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Size and condition of larval *Sebastes* spp. on Flemish Cap during spring 1980

by

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INTRODUCTION

Studies examining recruitment success in fishes have concentrated on annual estimates of population abundance and mortality. Too often these estimates have proven to be poor estimators of future recruitment. Recent theory into recruitment success has emphasized the match or larvae with their food supply on the assumption that faster growing larvae will be in better condition and hence have a greater probability of survival (Cushing 1975; Lasker 1981). Implied is that some larvae will be better positioned in space and time to capitalize on conditions favourable to growth. From samples collected on Flemish Cap during the spring of 1980, measurements were made for body weight and proportion in larval *Sebastes* sp. These data were collected to determine what differences, if any, existed in growth and condition of larval *Sebastes* sp. on Flemish Cap. Preliminary results of this study are presented here.

MATERIALS AND METHODS

From two cruises to Flemish Cap in the spring of 1980, 8-13 April and 20-26 May (Anderson MS 1981), redfish larvae were subsampled from each station for morphometric and weight measurements, selecting three redfish larvae per mm standard length size group, where numbers permitted. Five measurements were made for morphometrics. Standard length was measured to the nearest 0.1 mm, while maxillary length, head width, head height, and body height were measured to the nearest 0.01 mm. Maxillary length was measured from the tip of the snout to the posterior end of the maxilla. Head height was measured at the position of the eye, while head width was the inter-orbital distance measured immediately behind the eyes. Body height was measured at the insertion of the pelvic fin. Measurements for dry weight and ash-free dry weight (AFDW) were done to the nearest 0.01 mg using a Perkin-Elmer autobalance. Larvae were dried at 55°C for 24 hr, weighed and then ashed at 550°C for 4 hr and weighed again for ash content. Weight measurements were done independent of stomach contents.

An estimate of fish volume (mm^3) was made using the following formula:

$$\text{Fish Volume} = ((HH \times HW)\ 0.33\ (0.14\ SL)) + (BH \times HW\ (0.11\ SL)) + (BH \times HW)\ 0.33\ (0.75\ SL)),$$

where HW = head width, HH = head height, BH = body height, and SL = standard length. Condition was estimated by dividing individual measurements of body weight, body proportion and fish volume by standard length.

RESULTS

GROWTH AND CONDITION

Data from samples collected 6-13 April 1980 were limited to sizes 5-7 mm standard length (SL), most larvae having been recently extruded during the initial stages of the spawning cycle (cf. Anderson MS 1981). Samples collected 20-26 May 1980 ranged from 5-13 mm SL, with a modal value of 9 mm SL (Fig. 1). These data were collected approximately 3 weeks past the peak extrusion date. Comparison of data 5-7 mm SL collected during these two periods indicated lower values of body weight and sizes for the earlier larvae (Fig. 2). Standardized values of dry weight and fish volume, to standard length, indicated this difference was significant at 7 mm SL ($P < 0.05$) (Fig. 3). It is apparent that April spawned redfish larvae were growing at a slower rate and had a poorer condition than those sampled during late May.

Growth of redfish larvae sampled during May 1980 was first evident in body weight between 6 and 7 mm SL. From 8 to 13 mm SL increases in dry weight were linear (Fig. 2a). Fish volume increased exponentially from 5 through 13 mm SL, with the largest increases occurring after 11 mm SL, coincident with the onset of flexion (Fig. 2b). Measurements of condition, based on dry weight, again indicated the first increase occurred between 6 and 7 mm SL, increasing linearly from 9 to 13 mm SL (Fig. 3a). Condition based on fish volume increased linearly until 11 mm SL, after which values increased at a greater rate (Fig. 3b).

Simple correlations between variables of body weight and size indicated the best relationships occurred between dry weight, ash-free dry weight, fish volume and maxillary length, all values being $>r = 0.90$ (Table 1). The poorest correlations were consistently with standard length, r-values ranging from 0.41 to 0.72. Overall fish volume gave the highest correlations, while the best linear measurements of fish proportion were maxillary length and head width. Standardized values of dry weight and fish volume were highly correlated indicating an increasing degree of condition with body size. Plots of head width, head height, body height and maxillary length against standard length indicated increases in fish volume with standard length was due more to head width, as indicated here by the simple correlations. As these fish increased in length their heads became increasingly wider while body depth proportionally narrowed.

SIZE DISTRIBUTION ON FLEMISH CAP

Distribution of larval size and condition variables in Flemish Cap from samples collected during May 1980 was heterogenous but showed the same overall distributions. In general, values were lower in a broad band across the northwest corner with the highest values being observed to the south and over the central waters of Flemish Cap. High values of standard length were most extensive in a large area over the central area, lowest values being observed in the extreme northwest (Fig. 4). For dry weight and fish volume the most extensive area of high values was in the southwest quadrant of the sampling grid (Fig. 5 and 6). Higher values were also scattered throughout central Flemish Cap and at two stations in the southeast corner. In both cases low values extended in a broad band across the northeast corner of the sampling grid. Standardized values of dry weight and fish volume showed similar distributions (Fig. 7 and 8).

Values from 6-13 April 1980 have not been presented here due to a lack of data from many stations sampled on the Flemish Cap grid and the small range of sizes and poor growth and condition in these larvae.

