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LARVAL LENGTH-WEIGHT RELATIONS FOR SEVEN SPECIES OF NORTHWEST ATLANTIC FISHES REARED IN THE LABORATORY

Growth is an important connecting link in the functional influence of biotic and abiotic factors on the dynamics of fish populations. Length-weight relations are used by fishery scientists to describe the growth characteristics of species or populations and as a basis of evaluating the consequences of environmental influences on growth. Length-weight relations are also used in assessing production when combined with age and growth information and in determining length or weight in a situation where either one or the other is unknown due to sampling procedures.

Studies of the early life of fishes are receiving increasing emphasis, particularly with regard to growth and survival in the larval stage. Survival during this period is thought to be minimal and potentially variable from year to year. Small changes of tenths of a percent in mortality have the potential to produce orders of magnitude differences in eventual adult populations. Larval growth can be influenced due to food limitations and varying abiotic factors (Houde 1974; Lasker 1975; Laurence 1977). Because of these facts, fishery scientists are particularly concerned with two aspects: 1) quantifying variable larval growth and survival, relating it to subsequent year-class recruitment, and applying it to traditional stock-recruitment relationships where recruitment has often been considered constant; and 2) the potential use of this type of information in evaluating the increasing effects of pollution or other environmental perturbations because of the fragility and sensitivity of larvae to changing or altered environmental variables.

Solutions to these problem areas require quantitative knowledge of growth parameters of larval fishes, and length-weight relations can be helpful in providing information or establishing relationships between pertinent sets of data. It is generally thought that weight[1] is a better measure of absolute growth of fish larvae than length as well as the prime determinant of condition when combined with length. Many species exhibit allometric or disproportionate length-weight growth. This is especially true during the period of metamorphosis when some species display varying or unusual body proportions with age (Blaxter 1969) and length does not increase in proportion to increasing weight. Additionally, recent attempts to construct models of larval survival, as influenced by environmental variables and density dependent feeding relationships, require weight determinations for estimates of biomass and caloric turnover between larval and prey trophic levels.

There is an extensive data base to asses larval fish growth and survival based on ichthyoplankton collected on survey cruises during the last 75 yr by marine laboratories throughout the world. Unfortunately, almost all of these data are in standard or total length measurements as they are much more easily and rapidly taken than dry weights. The difficulty involved in obtaining dry

[1]Weight for species in this research refers to dry weight. Dry weight is the most accurate for fish larvae because accurate wet weights are difficult to obtain and yield variable results on organisms as small as fish larvae.

weights of young stages has been overcome to a certain degree with the advent of experimental laboratory programs at a few research facilities during the last 10 yr.

The experimental larval fish program at the Northeast Fisheries Center Narragansett Laboratory, National Marine Fisheries Service, NOAA, has been studying growth, metabolic, and trophodynamic factors for a number of important commercial and sport species, and it is the object of this report to present larval length-weight relations for seven species including Atlantic cod, *Gadus morhua*; haddock, *Melanogrammus aeglefinus*; scup, *Stenotomus chrysops*; Atlantic herring, *Clupea harengus*; winter flounder, *Pseudopleuronectes americanus*; summer flounder, *Paralichthys dentatus*; and yellowtail flounder, *Limanda ferruginea*. The larval length-weight relations presented here are previously unreported in the literature for six of the seven species with the exception of the Atlantic herring, which is included because it represents the only data available for western North Atlantic stocks.

Materials and Methods

All larvae were obtained from experimental spawning of adults in the laboratory and reared by techniques reported by Smigielski (1975a, b) and Laurence (1975). The length-weight data were collected coincident with a variety of experimental studies on larval growth, survival, metabolism, and feeding reported by Laurence (1974, 1977, 1978, and as yet unpublished).

In all cases the data were collected from larvae reared at prey concentrations in the range of 0.5 to 3.0 organisms/ml. Concentrations of 0.5 and above have been shown to be adequate for normal growth in the studies cited above. Rearing temperatures were optimum for growth and survival or within a 3°C nonlethal range about the optimum depending upon the experiment from which the data were taken. Optimum temperatures determined in laboratory studies for rearing the seven species were 7°C for cod and haddock, 8°C for winter flounder, 10°C for herring and yellowtail flounder, 16°C for summer flounder, and 18°C for scup.

Length measurements were taken from the tip of the snout to the end of the notochord in the preflexion stage. During flexion of the notochord measurements were taken to a line vertically perpendicular to the tip of the notochord until the hypural bones became prominent or exceeded the line vertically perpendicular to the notochord tip. At this time, a standard length measurement to the posterior end of the hypural plate was recorded. Since the original experiments were not designed for developmental anatomy purposes, the different flexion stages were not recorded coincident with the length and weights.

