Biology and Fishery of Pacific Whiting, *Merluccius productus*, in the Strait of Georgia

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ABSTRACT—Pacific whiting, Merluccius productus, *in the Strait of Georgia constitute a distinct stock. Spawning occurs from March to May in the south central Strait. There is marked vertical segregation of the sexes during spawning. Active spawning occurs below 220 m. Post-spawning fish aggregate in the shallow waters (50-100 m) and are found in association with a dense plankton layer. By fall, most whiting have migrated out of the open Strait. In early winter, adults reappear and migrate into the south central Strait in preparation for spawning. Juvenile Pacific whiting were common but segregated from the adult concentrations. Eggs and larvae were abundant in the central Strait from March to May at depths of 100-300 m. By June, catches of larval whiting had decreased.*

Whiting were aged using broken and burnt otoliths and the technique validated to age 12 by following the strong 1970 year class. Whiting show a constant, relatively rapid growth to age 4, followed by little or no growth. The oldest fish captured was 20 years. Length at 50 percent maturity was 33 cm for males and 37 cm for females. Absolute fecundities were determined, and the relationship for all egg diameters from 180 to 780 mm was $F = (5.501 \times 10^{-1})L^{3.3896}$. *Also discussed is the presence of large numbers of yolked oocytes remaining in the ovary after spawning.*

Pacific whiting feed mainly on pelagic and semipelagic animals. Whiting may be an important predator on herring in the Strait with about 15 percent feeding exclusively on herring during April and May. Salmon have never been identified in whiting stomachs.

Pacific whiting is the most abundant resident fish stock in the Strait, with estimated stock size ranging from 85,000 to 130,000 t. The abundance of whiting appears to have increased substantially since 1970 because of a succession of strong year classes. Total annual mortality (A) is estimated to be 0.15-0.25. The Pacific whiting fishery in the Strait of Georgia is recent, ranging from 508 t in 1979 to 2,378 t in 1982. Preliminary MSY estimates range from 10,000 to 15,000 t. The resource represents a potentially attractive fishery. The absence of the myxosporean parasite Kudoa paniformis *and the proximity to land-based processing have increased interest in both the food fish and roe fisheries.*

Introduction

Discovery of large midwater concentrations of Pacific whiting, *Merluccius productus*, in British Columbia's Strait of Georgia was made in 1974 (Westrheim, 1974), and studies of biology, distribution, and abundance commenced in 1975 (Beamish et al., 1976a-e, 1978a, b, 1982; McFarlane et al., 1983; Thompson and McFarlane, 1982). Pacific whiting in the Strait of Georgia are now recognized as the most abundant resident fish.

The developing Canadian fishery for offshore whiting provided a stimulus for exploitation of resident stocks in the Strait of Georgia. Even though Pacific whiting in the Strait of Georgia are smaller, they are free of the parasite *Kudoa paniformis* which is responsible for the rapid degradation of the flesh of offshore whiting (Kabata and Whitaker, 1981). The absence of this parasite and the proximity of the stocks to land-based processing make this a potentially attractive fishery. In addition, there is a potential for harvesting roe[1] since large concentrations of spawning fish are available.

[1]H. Tsuyuki, Department of Fisheries and Oceans, Technology Laboratory, University of British Columbia, Vancouver, B.C., Canada. Personal commun., Jan. 1983.

This report summarizes current knowledge of the distribution, abundance, biology, and management of Pacific whiting in the Strait of Georgia by the Canadian Department of Fisheries and Oceans between 1974 and 1981 from commercial trawl catch data collected by vessel observers and port samplers. Survey and sampling methods are described in publications cited in the text. Commercial catch data were taken from Department of Fisheries and Oceans annual reports (Smith, 1981) and from computer files developed from sales slips and interviews with the crews at landing.

Stock Delineation

Pacific whiting in the Strait of Georgia constitute a distinct population and are much smaller than offshore whiting (Beamish et al., 1982). The shape and size of the otolith and the pattern of annuli formation are distinctive (Fig. 1, 2). Otoliths from the offshore whiting are more elongate and in section are less concave. The strong year classes present in the offshore whiting (Beamish, 1981) are not synchronous with those of the Strait of Georgia whiting. In addition, the absence of the myxosporean parasite. *K. paniformis* (Kabata and Whitaker, 1981) clearly indicates the absence of interchange with the offshore population.

Within the Strait of Georgia there are discrete whiting stocks. For example, a small stock of larger whiting has

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been found in spawning condition 4-6 months prior to main spawning (Beamish et al., 1976d). A stock of actively spawning whiting has been found northwest of Texada Island, near Montgomery Bank (Fig. 3). Small groups of whiting have been observed in other areas such as mainland inlets, and it is suspected that these constitute distinct local stocks.

Distribution

Adult

Pacific whiting spawn from March to May in the deeper water of the south central Strait (Fig. 4). Biomass surveys indicate that about 80 percent of adult Pacific whiting are present in this area at this time. The major spawning aggregation is located south and west of Halibut Bank at depths from 150 to 350 m (Fig. 5). During peak spawning, about 35 percent of the fish are concentrated in this aggregation (Cass et al., 1978; Thompson and McFarlane, 1982).

Two distinct midwater layers of whiting are present in the Strait during spawning (Cass et al., 1978; Thompson and McFarlane, 1982). The shallower layer is present at about 50-120 m (and appears as a light scattering layer over the spawning aggregation (Fig. 5a) and discrete schools elsewhere (Fig. 5b). The deeper layer exhibits a continuous distribution of varying densities from about 150 to 320 m.

During March and April, the percentage of prespawning fish remains constant, with females occupying the shallow layer (75 percent) and males occupying the upper portion of the deep concentration. At this time there is a marked increase of actively spawning males and females in the lower portion of the deeper concentration. The greatest percentage of actively spawning fish is below 220 m. By late April-early May, 85 percent of the males and females have completed spawning and are aggregating in shallow layer (50-80 m) on the west side of the Strait, along Vancouver Island (Fig. 6). During the day, these aggregations are found in association with a dense plankton layer (Fig. 7) common throughout the Strait at this time of year and form discrete dense schools (Fig. 8a). Below these schools the density is greatly reduced, but distribution is continuous. At night the dense schools disperse and whiting

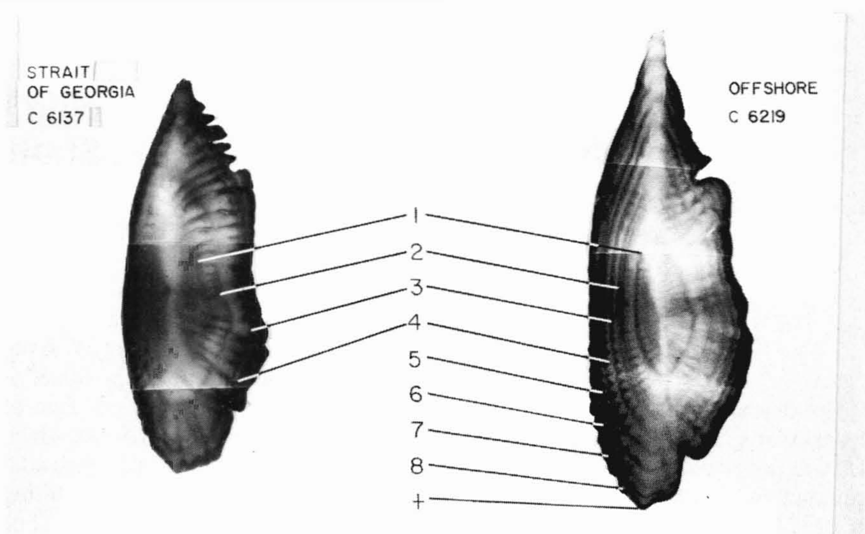

Figure 1.—Surface view of otolith from Strait of Georgia and "offshore" Pacific whiting showing the difference in size and shape of the otoliths from the two stocks. Both fish were age 8+ using the "broken and burnt" method (see Figure 2).