RELATION TO PHYSICAL VARIABLES

Correlations of temperature and salinity with variables of fish size and condition indicated temperature were highly correlated. For all but standard length highest correlations occurred with temperature at 20 m. Values at 20 m ranged from $r = 0.61$-0.80 (Table 2), while overall correlations were highest at depths ≤ 30 m. Overall, the lowest correlations with temperature were with standard length. Simple correlations with temperatures averaged to 20, 30 and 50 m indicated highest values for temperatures averaged in the upper 30 m, the highest correlation being $r = 0.82$ with fish volume.

Average temperatures in the upper 30 m ranged from 3.5-6.5°C. The distribution of these values on Flemish Cap closely resembled that of larval fish size and condition (Fig. 9). Lowest temperatures were observed in the northwest corner while highest temperatures were distributed to the south and over central Flemish Cap. In all cases regressions of fish variables with mean water temperature in the upper 30 m were highly significant, with R^2-values ranging from 0.50-0.66. The highest explained variation was for fish volume, where

$$\text{Fish Volume} = 1.80\ t - 2.17,\ R^2 = 0.66$$

where T = average water temperature in the upper 30 m from the Flemish Cap grid (Fig. 9).

Simple correlations indicated fish size was negatively correlated with salinity immediately below the mixed layer depth on Flemish Cap. Salinity was significantly correlated with values of body weight and fish volume at 50 m depth, and body weight at 75 m depth, r-values ranging from -0.40 to -0.48 (Table 1). Although not significant, most values in surface waters had positive signs indicating substantially different distributions of salinity in surface and subsurface waters.

As larval size and condition was most highly correlated at 50 m depth it infers waters at these depths are important with respect to larval growth and survival. It may also mean larvae are vertically distributed down to these depths. The non-significance and low correlations of standard length with salinity again indicate this variable is a poor indicator of size distribution in relation to physical data.

Multiple regressions of temperature and salinity versus fish size variables only marginally improved the amount of explained variation. Again the best relationship was with fish volume:

$$\text{Fish Volume} = 7.8\,T - 1.9S + 1.8, \quad R^2 = 0.69$$

where T = average water temperature in the upper 30 m and s = salinity at 50 m depth.

DISCUSSION

Central to most larval fish studies examining survival and recruitment success is the concept that timing of spawning is critical, both with respect to physical conditions and available food sources. The data examined here demonstrated larval Sebastes sp. spawned during 6-13 April 1980 were too early and did not survive. By 7 mm standard length (SL) these larvae experienced little or no growth and no increase in condition. These larvae occurred approximately 2.5 to 3 weeks prior to the estimated date of peak spawning (Anderson MS 1981). Water temperatures in the upper 30 m were low, mostly 2.5-3.5°C compared to 3.5-6.5°C observed in May 1980, and the spring phytoplankton bloom had not begun (Anderson, unpubl. data). It also appears none of these larvae survived. The largest larvae sampled during May were 12-13 mm SL; using a pre-extrusion length of 6.5 mm and growth rate of 0.15 mm d^{-1} (cf. Anderson MS 1981) means these larvae were spawned about 13 April 1981. It appears larvae spawned prior to this date were too early to survive. The greater size and higher condition values of May larvae at 7 mm SL supports this conclusion.

In larval fish studies growth is most often measured by increases in standard length. More recently otolith analysis has been used to estimate daily growth rates in larval fish, often expressed by increases in standard length. Results here indicate standard length was not the best indicator of larval fish growth. Compared to body weight, larval Sebastes sp. increased mostly as a function of girth, not length. Simple correlations of head width, head depth, body depth, maxillary length and standard length to dry weight and ash-free dry weight indicated standard length was the lowest ($r = 0.55$) while all other correlations were >0.82. In plots of these values it appeared that allometric growth in Sebastes sp. larvae was mostly due to an increase in head size, of which the most important variable was head width. Standard length therefore is not the best representative of growth in Sebastes sp. larvae.

The best single variable correlated with body weight was maxillary length. It appears growth in these larvae is weighted towards increases in head size and therefore their ability to feed. As gape, or mouth size, increases not only can they feed on larger particles but growth of gill rakers allows them to continue to feed on small particles as well (Bainbridge and McKay 1977). It appears that the growth strategy, at least through these sizes, is biased towards an ability to feed, versus an ability to swim.

Reason for the poor correlation of standard length with body weight may be due to flexion in Sebastes spp. larvae. As the hypural plates develop the notochord flexes upwards, which is quite marked in redfish larvae (Moser et al. 1977). At this point in their development measurements of standard length as indicators of size are baised towards lower growth as indicated by length increases. Flexion in these larvae did not begin until 11-12 mm SL. The effects of this can be seen in increases of dry weight, fish volume and condition factors which increases notably at 12 and 13 mm SL (Fig. 2 and 3). This bias will mostly affect data at these two standard lengths. Whether this explains the overall poor relationship of standard length in the data set is not known. In any event, standard length was a poor indicator of growth.

Important to note is increasing values of condition versus standard length. Standardized dry weight for May 1980 samples did not begin until 7 mm SL, whereas standardized fish volume increased from 5 mm SL onwards. This increase in condition, compared to standard length, indicates 'bigger-is-better'.

The pattern in distribution of these measurements of growth and condition indicated highest values occured at single stations and over 2-3 adjacent stations, at sampling distances of 20 nm. Spatially this indicates the biggest larvae with the highest condition are distributed at scales <400 nm^2 (741 km^2) to approximately 1600 nm^2 (2964 km^2) on Flemish Cap. Highest values of standard length was distributed over central Flemish Cap in a large area approximately 2400 nm^2 (4447 km^2).

