On the Early Life History of the Lingcod *(Ophiodon elongatus)*

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ON THE EARLY LIFE HISTORY OF THE LINGCOD (*OPHIODON ELONGATUS*)

by

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ABSTRACT

Phillips, A. C. and W. E. Barraclough. 1977. On the early life history of the lingcod (*Ophiodon elongatus*). Fish. Mar. Serv. Res. Dev. Tech. Rep. 756: 35 p.

Newly hatched 7 mm larvae of the lingcod (*Ophiodon elongatus*) are pelagic and appear, by early March, in the surface waters of the Strait of Georgia, British Columbia, where they are dispersed by currents. As the larvae grow, they move progressively inshore and, in late May, reach high concentrations in certain shallow areas. Shortly thereafter, at a length of about 80 mm, they disappear from the surface waters and become demersal.

Food at first consists of small copepods, their eggs and naupliar stages; shifting to larger copepods, decapod, and fish larvae as the lingcod grows in size. An abrupt dietary shift from zooplankton to juvenile herring immediately precedes commencement of demersal life.

Juvenile lingcod marked with fluorescent grit and held in aquaria retained their marks for 3 mo. They grew rapidly and readily accepted live or frozen juvenile herring, salmon, and sandlance as food.

Key words: *Ophiodon elongatus*, lingcod, early life history, developmental stages, ecological distribution, stomach contents.

RÉSUMÉ

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Les larves de morue lingue (*Ophiodon elongatus*) de 7 mm, nouvellement écloses, vivent à l'état pélagique jusqu'au début de mars; elles montent alors à la surface des eaux du détroit de Géorgie, en Colombie-Britannique, pour être dispersées par les courants. À mesure qu'elles se développent, les larves se rapprochent du rivage et, à la fin de mai, on les retrouve dans certaines eaux peu profondes. Peu après, ayant atteint une longueur de 80 mm, elles disparaissent de la surface pour mener une vie démersale.

Au début, elles se nourrissent de petits copédodes, des oeufs et des nauplius de ces derniers; puis, en grandissant, les morues lingues optent pour de plus gros copépodes, des décapodes et des larves de poisson. Un changement radical de régime survient immédiatement avant le début de leur vie démersale lorsqu'elles délaissent le zooplancton pour de jeunes harengs.

De jeunes morues lingues gardées en aquarium et marquées d'un corps fluorescent le sont demeurées pendant trois mois. Elles ont grandi rapidement et accepté facilement de se nourrir de harengs, de saumons et de lançons jeunes, vivants ou congelés.

Mots clés: *Ophiodon elongatus*, morue lingue, début du cycle évolutif, phases de développement, distribution, écologique, chyme.

INTRODUCTION

The lingcod (Ophiodon elongatus) is an important food fish harvested on the Pacific coast of Canada. The adult demersal phase of its life history has been studied extensively, but few studies have been made of its early life.

The major events in the life of the lingcod have been well established and were first described by Wilby (1937). A comprehensive description is given by Hart (1973). Chatwin (1954) traced the development of young lingcod through their first 2 yr of life, pooling 20 yr of data collected from the Strait of Georgia. However, the period of development from hatching and first appearance in the plankton in late February through to disappearance from nearshore surface waters in early June has been only partially examined due to the difficulty in obtaining continuous samples. An opportunity to collect continuous data arose in 1975 and 1976 when an intensive study was undertaken of juvenile fish populations in the vicinity of the Nanaimo River in the Strait of Georgia. Small pelagic fish in the surface waters from offshore to the intertidal zone were sampled weekly. These data together with data previously collected by surface trawling for larval fish in the Strait of Georgia from 1966 to 1969 provided a detailed account of the early life history of the lingcod.

METHODS

I. SAMPLING AND DATA COLLECTION

Information on the early life history of the lingcod was obtained from three sources as follows:

(1) Information on the planktonic larvae was obtained from Data Reports of surface trawling in the Strait of Georgia from 1966 to 1969. These comprised four separate studies listed below:

(a) Two-Boat Surface Trawl Series, Strait of Georgia 1966, 1968. Food of Larval and Juvenile Fish. Data is contained in Fisheries Research Board of Canada Manuscript Reports 922, 928 (Barraclough 1967c), 940 (Barraclough and Fulton 1967), 964, 972 (Robinson, Barraclough, and Fulton 1968), and 1067 (Robinson 1969).

(b) Isaacs-Kidd Trawl, Strait of Georgia Survey, April 25-29, 1966. Fisheries Research Board of Canada Manuscript Report 926 (Barraclough 1967b).

(c) Isaacs-Kidd and Miller Net Survey, Strait of Georgia, 1967. Unpublished data (Barraclough 1967).

(d) Two-Boat Trawl Series, Saanich Inlet, June and July, 1966; April 23-July 21, 1968. Fisheries Research Board of Canada Manuscript Reports 1003 (Barraclough and Fulton 1968) and 1004 (Barraclough, Robinson, and Fulton 1968).

(2) Data on post-larval stages of the lingcod were gathered by purse seining in the vicinity of the Nanaimo River (Strait of Georgia) in 1975 and 1976. A series of 17 stations, chosen to represent the range of habitats available to juvenile fishes, was sampled weekly from April through July (Fig. 1).

The locations were designated as either offshore, nearshore, or inshore stations. Offshore stations were located in channels chosen to monitor fish movements between the open Strait of Georgia and nearshore areas. Nearshore stations were located in bays and areas of known abundance of juvenile fish in water greater than 30 m depth. Inshore stations were located in shallow water (< 30 m) or restricted areas near the beach at the same locations as the nearshore stations.

A 120-fm (210-m) purse seine was used to sample offshore and nearshore areas of greater than 30 m depth. A 50-fm (90-m) purse seine was used to fish inshore areas and other selected sites too shallow for the larger seine. This series was supplemented in 1975 by a monthly two-boat surface trawl survey of the areas.

(3) On June 4, 10, and 17, 1976, the inshore area adjacent to the Pacific Biological Station, Nanaimo, was sampled intensively. Fish and plankton samples were taken and temperature, salinity, and current direction and velocity were measured throughout the water column. A total of 24 stations were sampled sequentially from 0600 to 1800 hr on the three dates. These studies attempted to correlate fish feeding patterns with water transport and zooplankton concentrations.

II. GEAR

(1) Multiple Miller Nets -- A conical plankton net suspended in a 20 cm diameter tube approximately 1 m long equipped with stabilizing fins at the rear and a tapered nose cone with a mouth opening of 0.01 m^2. These nets were arranged one above the other in a series to two or more. They were designed to sample different sizes of plankton simultaneously and were usually used in conjunction with an Isaacs-Kidd or midwater trawl.

(2) Isaacs-Kidd Trawl -- A 1.8 m^2 trawl of 1/4 inch-1/8 inch knotless nylon netting held open by a wing-like depressor along the base. The net was suspended from a boom and towed clear of the vessel's wake at a speed of approximately 6 knots with the headline just breaking the surface.

(3) Two-Boat Surface Trawl -- A trawl net with a mouth opening of 6.1 m wide $\times$ 3 m deep towed between two vessels, designed to catch everything from zooplankton to adult fish in the same tow. A full description is given in Barraclough (1967a) Fisheries Research Board of Canada Manuscript Report 922.

