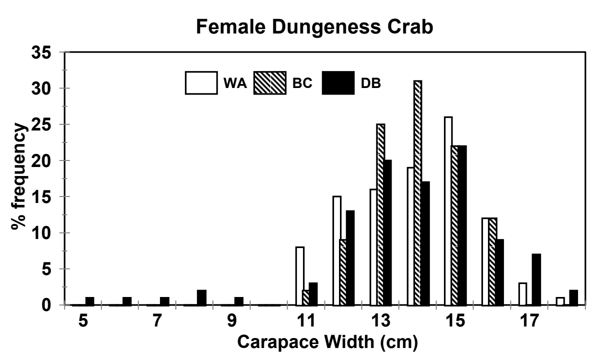


**Figure 46.** Carapace width frequency distribution of female Dungeness crab.

**Table 24.** Numerical (x 1,000) and Biomass (mt) Abundance of Male Dungeness Crabs in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 465.3 | 755.2 | 48.9 | 0.0 | 1,249.4 |
| (% CV) | 72.9 | 59.8 | 60.2 | | 44.6 |
| Biomass (mt) | 191.8 | 632.4 | 46.0 | 0.0 | 870.2 |
| (% CV) | 65.9 | 59.1 | 60.0 | | 45.4 |
| | | | | | |
| **British Columbia** | | | | | |
| Abundance | 29.4 | 0.0 | 0.0 | 0.0 | 29.4 |
| (% CV) | 100.0 | | | | 100.0 |
| Biomass (mt) | 22.4 | 0.0 | 00 | 0.0 | 22.4 |
| (% CV) | 100.0 | | | | 100.0 |
| | | | | | |
| **Discovery Bay** | | | | | |
| Abundance | 12.1 | 50.0 | | | 62.0 |
| (% CV) | 22.5 | 23.3 | | | 19.3 |
| Biomass (mt) | 7.3 | 41.6 | | | 48.9 |
| (% CV) | 15.3 | 27.4 | | | 23.4 |

**Table 25.** Numerical (x 1,000) and biomass (mt) abundance of female dungeness crabs in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 628.4 | 260.2 | 201.7 | 38.2 | 1,128.5 |
| (% CV) | 68.7 | 39.3 | 65.4 | 100.0 | 41.3 |
| Biomass (mt) | 268.7 | 95.6 | 102.9 | 25.4 | 492.6 |
| (% CV) | 66.6 | 37.2 | 65.7 | 100.0 | 39.9 |
| | | | | | |
| **British Columbia** | | | | | |
| Abundance | 114.6 | 0.0 | 202.3 | 0.0 | 317.0 |
| (% CV) | 100.0 | | 100.0 | | 73.4 |
| Biomass (mt) | 37.3 | 0.0 | 99.6 | 0.0 | 136.9 |
| (% CV) | 100.0 | | 100.0 | | 77.7 |
| | | | | | |
| **Discovery Bay** | | | | | |
| Abundance | 14.5 | 36.8 | | | 51.3 |
| (% CV) | 32.3 | 22.3 | | | 18.4 |
| Biomass (mt) | 5.9 | 17.8 | | | 23.8 |
| (% CV) | 31.4 | 21.9 | | | 18.2 |

## Spotted Prawn

Spotted prawn was a minor component of the invertebrate catch in all survey areas, accounting for less than 2.5% of the numerical or biomass population estimates (Tables 9 and 22). There were 2.6 million spotted prawns (32.6% C.V.) in the ESJF (Table 26), and they had a biomass of 87 mt (32.6% C.V.). Some 13,000 prawns inhabited Discovery Bay (50.5% C.V.), and they had an estimated biomass of 0.4 mt (47.3% C.V.). There was more than 20 times the numerical abundance of spotted prawns in Washington than there was in B.C. and 14 times the biomass. Spotted prawns were distributed throughout the eastern Strait of Juan de Fuca and in the mouth of Discovery Bay (Figure 47). The highest densities of prawns occurred on the deep margins of the banks including Hein Bank, Eastern Bank, Dallas Bank, and Protection Island. In the two large basins, 70% or more of the spotted prawn biomass was in the 41-60 fm depth stratum (Figure 48). In Washington, a quarter of the population was in the >60 fm stratum. In Discovery Bay, all of the spotted prawn biomass was in the 21-40 fm stratum.

Most of the spotted prawn population measured 4 cm in carapace length (Figure 49). In Discovery Bay, 80% of the prawn population was at 4 cm and in the Washington Survey area, most of the prawn population measured 4 cm in carapace length or 3 cm, the legal minimum size limit. In B.C., almost 20% of the population measured 2 cm, and the remainder either measured 3 cm or 4 cm in length. Average prawn length in Washington was 36.2 mm, in B.C. was 32.6 mm, and in Discovery Bay was 37.7 mm (Table 6).