The larger larvae are assumed to be older. It is not known, however, if their growth rate was significantly greater. The fact that the scales of distribution are not large and they are heterogenously distributed indicates important features in growth and condition for those larvae are mostly going on at scales smaller than the sampling distribution. The main features of this distribution, however, are evident at 200 nm station spacing.

Significant in the distribution of growth and condition factors of Sebastes spp. larvae on Flemish Cap was its non-correlation with fish abundance ($P < 0.01$). Abundant larvae were observed in a broad area over eastern Flemish Cap during May 20-26 1980 (Anderson MS 1981). There was only one station where larval abundance and condition were high while the rest were variable. Only in the NW area were low abundances and low size conditions observed. Apparently local abundance has no effect on growth and condition in Sebastes spp. larvae.

The direct relationship of temperature with larval size and condition indicates the importance of the physical regime in determining growth, and hence survival, of Sebastes spp. larvae. Average temperatures in the surface waters explained >60% of the variation in larval size and condition. Similar to the distributions of fish variables, highest water temperatures in the upper 30 mm (76°C) were distributed on scales <400 nm^2 (741 km^2) to ~1000 nm^2 (1853 km^2) (Fig. 9). Thus, the important physical scales appear to be localized to areas <400-1000 nm^2 and confined to surface waters. Important questions to be answered are: how stable are these localized, discrete water masses; and, how long are local populations of larvae associated with these water masses of higher temperatures? The significant negative correlations of salinity at 50 m depth is not readily explainable and must wait a better understanding of the physical oceanography and depth distribution of Sebastes spp larvae.

The occurrence of large larvae in good condition in the extreme SE corner of the grid coincides with area arc where surface water is known to move off Flemish Cap. Of six drogued satellite-tracked surface buoys deployed on FLemish Cap during 1979 and 1980 all eventually left the Cap in this region (Ross MS 1980). Apparently these 'good' larvae were lost from the system. On the other hand, good larvae in a large area in the SW corner occurred in the region of a belived counter current of water moving northwards at this part of Flemish Cap. Are these larvae being carried onto the Cap! Obviously the movement of these surface water masses and possible transport of larvae associated with them remain as important questions to answer with respect to larval survival.

SUMMARY

Data collected on Flemish Cap during April and May 1980 indicated large larvae were in better condition and that much of their distribution can be explained by higher water temperatures in the upper 30 m. Larval Sebastes spp. spawned 6-13 April 1980 experienved little growth and did not survive. The lack of correlation of fish abundance with growth and condition suggests that abundance is not an important variable relating to survival. It appears that it is the association of larvae with discrete water masses on the scale of 740-1850 km^2 which promotes higher growth, better condition and ultimately survival in Sebastes spp. larvae on Flemish Cap.

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Table 1. Spearman correlation coefficients of fish size variables for Sebastes spp larvae collected 20-26 May 1980 (n = 40). Each observation is the mean value observed per station (SL = standard length; DW = dry weight; AFDW = ash-free dry weight; Fish Vol = fish volume; HW = head width; MAXL = maxillary length; HH = head width; BH = body height; RDW = dry weight/SL; RFVOL = fish volume/SL).

	SL	DW	AFDW	FISHVOL	HW	MAXL	HH	BH	RDW	RFVOL	ABUUD
SL	-	0.55	0.55	0.72	0.69	0.53	0.57	0.53	0.41	0.59	0.51
DW		-	0.97	0.91	0.85	0.90	0.90	0.85	0.82	0.90	0.09
AFDW			-	0.91	0.86	0.91	0.87	0.85	0.95	0.97	0.05
Fish Vol				-	0.92	0.91	0.97	0.88	0.84	0.83	0.25
HW					-	0.79	0.86	0.86	0.81	0.92	
MAXL						-	0.89	0.82	0.86	0.90	
HH							-	0.87	0.81	0.95	
BH								-	0.82	0.95	
RDW									-	0.87	-0.01
RFVOL										-	0.11
ABUUD											-

Table 2. Spearman correlation coefficients of fish size variables for Sebastes spp. larvae collected 20-26 May 1980. Each observation is the mean value observed per station. (SL = standard length; DW = dry weight; AFDW = ash-free dry weight, FISHVOL = fish volume; HW = head width; RDW = dry weight/SL; RFVOL = fish volume/SL; MTEMP20, MTMEMP30 and MTEMP50 = temperatures averaged to 20, 30 and 50m for each station, respectively.)

	MSL	MDW	MAFDW	MFISHVOL	MHW	MRDW	MRAFDW	MRFVOL
Temp 1 m	.64	.67	.66	.77	.74	.63	.61	.76
10 m	.61	.70	.68	.79	.75	.65	.63	.77
20 m	.61	.72	.73	.80	.72	.67	.67	.77
30 m	.52	.66	.69	.73	.65	.58	.61	.68
50 m	.49	.56	.57	.62	.53	.50	.49	.56
75 m	.44	.42	.44	.50	.37	.38	.40	.46
100 m	.49	.57	.62	.69	.52	.52	.56	.66
150 m	.08	.51	.55	.45	.33	.53	.57	.49
MTEMP 20	.63	.71	.70	.79	-	.66	.65	.77
MTEMP 30	.64	.72	.73	.82	-	.66	.66	.79
MTEMP 50	.61	.71	.71	.80	-	.65	.64	.75

Table 3. Spearman correlation coefficients for salinity at 50 m depth versus fish size variables (n = 40).