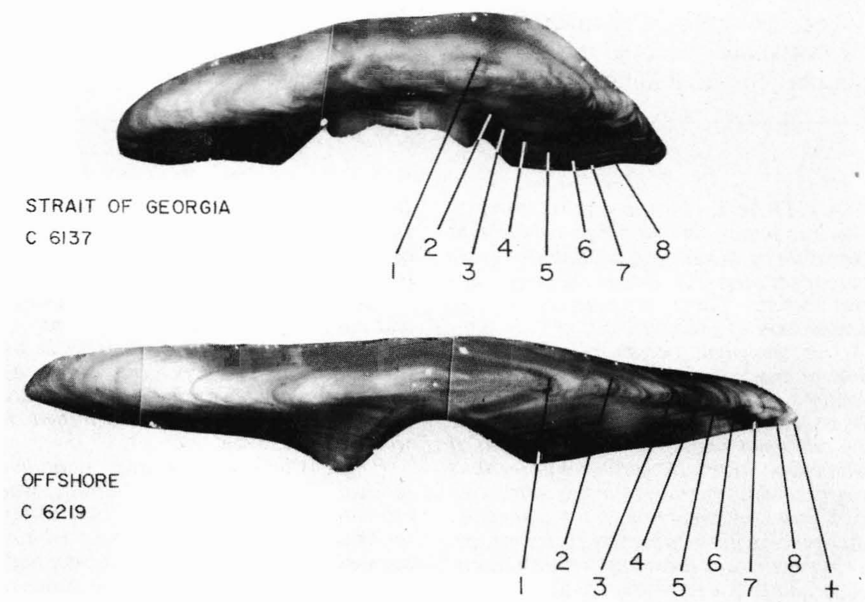

Figure 2.—Broken and burnt otolith sections from Strait of Georgia and "offshore" Pacific whiting showing the difference in the growth of the otolith in cross-section and in the pattern of annuli formation.

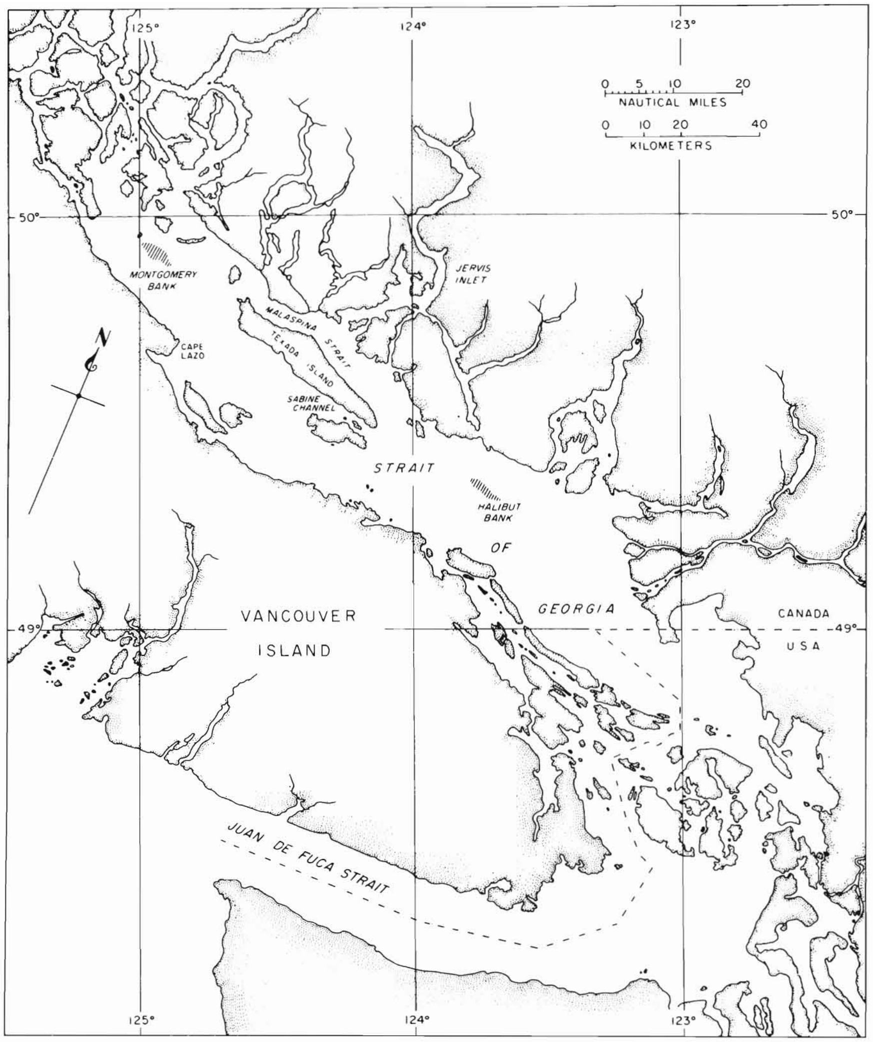

Figure 3. — The Strait of Georgia and its prominent banks.

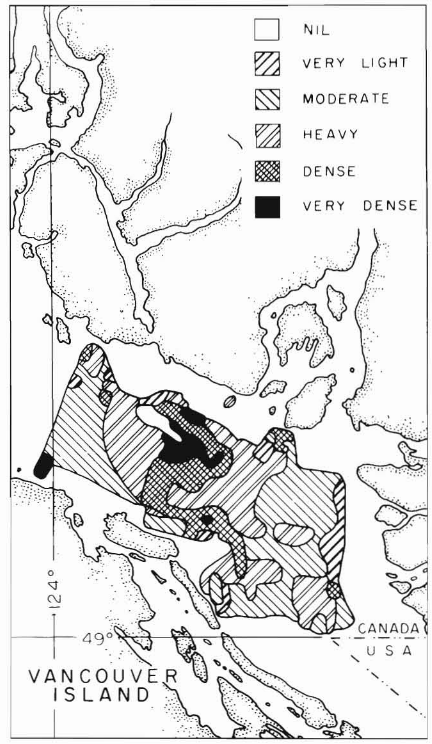

Figure 4. — Spawning distribution of Pacific whiting in the Strait of Georgia as represented by echogram and catch estimates (March).

migrate toward the surface (Fig. 8b). By fall, whiting aggregations have moved north and schools become dispersed (Fig. 9a). In late fall, few whiting are found in the Strait and it appears that they have migrated into the Johnstone Strait area (Fig. 9b). In early winter, aggregations reappear and adult whiting begin to migrate down Malaspina Strait and Sabine Channel toward the central Strait in preparation for spawning (Fig. 10).