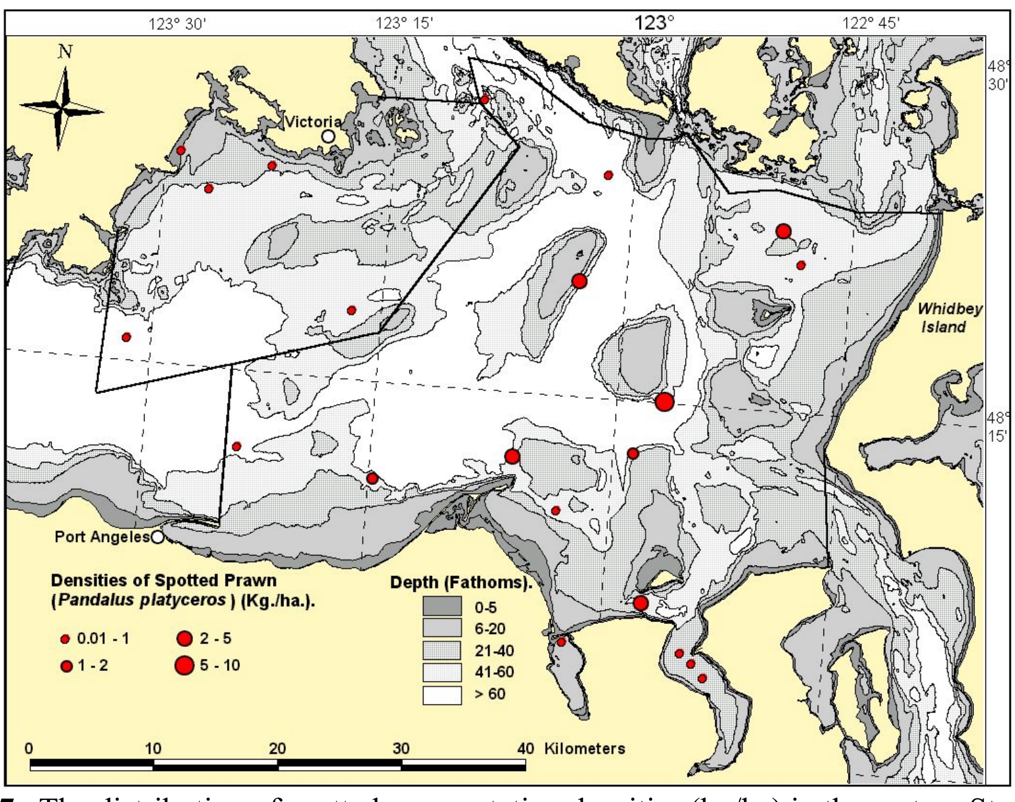


**Figure 47.** The distribution of spotted prawn station densities (kg/ha) in the eastern Strait of Juan de Fuca.

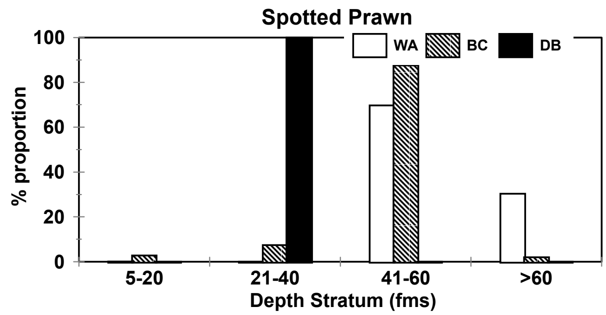


**Figure 48.** Depth distribution of spotted prawn.

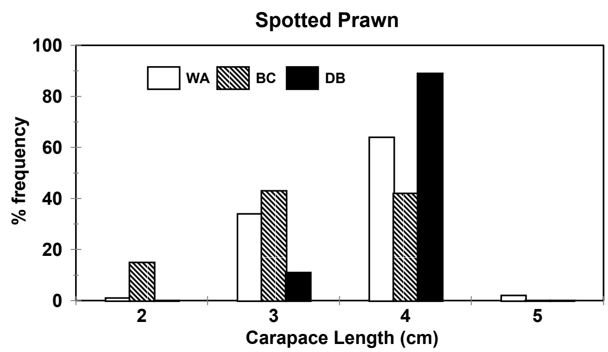


**Figure 49.** Carapace length frequency distribution of spotted prawn.

**Table 26.** Numerical (x 1,000) and biomass (mt) abundance of spotted prawns in the Eastern Strait of Juan de Fuca and Discovery Bay.