Salinity	MSL	MDW	MAFDW	MFISHVOL	MRDW	MRAFDW	MRFVOL
1 m	0.16	-0.02	-0.03	0.11	-0.02	-0.03	0.11
10 m	0.28	0.03	0.04	0.22	0.03	0.01	0.21
20 m	0.29	0.02	0.01	0.19	0.00	-0.02	0.16
30 m	0.16	-0.14	-0.16	0.00	-0.13	-0.19	0.00
50 m	-0.24	-0.48*	-0.47*	-0.40*	-0.41*	-0.40*	-0.32
75 m	-0.24	-0.40*	-0.40*	-0.34	-0.31	-0.33	-0.24
100 m	-0.18	-0.31	-0.27	-0.21	-0.22	-0.19	-0.10
150 m	-0.23	-0.09	-0.06	-0.12	0.03	0.05	-0.04

* significant at $p < 0.01$

FLEMISH CAP

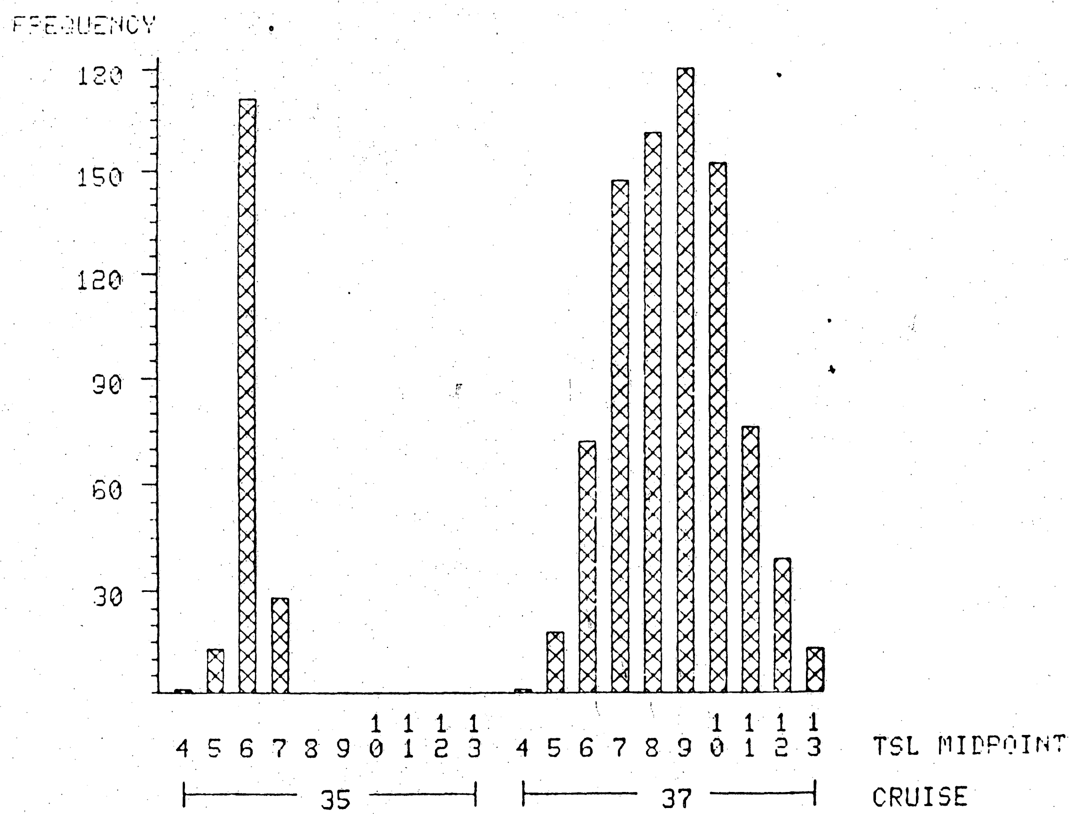

Figure 1. Size distribution (mm SL) of larval Sebastes spp. subsampled for measurements of weight and morphometrics from two cruises in 1980.

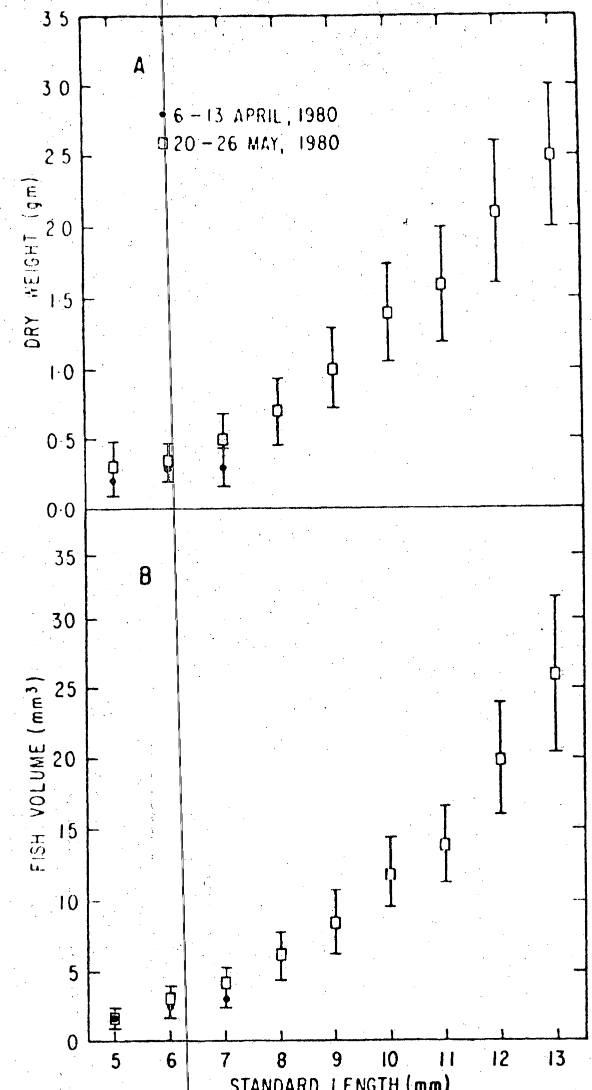

Figure 2. Mean values dry weight (mg) and fish volume (mm^3) versus standard length (mm) for Sebastes spp larvae from Flemish Cap, 1980. Vertical bars represent ± 1 standard deviation.

