International Council for the
Exploration of the Sea

C.M.1954
Special Scientific Meeting
"Problems and Methods of
Sampling Fish Population"
No.14

Problems of Sampling a Puget Sound Population of English sole, *Parophrys vetulus*.

Richard Van Cleve & Alonzo T. Pruter

Since the development by Baranov (1919) of a mathematical theory of the reactions of a fish population to a fishery and its application by Thompson and Bell (1934) to the halibut fishery, a number of attempts have been made to develop a more precise mathematical formulation and to apply the theory to other fisheries. These attempts have met varying degrees of success. In general because of the exploratory nature of most fisheries research it has not produced a sufficiently complete and consistent body of data to permit their use in refined mathematical relationships. Inaccuracies arise from a lack of adequate measures of most, if not all, of the parameters on which the population equations are based, but in spite of all such errors results have been encouraging (Beverton, 1953; Schaefer, 1954).

To simplify the mathematical concepts and equations, all treatments of the problem have followed methods developed for controlled experiments which describe variations in yield that would occur with changes in only one of the parameters of interest, such as fishing intensity, natural mortality, or age at recruitment, while the other parameters affecting yield or population size are held constant. Interaction between the competing rates has been mentioned but lack of data has prevented elucidation except on a purely hypothetical basis. In all cases both recruitment and growth have been treated as constant rates unaffected by changes in population size. The resultant curves that have been developed to describe the "equilibrium yield" (Beverton, ibid and others) under different conditions for different species have therefore been unrealistic and in fact completely uninterpretable in terms of what would actually occur under natural conditions. The closest approach to reproducing these conditions was made by Thompson and Bell (ibid) with their simple arithmetic treatment of individual year-classes.

Lack of realism stems first from the difficulty of developing mathematical hypotheses that can be solved without oversimplification of basic concepts as noted above. Data are usually available which permit assignment of values to annual amounts of fishing effort and total catch. In addition total catch and hence total effort, are the variables most accessible to artifical modification. Detection of changes in growth rate or natural mortality would involve extensive studies of any species and suitable data are not available except to those able or willing to execute such investigations. However, the great differences in growth of plaice on the Dogger Bank as compared with those living under more crowded conditions on the Flemish Coast (Hickling, 1937) indicate that changes in growth rate may be one of the major variables determining changes in productivity of a stock. Recent observations on the Pacific halibut have indicated an increase of almost 100 percent in weight of mature females of comparable ages since the first observations were made in Area 3 in 1926 (International Pacific Halibut Commission Report No.21, 1954). This growth increase did not occur instantaneously as the stocks in that area were reduced, but required some 17 years to develop after the time that the abundance had begun to increase again from the low population level of 1930. Assumption of constant recruitment

----

Acknowledgements

The work summarized briefly below comprises a joint project of the University of Washington School of Fisheries and the Washington State Department of Fisheries. Many people are participating in the field work and reports by all principal participants covering the phases of their interest will be published as the analysis of data progresses. The work of the University of Washington has been partially supported by funds allocated to this project under State Initiative 171.

for the purposes of mathematical treatment is also untenable in the light of available information but no fishery seems to be well enough documented to indicate how recruitment will vary with changes in population size. Major changes are also inevitable in natural mortality rates as population sizes are reduced or increased and must inevitably be measured to ascertain the true potentialities of our fish populations.

The second way in which current theoretical treatments of fish population dynamics depart from reality is in considering productivity in terms of "equilibrium catch" or yield. While this is probably necessary to permit simplification of mathematical treatment it must be recognized that equilibrium is seldom attained in any fishery for a sufficient period to establish the size of the equilibrium yield at any level of fishing. As an example, the apparent delayed reaction of both recruitment (Thompson, 1950) and growth in the halibut may be greater than in other species where maturity is reached at an earlier age but it must be present in varying degrees in all fisheries. Use of the available data on yield and average catch per unit of effort without evaluation of the other changes that are related to them can thus lead to results that may be quite misleading. For example Schaefer (ibid) calculated the maximum stabilized yield of the Area 2 halibut fishery as 28.2 million pounds at an average abundance of 78 pounds per skate although this fishery has for several years past exceeded both this yield and abundance. Other considerations involving distribution of the Pacific halibut fishery and the progressive shortening of the fishing season since 1930 indicate that the true figures are probably higher than Schaefer's estimates. The dangers of misinterpretation of results obtained by using so-called "equilibrium yield" curves to describe the manner in which a fish population will react to a fishery must be recognized.

