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Growth of Cod *(Gadus morhua)*

A Laboratory Study

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Growth rates of adult cod (600 to 4000 g) were followed over a period of one annual cycle with measurements being made at 2-month intervals. Cod were obtained by otter trawl from Passamaquoddy Bay and were held for at least 1 month prior to use. Twenty-five fish were randomly assigned to each experimental tank. Temperature and ration were varied in accordance with the following scheme:

	Tank #	Ration
	2, 12	Satiation
8°C (replicated)	5, 10	1.2% of wet body weight
	8, 9	0.7% of wet body weight
	6	Satiation
4°C (no replicates)	3	0.5% of wet body weight
	7	0.8% of wet body weight

Fish were tagged to permit individual recognition. Feeding was done 3 times daily and observations were made to insure that all presented food was eaten. The food formulation and chemical analyses are presented in Table 1. A natural photoperiod was used throughout the experimental period. Sampling periods were:

Month	Growth Period
June-July	1
Aug.-Sept.	2
Oct.-Nov.	3
Dec.-Jan.	4
Feb.-March	5

Table 1. Composition of cod food used in growth experiment

Component	%
Herring meal	16.4
Shrimp meal	10.9
Herring oil	8.7
Wheat middlings	13.7
Flounder fillets	27.3
Vitamin premix	1.0
Water	21.8
Total	100
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Protein	47.8
Lipid	20.5
Ash	14.0
Carbohydrate	17.7
Total	100

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Energy = 5325 cal/g

Data collected:

(a)	daily	temperature, ration, mortalities
(b)	monthly	oxygen, salinity, food moisture and composition
(c)	2 months	individual weights and lengths for all fish
(d)	May, November, January, March	(1) sex, maturity, and wet organ weights, plus % moisture of liver, gonad, muscle and carcass for all sampled fish (5 per tank)
		(2) lipid, protein and ash for liver, gonad, muscle and carcass for selected sampled fish
		(3 fecundity (to be determined) for selected fish

Appetite

Appetite of cod fed to satiation is presented in Fig. 1. Food intake varied seasonally despite constancy of temperature. Maximum food intake was observed during August-September, and fell off [illegible] thereafter. Feeding intensity of fish held at 4°C was about 12% lower than 8°C fish. Food intake of fish fed restricted rations was fairly uniform with minor variation following handling at weighing periods. However, feeding declined during February-March at all feeding regimes.

Ration-dependent growth

Growth rate of cod increased with increasing ration but eventually plateaued (Fig. 2). For a given ration level, growth rate was lower at 4°C that at 8°C. Maintenance ration levels were 0.27 and 0.22% body weight at 8°C and 4°C, respectively. Inter- and intra-tank variability was high, especially in tanks fed restricted rations. Alterations in experimental design will be required before a meaningful ration-dependent growth relationship can be made.

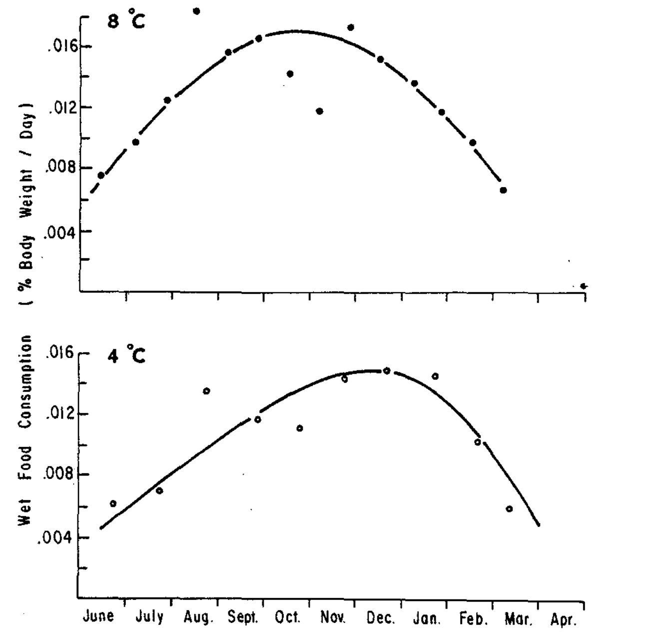

Fig. 1   Appetite of experimental cod fed to satiation at various times of the year.