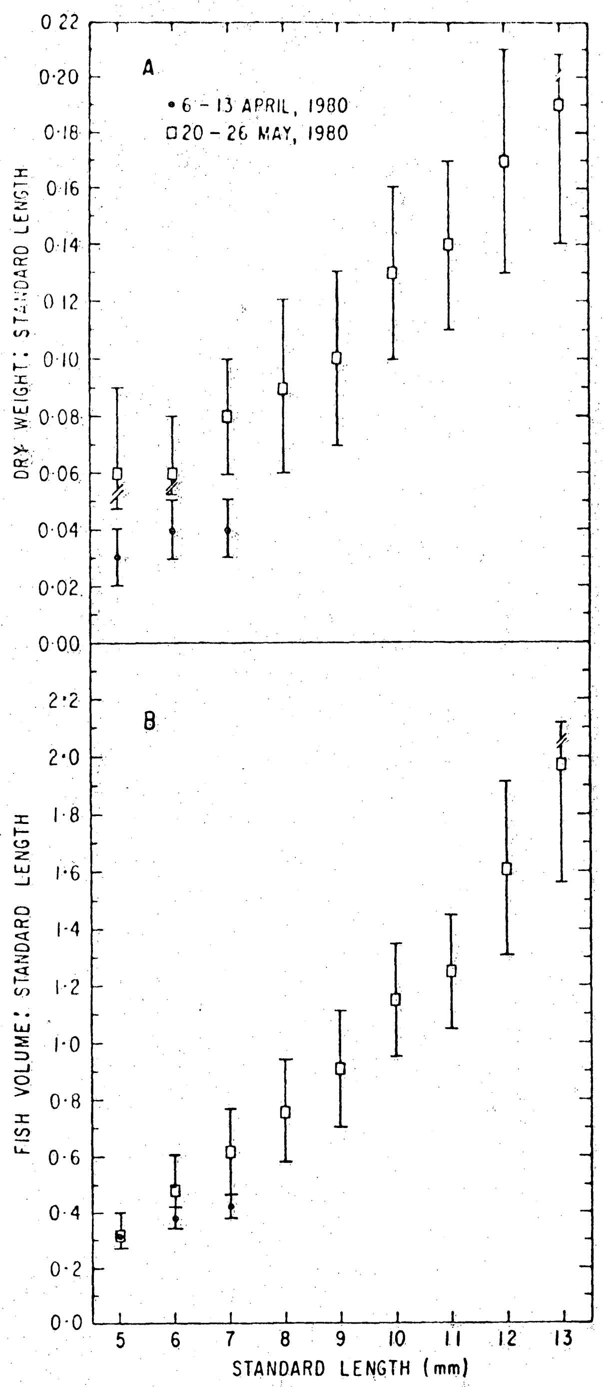

Figure 3. Mean values of standardized dry weight (mg) and fish volume (mm^3) to standard length (mm) for each millimeter size group of *Sebastes* spp. larvae from Flemish Cap, 1980. Vertical bars represent ± 1 standard deviation.

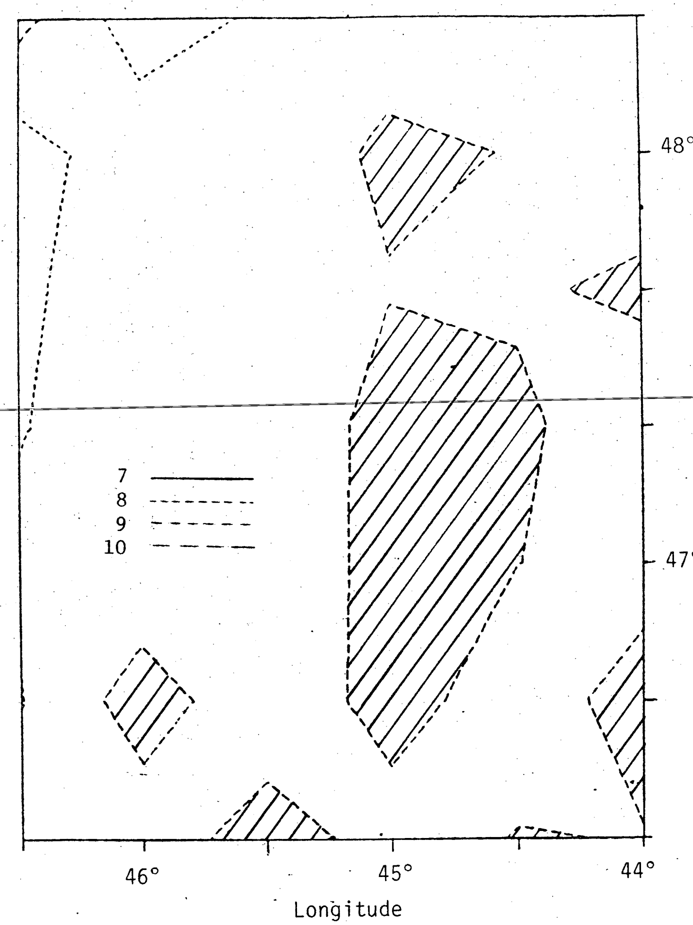

Figure 4. Size distribution (mm SL) of <u>Sebastes</u> spp. larvae on Flemish Cap, 20-26 May 1980.