The need for observations planned and collected specifically to fit into the conditions required for population investigations has long been felt and a search for a suitable fish population in Puget Sound has been in progress for some years. The discovery of what appears to be an isolated population of limited extent of Parophrys vetulus, the so-called "English sole", in the passages and bays to the eastward of Whidbey Island, (Figure 1), which supports a trawl fishery small enough to be easily observed has led to the development of the present program. The author's plan to observe this fishery as a controlled experiment with the purpose of discovering how recruitment, growth, natural mortality, fishing mortality, and other variables are related to yield and to the accumulated population. The relation of the Parophrys vetulus stock to other species in the area may shed much light on similar situations elsewhere where one or two species are exploited heavily with only casual interest in other fish.

Before the more detailed development of estimates of population parameters which will appear in later publications it is of interest to consider the adequacy of our present system of sampling as well as various problems that have arisen while devising methods of obtaining data that will permit evaluation of the sources of error.

The Fishery.

Table 1 lists the different species of fish taken by trawl in this area. Forty-seven species of fish have been recorded by the University of Washington's research vessel, "M.V. Oncorhynchus", in Penn Cove, Saratoga Passage and Holmes Harbor in 1952-53. All of these species are caught by commercial trawlers but only eight are landed in quantity for human consumption. However, large numbers of hake, pollack, skates, and dogfish are sold to reduction plants. The remaining 35 species are either uncommon, relatively unvailable to trawls, or are too small to be caught in quantity with the mesh size used by the commercial boats. Therefore a true picture of the species composition cannot be obtained from an examination of the commercial catches but instead requires sampling with nets of various mesh sizes such as those used by the "M.V. Oncorhynchus" (x)

The species in greatest abundance and demand is Parophrys vetulus which is found throughout most of the area in 5 to 110 fathoms, the particular depth varying both as to time and location. The presence of several desirable species in considerable numbers, the proximity of local markets, and the advantage of fishing in sheltered waters results in a rather intense winter trawl fishery by boats landing their fares in Seattle, Everett, and Bellingham (Figure 1). Vessels engaged in the fishery are of the ocean-going type, ranging in length from 50 to 85 feet and from 20 to 60 net tons capacity. Three men, including the captain, comprise the average crew. The trawl is set off the vessel's stern and brought aboard over the starboard side. The average net is about 350 meshes in circumference and the legal minimum mesh size is 4 1/2 inches (opening between knots). However, some boats use nets as small as 275 and as large as 400 meshes in circumference and the mesh size varies from 4 1/2 to 5 1/2 inches. The effect of these variations in the trawls on the size of Parophrys vetulus caught is being studied by comparing length samples of the catches, taken aboard the vessels before selection is exercised by the fishermen with those taken in the markets, and samples on the "M.V.Oncorhynchus".

Reefs. logs, snags, and legal closures render a considerable portion of the region inaccessible to trawling, and the percentage of the trawlable bottom varies considerably in the different areas. For example, about 67 percent of Holmes Harbor, 87 percent of Penn Cove, 22 percent of Saratoga Passage, and 68 percent of Port Gardner (Figure 2) can be fished. Parophrys vetulus and other species undoubtedly inhabit a considerable portion of the inaccessible areas. Their movements into and out of the accessible trawling grounds may be an important cause of some of the observed variations within the fishery during the season.