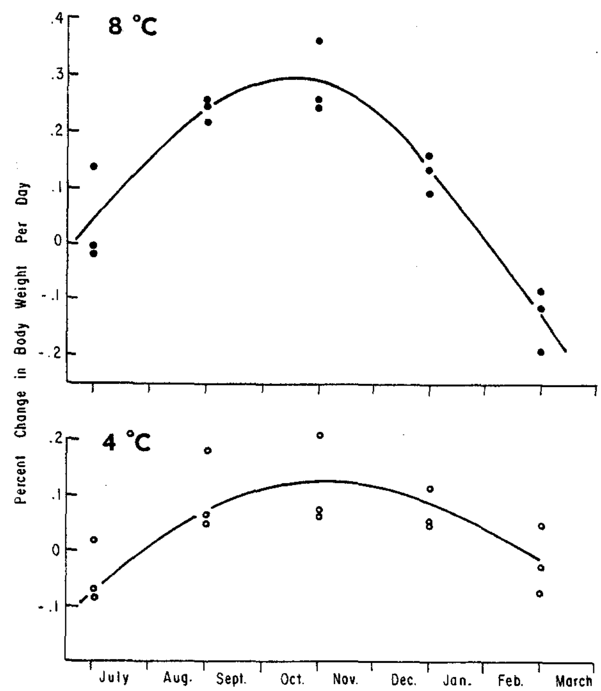

Fig. 3   Growth rate $\left(\frac{\text{Final wt - initial weight}}{\text{initial weight}} \times 100\right)$

of experimental cod as a function of time of year.

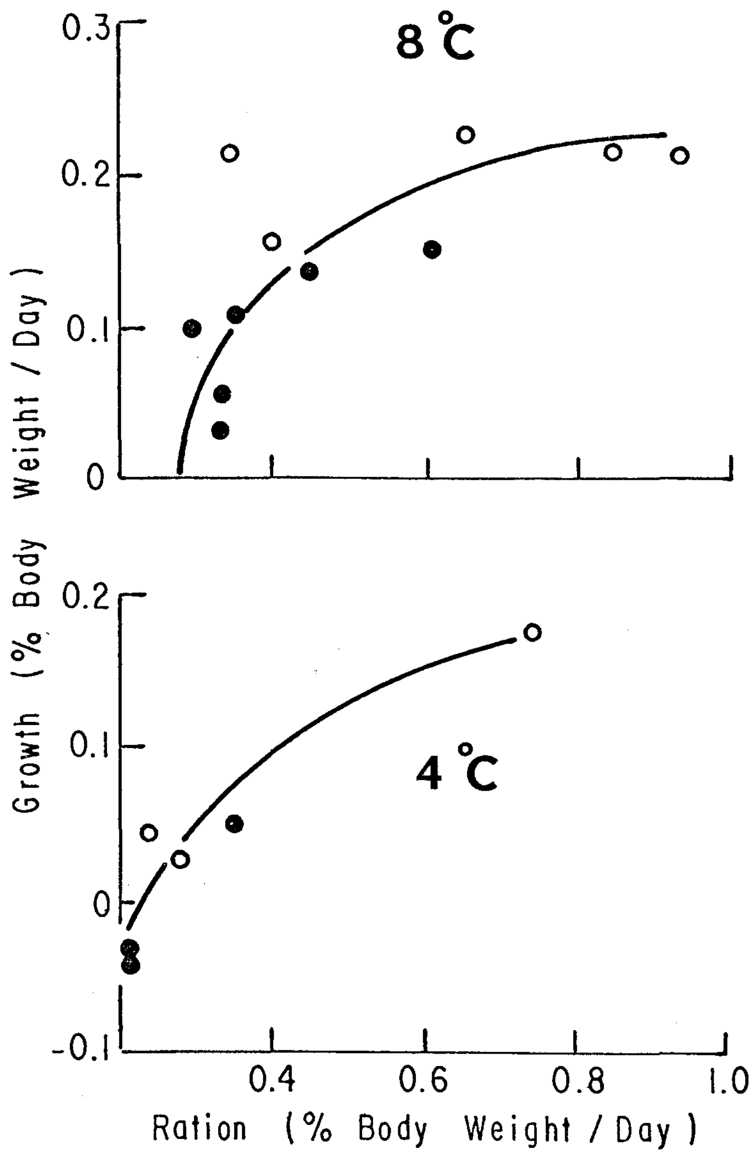

Fig. 2. Growth rates of cod in relation to temperature and ration level. Closed circles represent June-July growth period while open circles are for August-September period. Ration is expressed as dry weight of food to wet body weight x 100.