Juvenile

Juvenile Pacific whiting aged 1-3 years are distributed throughout the Strait of Georgia. During February 1981 (McFarlane et al., 1982b; 1983), age 1+ whiting were captured throughout the open Strait from the Apex to Montgomery Bank in the northern Strait. Previous studies (Beamish et al., 1978a; Cass et al., 1978; McFarlane et al., 1983) have reported Strait-wide distribution of age 1+ whiting with relatively large catches in Malaspina Strait and Jervis Inlet. Age 1+ whiting were found throughout the water column but the majority were caught in sets where the average net depth was less than 200 m. Whiting, estimated to be age 2+ and age 3+ from length-frequency analysis, have been captured at all depths throughout the Strait of Georgia. Comparison of size composition of whiting by depth shows no obvious spatial separation (Beamish et al., 1978a; McFarlane et al., 1982a, b, 1983); however, large numbers of juveniles were generally captured in areas where adult catches were small, particularly away from spawning concentrations in the central Strait. Some young-of-the-year whiting moved into the shallower inshore waters, such as the Gulf Islands and remained there for 2 years (Beamish et al., 1978b). During their third year of life (age 2+), they moved out of this area and appeared to concentrate in the south central Strait.

Ichthyoplankton

Egg and larval plankton surveys carried out in the Strait of Georgia in

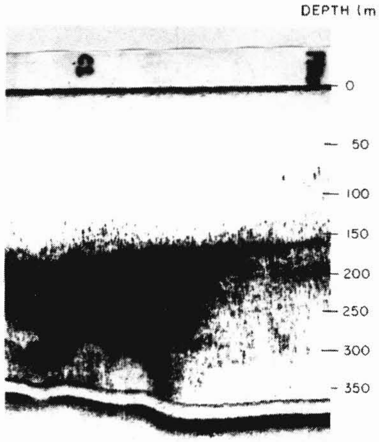

Figure 5a. — Echogram representing the spawning aggregation in the south central Strait during March.

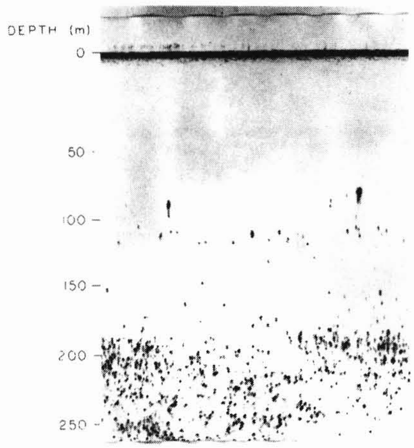

Figure 5b. — Echogram representing two distinct midwater layers common throughout the south-central Strait just prior to spawning.

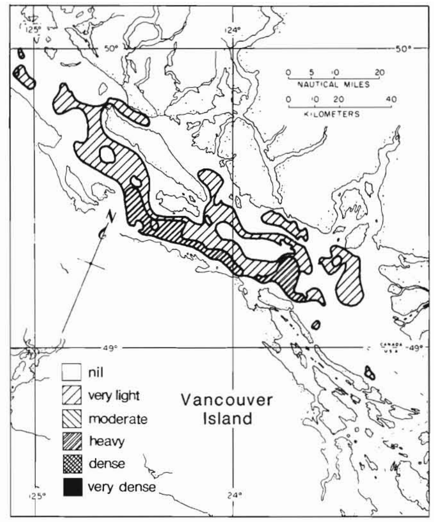

Figure 6. — Distribution of post-spawning Pacific whiting in the Strait of Georgia (April-May). Note the heavier concentrations found on the west side of the Strait along Vancouver Island.

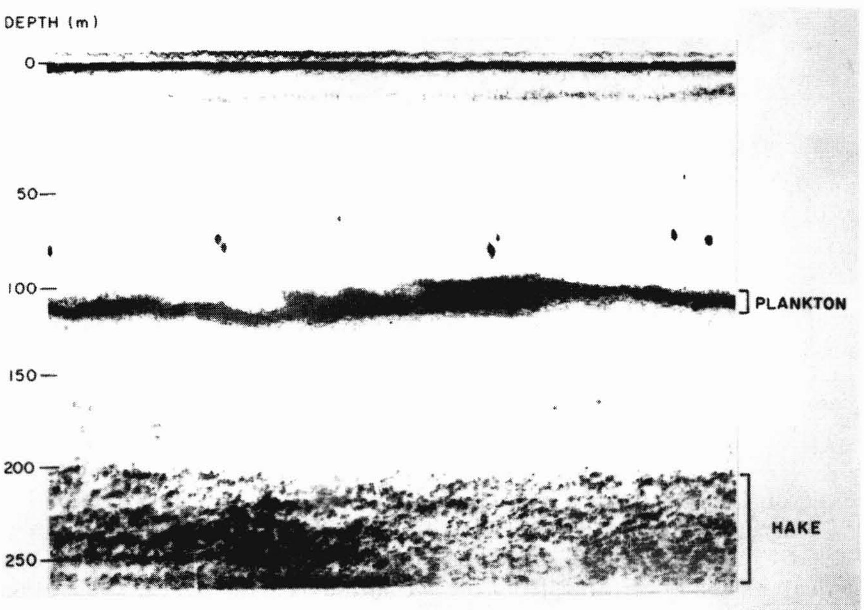

Figure 7. — Echogram showing discrete schools of Pacific whiting in association with dense plankton layer during April-May.

1979, 1980, and 1981 suggested a distribution of spawning whiting[2] similar to that described from trawl surveys. Eggs were common throughout the south central Strait and were densest off Halibut Bank. A smaller dense concentration was present northwest of Texada Island, near Montgomery Bank. Whiting eggs were found at depths of 100-300 m in the open Strait from March to May. Maximum density occurred at 170-220 m in early April. Larvae were found at 200-250 m and at shallower depths as they developed.

Surveys with Isaacs-Kidd and plankton nets carried out from 1961 to 1973 (Barraclough, 1967a, b, c; Barraclough and Fulton, 1967, 1968; Barraclough et al., 1968) indicated that whiting larvae were rare in the surface waters of the open Strait. Mason (footnote 2) found whiting larvae as deep as 300 m but the highest density was 200-250 m during April. Whiting larvae were abundant throughout the midwater during April-May, but by June catches of larval whiting had decreased substantially.