To obtain accurate catch and tag recovery data the trawling grounds have been subdivided into numbered areas (Figure 2) and the captains have been requested to record the area, depth, and nature of their catches on special statistical forms supplied to them (Pruter and Van Cleve, 1954). Besides providing for estimates of the pounds of individual species of fish caught in each haul, the catch forms were designed so that the tag number of all tagged fish could be readily entered under the appropriate haul number. The catch records and information on tag recoveries have all been supplied by the fishing boats without reward and their cooperation is largely responsible for the success of the program so far. These forms provided a detailed record of 79 percent of the total Parophrys vetulus taken in the study areas during the past season.

Penn Cove, Saratoga Passage, and Port Gardner have long been among the major Puget Sound trawling grounds. Over a number of years seasonal regulations have assumed a complex pattern. Trawling in Penn Cove and the upper half of Saratoga Passage (areas 1-5) has been restricted to a season which in 1953-54 extended from September 15 through February 15. Trawling is permitted in the lower half of Saratoga Passage (area 8), Port Gardner (area 10) and Port Susan (area 9) at all times of the year except from February 16 to April 14. Holmes Harbor (areas 6 and 7) was closed to trawling from 1937 through 1952. A six week season was permitted in 1953 which extended from January 1 through February 13, and a fishery was again allowed in Holmes Harbor in 1954, with a minor adjustment which extended the closing date to February 15.

The complexity of the seasons has not been reflected in the activity of the fishing fleet since a large number of the vessels convert to other fisheries such as halibut and salmon, during the spring and summer months, and the remainder participate in the ocean trawl fishery at that time. The result is that the fishery in areas 1-10 is almost entirely restricted to the late fall and winter months.

(x) The smallest mesh used in our nets is still large enough to permit the escape of small fish such as most Aulorhynchus and all Sygnathus which occur in great numbers in Puget Sound. Moreover, trawls do not adequately sample most pelagic species. It is hoped that funds will be found to develop methods for sampling these other species. Until they are sampled quantitatively and their relationship to the whole population complex determined, this gap will remain in our population picture. Filling this gap may be impractical, however, unless a fishery is built up to sample the pelagic species.

Sixteen vessels fished in areas 1-10 between September 15, 1953 and February 15, 1954 and landed about 600,000 pounds of fish, 445,000 pounds of which were *Parophrys vetulus*. An additional 600,000 to 1,000,000 pounds of scrap fish were sold to reduction plants. Total landings of all fish will be considered in assessing the productivity of the area but present studies are concentrated on the one species for which detailed records are available.

Market Samples.

The fishermen normally discard all of the smaller *Parophrys vetulus*, keeping only those of legal size ($\geq$ 292 mm. in total length) but the degree of selection exercised by the fishermen varies with both the relative abundance and the demand for the fish. During periods of scarcity or high price, care is taken by the fishermen to keep all fish caught which are of legal size. When fish are abundant the fishermen sort their catches rapidly and tend to discard fish considerably above the legal minimum size. Since the male *Parophrys vetulus* are considerably smaller than the females, such varying selection by the fishermen causes changes in the sex ratio in the landings.

Unusually moderate winds during January and February of 1954 permitted trawlers to fish the ocean banks more intensively than normal at that time of the year. The consequent influx of the more desirable ocean-caught fish on the markets depressed the demand for Puget Sound fish, and the buyers progressively raised the size limit on Puget Sound *Parophrys vetulus* after January 11. The above is best shown by length frequencies of males and females caught in areas 1-10 and landed between November 2, 1953 and February 15, 1954 (Figure 3) obtained from market samples. As may be seen from the Figure 3, the sizes and sex ratios were fairly constant until January 11. From that time on, however, the length of both males and females increased progressively with a marked change in the relative number of males which made up 40.6 percent of the December 16 sample but only 1.5 percent of the February 15 sample.

Significant changes of this type occur irregularly in many West Coast fisheries. Such changes can have a profound effect on the average size of fish landed and consequently on the calculated catch per unit of fishing effort. Although such changes are economic rather than biological in origin they are just as real as biological changes and must not be confused with actual changes in population parameters.