| Stratum | 5-20 fm | 21-40 fm | 41-60 fm | >60 fm | Total |
|---|---|---|---|---|---|
| **Washington** | | | | | |
| Abundance | 4.2 | 0 | 1,820.8 | 674.8 | 2,499.8 |
| (% CV) | 100.0 | | 29.8 | 97.0 | 34.0 |
| Biomass (mt) | 0.04 | 0 | 58.7 | 25.6 | 84.4 |
| (% CV | 100.0 | | 32.0 | 98.6 | 37.3 |
| **British Columbia** | | | | | |
| Abundance | 7.4 | 17.2 | 91.1 | 1.6 | 117.2 |
| (% CV) | 100.0 | 100.0 | 72.7 | 100.0 | 58.7 |
| Biomass (mt) | 0.1 | 0.2 | 2.3 | 0.05 | 2.6 |
| (% CV) | 100.0 | 100.0 | 70.3 | 100.0 | 62.2 |
| **Discovery Bay** | | | | | |
| Abundance | 0 | 12.8 | | | 12.8 |
| (% CV) | | 50.5 | | | 50.5 |
| Biomass (mt) | 0 | 0.4 | | | 0.4 |
| (% CV) | | 47.3 | | | 47.3 |

## Benthic Marine Debris

Almost 694.5 mt of human-generated marine debris was estimated from the benthos of the ESJF (Table 27). Only 28 mt of debris was estimated from B.C. while the Washington survey contained 666.5 mt of debris. Discovery Bay contained 5 mt of debris. The greatest estimate of debris was in the Other Marine Debris category which primarily consisted of large tires. In Washington, Fishing Gear debris was second in magnitude to the Other Marine Debris category. In Discovery Bay, Glass was the primary debris category.

**Table 27.** Marine debris estimates (metric tons) from the Eastern Strait of Juan de Fuca and Discovery Bay.

| | B.C. | | Washington | | Discovery Bay | |
|---|---|---|---|---|---|---|
| **Category** | **MT** | **%CV** | **MT** | **%CV** | **MT** | **%CV** |
| Aluminum | 0.01 | 100 | 0.2 | 100 | 0.1 | 89.8 |
| Fishing gear | 0.01 | 100 | 95.1 | 70.5 | 0 | 0 |
| Glass | 1.0 | 100 | 17.4 | 80.7 | 3.6 | 38.4 |
| Plastic | 0.1 | 100 | 2.5 | 71.5 | 1.2 | 75.0 |
| Other marine debris | 26.9 | 100. | 551.4 | 91.1 | 0.3 | 54.5 |
| Total man-made debris | 28.0 | 95.9 | 666.5 | 79.9 | 5.2 | 43.3 |

# DISCUSSION

The successful completion of the 2000 Transboundary Trawl Survey in the eastern Strait of Juan de Fuca represents the first comprehensive 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 can also serve as an environmental baseline for evaluating changes in the transboundary waters due to management actions, catastrophic damage, or natural changes.

The survey precision generally achieved the 30% C.V. goal for all fish species, abundant species and ubiquitous key species. The survey achieved a 10% C.V. for the total fish biomass estimate of 27,000 mt. For individual fish species biomasses, C.V.s were less than 24% for spotted ratfish and spiny dogfish, two species that were abundant in both of the main regions. Other species that had higher basin wide C.V.s but were still less than 30% included Pacific cod, lingcod, southern rock sole, and Dover sole. For individual survey areas, common species met the C.V. goal. In Washington where 40 samples were taken, walleye pollock, English sole, southern rock sole, and Dover sole has C.V.s less than 30%. In B.C. where 25 samples were taken, Pacific cod, southern rock sole, and Dover sole in addition to dogfish and ratfish met the 30% C.V. criterion. The limited survey of Discovery Bay, which consisted of only 12 samples, achieved the 30% C.V. goal for only three of the fourteen key species. These included English sole, starry flounder, and Dungeness crab. Species that generally did not meet the C.V. goal in the main basins included skates, male Dungeness crab, sand sole, starry flounder, and spotted prawn. Achieving the 30% goal for contagiously distributed or rare species would likely require much more sampling or a re-allocation of stations among the depth strata. In general, 25 to 40 samples within a region were sufficient for common species but sampling would likely need to be doubled or tripled or all effort reallocated to shallow waters to achieve reasonable variance estimates for rare or shallow species. The twelve samples allocated to Discovery Bay did provide sufficiently low variances for some of the common targeted species such as English sole and starry flounder, and Dungeness crab. Forty or perhaps fifty samples per region appear to be a sufficient level of sampling for most key species.