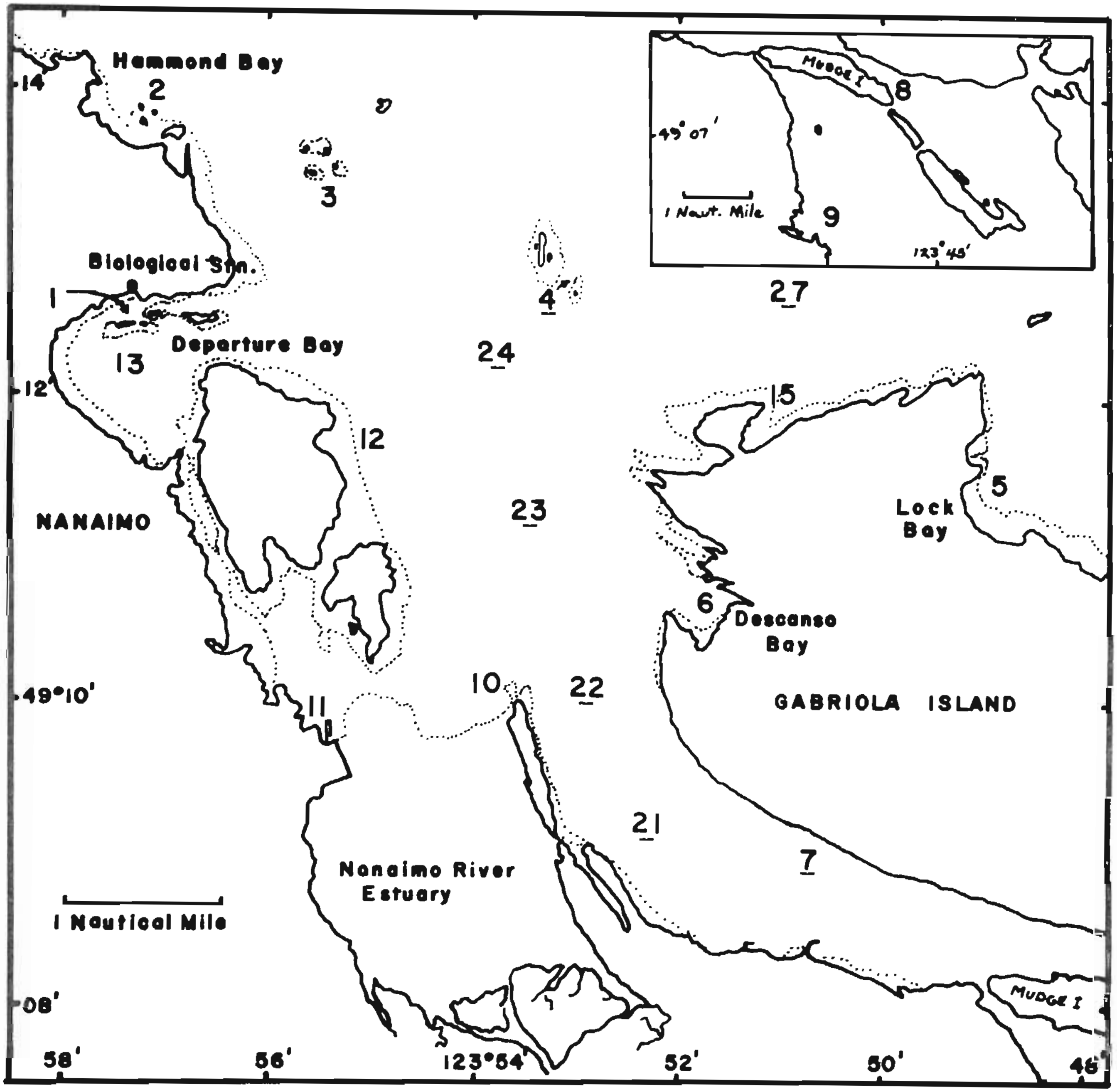

Fig. 1. Map of the study area near Nanaimo showing locations sampled by purse seine during 1975 and 1976. Offshore stations are underlined.

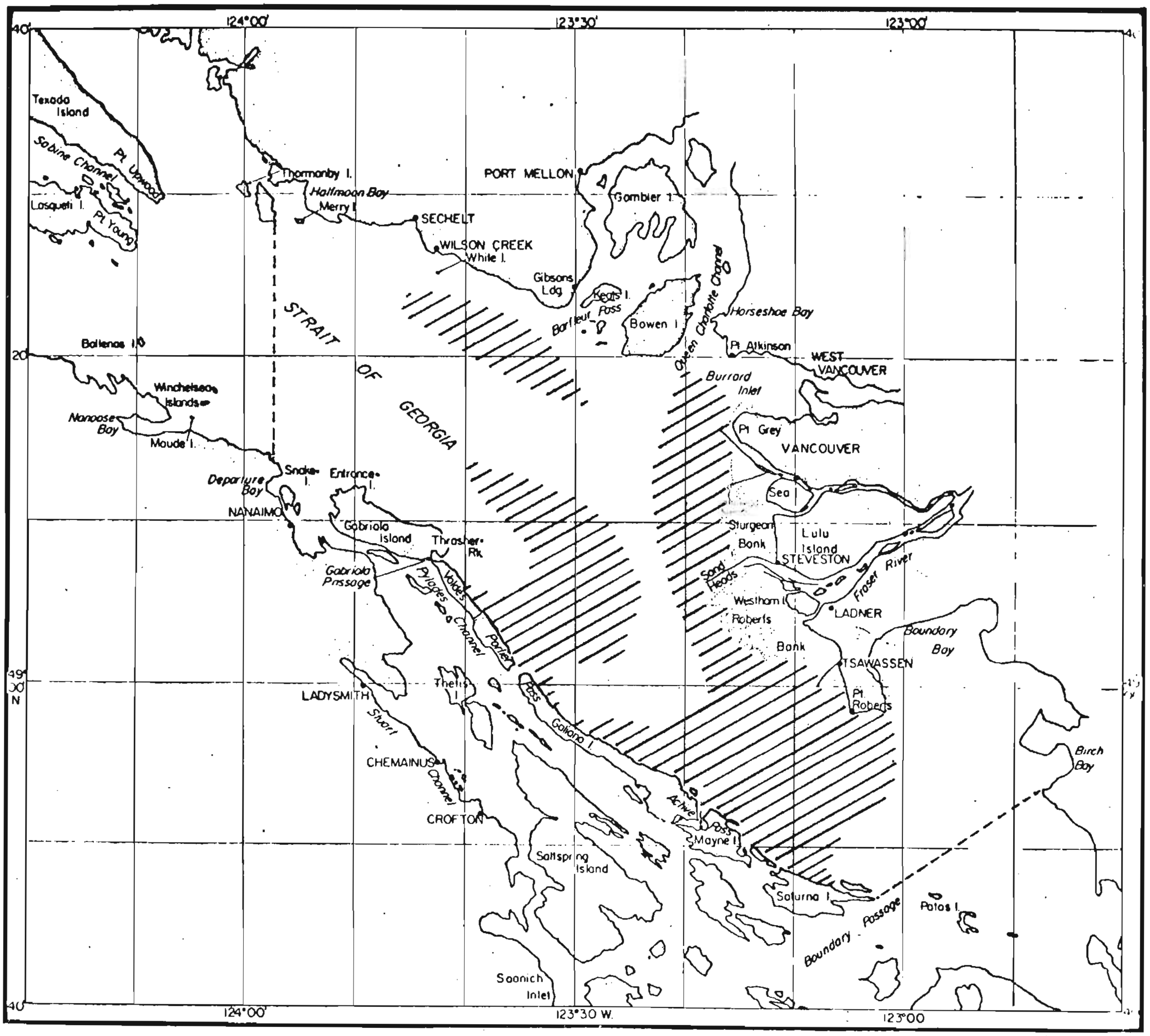

Fig. 2. Map of the southern Strait of Georgia showing the area sampled by surface trawl (between the dashed lines) and the areas of larval lingcod abundance (cross-hatched) during the period of maximum offshore distribution in late April, for the years 1966-1968 combined.