The progressive increase in the size limit of *Parophrys vetulus* during this season has made it necessary to adjust the catches of individual hauls as recorded to make them comparable with earlier catches, because as the size limit rose greater numbers of *Parophrys vetulus* had to be caught by the vessels in order to obtain as many marketable fish as during previous periods. While smaller fish were discarded we have reason to believe most of them did not survive and they should be considered as part of the catch. The actual amounts by which the catches were corrected during the latter part of the season varied between eight and 35 percent. Sampling can be gauged to provide a sufficient amount of data to give statistically uniform results at any time. However, statistical techniques would not normally take into consideration the above changes and they would probably be overlooked in routine market sampling or in an analysis of catch per unit of effort.

Selectivity of Gear.

The selective action of trawls is well known for some species but the adjustment of data to overcome this handicap has not been handled uniformly, and in some cases has not been handled well. Trawls that are designed to capture only the legal or marketable sizes of a particular species can give no idea of the nature of the age or size-distribution of fish too small to be completely sampled. An adjustment is not valid which assumes that the probability of capture of fish below the size of complete availability are expressed by the ratios of distributions that have no relationship to the relative abundance of those sizes in the population. Unless the true population curve can be established at sizes below that of complete availability it seems best to confine attention for the present to sizes and ages above the critical point.

In this respect the difference in size of the two sexes of Parophrys vetulus poses a problem that is illustrated by the growth curves of males and females shown in Figure 4. These curves are composed of the combined distributions obtained from comparable catches made with trawls equipped with cod-ends of 1 1/2, 3 1/2, and 4 1/2 inch mesh. The minimum size limit of 292 mm. permits the landing of all females of six years and older. However in our March, 1954 samples it excluded some males as old as 14 years. Whether or not this will force us to consider only the females in our population studies can only be determined after further study of the effect of this selection on the relative mortality rates of the two sexes. The landings can be separated as to sex if sufficient labor can be assigned to market observations but this will be of little use without a throughough biological study of the stocks remaining on the grounds.

An important effect of net selection was seen in the shapes of growth curves obtained from comparable hauls made with the three different mesh-sized cod-ends in the same area. An effect of the smaller meshed that is not often recognized is that they permit the escape of larger fish (Jurkovich,1954). This probably results from the slower speed of dragging due to the greater resistance of the net and perhaps also to the more rapid clogging of the finer net with fish or debris thus decreasing the entering current speeds at the trawl mouth, and allowing the larger, more rapidly swimming fish to escape. The resulting length distributions taken from each mesh size therefore yield different growth curves. The 4 1/2 inch mesh net, by permitting the escape of the smaller sizes of the younger ages, flattens the curve significantly especially for the males. Other differences are seen in the relative scarcity of larger fish in the 1 1/2 inch mesh net hauls as well as in the absence of the first year fish and scarcity of two-year-olds in catches taken with the 3 1/2 and 4 1/2 inch meshes. Because of these differences in selectivity, samples from a single mesh size could hardly give an accurate measure of the growth rate. An attempt to obtain accurate growth data has been made by combining samples from different mesh sizes and weighting each sample to represent a standard area trawled.

The difference in growth rate between males and females and the resultant differences in net selection also make it impossible to draw conclusions as to relative numbers in the different age-classes except from samples obtained with a variety of mesh sizes. Age frequencies of females in such samples obtained in March, 1954 soon after the close of the fishing season show a regular decline after age six, indicating little variation in the strength of age-classes of females. A straight line fitting the logarithms of the frequencies gives a survival rate of 47 percent. The males on the contrary show wide variations in the strength of year-classes from age 7 to age 16. A line fitted to the logarithms of their frequencies shows a survival rate of about 81 percent but the variation around this line is so great that its significance may be questionable. The size limit imposed by law and the large-mesh trawls used by commercial fishermen apparently tend to preserve the males. Further information concerning survival rates is now being obtained from a study of comparative tag recoveries of males and females. Samples of Parophrys vetulus obtained periodically for the past two years form the basis for a study of age and growth of this species now in progress. Some indication is now at hand that an increase in growth has already occurred in Holmes Harbor following its opening to commercial fishing in January, 1953. Further changes in growth will be watched with interest in future years.