Age Growth and Maturity

Initially, age was estimated from the exterior surface of the otolith. However, it was soon evident that the annuli on the periphery of otoliths of older fishes were difficult to distinguish. Examinations of sections

[2]J. C. Mason, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6. Personal commun., Nov. 1982.

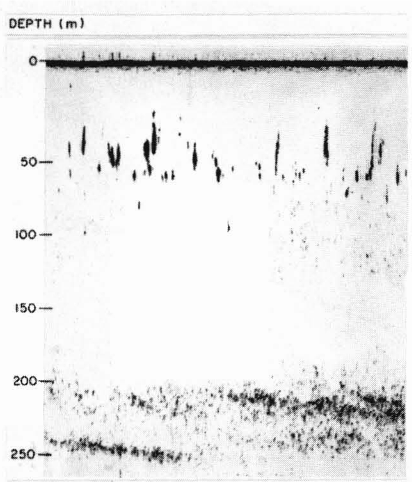

Figure 8a.—Echogram showing concentrations of Pacific whiting during daylight hours. Note discrete schools of whiting in shallow layer.

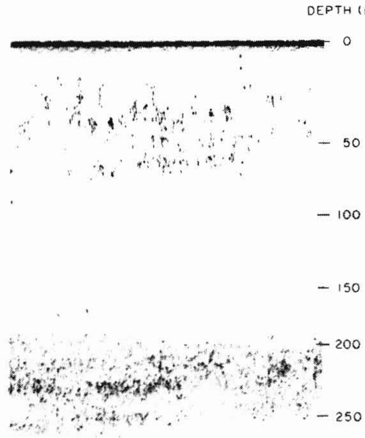

Figure 8b.—Echogram showing concentrations of Pacific whiting during night. Shallow layer schools have dispersed throughout the upper 100 m.

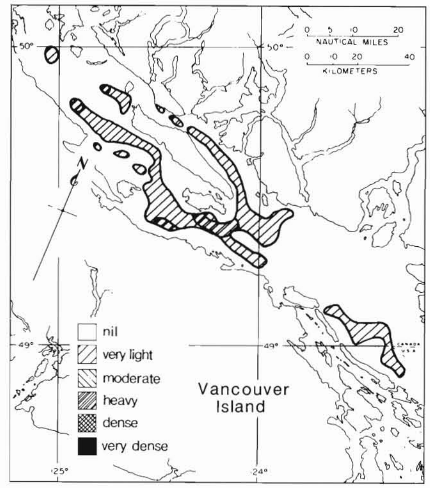

Figure 9a.—Distribution of Pacific whiting in the Strait of Georgia during fall (September).

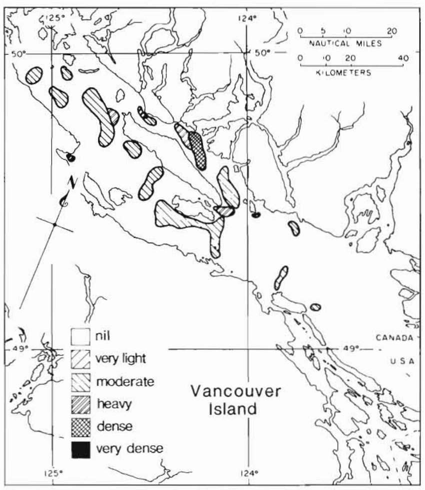

Figure 9b.—Distribution of Pacific whiting in the Strait of Georgia during late fall (December). Note the absence of whiting in the Strait at this time.

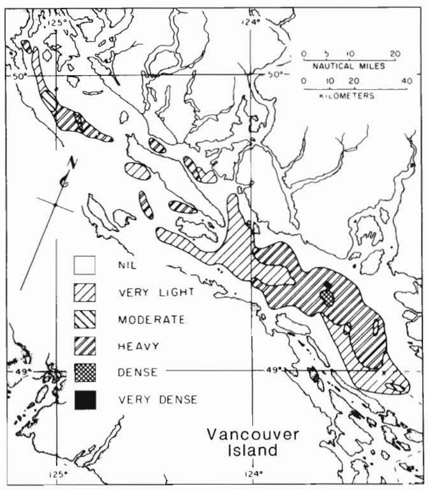

Figure 10.—Distribution of Pacific whiting in the Strait of Georgia just prior to spawning (February).

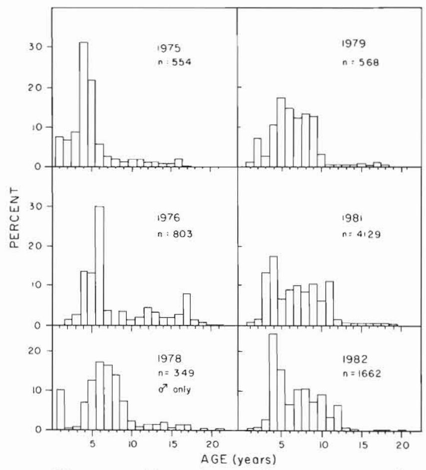

Figure 11.—Age frequency of Pacific whiting in the Strait of Georgia (1975-1982) showing the persistence of the strong 1970 year-class and the apparent increase in abundance of strong year-classes compared to the 1960's.

of otoliths (Beamish, 1979) indicated that annuli could be more readily identified. At present, otoliths are broken through the nucleus and burned (Chilton and Beamish, 1982) and sectioning is used only for otoliths that are very dificult to determine.

The ages estimated from the sectioning or broken and burnt methods have been validated for ages up to 3 years by comparison with length frequencies. Whiting aged 1, 2, and 3 years had modal lengths corresponding to similar modes in the length frequency at 11, 23, and 33 cm (Beamish et al., 1978a; Cass et al., 1978; McFarlane et al., 1982a; 1983). The 1970 year class in the Strait of Georgia has been identified each year since 1975 (Fig. 11), indicating that the zone identified as an annulus does