The precision goals were generally achieved, 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). The catching process potentially suffers from three sources of bias: vertical herding, horizontal herding, and escapement (Somerton et al. 1999). 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 length with larger fish resulting in less herding efficiency. 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 crabs (Somerton and Otto 1999). Net efficiency decreased as carapaces widths approached 50 mm but then increased asymptotically with length. How the smaller Eastern Trawl 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 to begin to understand the potential for fishing bias. Other comparison 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 WDFW Trawl Survey may be an effective population estimation tool to manage commercial and recreational crab fisheries if experimental studies are conducted to estimate net efficiency.

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 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 1863 $km^2$ of benthic habitats between the depths of 5 fms and over 100 fms. The Washington portion represented about 75% of the surveyed area, or a 3 to 1 ratio of area between Washington and B.C. Species abundance in terms of numbers and biomass was not uniformly distributed over these two survey areas. There were proportionately more individual fish on the Washington side of the ESJF than B.C., but B.C. had proportionately more biomass. Spotted ratfish, Pacific cod, and lingcod were distributed in higher ratios in B.C. than predicted by the survey area. In contrast, all of the other key species were more abundant in Washington than survey area alone would predict. In particular, there were more flatfish, skates, walleye pollock, Dungeness crab, and spotted prawn in Washington than in B.C.

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. The B.C. ESJF is dominated at times by high currents exiting Haro Strait, and we found that our trawls encountered rougher bottom in the B.C. survey area. This regime seemed to favor hard bottom species such as lingcod, kelp greenling, and some of the sculpins. In contrast, the trawls in many of the Washington areas tended to occur on softer bottoms which appeared to favor flatfishes and crabs. Fish habitat relationships may be better defined through a closer examination of modern geological studies such as conducted by Mosher and Johnson (2000) or by direct sampling with submersibles and remote observation technology.

Understanding the patterns of species distributions imposed by fishing and other extractive activities is more complex. Fishery information Canadian sources indicate that fishing for groundfish is presently at low levels. In Washington, bottom trawls, jig, and troll gears were prohibited in the study area in 1994, and only minor longline and set net fisheries have occurred for spiny dogfish. Tribal longline fisheries for Pacific halibut have also been occurring. Recreational fisheries for salmon and bottomfish have continued over time but have been much diminished by restrictions in salmon seasons and decreases in allowable seasons and daily bag limits for bottomfish. Undoubtedly, high harvests of rockfish, lingcod, and other sensitive species have affected species distributions in the past and may still have an impact on current species distributions. In Discovery Bay, commercial trawl fisheries for flatfishes were discontinued in the early 1990s after substantial declines in fishing success occurred in prior years.

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. In the ESJF, species such as skates, English sole, most flatfish, crabs, and shrimp that are preferential targets of commercial and recreational fisheries were mostly distributed in Washington over a combination of deep or shallow depth strata. Many species, both shallow and deep, were continuous in distribution over the entire Strait and are likely a shared resource between the B.C. and Washington. The mosaic of deep basins in the center of the strait interrupted by shallow banks resulted in a series of stepping stones in which shallow and deep water species inhabit throughout the central basin. These species include deep water species such as Dover sole and spotted ratfish, and species that occur in intermediate or shallow depths such as spiny dogfish, Pacific cod, walleye pollock, lingcod, and southern rock sole. Some nearshore species or species more associated with deep troughs on the Washington side are less likely to be shared and require transboundary management. These species include skates, English sole, starry flounder, sand sole, Dungeness crabs, and spotted prawns.

The presence of shallow and intermediate depth banks in the center of the ESJF and the association of shallow and intermediate depth fishes to these banks causes greater complexity for the need of transboundary management than the pattern observed in the Strait of Georgia. The 1997 Transboundary Trawl Survey in the Strait of Georgia found that only deep water species such as Pacific cod, Pacific hake (whiting), 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 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. In the ESJF, the shallow banks around the international border and throughout the basin complicates the deep-shallow pattern and makes the need for considering fisheries on both sides of the border more important to a wider array of species than was the case in the Strait of Georgia.

Transboundary intermingling patterns have been documented before by Ketchen et al. (1983) and Westrheim and Pedersen (1986). Review of tagging data identified Pacific cod as a transboundary species in the Strait of Georgia with spawning grounds in Nanoose Bay, but which 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 indicating the ESJF is a corridor for dogfish movement (McFarlane and King, In Press). 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). For the ESJF, Westrheim and Pedersen (1986) cooperated in a transboundary study of an anomalous aggregation of Pacific cod in the ESJF that occurred during the period 1974-1984. Fisheries on either side of the border were targeting these fish that apparently were spending time in inland waters feeding on herring instead of foraging on the southwest coast of Vancouver Island.