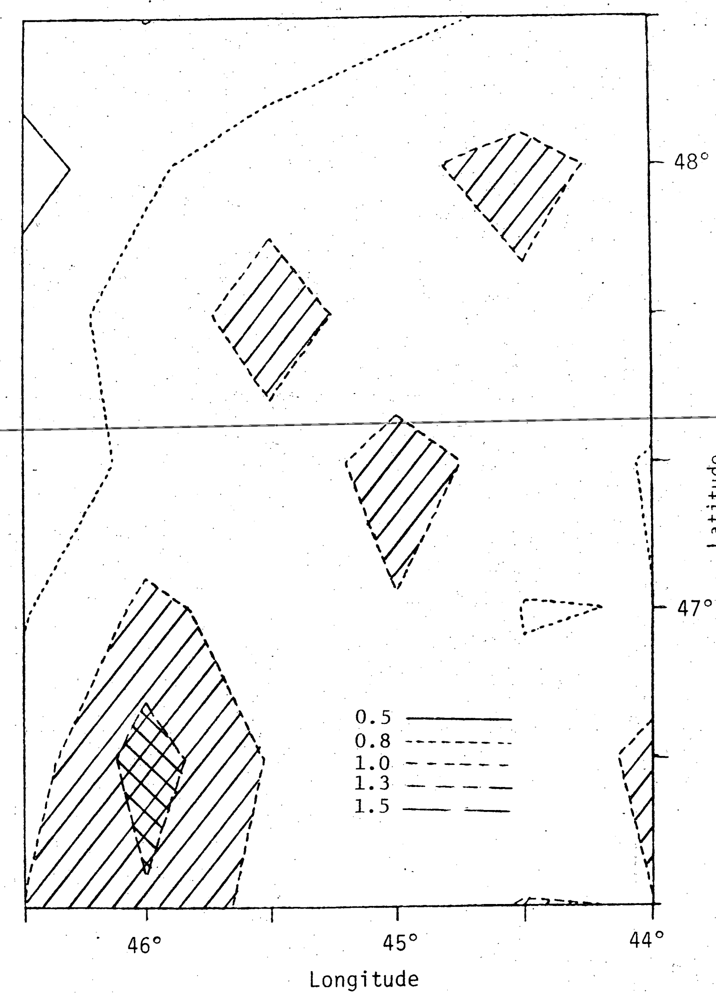

Figure 5. Dry weight distribution (mg) of <u>Sebastes</u> spp. larvae on Flemish Cap, 20-26 May 1980.

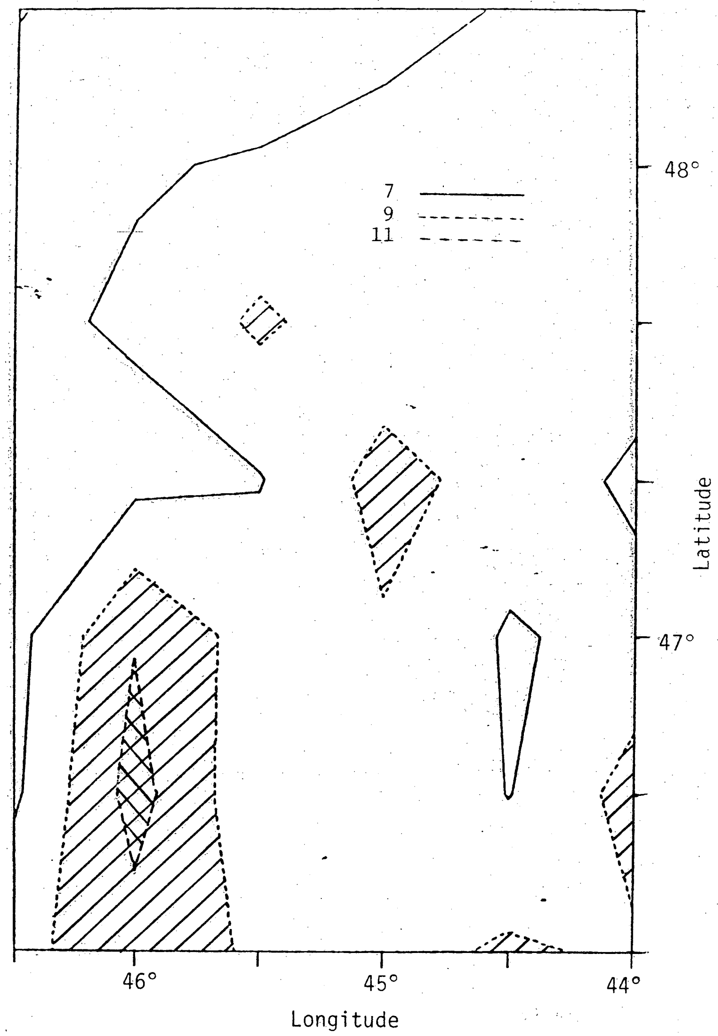

Figure 6. Fish volume distribution (mm^3) of Sebastes spp. larvae on Flemish Cap, 20-26 May 1980.