Tagging Experiments.

Pruter and Van Cleve (ibid) described an exploratory tagging experiment that involved the release of 2741 tagged Parophrys vetulus in Holmes Harbor between December 26 and 31, 1952. Tags recovered during January and February, 1953 showed a close relationship of the Holmes Harbor fish with those in neighbouring areas but lack of tag releases outside the harbour prevented accurate estimates of the size of the population or of mortality rates. The past year's program was designed to overcome these deficiences and a total of 5034 tagged fish was released in areas 1-8 (Figure 5) in two experiments: 3948 fish were released between September 1 and 5, 1953, and a second group of 1086 fish between December 27 and 30, 1953. In addition, 430 fish were released in area 10 on October 15, 1953.

Recoveries from all 1953 experiments totaled 949 fish by February 15, 1954, the last day of fishing of the current season. In addition, 161 tags released in the initial Holmes Harbor experiment in 1952 were recovered during the current season. The distribution of all recoveries from the study area and from neighbouring fishing grounds is compared with the distribution of fishing effort and catch in Figure 6. Recovery of two tags off the Washington coast, one from the 1952 experiment and one from the September, 1953 experiment, and 2 tags in area 11 just south of the experimental area represents a total loss of less than 0.5 percent of all tags recovered this season. It thus appears at present that we can consider this population as an almost independant unit. Efforts will be continued to recover all tags captured by fishermen in contiguous areas as well as in the study area.

The availability of tagged fish in Holmes Harbor varied widely during the fishing season of January and February, 1953, leading us to suspect marked differences between the actions of tagged and untagged fish. Comparison of this year's Holmes Harbor recoveries from the 1952 experiment with those from the September, 1953 tag releases indicates that the same type of variations in numbers of tagged fish caught per hour of trawling occurred in both (Figure 7). The cause can hardly be ascribed to differences in activity of tagged and untagged fish unless the effect of the tagging is still apparent a year after release. It could be considered as evidence of schooling. Since the fish that were tagged from each haul were released in one spot at the end of the haul in which the fish were captured, they may have remained in a school so that the fortuitous encounter by a trawl with a school of fish containing tagged members could have given the appearance of the variations noted. However, even this hypothesis cannot explain the correlation in rate of capture of tags from two experiments in which the tags were released almost one year apart. Since the use of tags to calculate population size or mortality rate assumes random sampling the use of tag recoveries from the experiments involved will require a sufficiently wide distribution of fishing to counterbalance the variations in distribution of tags. Care must be taken in such an analysis to use large enough subdivisions of the fishing season that randomness may be approximated in the sampling.

If sampling of tagged fish was sufficiently random to give usable results, the populations of Parophrys vetulus for areas 1 to 8 can be calculated from the recoveries of tagged fish released in September, 1953 that were greater than 295 mm. in total length and again from those recovered from the December, 1953 releases. The first result which would correspond to an estimate of the population at the time of release in September was 821,000. Ninety-five percent confidence limits (Chapman, 1948) were estimated to be 736,000 and 922,000. The second estimate of the same population in December after a total of about 70,000 fish of commercial size had been taken was 650,000 (95 percent confidence limits 548,000-780,000). The agreement between the population decline and size of catch is well within the limits of error. Areas 9 and 10 were excluded from these preliminary estimates because of the rather/small/exchange of tags between those areas and areas 1 to 8. However, it is interesting to note that an estimate of the total population in areas 1 to 10 from the September tags gave a total population of 2,560,000 fish. Total landings from all areas for the season amounted to about 518,000 fish, which would thus be a withdrawal of about 20.2%. The fishing rate for Holmes Harbor for the previous season was about double this figure. Total tag recoveries for the September, 1953 experiment amounted to 16.7 percent of releases while 12.8 percent of the December tags were returned. Recoveries from the 420 tags released in Port Gardner amounted to 24.3 percent. A study of the relationship of these recoveries to fishing pressure and total catch within the different areas is in progress to determine if they can be used with confidence to calculate population parameters.