Macro-invertebrate populations were more diverse and abundant on the Washington side of the ESJF and differed in nature from the B.C. portion, a result that was most likely due to the differences in bottom substrates between the northern and southern Strait. Soft-bottom species such as Dungeness crabs, Northern horse mussels, and pandalid shrimps were among the most dominant invertebrate species in Washington. In comparison, red sea urchins, which are most common on hard substrates, predominated in B.C.

Comparable bottom trawl survey data are not available for B.C., but the Washington portion of the ESJF has been surveyed in 1987, 1989, and 1991 (Quinnell and Schmitt 1991, Palsson et al. 1997). Fish populations in 2000 are substantially less than for most previous surveys indicating that continued fishery closures and restricted harvest management is warranted (Table 29). The 2000 total fish biomass is almost one half less than the 1991 survey estimate for the ESJF, and one third less than the 1987 or 1989 estimates. Almost all individual species were substantially lower including spotted ratfish, spiny dogfish, skates, Pacific cod, and rockfishes. Lingcod and English sole showed continued low abundances similar to the 1991 estimates but which were lower in comparison to the population abundances estimated in the 1980s. Notable exceptions to this pattern are Pacific halibut, rock soles, and walleye pollock, which have apparently increased in abundance in 2000 compared to previous surveys.

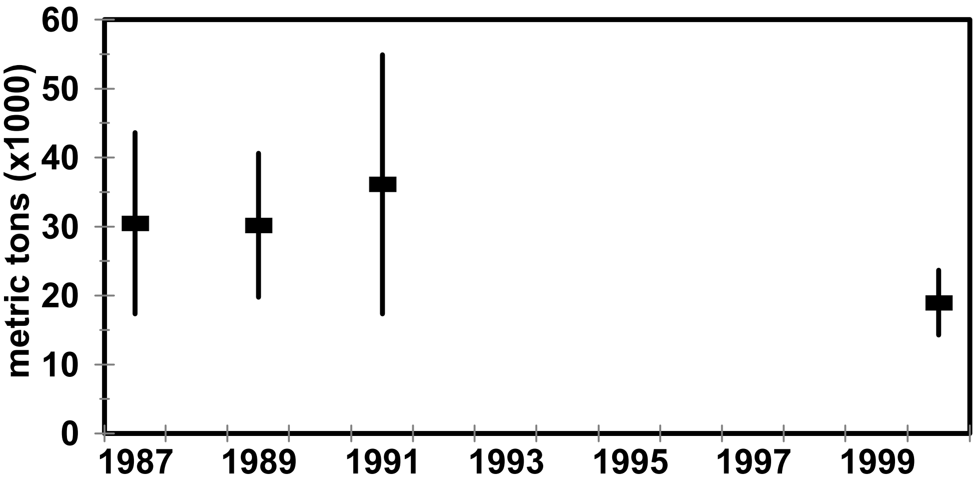


**Figure 50.** Total fish abundance (mt) and 95% confidence limits estimated during bottom trawl surveys in the eastern Strait of Juan de Fuca.

Commercial bottom trawl and other bottomfish fisheries targeting flatfishes such as English sole, and Pacific cod and spiny dogfish once harvested more than 50 mt, 150 mt, and 200 mt, respectively, each year from the entire Washington Strait of Juan de Fuca. Most Washington fisheries previous to 1994 occurred in the eastern Strait of Juan de Fuca. Current population sizes are not capable of supporting the magnitude of these past fishery harvests. English sole, for example, must be at least 30.4 cm in length to be legally landed. The proportion of English sole in Washington above this legal limit is 12% based upon the numerical population at length and weight-length relationships published by Quinnell and Schmitt (1991) and the population estimates from this study. The 497 mt of English sole, therefore, consisted of 60 mt of legal size sole. A liberal harvest rate of 20% would provide a fishery harvest of 12 mt (26,000 lbs), a quantity that would not provide an economically sustainable fishery.