Lengths were recorded to the nearest 0.1 mm with a filar ocular micrometer. Dry weights were determined after rinsing larvae in distilled water, pipeting onto a glass Petri dish, and drying to a constant weight at 60°-90°C for 24 h. Individual dry weights were recorded to the nearest 0.1 μg on a gram electrobalance.

All measurements were made on post yolk-sac larvae that were freshly sacrificed and unpreserved. The data points for each species represent lengths and weights for individual larvae except for winter flounder and haddock. The data for these two species are the means of lengths and weights for samples of 10-25 larvae collected on a weekly basis during different experiments. The experimental procedures precluded the matching of individual lengths with weights for these two species.

Regression equations and associated parameters were calculated as geometric mean, functional regressions using log base 10 transformed data according to the methods of Ricker (1973) rather than using the previously standard predictive, regression techniques. Ricker demonstrated the advantages of using functional rather than predictive regression calculations to reduce bias in length-weight conversions where the populations of measurements are typically open ended, where only a portion of the length and weight distributions are represented, and where the variability may be more inherent in the biological material itself rather than the means of measuring length and weight.

Results and Discussion

The exponential relation between length and weight for all seven species are presented in linearized form by logarithmic transformation in Figures 1-7. The larvae studied in this research are from different taxonomic families (Clupeidae, Gadidae, Sparidae, Bothidae, and Pleuronectidae), represent different adult life styles (pelagic and demersal), develop in a range of different temperatures, and demonstrate different patterns of metamorphosis from larval to juvenile stages.

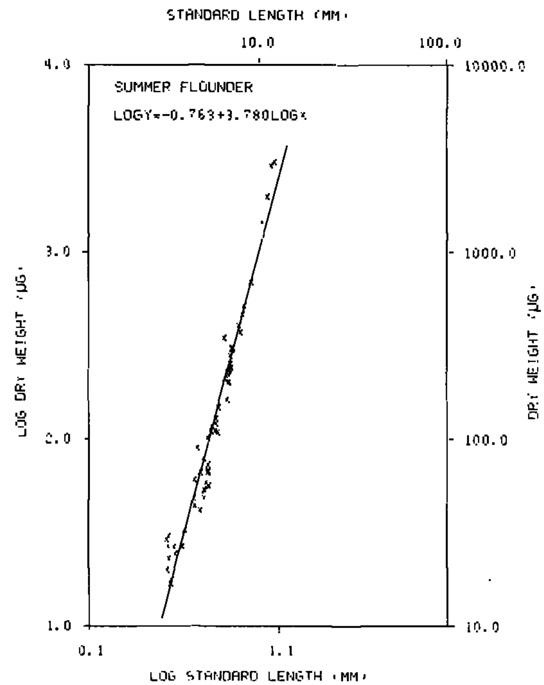

FIGURE 1.—Standard length-dry weight relationship of larval summer flounder.

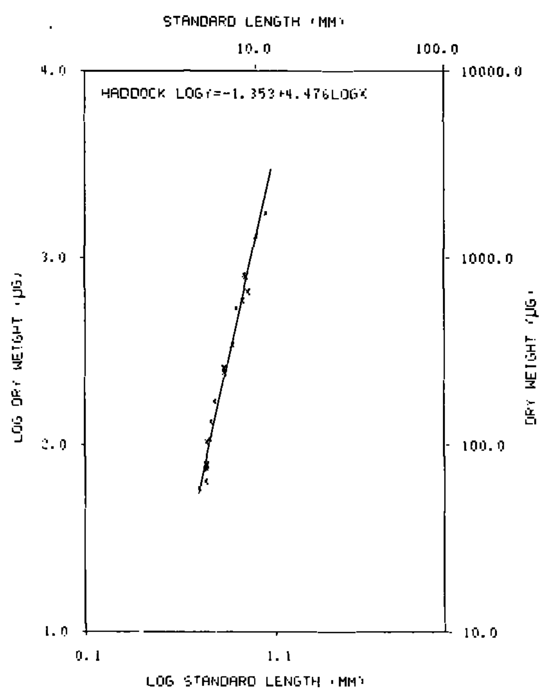

FIGURE 2.—Standard length-dry weight relationship of larval haddock. Points represent means for length and weight of samples of 10-25 larvae.