Relation of Population and Environment.

Attempts to relate variations in populations with variation in environment require first a definition of what the environment encompasses. In marine studies predator-prey or food relationships have been treated on theoretical mathematical lines by Lotka (1925), Volterra (1928), and others, but the assumptions involved in their work are difficult to reconcile with conditions as they occur in nature. Simplification of conditions has again been carried too far in this field which in reality should involve a synthesis of information from all phases of the environment. The complications involved in such a synthesis make it impractical at present for the simple reason alone that most data that are now available have resulted from programmes of observation that were either not sufficiently complete or well enough coordinated to provide data that are comparable.

A start can be made by accepting the fact that a particular species of fish is in itself an inseparable part of its own environment and that all fish species living together in any area really form a population of greater complexity than that of a single species but one which is inextricably bound with the fluctuations in abundance of its component species. It seems inconceivable that variations in the population size of one species can be isolated from variations in numbers of other fish inhabiting the same area and either competing with it for food, furnishing part of its food supply, acting along with man as a predator, or just occupying space. Elucidation of all the complex interrelationships involved would be an ambitious undertaking indeed but it should be possible to follow variations in relative abundance of the different species if adequate sampling techniques can be developed.

Detailed population studies of 47 different species of fish (our species list is probably incomplete) would be impractical, but exploratory work in several directions is under way. Standardized hauls with the experimental vessel are being used to obtain periodic estimates of the relative abundance of different species in terms of trawl catches. Development of accurate records of commercial landings of all species whether food fish or scrap fish will be used to measure the productivity of each and of the area as a whole in terms of fish protein. Finally, if the abundance of other species can be related to the size of our intensively investigated Parophrys vetulus population, relative changes in the various segments of the fish population itself can possibly be evaluated. It is not expected that correlations between variations in hydrographic environment and fish populations can be intelligently investigated until the complex of what we may term the fish environment is better understood. When such correlations are attempted, hydrographic observations of both area and temporal detail at least comparable with our fishery observations will be required.

In fulfillment of this objective, complete enumeration and weights of each species taken in experimental hauls by the research vessel are being accumulated. Landings of scrap fish as well as food fish by the commercial vessels are also being recorded and will be refined as the program proceeds. Results are still in the realm of speculation while techniques of sampling and treatment of data for Parophrys vetulus are worked out. It is hoped that development of the mathematical concepts of socalled "population dynamics" will be possible as sounder foundations for basic assumptions and hypotheses are developed.

Literature Cited.

BARANOV, F. I. 1918. "On the question of the biological basis of fisheries". Proc.Inst,Sci.Ichthyol.Inves.(1) 1: 81-128.

BEVERTON, R.J.H. 1953. "Some observations on the principles of fishery regulations". J.Cons.Int.Explor.Mer., 19 (1): 56-68.

CHAPMAN, D. G. 1948. "A mathematical study of confidence limits of salmon populations calculated from sample tag ratios." Bull.Int.Pac.Salm.Fish.Comm. 2 (2): 67-85.

HICKLING, C.F. 1937. "The English plaice marking experiments, 1929-32." Min.Ag. & Fish., Fish.Invest.,Ser.II, 16 (1).

INTERNATIONAL PACIFIC HALIBUT COMMISSION 1954. "Regulations and investigations of the Pacific halibut fishery in 1953." Int.Pac.Hal.Comm. Report No.21: 1-22.

JURKOVICH, JERRY 1954. "Selectivity of cod-end mesh sizes in otter trawling." Wash.Dept.Fish., Fish.Res.Papers 1 (2): 19-24.

LOTKA, A.J. 1925. "Elements of physical biology". Baltimore, Williams and Williams Co., 460 pp.

PRUTER, A. T. and VAN CLEVE, R. 1954. "A preliminary study of the population of English sole, <u>Parophrys vetulus</u>, in Holmes Harbour, Washington." Wash.Dept.Fish., Fish.Res.Papers 1 (2): 3-18.