Because of the closure to bottom trawl fisheries in the ESJF, only dogfish and halibut are harvested in commercial fisheries. In comparing the catches of these species during the twelve months subsequent to the trawl survey, annual exploitation rates were 0.5% for spiny dogfish and 0.8% for Pacific halibut (Table 30). Special caution must be taken in interpreting halibut population numbers which were based upon only two captured specimens and are not precise. For B.C., more groundfish species were harvested during the 12-month period subsequent to the trawl survey, but the catches of English sole, Dover sole, rock sole, Pacific cod, and lingcod were small and in total were far less than 0.5 mt. The annual exploitation rates were less than 1% for these species relative to the survey biomass for the BC ESJF. For the ESJF in total, annual exploitation rates were far less than 1% for any species.

Among other species of concern, copper and quillback rockfishes, and Pacific cod which were recently considered for endangered species status (Gustavson et al. 2000, Stout et al. 2000b) are present but in low abundance in comparison to previous trawl survey estimates (Table 29). Continued monitoring of these populations through trawl and other surveys is warranted as well as continued conservation measures to protect these diminishing resources. The predominance of small Pacific cod which were almost uniformly 30 cm in length is encouraging, suggesting that these fish that are likely two or three years old (Palsson 1990) and may have been born in 1998 when young of the year cod were observed commonly in kelp beds in the San Juan Archipelago (Palsson, personal observation). This pattern indicates recruitment is possible in these local waters, and a strong year class may form the basis of the recovery of the Pacific cod stock in the ESJF. The numerous walleye pollock have increased in abundance compared to previous surveys in the ESJF but the whereabouts of the adults that spawned these small fishes is intriguing and unknown.

The survey of Discovery Bay did not find any adult English sole or any Pacific cod, lingcod or rockfish. These species were harvested in commercial quantities during the 1960s ranging from 0.4 mt for lingcod, 1.3 mt for rockfishes, and 35 mt for English sole (Reeves and DiDonato 1972). These trawl fishery was judged to be healthy during these years, and English sole were found to be a local population. Commercial catches of groundfish from this winter-time trawl fishery exceeded 200,000 lbs (100 mt) each year during most of the 1970s but then steadily declined during the 1980s and was low until 1994 when the fishery was permanently closed (Figure 31). English sole and Pacific cod dominated trawl catches during the 1970s but their relative importance declined as the fishery progressed and starry flounder became relatively more important in the commercial catches. Young English sole observed during the 2000 survey indicated adults are present in the area and contributing to recruitment, the lack of adults in the Discovery Bay may indicate a change has occurred to the local population structure. It is, however, unclear whether adult English sole are present during the winter in the bay and simply moved out of the bay during the spring resulting in the lack of adult catches during the spring survey period. The trawl survey should be repeated during the winter to test for the presence of adult English sole and other of previously targeted species during the winter-time fishery.