(4) 120-fm (210-m) Purse Seine -- A seine net with a diameter of about 75 m and a depth of 27 m when fully set which was fished off bottom from an 11 m seine boat. The net used had a bunt constructed of 1/2 inch knotless nylon netting which allowed quantitative sampling of fish of larger than 35 mm although smaller fish could be dip-netted out as the net was being pursed. This net was first equipped with a 1/4 inch knotless nylon netting bunt which proved unmanageable on any sort of current or wind and was abandoned in late April 1975 for the larger mesh netting.

(5) 50-fm (90-m) Purse Seine -- A smaller hand operated version of the above seine with a 1/4 inch knotless nylon netting bunt. The net measured approximately 15 m diameter × 4 m deep and could be set on or off bottom from a 8-m power boat.

RESULTS

I. DISTRIBUTION, ABUNDANCE, AND DEVELOPMENT

Newly hatched lingcod 6-10 mm in length first appeared in surface trawl catches from the Strait of Georgia in early March. Multiple depth Miller net sampling revealed them to be confined to the upper 3 m of the water column. Although widely distributed throughout the Strait of Georgia, the larvae were consistently more abundant inshore than in the open waters of the Strait and more numerous along the outside (eastern) shore of the Gulf Islands, in the areas of Porlier and Active passes and in the low salinity plume waters of the Fraser River discharge (Fig. 2).

During 1967, for which continuous data is available (Fig. 3), larval abundance in surface trawl catches from the Strait of Georgia increased through March to reach a maximum by late April. Thereafter numbers declined rapidly until by mid-May lingcod larvae were no longer present in catches from the open Strait. The two-boat surface trawl samples from Saanich Inlet in 1968 (Fig. 3), also show a decline in numbers of larvae during early May and disappearance from samples by the end of the month. Samples from subsequent years indicated a similar sequence.

Meanwhile, post-larval abundance increased inshore. Seining near Nanaimo during 1975 and 1976 showed a build-up and decline in catches occuring progressively later in moving from the offshore to the inshore stations (Fig. 3, 4). Maximum catches from the offshore seine stations were reached by the middle of May in both 1975 and 1976 although lingcod persisted in offshore samples until mid-June. Nearshore and inshore catches showed a similar build-up through April and early May, peaking in late May in 1976 and early June in 1975. Total numbers of lingcod caught at each station are listed in Table 1.

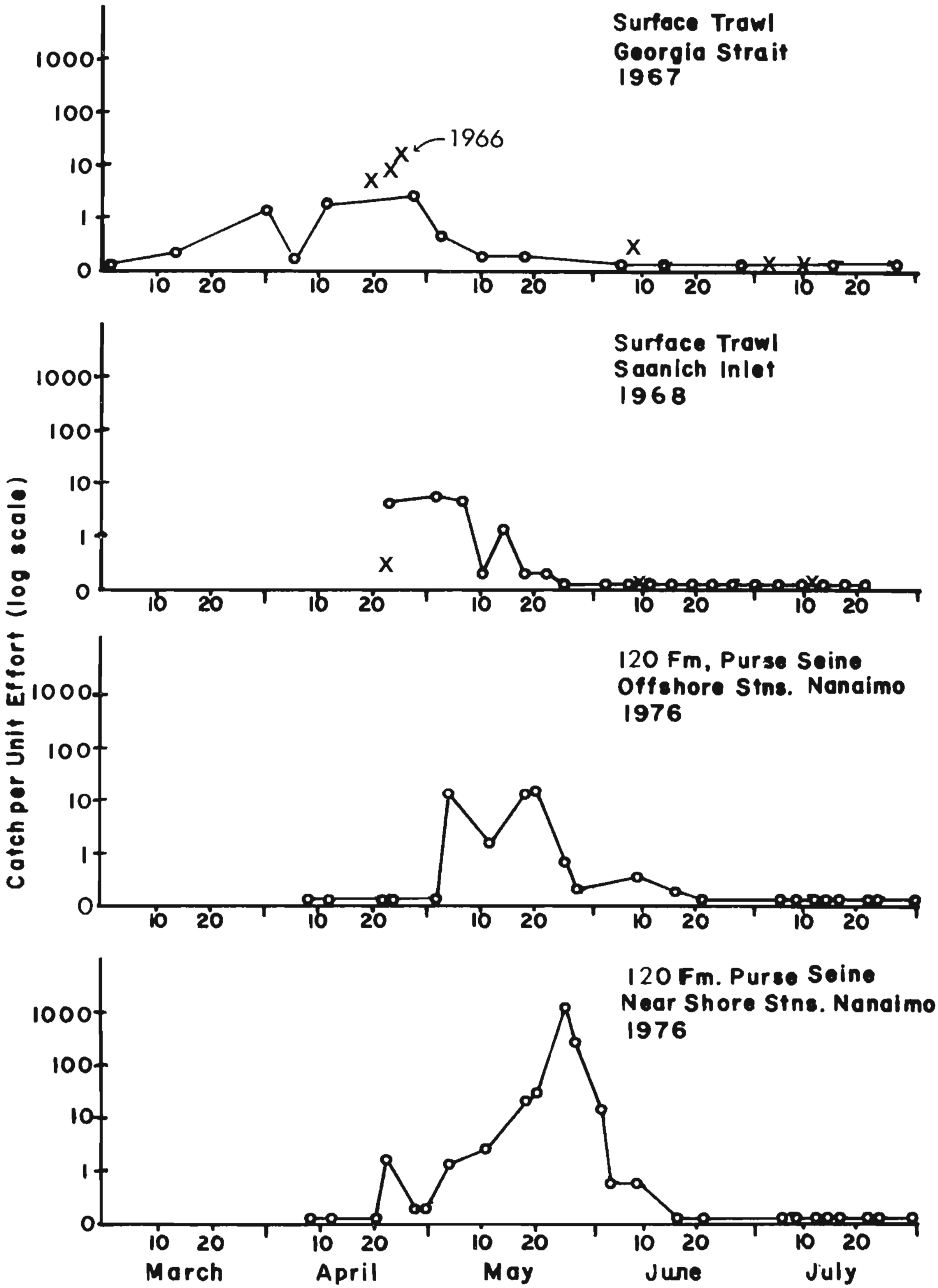

Fig. 3. Numbers of young lingcod caught during the 1976 purse seine survey in the Nanaimo area combined with earlier surface trawl data from the Strait of Georgia showing an inshore shift in abundance with development. Each circle represents one sample. Circles along the bottom axis represent zero catches.