SCHAEFER,MILNER B. 1954. "Some aspects of the dynamics of populations important to the management of the commercial marine fisheries." Bull.Inter-Amer.Tropical Tuna Comm.1(2): 27-56.

THOMPSON, W.F. 1950. "The effect of fishing on the stocks of halibut in the Pacific." Publ.Fish.Res.Inst.,Univ.Wash.,Seattle,Wash.,60 pp.

THOMPSON, W.F. and BELL, F.H. 1934. "Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear." Int.Fish.Comm.Rept. No.8, 49 pp.

VOLTERRA VITO 1928 "Variations and fluctuations of the number of individuals in animal species living together." J.Cons.Int.Explor.Mer., 3 (1): 3-51.

Table 1.

Species of fish caught in Penn Cove, Saratoga Passage, and Holmes Harbor by the "M.V. Oncorhynchus" in 1952-53. Important food fish denoted by (x).

Pleuronectidae

(x) Parophrys vetulus (English sole)
(x) Platichthys stellatus (starry flounder)
(x) Lepidopsetta bilineata (rock sole)
(x) Psettichtys melanostictus (sand sole)
Hippoglossoides elassodon (flat-head sole)
Lyopsetta exiles (slender sole)
Microstomus pacificus (Dover sole)
Eopsetta jordani (petrale sole)
Glyptocephalus zachirus (rex sole)
Pleuronichtys coenosus (C-O sole)
Atheresthes stomias (turbot)
Isopsetta isolepsis (Bellingham sole)

Bothidae

Citharichthys sordidus (mottled sand-dab)
Citharichthys stigmaeus (speckled sand-dab)

Scorpaenidae

(x) Sebastodes caurinus (red rockfish)

Gadidae

(x) Gadus macrocephalus (true cod)
Merluccius productus (hake)
Theragra chalcogramma (pollack)
Microgadus proximus (tomcod)

Embiotocidae

(x) Taeniotaca lateralis (blue sea-perch)
Damalichthys vacca (dusky sea-perch)
Cymatogaster aggregatus (yellow shiner)

Hexagramidae

(x) Ophiodon elongatus (ling cod)
Hexagrammos stelleri (white-spotted greenling)
Zaniolepsis latipinnis (long-spined greenling)

Anoplopomidae

Anoplopoma fimbria (sablefish)

Agonidae

Xenopyxis latifrons (black-tipped sea-poacher)
Agonus acipenserinus (sturgeon-like sea-poacher)
Odontopyxis trispinosus (pigmy sea-poacher)

Cottidae

Leptocottus armatus (cabezon)
Chitonotus pugetensis (rough-backed sculpin)
Dasycottus setiger (spiny-headed sculpin)
Radulinus asprellus (darter sculpin)

Batrachoididae

Porichthys notatus (midshipman)

Zoarcidae

Lycodopsis pacificus (black-bellied eel-pout)

Aulorhynchidae

Aulorhynchus flavidus (tube-snout)

Clupeidae

Alosa sapidissima (shad)
Clupea pallasii (herring)
Engraulis mordax (anchovy)

Osmeridae

Hypomesus pretiosus (silver smelt)
Thaleichthys pacificus (eulachon)
Spirinchus dilatus (long-finned smelt)

Chimaeridae

Hydrolagus colliei (rat-fish)

Rajidae

Raja rhina (long-nosed skate)
Raja binoculata (big skate)

Scylliorhinidae

Apristurus brunneus (brown shark)

Squalidae

Squalus acanthias (dog-fish)

List of Figures.

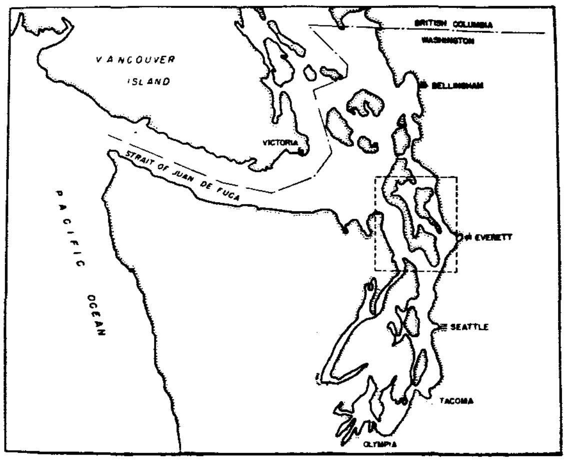

Fig. 1.