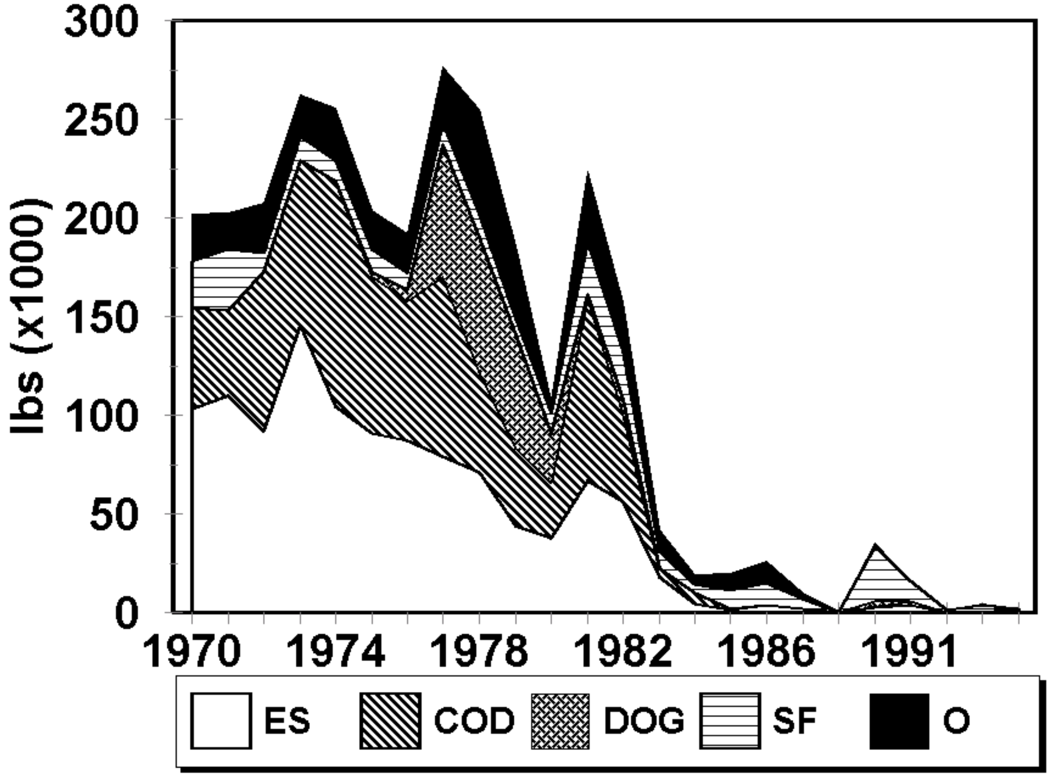


**Figure 51.** Commerical catch (pounds) of English sole (ES), Pacific cod (cod), spiny dogfish (dog), starry flounder (SF), and other groundfish from Discovery Bay.

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 29.** Biomass estimates (mt) and coefficients of variation from trawl surveys in the Eastern Strait of Juan de Fuca.

| | 1987 | | 1989 | | 1991 | | 2000 | |
|---|---|---|---|---|---|---|---|---|
| **Species** | **mt** | **% CV** | **mt** | **% CV** | **mt** | **% CV** | **mt** | **% CV** |
| Spiny dogfish | 4875.4 | 24.4 | 3147.4 | 29.0 | 4319.4 | 41.8 | 502.2 | 14.2 |
| Total skates & rays | 905.8 | 21.3 | 1847.4 | 46.9 | 1622.1 | 22.6 | 650.1 | 39.2 |
| Big skate | 736.3 | 26.4 | 1168.1 | 46.5 | 571.9 | 74.1 | 371.6 | 65.4 |
| Longnose skate | 34.1 | 100.0 | 602.9 | 61.5 | 941.8 | 38.4 | 230.4 | 36.3 |
| Spotted ratfish | 19495.7 | 32.5 | 22291.9 | 21.7 | 28460.0 | 31.4 | 14244.4 | 16.5 |
| Total smelts | 23.8 | 59.9 | 1.6 | 63.6 | 3.8 | 64.4 | 2.9 | 73.7 |
| Plainfin midshipman | 17.9 | 54.0 | 0.9 | 100.0 | 0.0 | 0.0 | 4.2 | 49.5 |
| Pacific cod | 997.0 | 17.7 | 503.9 | 62.4 | 111.5 | 31.4 | 73.7 | 36.6 |
| Pacific tomcod | 448.8 | 44.1 | 183.2 | 63.5 | 89.1 | 41.6 | 121.3 | 41.5 |
| Walleye pollock | 614.6 | 35.7 | 99.6 | 26.4 | 291.1 | 29.5 | 830.2 | 25.0 |
| Pacific whiting (hake) | 2.6 | 85.3 | 0.0 | 0.0 | 0.2 | 82.7 | 0.1 | 100.0 |
| Total eelpouts | 17.1 | 93.3 | 0.6 | 61.3 | 2.2 | 82.5 | 1.3 | 75.7 |
| Brown rockfish | 0.7 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Copper rockfish | 60.5 | 84.3 | 0.0 | 0.0 | 0.0 | 0.0 | 2.9 | 100.0 |
| Quillback rockfish | 28.6 | 74.7 | 87.8 | 43.6 | 18.3 | 61.5 | 27.6 | 53.4 |
| Redstriped rockfish | 2.6 | 42.4 | 0.4 | 100.0 | 1.1 | 56.8 | 0.0 | 0.0 |
| Total rockfish | 92.4 | 68.1 | 88.3 | 43.3 | 19.4 | 58.8 | 31.2 | 51.7 |
| Kelp greenling | 3.9 | 100.0 | 1.5 | 100.0 | 0.5 | 100.0 | 1.8 | 100.0 |
| White-spotted greenling | 3.3 | 71.4 | 0.0 | 0.0 | 0.0 | 0.0 | 9.6 | 50.9 |
| Lingcod | 152.8 | 58.9 | 115.0 | 65.5 | 0.0 | 0.0 | 14.2 | 40.2 |
| Sablefish | 59.2 | 59.5 | 0.0 | 0.0 | 45.6 | 43.4 | 0.0 | 0.0 |
| Total sculpins | 49.9 | 57.5 | 106.6 | 56.3 | 63.8 | 29.2 | 251.4 | 39.4 |
| Sturgeon poacher | 60.5 | 75.5 | 10.0 | 73.1 | 6.4 | 68.1 | 19.4 | 43.0 |
| Total surfperch | 389.3 | 63.9 | 61.6 | 81.3 | 18.0 | 55.9 | 64.6 | 86.2 |
| Pacific sanddab | 41.8 | 84.4 | 26.8 | 50.3 | 25.4 | 47.0 | 600.2 | 29.7 |
| Speckled sanddab | 0.0 | 0.0 | 1.5 | 79.3 | 2.8 | 57.3 | 21.3 | 46.1 |
| Arrowtooth flounder | 220.6 | 23.1 | 167.0 | 28.7 | 107.2 | 32.8 | 5.7 | 41.5 |
| Total rock sole | 93.1 | 31.6 | 176.6 | 27.9 | 87.3 | 80.3 | 360.9 | 30.7 |
| Dover sole | 254.6 | 22.1 | 58.3 | 43.2 | 39.9 | 24.8 | 91.8 | 24.9 |
| English sole | 1036.5 | 36.3 | 752.0 | 71.2 | 534.9 | 34.8 | 525.6 | 29.5 |
| Starry flounder | 5.2 | 100.0 | 337.4 | 100.0 | 52.4 | 94.4 | 190.1 | 63.5 |
| Sand sole | 4.7 | 100.0 | 4.1 | 68.8 | 3.4 | 100.0 | 5.1 | 94.6 |
| Pacific halibut | 17.8 | 100.0 | 14.5 | 100.0 | 114.3 | 100.0 | 183.7 | 70.8 |
| Total flatfish | 2033.5 | 18.0 | 1679.7 | 37.9 | 1045.0 | 24.8 | 2058.9 | 18.1 |
| Total Fish | 30473.2 | 21.5 | 30168.6 | 17.3 | 36129.1 | 26.0 | 18952.3 | 12.4 |
| Total Dungeness crabs | 14.2 | 88.8 | 57.1 | 54.1 | 36.9 | 58.8 | 1363.8 | 35.9 |