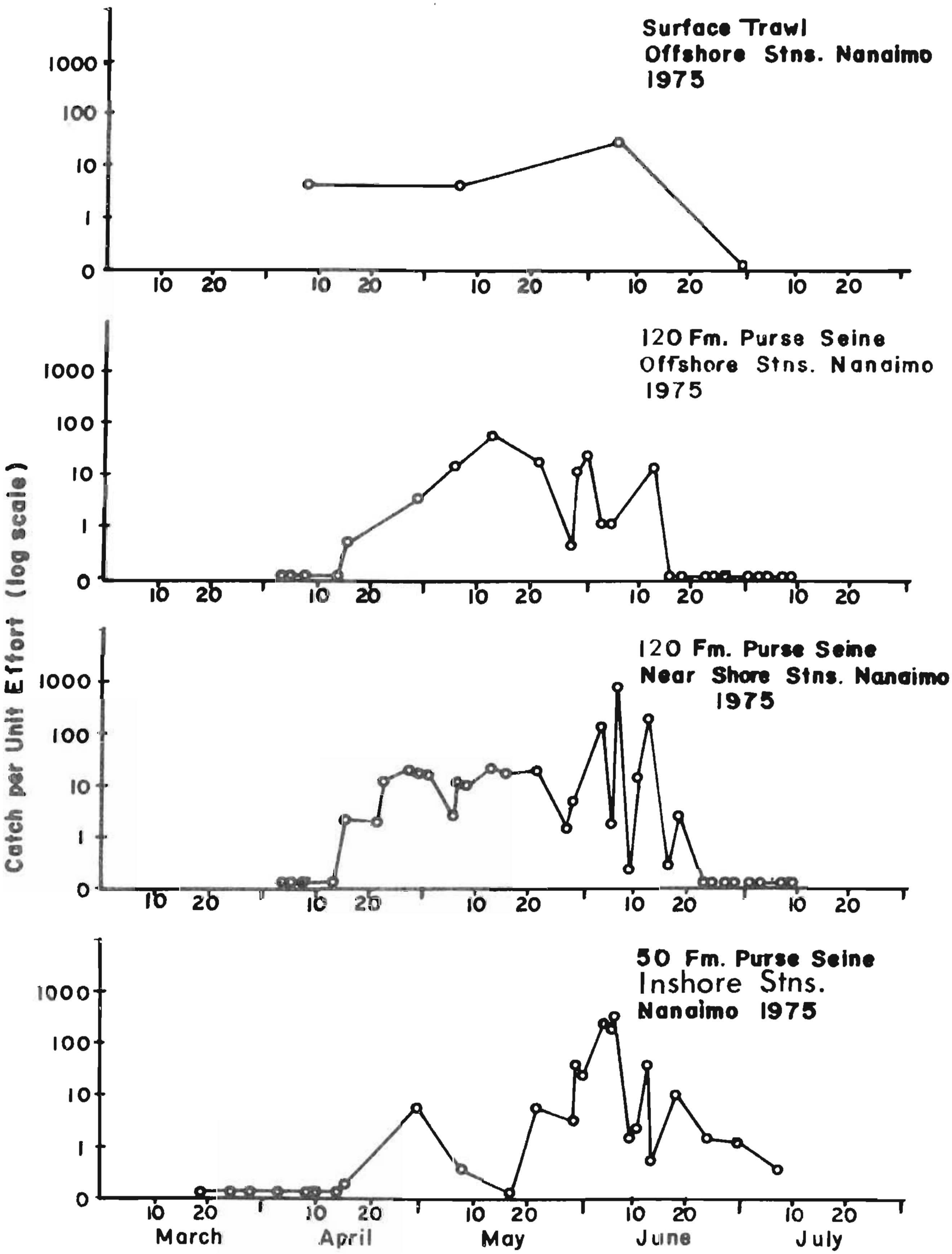

Fig. 4. Numbers of young lingcod caught during the 1975 purse seine survey in the Nanaimo area showing the progressive shift in abundance and disappearance from samples with movement inshore.

Table 1. Catch at each station over 7-day intervals for 1975 and 1976 purse seine surveys. N = nearshore station, I = inshore station, O = offshore station.

		1975												
		April			May				June					July
Station		14	21	28	5	12	19	26	2	9	16	23	30	7
1	N				50	50	31		1	982	70	41		
	I								50	1,500	10	23	3	3
2	N				10	20	100		10	500				
	I								30	1,200	175			
3	N					30	40			2				
	I													
4	N				10	5		25	1		1			
	I										9	44		
5	N				30	4		40						
	I									55	8	2		
6	N				10		8	20	4	4				
	I				1			5	3	2				
8	N							1						
	I								300	600	3	1	8	4
9	N				40	15	10		1					
	I										2			
10	N								1					
	I		1						1	9				
11	N													
	I							1		180				
13	N			13	10		100	150	26	1	1			
	I							47		51		37		
15	N		20	10	30	2				3				
	I				50							2		
7	O		2		5	15	100		10	1	2			
12	O				100									
21	O								10					
22	O								70					
23	O									20				

Table 1 (cont'd)

		1976												
		April			May				June					July
Station		14	21	28	5	12	19	26	2	9	16	23	30	7
1	N				10		110	5,000	2,000	73				
2	N				1									
5	N			10	2		7							
6	N				3		8							
10	N					20	1							
4	O			1	1	2	2	1						
7	O				50	1		1						
23	O						53							
24	O					21	21	4						
27	O					2	1	1		2				

Towards the end of May in both years, lingcod congregated in particular inshore locations. Large catches of pelagic juveniles 70-80 mm long were taken in Departure and Hammond bays in 1975 and in Departure Bay in 1976 (Table 1). Continuous inshore data were not available for 1976; however, sampling in Departure Bay during May and June showed the maximum concentration of juveniles inshore occurring approximately 1 wk later than in nearshore areas.

Within several weeks of their peak abundance inshore, lingcod were no longer present in any of the samples. In 1976, disappearance from the inshore surface waters took place over a 3-wk interval coinciding with the intensive sampling on June 4, 10, and 17. Juveniles were present at all stations sampled on June 4. On June 10, they were taken only at those stations shallow enough to permit the seine to be set on bottom. On June 17, only a few specimens were taken at the shallow stations.

In 1975, occasional individuals 90-140 mm long were taken until the end of the sampling period in July; however, these were all from stations where the net was fished on bottom in kelp or eelgrass beds. Young demersal lingcod are known to occur immediately offshore from kelp and eelgrass beds during the summer months (Clemens and Wilby 1967).

The sequence of development from first appearance as 7-mm larvae to disappearance from the surface waters as 80-mm juveniles is illustrated in Fig. 5. Approximate dates are given for each stage. The transition from larva to juvenile is a gradual one. Larval lingcod are dark above with spots of pigment over an otherwise opaque body and have distinctive blue eyes. At a length of 20 mm they are bright green above with silvery sides and eyes which are yellowish. By the time the lingocd has reached a length of 30 mm it has begun to assume adult features including the pointed, overshot lower jaw, wide gape, and general body form. Pelagic coloration is replaced, prior to commencement of bottom life, by the mottled green or brown camouflage of the adult. The 80-mm juvenile is a miniature adult in appearance with backward pointing teeth in both jaws, large pectoral fins, and a cirrus above each eye.

II. FOOD AND FEEDING

The diet of young lingcod in their early stages consisted mainly of small and medium sized calanoid copepods, their eggs, naupliar and copepodid stages. Larger food items including large copepods, decapod larvae, amphipods, euphausids and larval herring were taken as the lingcod grew. For dietary analysis, the fish examined were arbitrarily assigned to five length-classes and the change in diet with size is shown in Table 2 and Fig. 6.

As the lingcod moved inshore in preparation for demersal life, stomach samples indicated they underwent a dietary change from zooplankton to newly metamorphosed juvenile herring. This change, which was well documented in 1975 and 1976, occured when the fish reached a length of about 70 mm. The entire inshore population underwent this transition over