Seasonal variation in growth rate

Growth rates of cod during the year showed annual variations paralleling those observed with appetite (Fig. 3). This pattern was shown at all feeding temperature regimes indicating a period of accelerated growth July-October followed by a period of reduced growth rate (Dec. to March) which coincided with advanced sexual maturation. Although growth rates were higher at 8°C than at 4°C, the deceleration in January-March was more pronounced at the higher temperature. A combination of reduced feeding and higher maintenance costs could account for the negative growth observed in February-March.

Seasonal variation in gonads and liver

Although time did not permit evaluation of fecundity during the annual cycle, sexual development was estimated from the gonado-somatic ($\frac{\text{gonad weight}}{\text{body weight}}$) and maturity indices (1 = resting; 2 = ripening 1; 3 = ripening 2; 4 = running; 5 = spent). These results are presented in Figs. 4 and 5. Maturity index of experimental fish showed an increase from resting level in October and reached maximum levels at the termination of the experiment (March). This trend followed a similar pattern to that demonstrated for Passamaquoddy Bay cod. The single point representing Gulf of St. Lawrence cod in September is also in agreement. Generally, male experimental fish were sexually more advanced than female fish for a given date. The gonado-somatic index (Fig. 5) showed a pattern similar to that for maturity index. Similarly, the hepato-somatic index (liver weight/body weight) increased during the summer months, reaching a maximum value in March (Fig. 13)

Growth rate and size

When growth rate was expressed as Δw/day, growth was highly correlated with total weight for every growth period (Table 2). No significant

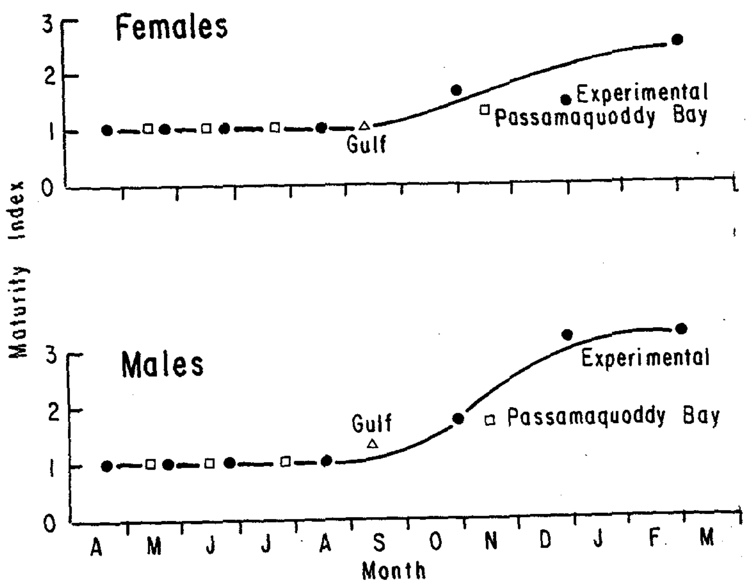

Fig.4 The relationship between maturity index and time of year for experimental Passamaquoddy Bay and Gulf of St. Lawrence cod. Maturity index: 1 = resting; 2 = ripening 1; 3 = ripening 2; 4 = running; 5 = spent.