**Table 30.** Biomass and catch comparison for the Eastern Strait of Juan de Fuca.

| Species | WA Biomass (mt) | 2001 Washington Catch (mt) | WA Exploitation Rate (%) | B.C. Biomass (mt) | 2001 B.C. Catch (mt) | B.C. Exploitation Rate (%) | Juan de Fuca Exploitation Rate (%) |
|---|---|---|---|---|---|---|---|
| Spiny dogfish | 502.2 | 2.7 | 0.5 | 159.3 | | | 0.4 |
| Skates | 650.1 | | | 39.9 | | | |
| Spotted ratfish | 14,244.4 | | | 7,285.9 | | | |
| Pacific cod | 73.7 | | | 30.5 | 0.18 | 0.6 | 0.2 |
| Walleye pollock | 830.2 | | | 63.0 | | | |
| Lingcod | 14.2 | | | 15.4 | 0.01 | 0.1 | 0.03 |
| English sole | 525.6 | | | 19.5 | 0.02 | 0.1 | 0.003 |
| Rock sole | 360.9 | | | 82.1 | 0.06 | 0.1 | 0.01 |
| Starry flounder | 190.1 | | | | | | |
| Sand sole | 5.1 | | | 0 | | | |
| Dover sole | 91.8 | | | 16.6 | 0.03 | 0.2 | 0.03 |
| Pacific halibut | 183.7 | 1.4 | 0.8 | 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.

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.

Wesrheim, 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.

## ACKNOWLEDGEMENTS

The authors thank all the participants in the 2000 Transboundary Trawl Survey. Special thanks are extended to Kurt Dobszinsky, skipper of the F.V. *Chasina*, and his fishing crew including Erin and Blanca Fristad whose patience and skill made this survey a success. Greg Lippert provided great support in developing computer databases and data entry procedures. Dale Gombert provided excellent work in digitizing nautical charts and preparing computer-aided information for survey planning. Tony Parra is acknowledged for producing the useful distribution maps of the key groundfish species. Greg Lippert, Steve Quinnell, Jason Basarich, and the volunteers and guests are thanked for their help during the survey. Jeff Fargo of the Pacific Biological Station, Department of Fish and Oceans provided support for the Canadian survey. Mr. W. Thomas Cocke of the U.S. State Department processed the vessel clearances required for international surveys in a timely manner.

The analysis and reporting was supported by the Supplemental Budget for the Recovery of Puget Sound Bottomfish supported by the Washington Department of Fish and Wildlife and the Puget Sound Action Team. This work was conducted in conjunction with the Fish Task of the Puget Sound Ambient Monitoring Program, and Steve Quinnell, Greg Lippert, Sandy O'Neill, and Jim West are recognized for their work and cooperative efforts. Mr. Scott Redman (Puget Sound Water Quality Action Team) is gratefully acknowledged for his help in securing funding for this survey.