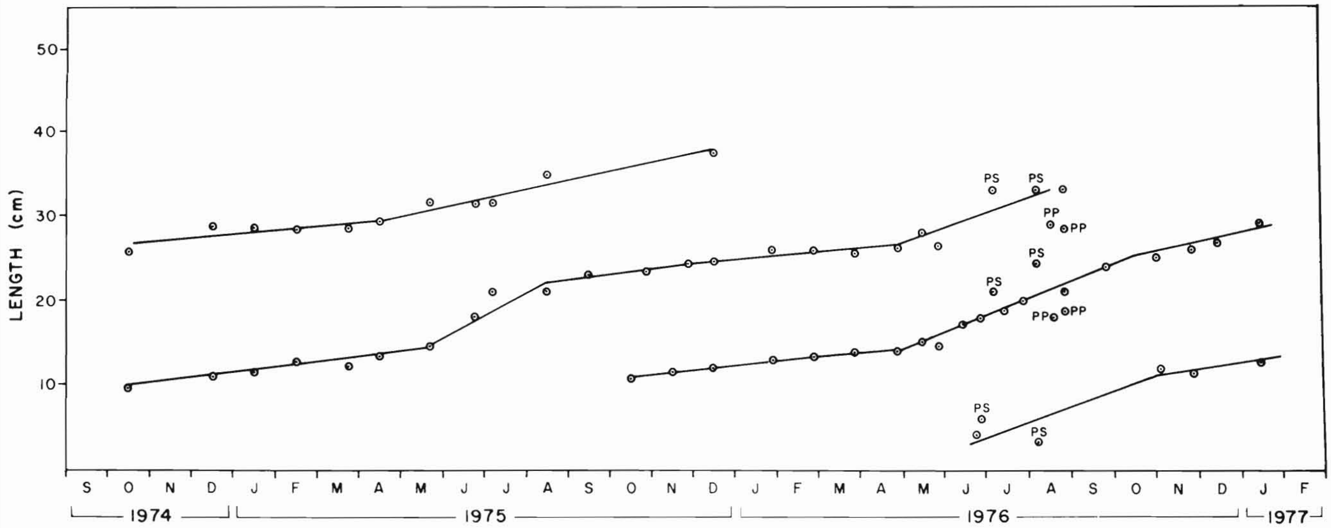

Figure 12.—Comparison of mean fork lengths, by year-class, of juvenile (0-3 years) Pacific whiting, 1974-77. Samples collected from Stuart Channel in Gulf Islands area of the Strait. (PS = purse seine; PP = samples from Porlier Pass).

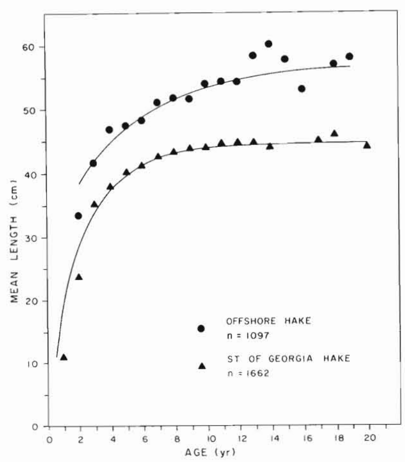

Figure 13.—Mean lengths at age from Strait of Georgia and "offshore" Pacific whiting. Solid lines derived from the von Bertalanffy growth equation with parameters of t_0 = -0.173, K = 0.457, L = 44.5 cm and t_0 = -3.043, K = 0.233, L = 56.9 cm for Strait of Georgia and "offshore" Pacific whiting, respectively.

form once a year at least up until the age of 12.

Growth of juveniles (age 1+ and 2+) occurs mainly during May-November (Fig. 12). The pattern of annual growth throughout the year

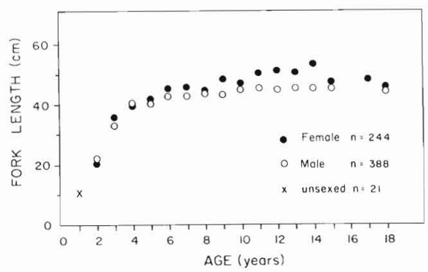

Figure 14.—Mean lengths at age for male and female Pacific whiting in the Strait of Georgia.

during the study period (1975-77) was similar.

Pacific whiting in the Strait of Georgia grow rapidly up to the age of 4, but at a slower rate than shown by the "offshore" whiting (Fig. 13). Population growth curves for males and females combined show a similar constant, relatively rapid, growth to age 4 and substantially slower growth thereafter. Male and female whiting (Fig. 14) show similar annual growth up to age 4 or 5, after which mean lengths for females are significantly larger (t-test $P \geq 0.05$). Mature males average 2-3 cm smaller than mature females. Both males and females continue to live for long periods during which little growth occurs.

The oldest fish was 20 years (McFarlane et al., 1983) but 83 percent of the fish from research and commercial catches during 1981 were in the range of 4-11 years.

The catch curves indicate a substantial increase in the abundance of year classes since 1970 (Fig. 15). The reason for this increase in abundance is currently being investigated.

Most (95 percent) adult whiting range from 40 to 50 cm with a mode at 44 cm. Modal length is 44 cm and 46 cm for males and females, respectively. The largest female sampled was 80 cm; however, less than 5 percent were larger than 50 cm.

The length-weight relationship is exponential (Fig. 16a, b). Estimates are given in Table 1. These estimates reflect prespawning and postspawning differences. McFarlane et al. (1983) found that growth in weight is seasonal and that during spawning adult whiting lose between 15 and 20 percent of their body weight.

The mean lengths (cm) of Pacific whiting at 50 percent maturity were calculated by probit analysis following the technique of Leslie et al. (1945) as described in Beacham and Nepszy (1980). Length at 50 percent maturity was 33 cm for males and 37