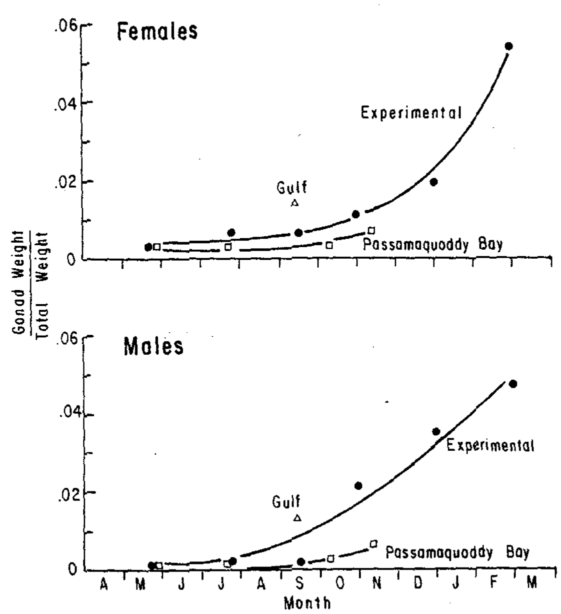

Fig. 5 The relationship between GSI and time of year for experimental Passamaquoddy Bay and Gulf of St. Lawrence cod.

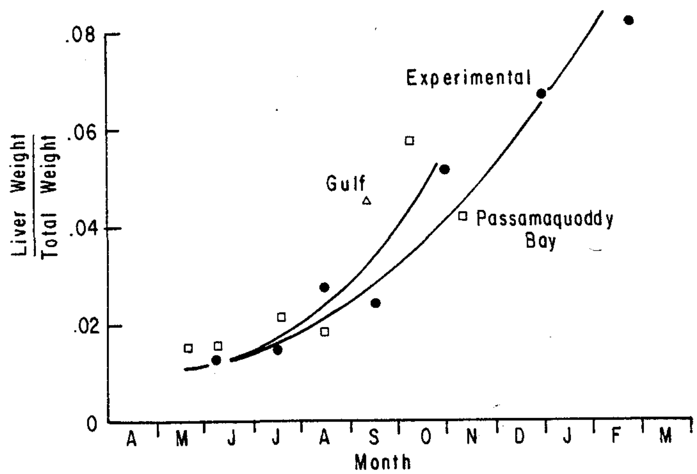

Fig. 13 The relationship between HSI and time of year for experimental Passamaquoddy Bay and Gulf of St. Lawrence cod.

difference was observed between sexes although the slope increased at higher growth periods. It is interesting to note that no significant (P = 0.05) relations between ΔL/day and length could be demonstrated and when growth was expressed as Δw/g/day or ΔL/g/day, no significant correlations were found.

Gonado-somatic and maturity indices as a function of size

Gonado-somatic index was significantly correlated (P = 0.01) with size (length or weight) for both sexes. This relationship was plotted for growth periods 3, 4 and 5 (Fig. 6A & B). An increase in slope was observed as season progressed. The relationship between maturity index was less pronounced and significant (P = 0.01) correlation coefficients were calculated for only 2 regressions (males, MI vs. weight, March, and females, MI vs. weight, December).

Growth rate and sexual maturation

A positive correlation was demonstrated (Fig. 7A & B) between growth rate and gonado-somatic index. This relationship was much more pronounced in males than in females. However, the correlation held whether growth was expressed on a per-gram basis (i.e., taking out size effect on growth) or whether length was used instead of body weight. This relation was demonstrable at all growth periods (males) and the later 2 for females. Generally, the slope was higher at later growth periods.

It was further established that growth rate from June to November gave the highest correlation coefficients with GSI in March (Fig. 8A,B) indicating the importance of early growth rate in determining final gonad weight.

The relationship between growth rate and maturity index was less pronounced but also demonstrable for males (Fig. 9).

Table 2.