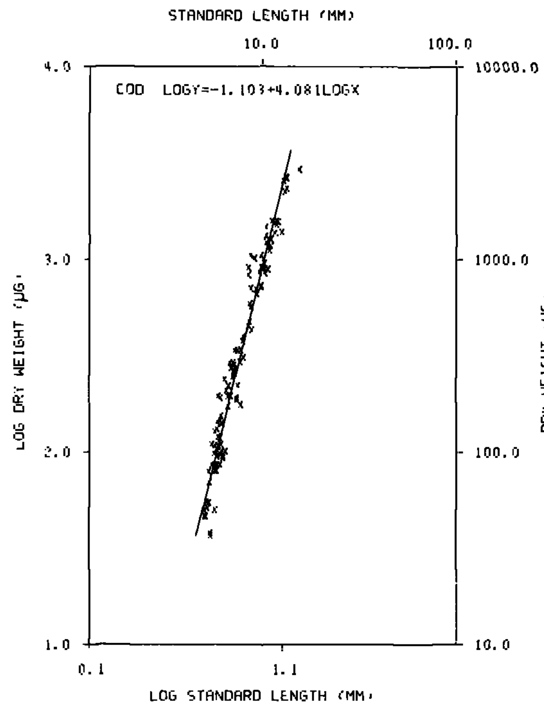

FIGURE 3.—Standard length-dry weight relationship of larval cod.

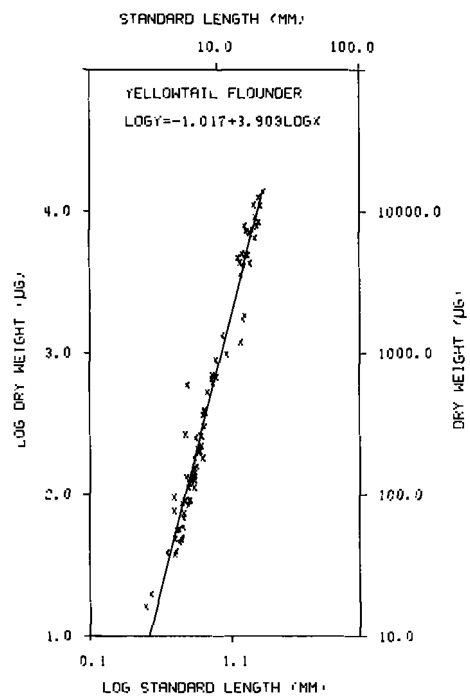

FIGURE 4.—Standard length-dry weight relationship of larval yellowtail flounder.

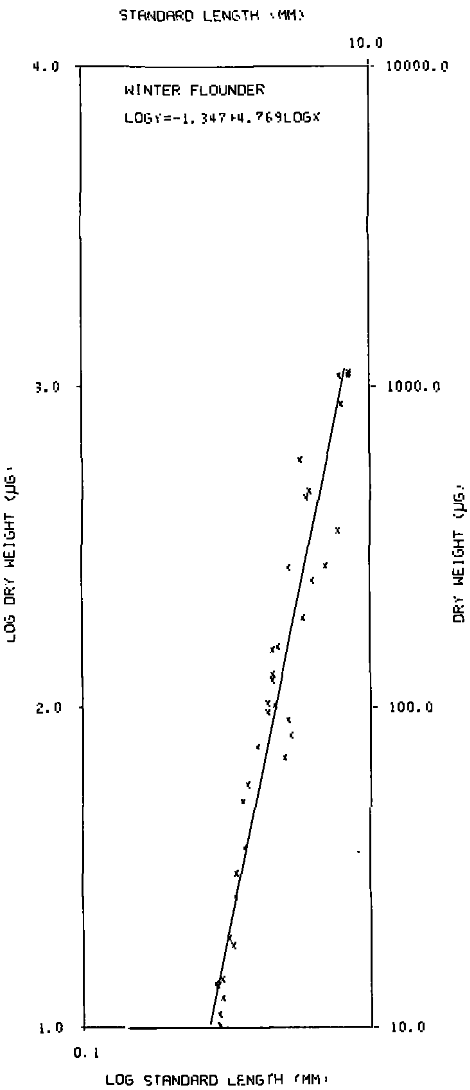

FIGURE 5.—Standard length-dry weight relationship of larval winter flounder. Points represent means for length and weight of samples of 10-25 larvae.