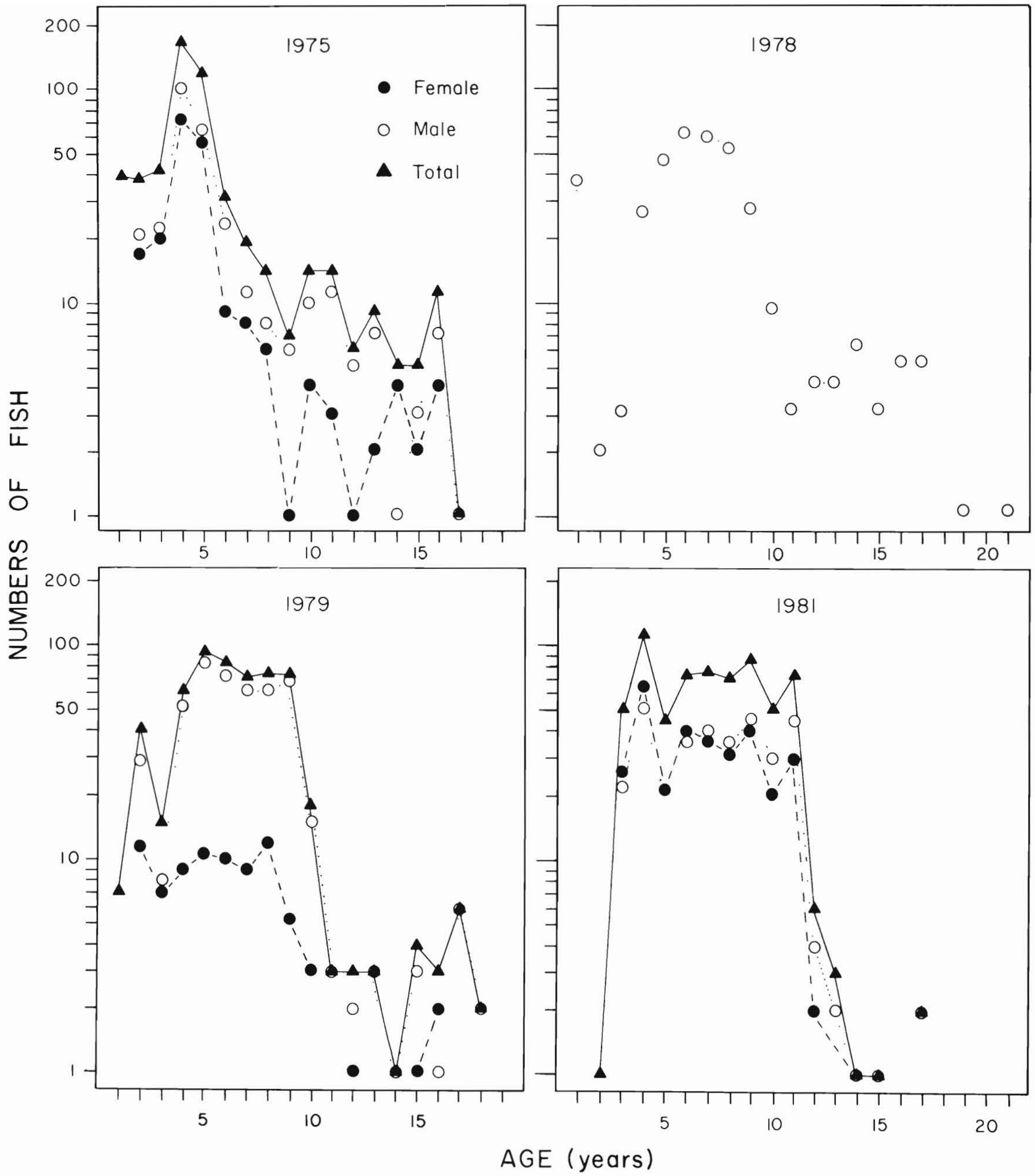

Figure 15.—Comparison of catch curves for Pacific whiting in the Strait of Georgia from 1975, 1978, 1979, and 1981, showing the progress of strong year-classes through the fishery and the apparent increase in abundance of strong year-classes compared to the 1960's.

Table 1.—Summary of Pacific whiting length-weight relationship values estimated using geometric regressions ($W = al^b$).

Sampling period	Male				Female				Total		
	n	a	b	r	n	a	b	r	n	a	b
20 Feb.-3 Mar	160	0.0155	2.7412		219	0.0056	3.029		379	0.0065	2.9969
24 Apr.-2 May	142	0.1406	2.1103	0.88	143	0.0619	2.337	0.83	326	0.0074	2.8923
3 July	137	1.0882	1.5712	0.83	99	0.2586	1.9693	0.91	237	0.5134	1.7791
Means (weighted)			2.172				2.5867				2.6543
Total	439				461				942		

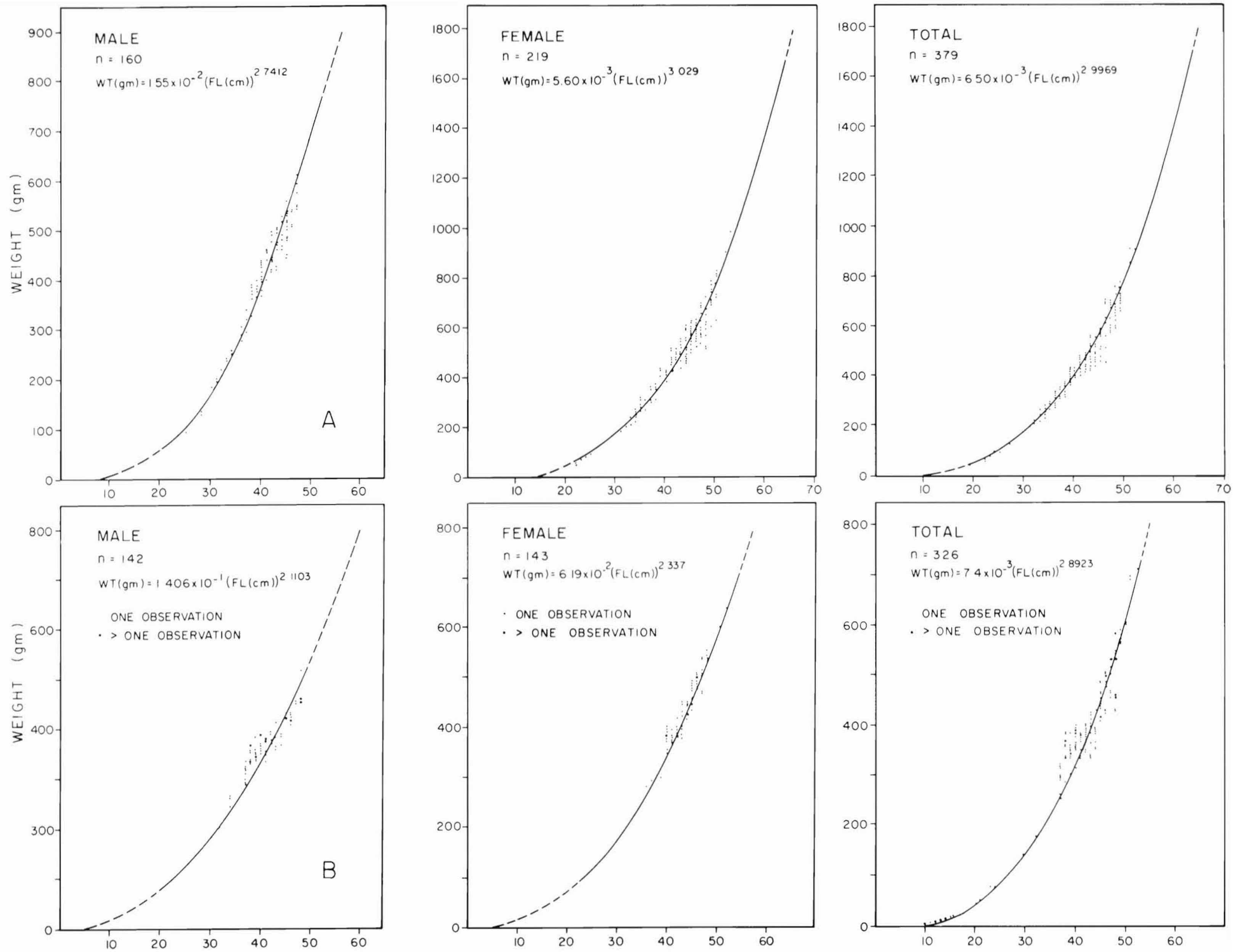

Figure 16a.—Length-weight relationships for Pacific whiting in the south-central Strait of Georgia. A, 20 February-3 March 1981. B, 24 April- 2 May 1981.