Correlation	R^2	n	Intercept	Slope	Month
w3 vs. Gl3w male	.24	17	1228	199	October
w3 vs. Gl3w female	.34	21	1106	225	October
w4 vs. Gl4w male	.60	22	1042	285	December
w4 vs. Gl4w female	.38	17	1392	239	December
w5 vs. Gl5w male	.53	20	739	491	March
w5 vs. Gl5w female	.68	23	839	430	March

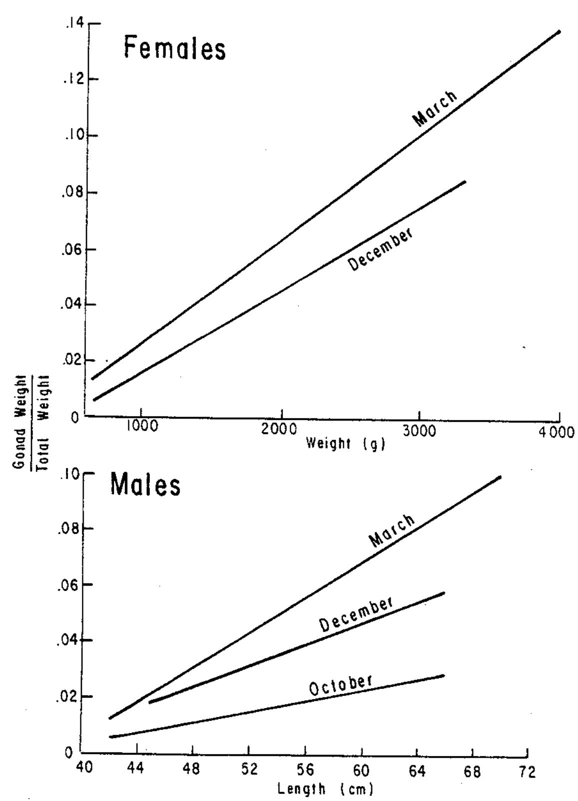

Fig. 6 GSI of male and female experimental cod as a function of size at different times of the year.

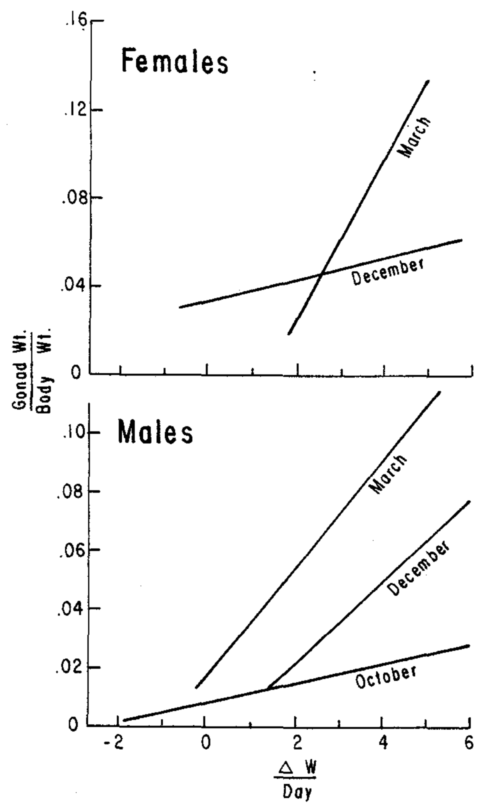

Fig. 7 The relationship between GSI and growth rate of female (A) and male (B) experimental cod at various times of the year. All correlation coefficients are significant at P = 0.01.

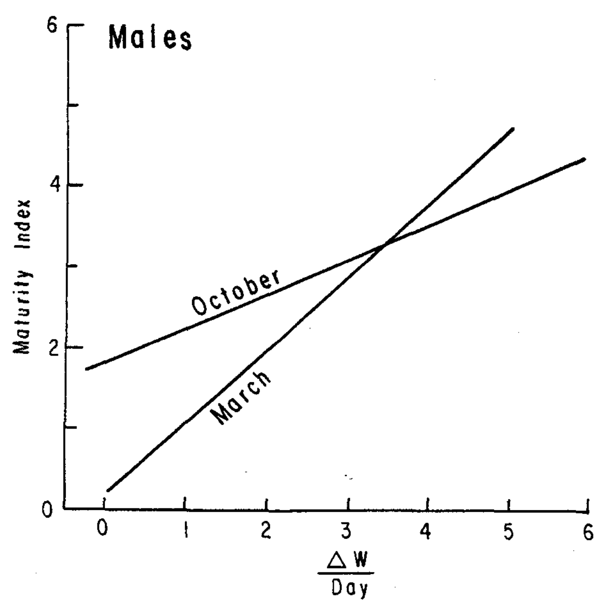

Fig. 9 The relationship between maturity index and growth rate of male experimental fish in October and March. Correlation coefficients are significant at P = 0.01.