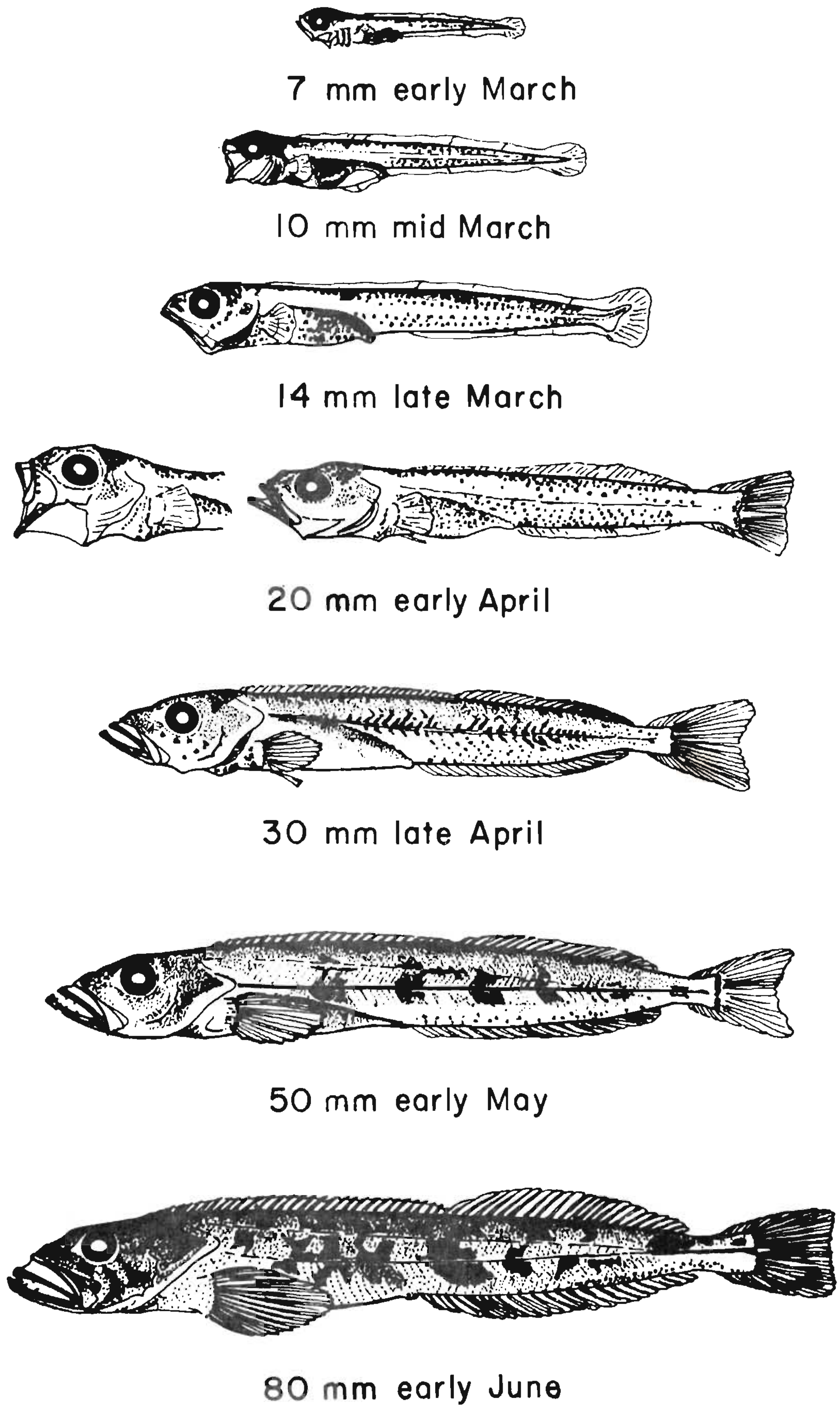

Fig. 5. Sequence of development of young lingcod from the time of their first appearance in the surface plankton in March to their disappearance from inshore surface waters in June.

Table 2. Food of young lingcod showing size, weight, frequency of occurrence, numbers and relative contribution by weight of food items ingested. s = number of samples, n = total number of fish in samples.

			Lingcod fork length groups (mm)					
			10-20 s = 51 n = 117			21-30 s = 130 n = 462		
Food items	Size range of food item (mm)	$\bar{X}$ wt. of food organism (mg)	Percent occurrence in samples	$\bar{X}$ no. per fish	Percent ingested biomass	Percent occurrence in samples	$\bar{X}$ no. per fish	Percent ingested biomass
Crustacean eggs	0.2- 0.5	0.035	87	10	18	73	20	25
Copepod nauplii	0.3- 1.0	0.10	25	3	5	3	3	<1
Fish eggs	0.5- 1.0	0.10				3	10	<1
Copepodites	0.5- 1.5	0.20	30	5	18	3	2	<1
Harpacticoids	0.5- 1.5	0.30						
Calanoids, small	0.5- 1.5	0.20	80	3	28	90	5	44
Larvaceans	1.0- 2.0	0.20	5	20	12			
Calanoids, medium	1.5- 3.5	1.0	30	1	17	83	3	25
Decapod larvae	1.5- 4.0	1.0						
Euphausiid juveniles	2.0- 4.0	1.0				3	2	3
Amphipods	3.0- 5.0	2.0				1	1	<1
Calanoids, large	3.5- 5.5	2.0				1	2	1
Herring larvae	7.0-15.0	5.0						
Herring larvae	15.0-30.0	25.0						
Juvenile herring	<30.0	100.0						
Miscellaneous						5	1	1
Nil			20			10	-	-

Table 2 (cont'd)

Food items	Size range of food item (mm)	$\bar{X}$ wt. of food organism (mg)	Lingcod fork length groups (mm): 31-50, s = 165 n = 576: Percent occurrence in samples	$\bar{X}$ no. per fish	Percent ingested biomass	51-70, s = 24 n = 115: Percent occurrence in samples	$\bar{X}$ no. per fish	Percent ingested biomass
Crustacean eggs	0.2- 0.5	0.035	51	50	9	20	20	<1
Copepod nauplii	0.3- 1.0	0.10				20	3	<1
Fish eggs	0.5- 1.0	0.10						
Copepodites	0.5- 1.5	0.20						
Harpacticoids	0.5- 1.5	0.30	3	2	<1	16	5	<1
Calanoids, small	0.5- 1.5	0.20	86	10	19	84	20	6
Larvaceans	1.0- 2.0	0.20						
Calanoids, medium	1.5- 3.5	1.0	94	5	50	80	20	30
Decapod larvae	1.5- 4.0	1.0	40	3	13	20	10	4
Euphausiid juveniles	2.0- 4.0	1.0	3	1	<1	2	<1	<1
Amphipods	3.0- 5.0	2.0	3	1	<1	2	2	<1
Calanoids, large	3.5- 5.5	2.0	12	2	5	45	10	17
Herring larvae	7.0-15.0	5.0	6	1	3			
Herring larvae	15.0-30.0	25.0				28	1	13
Juvenile herring	<30.0	100.0				16	1	30
Miscellaneous			5	1	<1	5	1	<1
Nil			10	-	-	10	-	-

Table 2 (cont'd)

Food items	Size range of food item (mm)	$\bar{X}$ wt. of food organism (mg)	Lingcod fork length groups (mm)		
			> 70 s = 23 n = 162		
			Percent occurrence in samples	$\bar{X}$ no. per fish	Percent ingested biomass
Crustacean eggs	0.2- 0.5	0.035			
Copepod nauplii	0.3- 1.0	0.10			
Fish eggs	0.5- 1.0	0.10			
Copepodites	0.5- 1.5	0.20			
Harpacticoids	0.5- 1.5	0.30			
Calanoids, small	0.5- 1.5	0.20	5	10	<1
Larvaceans	1.0- 2.0	0.20			
Calanoids, medium	1.5- 3.5	1.0	5	5	<1
Decapod larvae	1.5- 4.0	1.0	5	5	<1
Euphausiid juveniles	2.0- 4.0	1.0			
Amphipods	3.0- 5.0	2.0			
Calanoids, large	3.5- 5.5	2.0	10	5	<1
Herring larvae	7.0-15.0	5.0			
Herring larvae	15.0-30.0	25.0			
Juvenile herring	<30.0	100.0	80	1	98
Miscellaneous					
Nil			10	-	-