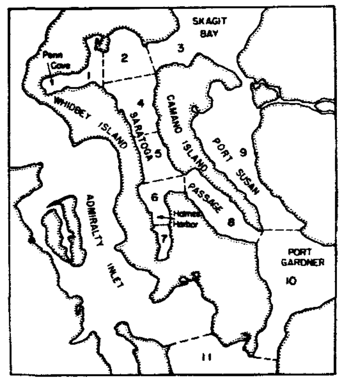

Fig. 2.

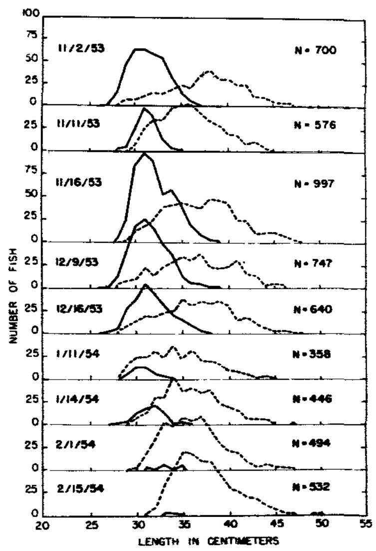

Fig. 3.

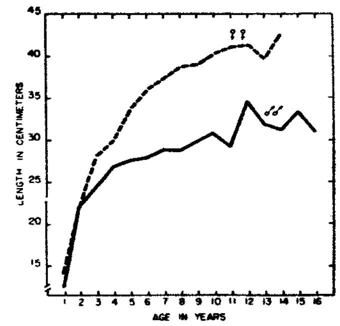

Fig. 4.

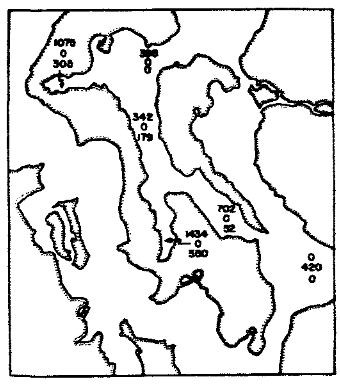

Fig. 5.

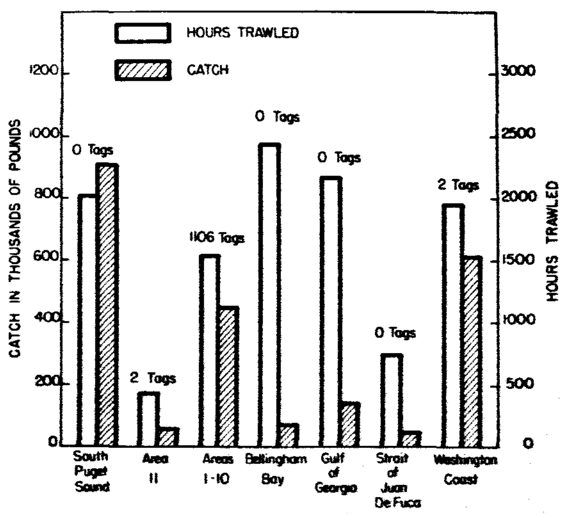

Fig. 6.

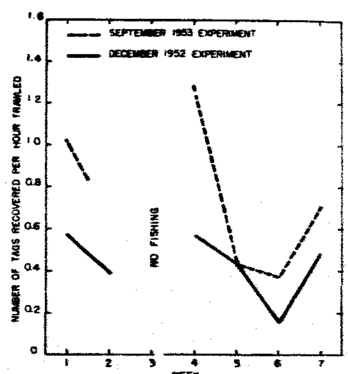

Fig. 7.