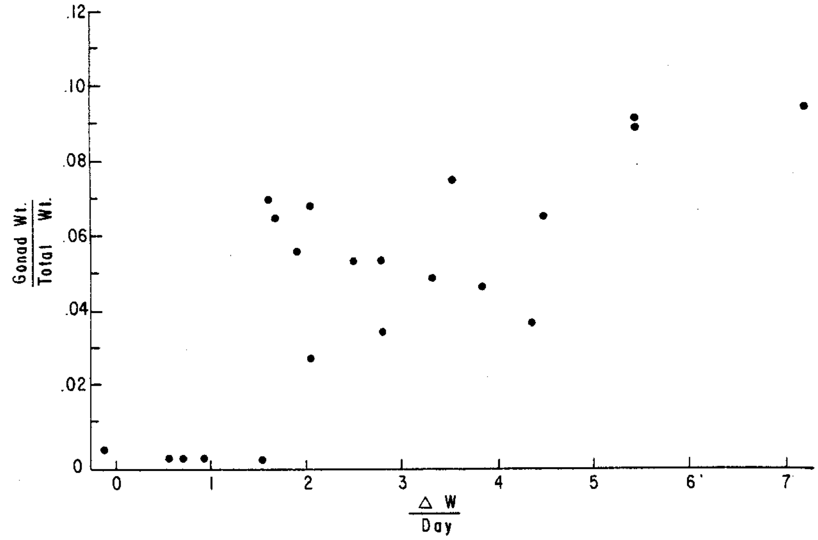

Fig. 8 A GSI of male cod in March vs growth rate from June to November.

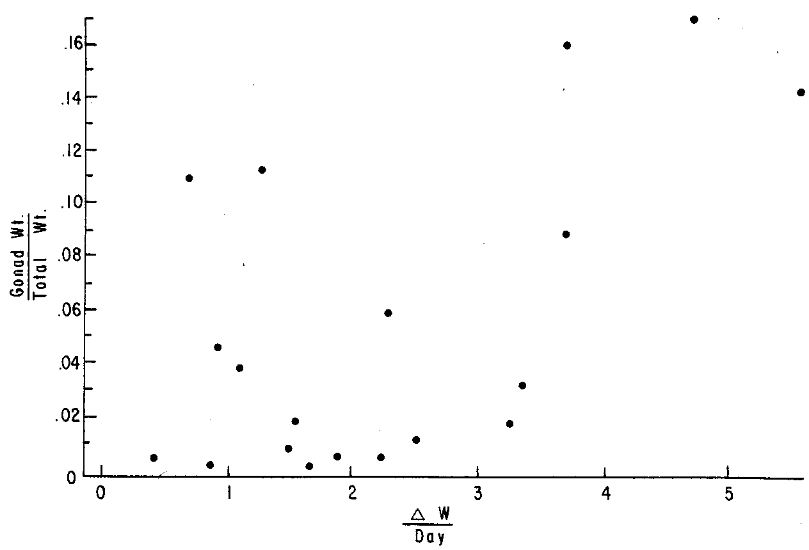

Fig. 8B GSI of female cod in March vs growth rate from June to November.

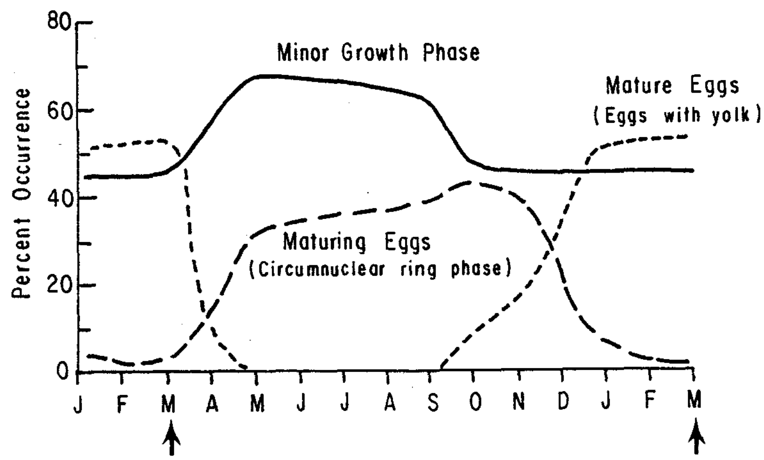

Fig. 12 The % of occurance of 3 growth phases of cod eggs at various times of reproductive cycle (from Woodhead and Woodhead, 1964).