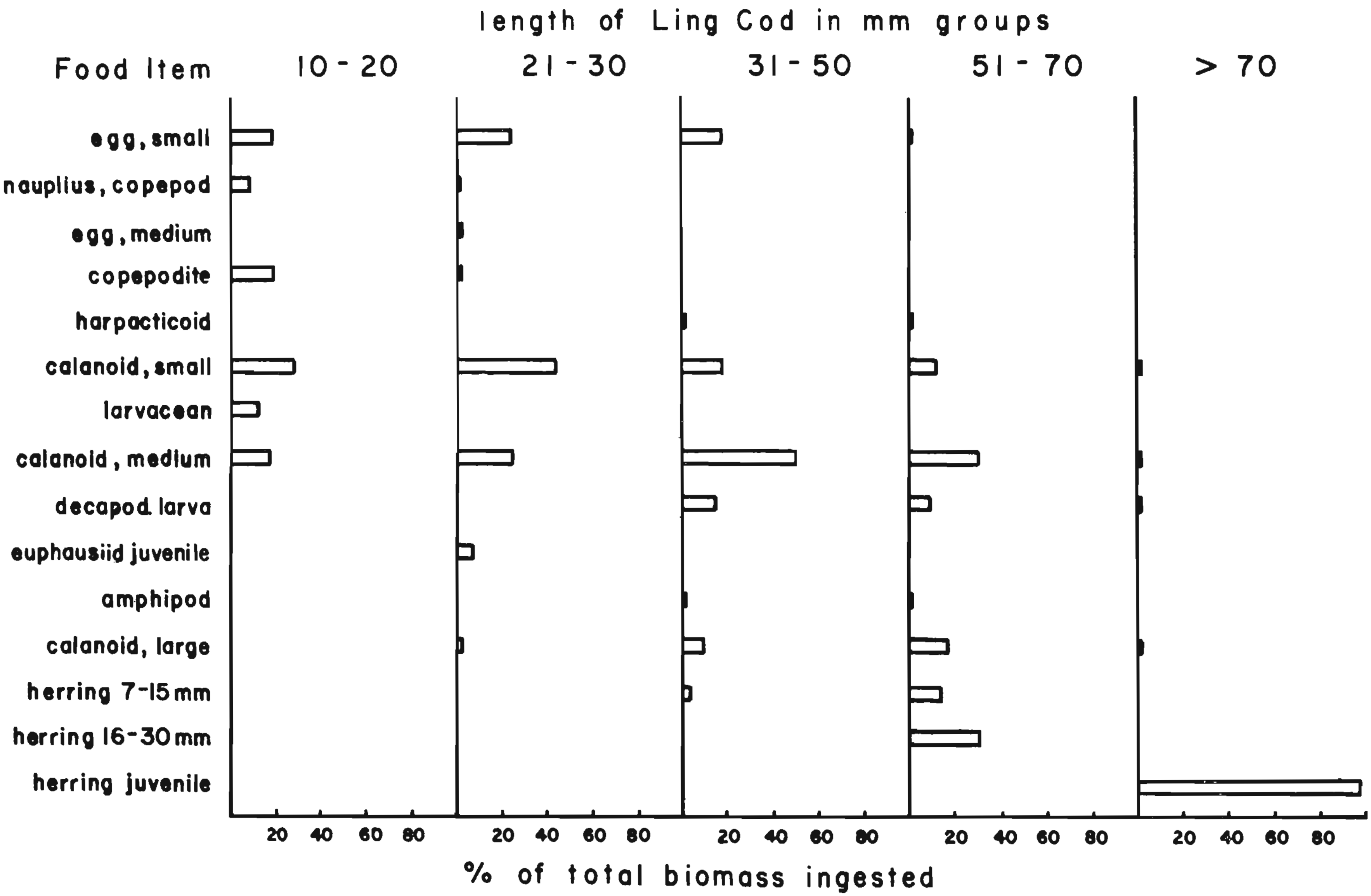

Fig. 6. Diet of young lingcod expressed as a percentage of the total food biomass ingested, showing the increasing importance of larger food items with growth and the abrupt shift from zooplankton to juvenile herring when the lingcod has reached a length of about 70 mm.

the period of 1 wk. Smaller fish were the last to switch to the totally piscivorous diet. In 1976 the change in diet occurred during the week preceding the first of the intensive sampling activities in Departure Bay on June 4. On that date, juvenile lingcod were feeding exclusively on juvenile herring although plankton samples contained large numbers of decapod larvae and the adult copepod Calanus plumchrus. The previous week, lingcod taken in the same location ate Calanus plumchrus exclusively although net catches showed large numbers of juvenile herring to be present. Interim samples showed the fish to be feeding on a mixture of food items. From June 4 onward to the end of July, young lingcod fed exclusively on juvenile herring.

III. MARK RETENTION AND FEEDING BEHAVIOUR IN THE AQUARIUM

The marking procedure using fluorescent grit applied to juvenile chum and pink salmon (Healey, Jordan, and Hungar 1976) was similarly applied to 150 lingcod. The marked fish retained their marks in an aquarium for more than 3 mo.

Some adverse effects of the spraying technique were observed. The grit, which is sprayed into the skin under pressure, caused gas bubble formation in the eyes of some fish, impairing their ability to capture food. Ultimately, such fish were eaten by larger lingcod. Bubbles occurred in 5% of the fish marked and would likely affect the survival of those fish in the wild. Some fish developed bubbles some time after marking, suggesting that gas bubbles may form as the result of an infection brought about by abrasion.

Juvenile (70 mm) lingcod adapted easily to aquarium culture and were not adversely affected by moderate changes in water temperature and handling. They readily accepted frozen herring once feeding on live herring had been established and also ate live or frozen sandlance and salmon fry.

Initially, the lingcod refused to eat freeze-dried Calanus plumchrus or freshly killed or frozen herring. Feeding in culture was triggered by the introduction of live 30-mm herring. Subsequently they accepted, as food, dead herring of the same size if the herring were dropped into the water so that they made darting movements as they sank. The young lingcod ultimately learned to feed from frozen blocks of herring, picking off individual fish as they thawed.

Growth of captive lingcod during the 1st mo was negligible due to initial feeding problems. Meanwhile, lingcod in the wild had grown from 70 mm to 110 mm in length. After 1 mo in culture, the 70 mm aquarium fish which had undergone little growth, were unable to feed efficiently on freshly caught live herring whose length in the wild had increased from 40 mm to 60 mm during that time. However, once the aquarium fish had grown to a length of about 80 mm, live herring, sandlance, and juvenile pink and chum salmon were readily accepted.

Lingcod showed no difficulty in capturing prey, which was usually caught and swallowed tail first. An 82-mm lingcod was observed to capture and, over a period of 12 hr, swallow a 74-mm (4-g) chum salmon. Digestion of that meal took 36 hr. A 1-g herring was digested in 6 hr at 12 C.

A brief feeding experiment was conducted in which groups of lingcod were fed weighed amounts of frozen herring. For every gram (wet weight) of herring eaten, the lingcod increased its live body weight by 0.5 g, suggesting a 50% net conversion efficiency.

Some of the fish kept in the aquarium did not eat and were themselves eaten by a larger lingcod, some with only a 1-cm length advantage over their prey. One wk after the commencement of cannibalism, a marked disparity appeared in the lengths of the fish, the large ones becoming rapidly larger at the expense of smaller fish which were unable to eat one another or gain a size advantage which would permit them to do so. By September 12, after 3 mo, the population was reduced from 150 to 12 large individuals 132-147 mm long. At this time the experiment was discontinued. All mortality was directly due to cannibalism or to accidental escape from the aquarium.

IV. GROWTH-RATE AND LENGTH-WEIGHT RELATIONSHIP

Length was plotted against date of capture for fish taken in 1967, 1968, 1975, and 1976 for which continuous data was available, (Fig. 7). During the period from early May to the end of June, lingcod appear to grow at a rate of 1.3 mm, or approximately 6% of their body weight, per day.

The ratio of length to weight for young lingcod (Fig. 8) is a logarithmic function defined by the equation:

$$\text{Log } Y \text{ (grams)} = 3.097 \text{ Log } X \text{ (mm)} - 5.477$$

A sample of 1,320 preserved fish from all years and gear types was used to construct the graph.