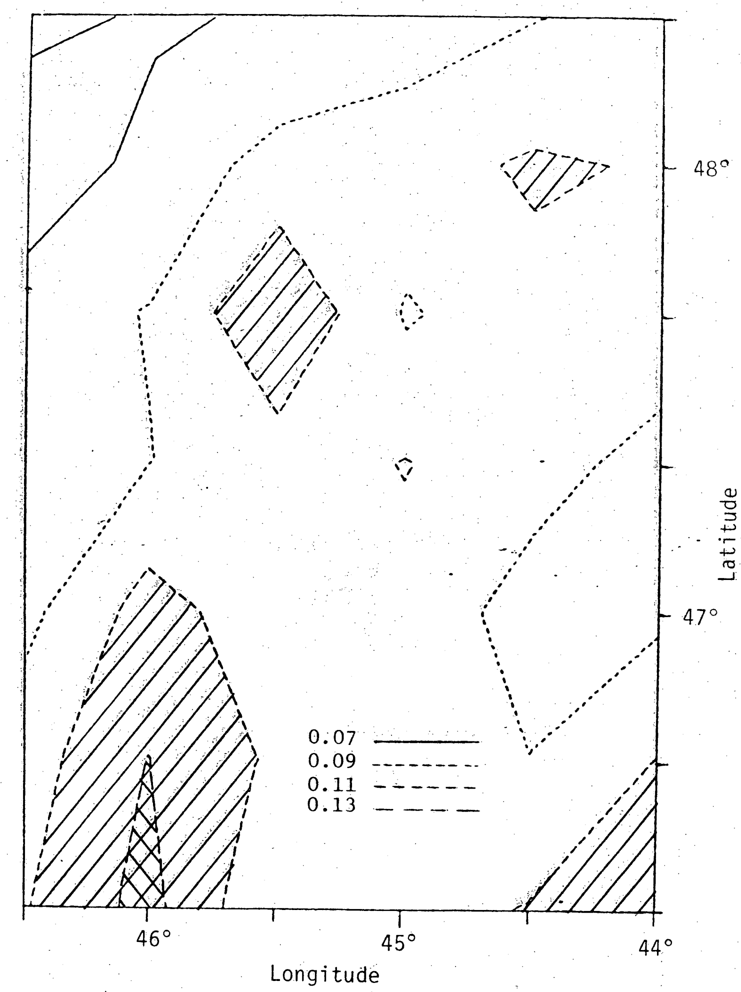

Figure 7. Standardized dry weight, per unit standard length, of Sebastes spp. larvae on Flemish Cap, 20-26 May 1980.

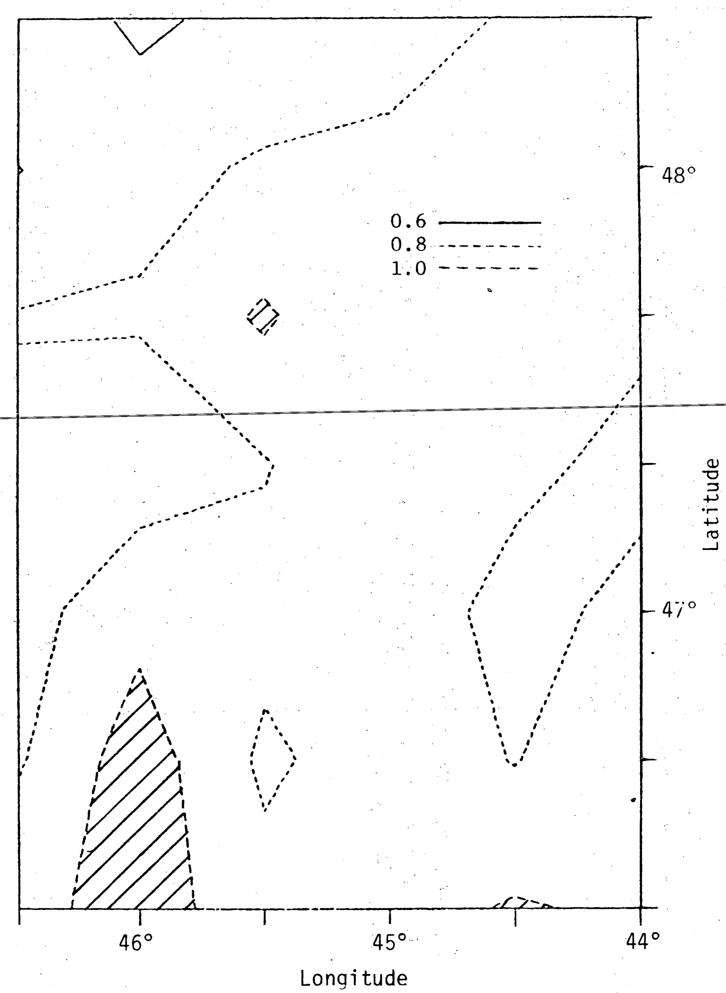

Figure 8. Standardized fish volume, per unit standard length, of Sebastes spp. larvae on Flemish Cap, 20-26 May 1980.