Growth rate and hepato-somatic index (HSI)

When HSI is regressed against growth rate (Δw/day), a significant positive correlation can be shown (Figs. 10 and 11). Since no significant relationship could be demonstrated between size (length or weight) and HSI (at least over the size range tested), it is interesting to speculate on the exploitation of this relationship for predicting growth rates of landed fish. When the HSI of Gulf of St. Lawrence and Passamaquoddy Bay cod is fitted on the "October" line (Fig. 10), predicted growth rates of 2.25 g/day and 1.60 g/day can be made for the 2 locations respectively. It is important to note that any such prediction of growth rate should take into account the stage in the annual cycle.

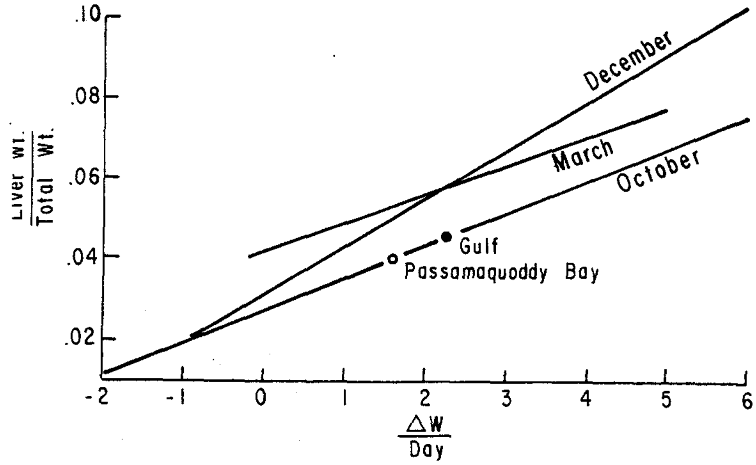

Fig. 10 The relation between HSI and growth rate for experimental fish at different times of the year. HSI values for cod taken in the Gulf of St. Lawrence (September 1977) are fitted on the October line to give predicted growth rates. Correlation coefficients are significant at P = 0.01.

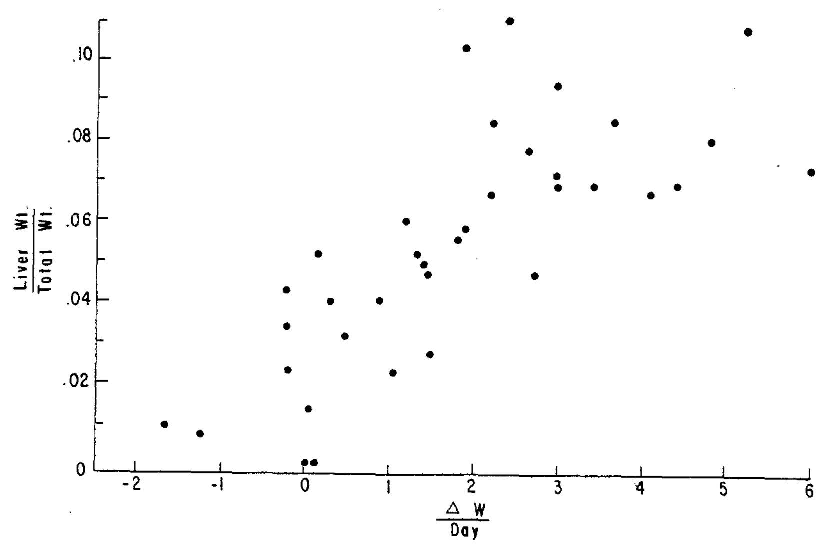

Fig. 11 Hepato-somatic index vs growth rate for experimental cod (June to December)