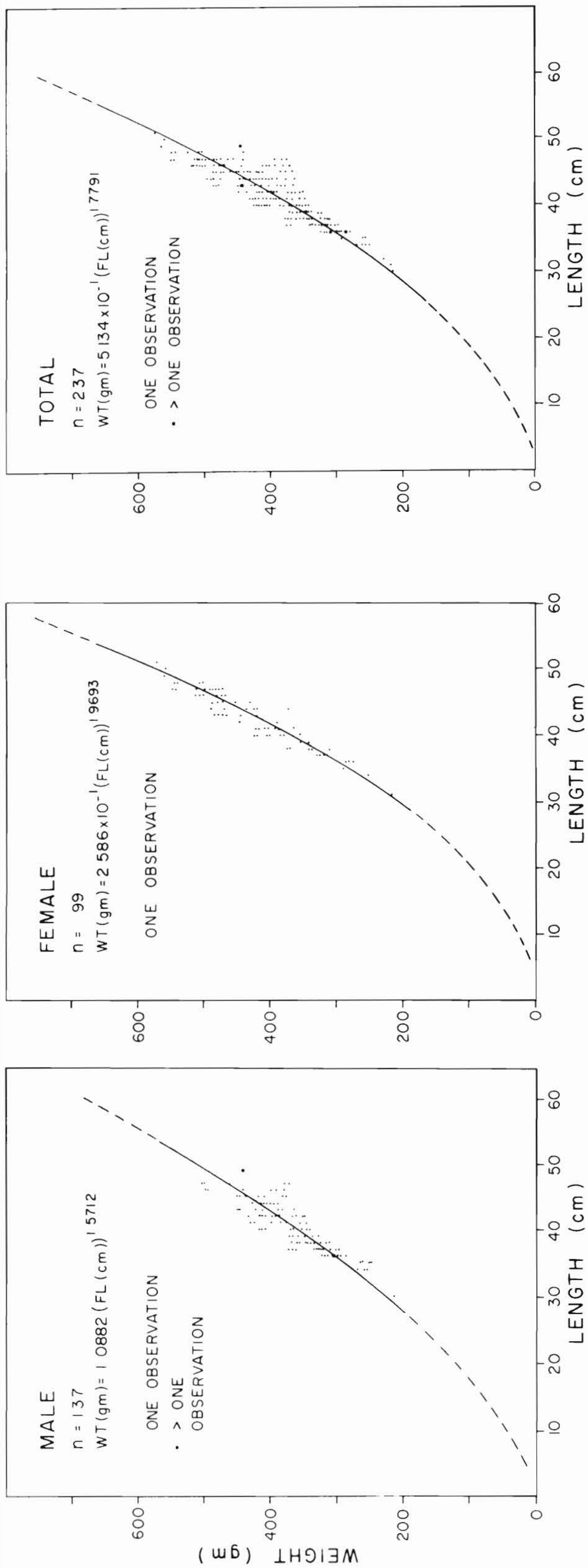

Figure 16b.—Length-weight relationship for Pacific whiting in the south-central Strait of Georgia. C, 3 July 1981.

cm for females, indicating that the year preceding first spawning is a period during which many of the recruiting year classes appear isolated from adults and other juveniles. By age 4, 100 percent of males and females are mature.

Fecundity and Egg Development

A histological study of Pacific whiting ovaries (Foucher and Beamish, 1980) indicated that multiple size modes of oocytes were present. Oocytes in the smallest mode (50-150 mm) contained no yolk and represent the reserve stock from which, each year, a proportion proceeds with further growth and maturation. Relatively large numbers of small- and large-yolked oocytes remained in the ovaries and were resorbed so that a second spawning did not occur. Nikolskii (1965) defined fecundity as "the number of eggs (oocytes) for the generation of that year present in the ovaries," i.e. the number that should be laid in that year. The occurrence of large, yolked oocytes remaining in the ovaries indicates that the assumptions used when making fecundity measurements must be clearly identified and that fecundity should be defined as the number of oocytes that are actually released to be fertilized (viable oocytes). It may be that an increased commercial fishery in the Strait would reduce stock size, resulting in an increase in the production of viable oocytes.

Absolute fecundities were determined for ripening whiting in the Strait of Georgia in February 1981. Predictive least squares linear regression of log fecundity (F) on log fork length (L), transformed to the exponential relationship, produced the following preliminary relationship from each egg diameter category.

Egg dia. (μm)	Geometric equation (Power curve)	Correlation r^2(%)
40-180	$F=(6.92\times10^{-2})\ L^{3.9766}$	88
181-380	$F=(4.46\times10^{-2})\ L^{3.7097}$	86
381-580	$F=(2.08\times10^{-1})\ L^{3.4174}$	71
581-780	$F=(8.00\times10^{-4})\ L^{4.647}$	65
181-780	$F=(5.50\times10^{-1})\ L^{3.3896}$	81

These relationships indicate that the relative potential fecundity per unit weight increases with size (and presumably age) of the fish. However, as it is difficult to differentiate between viable and nonviable oocytes in each size category, current studies of whiting fecundity include oocyte counts and a histological examination of spent and recovering ovaries to examine this relationship. It is apparent that the fishery must be monitored closely to determine the reproductive response to increased exploitation.

Feeding and Predation

There has been no comprehensive study of the diet of Pacific whiting in the Strait of Georgia. Food observations have been taken incidental to other studies (Beamish et al., 1978a, 1982; Cass et al., 1978, 1980; McFarlane et al., 1982b, 1983).

The diet of adult Pacific whiting in the Strait is composed mainly of pelagic and semipelagic animals. Fish captured in the dense aggregations fed primarily on euphausiids (60-82 percent of the diet by volume) throughout the year. Other invertebrates, comprising 1-5 percent of the stomach contents, were amphipods (*Euprimo abyssolis*, *Parathemisto pacifica*, *Cyphocaris* sp., and *Calliopius* sp.); glass shrimp, *Pasaphia pacifica*, and squids. Also present were small, off-bottom fishes such as Pacific herring, *Clupea harengus pallasi*; *Bathylagus* sp.; eulachon, *Thaleichthys pacificus*; unidentified myctophids, and juvenile whiting.

Pacific whiting not associated with the dense aggregations fed more heavily on fish, primarily *Bathylagus* sp. Glass shrimp was also a major prey species of the nonschooling whiting.

Pacific whiting fed throughout the year, but the proportion of empty stomachs was larger and mean stomach content lower in winter samples than summer (Beamish et al., 1976b, 1982; Weir et al., 1978; Cass et al., 1978; McFarlane et al., 1982b, 1983). Adults feed very little during spawning. After spawning, dense feeding aggregations form at depths of 40-100 m in association with the heavy plankton layer. Euphausiids remain an important component of the whiting diet; however, during this time herring become the dominant fish species in the diet, comprising between 15 and 20 percent in May and 9 percent in June. There was some indication of seasonality and size selectivity of prey; however, data are insufficient to quantify those observations.

Juvenile whiting have been identified in adult stomachs, but the extent of cannibalism is unknown. One survey (Shaw et al., 1983) carried out in March-April 1976 identified young-of-the-year whiting as the dominant food item of adults in the south-central Strait.

Dominant fish predators in the Strait of Georgia are Pacific whiting; walleye pollock, *Theragra chalcogramma*; rockfish, *Sebastes* spp., Pacific salmon, *Onchorhynchus* spp., Pacific herring; and, to some extent, juvenile sablefish, *Anoplopoma fimbria*. Although quantitative studies of interactions have not been made, predation and competition for food may have an effect on developing and established fisheries. Observations made during a series of cruises in 1981 (McFarlane et al., 1983) indicated that about 15 percent of whiting were feeding exclusively on herring. It was estimated that more than 50 percent of the whiting stock was present in this area during this time (April, May) and may have consumed 4,000-8,000 metric tons (t) of herring. While this estimate is preliminary, it does indicate that whiting predation on herring could be important, particularly considering that the annual herring landings have ranged from 10,000 to 18,000 t. It is important to note that of the 10,000 whiting examined for stomach contents since 1975, not one salmon has ever been identified.