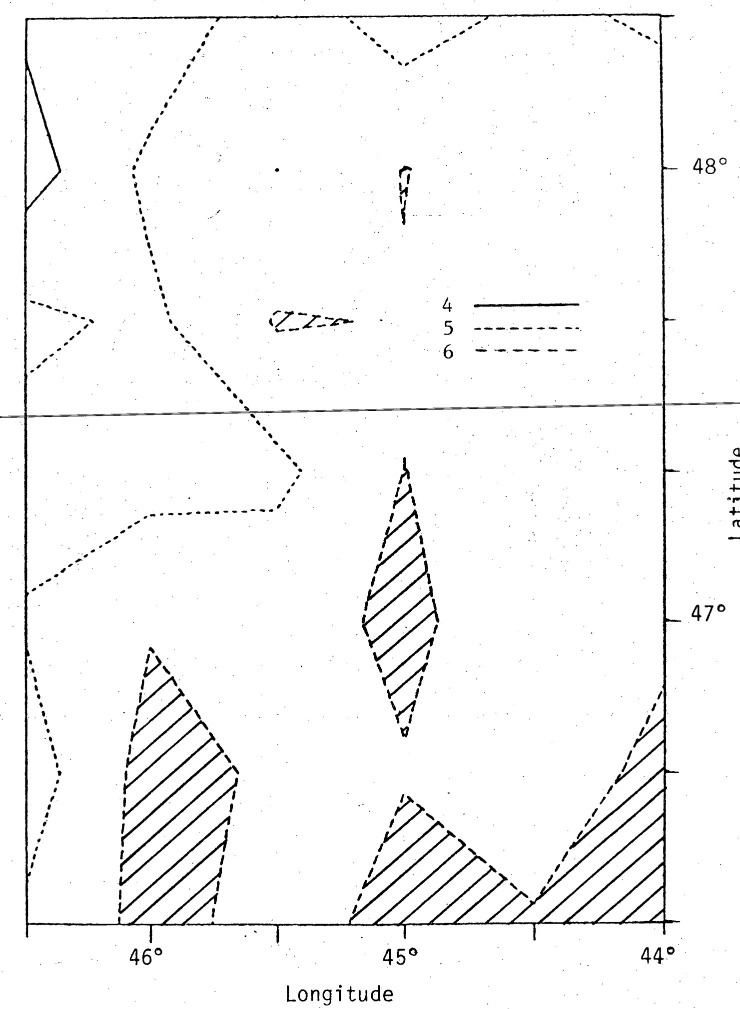

Figure 9. Mean water temperature (°C) in the upper 30m on Flemish Cap, 20-26 May 1980.

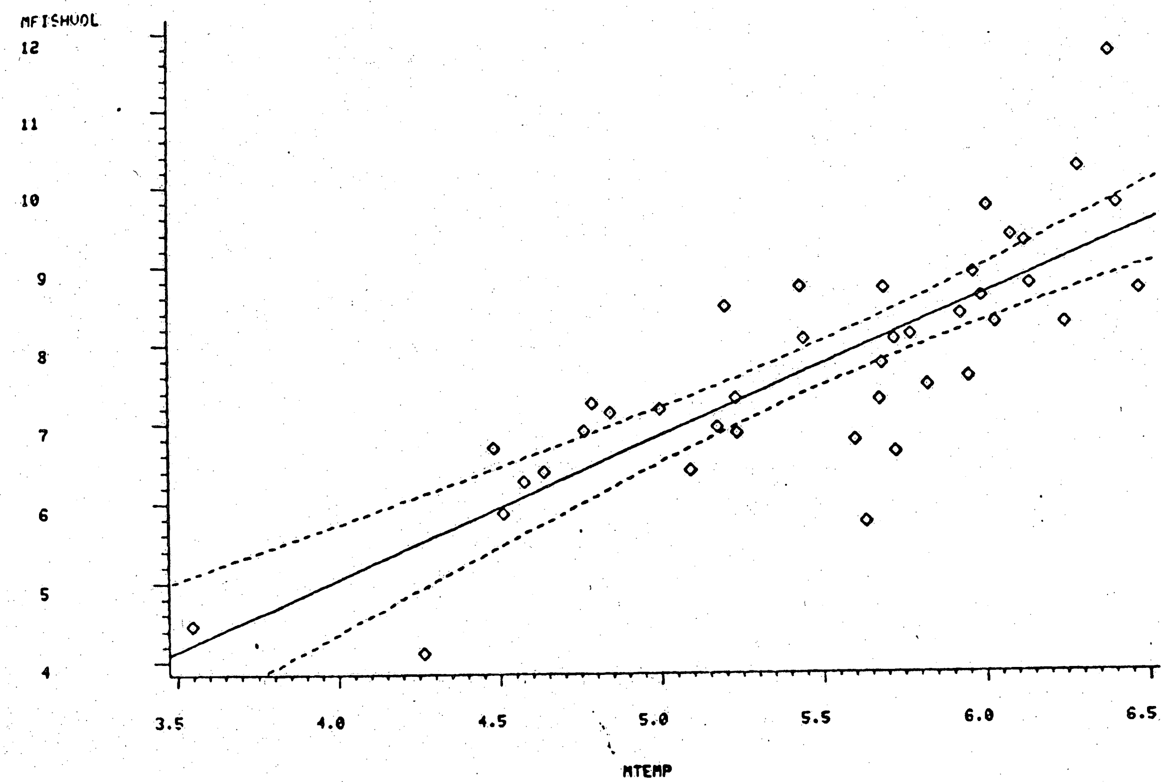

Figure 10. Mean fish volume versus mean water temperature in the upper 30 m on Flemish Cap, 20-26 May 1980 (Fish Volume = 1.80 Temp. -2.17, R^2 = 0.66, n = 40.