DISCUSSION AND CONCLUSIONS

I. DISTRIBUTION, ABUNDANCE, AND DEVELOPMENT

Lingcod spawn between November and March in shallow rocky areas inshore. The female attaches a large pinkish-white mass of up to 500,000 eggs to rocks subtidally. The male guards the eggs and aerates them with its large pectoral fins until they hatch sequentially from the outside of the mass in about 6 wk (Hart 1973).

Upon hatching, larval lingcod assume a planktonic life in the nearshore surface waters of the Strait of Georgia. Surface currents are likely responsible for the observed distribution of the larvae. The currents

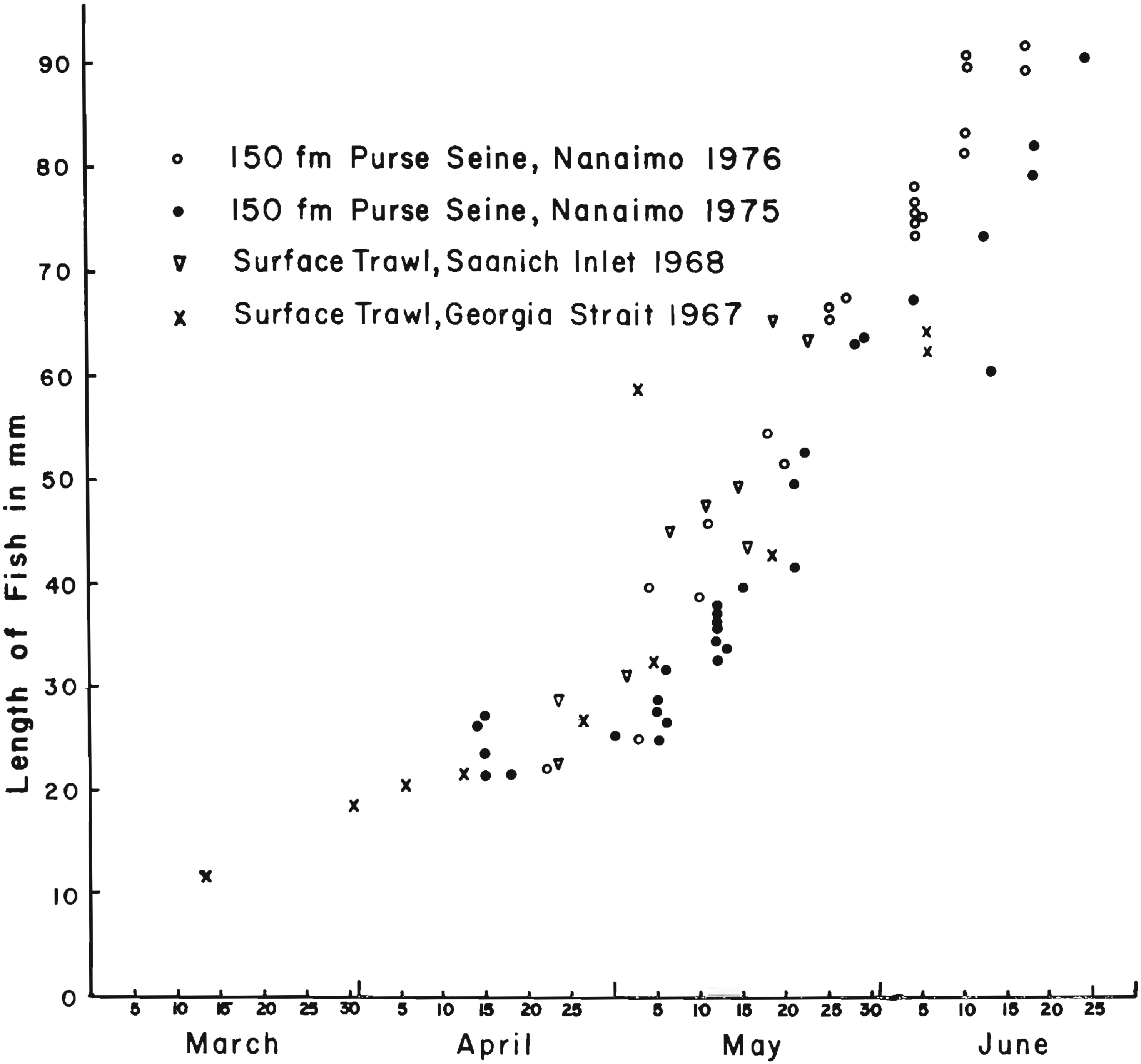

Fig. 7. Growth rate of young lingcod. Each point represents the mean length of the fish in a sample.

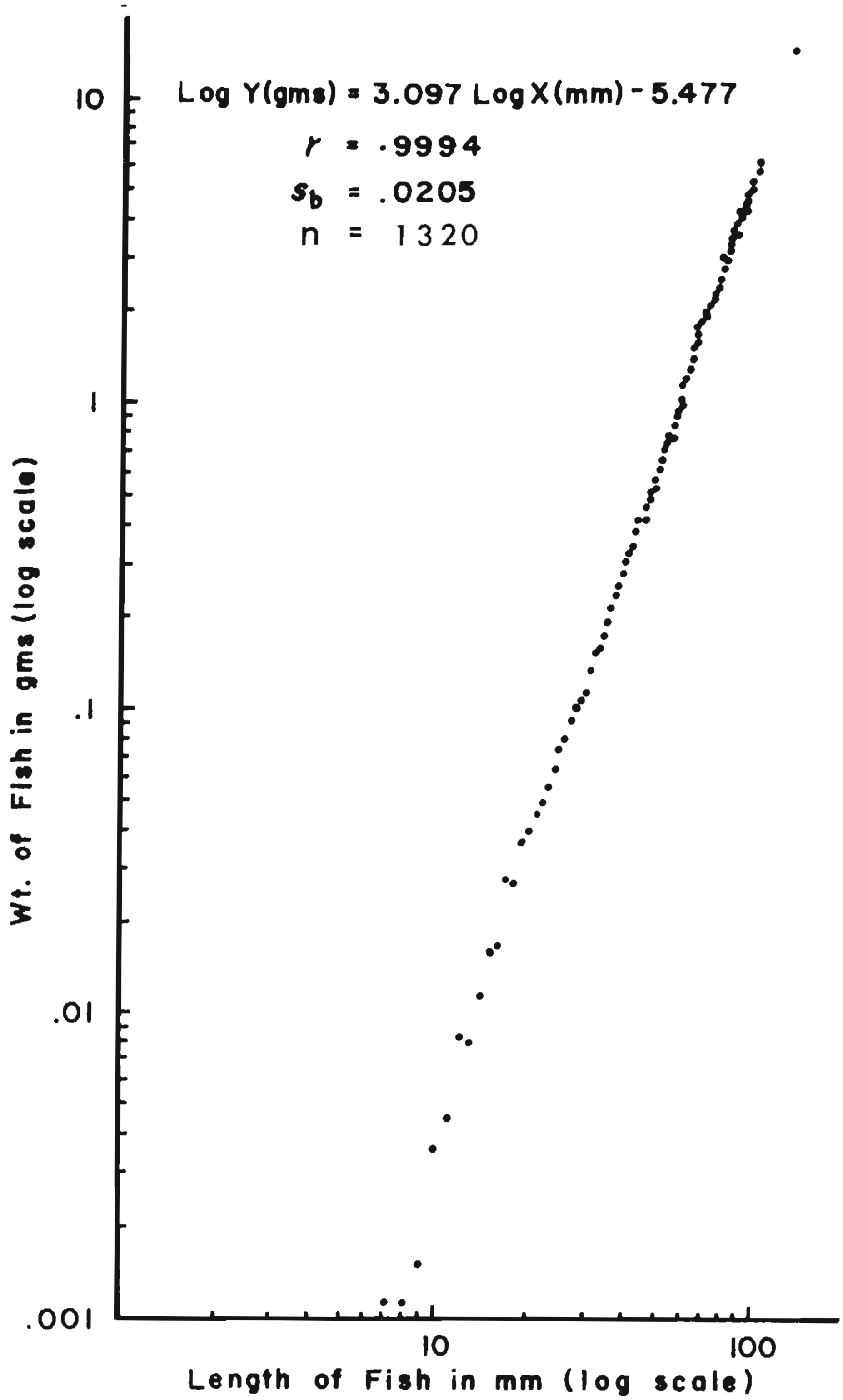

Fig. 8. Length to weight relation for young lingcod. Each point represents the mean weight, in grams, of preserved fish in each millimeter-length interval.