In the Strait of Georgia, Pacific whiting are preyed upon by spiny dogfish, *Squalus acanthias*; walleye pollock; and Pacific cod, *Gadus macrocephalus*, and, in the inshore waters, juveniles are preyed upon by lingcod, *Ophiodon elongatus*, and rockfish species. Whiting eggs at all stages of development have been found in pollock stomachs and, though rarely, whiting. Marine mammal predators include the fur seal, *Callorhinus ursinus*; California sea lion, *Zalophus californianus*; and the Steller sea lion, *Eumetopias jubatus*[3].

Lamprey, *Lampetra* sp., attacks account for some natural mortality. In sets made in the south central Strait during 1981, <1 percent of the fish bore lamprey wounds. This agrees with previous reports (Beamish et al., 1976d).

As the dominant resident species in the Strait of Georgia, one would expect Pacific whiting to be important both as predator and prey for a variety of other animals at some stage in their life history. The importance of these interactions remains to be clearly identified.

Abundance

Preliminary estimates of abundance of adult whiting ranged from 100,000 to 200,000 t based on hydroacoustic surveys carried out in the mid-1970's[4] and ichthyoplankton surveys in 1979 (footnote 2). During 1981, three methods (swept-volume trawl surveys, hydroacoustic surveys, and ichthyoplankton surveys) were employed to determine the abundance of Pacific whiting. Surveys were carried out in the entire Strait, but emphasis was placed on the spawning population present in the south-central portion of the Strait. The results of the study will form the basis for future management of whiting. At this time the results of the ichthyoplankton surveys are not available; however, preliminary estimates from the swept-volume trawl surveys and hydroacoustic surveys range from 85,000 to 130,000

[3]M. Bigg, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6. Personal commun., Jan. 1983.

[4]R. Kieser, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6. Personal commun., Nov. 1982.

t (Thompson and McFarlane, 1982) and 40,000 to 150,000 t (Kieser, 1983), respectively. These estimates are lower than the earlier hydroacoustic estimates.

It appears that since 1970 there has been a period of increased abundance of whiting because of a succession of strong year-classes relative to the 1960's (Fig. 15). The reason for the relative success or abundance remains to be identified. It also remains to be shown whether there has been a periodicity in whiting abundance.

Mortality

Total annual mortality (A) and total instantaneous mortality (Z) have been estimated from the slope of the right-hand limb of the catch curves (Jackson, 1939). The slope of the catch curves (Fig. 15) indicates that annual recruitment is not constant and that at least one of the assumptions required by the method was violated. Early studies indicated the presence of a plateau in the vicinity of ages 5-7 (Beamish et al., 1976a. 1978a; Thompson and Beamish, 1979). Depending on where on the catch curve fish were considered to have been recruited, mortality estimates of A = 0.21-0.74 were obtained, corresponding to instantaneous mortality rates of Z = 0.24-1.35.

Recent studies (Beamish et al., 1982; McFarlane et al., 1982a) have indicated that strong year classes are an important component of this population. Comparing the change in relative abundance of strong and weak year classes (McFarlane et al., 1983), using simple linear regression (Ricker, 1975), produced total annual mortality estimates of A=0.15-0.25 and corresponding to instantaneous mortality rates of Z=0.16-0.29. The lower estimates were determined for the weak 1967 year class and may be indicative of differential mortality rates between year classes or of year-specific mortality rates. Several consecutive years of age samples will be required to calculate accurate age, sex, and year-class mortality rates.

Management

The Pacific whiting fishery in the Strait of Georgia was not initiated until 1979; therefore, no historical data base is available with which to study possible effects of the fishery on the stocks. Catches during 1979 and 1980 were small, 516 t and 508 t, respectively. However, 2,400 t were landed in 1981, 2,824 t in 1982, and 3,111 t in 1983. As interest in the fishery increases and potential markets are explored, it is anticipated that this fishery will increase substantially over the next decade. The initial management approach was to calculate theoretical maximum sustainable yields (MSY), utilizing estimates of unexploited biomass (*Bo*) from hydroacoustic and swept-volume surveys during the mid-1970's as well as estimates of instantaneous natural mortality rates (M) (0.45-0.63).

The Gulland (1970) formula, $MSY = 0.5(M)(Bo)$, produced estimates ranging from 11,000 to 38,000 t. As these were preliminary parameter estimates, it was recommended that the total allowable catch not exceed 10,000 t until a reassessment of abundance estimates and other biological parameters was undertaken (Ketchen, 1980; Westrheim, 1980).

Using recent estimates of abundance (60,000-130,000 t) and mortality (0.19-0.29), the range in MSY is 6,000-19,000 t. Assuming abundance is near the midpoint of the estimates (100,000 t) obtained from the recent swept-volume midwater trawl, hydroacoustic, and ichthyoplankton surveys, and that mortality is in the range of estimates taken using changes in relative abundance of good year classes (0.19-0.29), then MSY is 10,000-15,000 t.

Estimates of MSY presented here may not represent the long-term average if there are large cycles in population size. Since the response of the stock to exploitation in terms of growth, survival, or reproductive potential cannot be assessed at this time, a conservative management strategy should be adopted until the combined effects of recruitment fluctuations and fishing are determined. Because female whiting produce a number of nonviable eggs that are resorbed, it is possible that a fishery will reduce the virgin stock which may result in increased fecundity. This increase in egg production per adult could conceivably result in increased yield.

Processing and Markets

Offshore Pacific whiting contain two myxosporean parasites. One of these parasites has recently been identified as a new species, *Kudoa paniformis* (Kabata and Whitaker, 1981), and shown to be responsible for the rapid degradation of the flesh (Tsuyuki et al., 1982). In addition, this parasite can induce a tissue response that results in the concentration of melanin which causes unsightly blotches in the flesh. In the Strait of Georgia, *K. paniformis* is absent and whiting flesh has a much better storage life (Tsuyuki et al., 1982). Whiting properly stored aboard the fishing vessel can be kept for up to 5 days. Thus, despite the smaller size, the better quality flesh makes this population an attractive fishery.

To date, most whiting have been processed as fillet blocks for institutional use. The white, mild-tasting, flaky flesh makes it a desirable substitute for cod. The fillet block product appears to have the most potential, particularly in the fast-food industry.

Recently, interest has been increasing in both headed and gutted and cured (salted) whiting. The demand is high for these types of products and the export potential appears good. Inquiries have also been received on the feasibility of using whiting for surimi. In addition, whiting roe harvested during February and early March exhibits the characteristics associated with good quality pollock roe (footnote 1).

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