resulting from the interaction of wind, freshwater discharge from the Fraser River and tide are subject to a high degree of seasonal and regional variability (Waldichuk and Tabata 1955; Waldichuk 1957). Apart from a persistent movement of surface water seaward through Juan de Fuca Strait, there appears to be a general counterclockwise circulation within the Strait of Georgia. Studies of surface water movement by Waldichuk (1955; 1957) and Giovando and Tabata (1970) and surface trawl data from the Strait of Georgia (Barraclough, report in preparation) show that lingcod larvae entering the low salinity waters of the Fraser River discharge may be transported across the Strait of Georgia and concentrated on the southeastern shore of Vancouver Island and in the areas of Porlier and Active passes (Fig. 2). Alternately, depending upon different conditions of wind, river discharge, and tide, the larvae may be carried northward and along the mainland coast or into the open waters of the Strait of Georgia. As a result, the larvae become widely dispersed and may be captured at a considerable distance from the area of hatching.

Larvae begin to appear in the plankton in late February, their numbers increasing steadily until they reach their maximum abundance in the open waters of the Strait of Georgia in late April. Thereafter offshore catches diminish as the 20 mm long post-larval lingcod begin an active and progressive movement towards shore as indicated by increasing catches there. In early May they form small nearshore schools at the surface. By mid-May, at a length of 50 mm, the post-larval lingcod is totally absent from the open waters of the Strait of Georgia. They grow rapidly and increase in abundance inshore throughout May reaching maximum concentrations at particular inshore sites in late May or early June. In mid to late June, at a length of 70-80 mm they leave the surface waters and assume a demersal life.

The degree of movement and rate of dispersal in the nearshore habitat are not known for the lingcod. However, observations on aquarium held fish suggest that spray marking with ultraviolet fluorescent grit could be a useful technique for tracing their activities in the wild.

Barraclough (1966 unpublished data) using two-boat surface trawl data estimated the numbers of larval lingcod present in the open waters of the Strait of Georgia to be about 60 million, during their peak offshore abundance in late April over an area of 6,900 km^2 between Cape Mudge in the north and Point Roberts in the south. A similar calculation for the Fraser plume, an area of 267 km^2, gave an estimate of 2-3 million or a density of about 8,500/km^2 in both cases. The numbers of lingcod larvae present inshore at this time are not known; however, densities of 12,000/km^2 were recorded for the Nanaimo area in 1975 and periodic sampling indicates that the larvae are at least as abundant inshore as offshore.

Estimates of juvenile lingcod in the nearshore waters of Nanaimo were made from purse seine catch data from the latter part of May in 1975 and 1976. Densities of 13,000/km^2 in 1975 and 5,200/km^2 in 1976 were obtained which, over the 50 km sample area (Fig. 1), gave population estimates of 650,000 and 260,000 for 1975 and 1976, respectively. Those numbers did not take into account fish which had already moved inshore and should be considered as minimum estimates.

During the last week of May in 1976, large numbers of juvenile lingcod appeared inshore in Departure Bay. An estimate of 100,000-150,000 was obtained for the sample area of approximately .33 km^2 adjacent to the Pacific Biological Station. Numbers decreased logarithmically over the ensuing 2 wk when an estimated 500 fish remained in the sample area. Data for a corresponding period in early June 1975 yielded estimates of 90,000 fish for Departure Bay and 50,000 fish for Hammond Bay where they also occurred in that year.

Concentrations of fish were not found in any of the other areas sampled concurrently with the exception of inshore station 8 in 1975, although some of these locations were superficially similar. It seems probable, therefore, that the concentrations observed in Departure Bay in 1976 and in Departure and Hammond bays in 1975 represented a significant proportion of the underyearling lingcod population in the Nanaimo area for those 2 yr.

Prior to abandoning the surface waters for the demersal habitat, juvenile lingcod appear to select shallow inshore areas with an abundance of food and a suitable bottom habitat where they affect the change to bottom life. Departure and Hammond bays are apparently favourable in these respects. Both have an abundance of zooplankton, continually replenished by currents from offshore, which in turn attracts juvenile salmon and newly metamorphosed herring. The lingcod are able to make the transition from zooplankton to herring, which may be a species prerequisite to bottom dwelling, while being afforded the protection and cover of the rocky bottom and kelp beds found in these two bays.

In 1976, lingcod were found in numbers in Departure Bay only, while in 1975, with twice the estimated population, both Departure and Hammond bays were utilized. Possibly, in years of higher population, other areas might be used.

II. FOOD AND FEEDING

The diet of the young lingcod is greatly influenced by the size of its mouth. Any sized food particle that can be swallowed is apparently eaten, a trait which continues through adult life. On the basis of several hundred stomachs examined, the lingcod appears to select food items of similar size to those fish with mouths of comparable size. However, since the lingcod has such a large gape in comparison to body size (Fig. 5), a 40-mm long lingcod can eat food items of comparable size to those found in the stomachs of juvenile salmon 60 mm or more in length.

Fish held in culture were observed to eat very large prey. Apart from the cannibalism mentioned earlier, a 84-mm lingcod was easily able to capture and swallow, whole, a 72-mm sockeye salmon, although similar-sized lingcod captured in the wild were not found to be eating anything larger than 40-mm juvenile herring.

During the course of sampling during 1975 and 1976, the question arose as to whether juvenile lingcod were competing for the same food resource as juvenile salmon. Although both species appear to feed on organisms of comparable size, the two remain spacially isolated from April through May, during which time the bulk of the lingcod population is found in nearshore waters while that of the salmon remains inshore near eelgrass beds and in sheltered locations. Only in late May do the two species briefly cohabit the same environment and share the same food resource. However, within several weeks the lingcod become piscivorous and demersal, whereas the salmon move offshore.

III. GROWTH-RATE AND LENGTH-WEIGHT RELATIONSHIP

The distribution of points (Fig. 7) suggests a sine curve. The level portion of the curve at the bottom probably reflects recruitment of larvae. The flattening of the curve towards the top shows a reduction in growth rate also evident in Chatwin's (1954) data. The change in rate is probably real although it could also be a function of the limited number of fish greater than 90 mm in length sampled during this study. Variations in oceanographic conditions at the time of spawning and early development likely result in the observed variations in growth patterns from one year to another.

The growth rate of 1.3 mm per day for pelagic juveniles is slightly less than that of 1.5 mm per day derived from data by Chatwin (1954) over a similar growth period. Since Chatwin (1954) was primarily concerned with slightly older fish, and because of the varied and limited nature of his collections, the difference in growth rate might arise from sampling as well as from variance between years.

The length to weight relationship (Fig. 8) defines an allometric growth curve typical for fish. The logarithmically transformed values yield a linear function with a slope slightly less than that calculated for adult lingcod (Wendler 1953; Hart 1967). This means young lingcod weigh slightly less in relation to their length than do adults. The difference might be expected due to the morphological changes undergone by the younger fish during development.

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