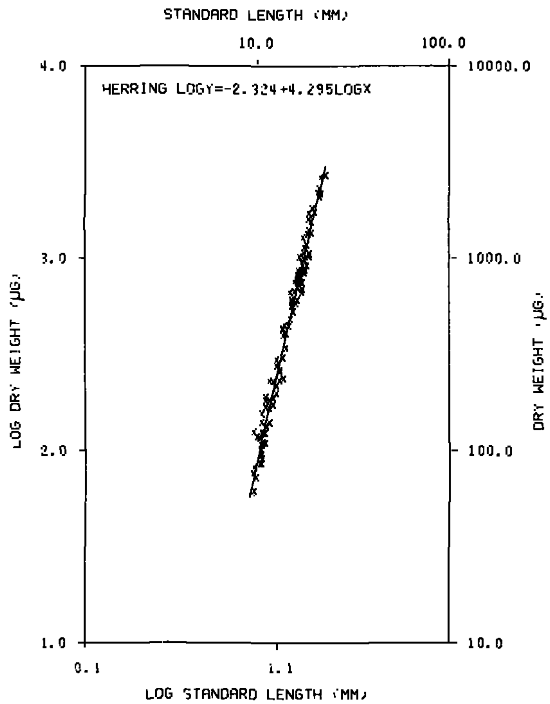

FIGURE 6.—Standard length-dry weight relationship of larval Atlantic herring.

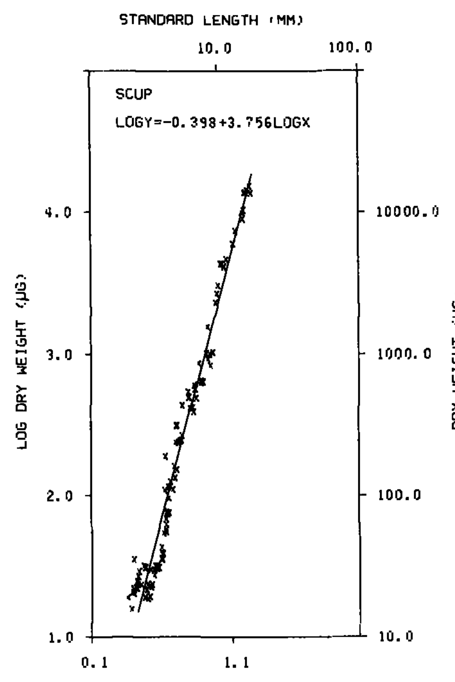

FIGURE 7.—Standard length-dry weight relationship of larval scup.

In spite of these differences, a visual examination of the length-weight regression equation coefficients and associated parameters for all species reveals no obvious correlations with the differences (Table 1). It would not be prudent to statistically test for differences or associations between the species because data for haddock and winter flounder were averaged. Ricker (1973) cautions that averaging changes the variances associated with the variables, particularly the independent variable, so that a comparison between

TABLE 1.—Regression parameters for length-weight relations of seven species of laboratory-reared larval northwest Atlantic fishes.

Larval species	Number sampled	Correlation coefficient	Coefficient of determination	Regression coefficient	Standard error of regression coefficient	95% C.I. about regression coefficient
Summer flounder	57	0.997	0.994	3.780	0.039	3.702-3.858
Yellowtail flounder	80	0.995	0.990	3.909	0.044	3.821-3.953
Herring	98	0.997	0.993	4.295	0.037	4.221-4.369
Scup	100	0.997	0.993	3.756	0.028	3.692-3.820
Cod	104	0.997	0.995	4.081	0.029	4.023-4.104
Haddock[1]	23	0.997	0.995	4.476	0.071	4.328-4.624
Winter flounder[1]	36	0.991	0.982	4.769	0.110	4.545-4.993

[1]Data represent means for length and weight of samples of 10-25 larvae.

averaged and unaveraged data is not valid: although he does not discredit the use of averaged data by itself. Also, seven species, some of which are closely related taxonomically, probably do not constitute enough cases for drawing conclusions about functional differences. Consequently, these length-weight relations should properly be considered individually as empirically derived relations for each particular species.

The length-weight relation of fishes usually approximates the cube law relationship in which the weight is proportional to the cube of the length (Beckman 1948; Rounsefell and Everhart 1953). This is usually true for adult fishes; however, results of this research imply that it is not necessarily so for larvae. All the length exponents for the species investigated in these studies were >3.6 with a mean value of 4.152. It would seem then that the dry weight of larval fishes may be more closely proportional to length to the fourth power rather than cubed. Length-weight relations for fish larvae are scarce in the literature. Examination of the data available ($\log_{10}$ formulation) seems to substantiate that the length exponent is always greater than three and more closely approximates four. Marshall et al. (1937) presented a total length-dry weight equation for larval herring, the only species with data available to compare with this study, equivalent to $\log W = -5.6990 + 4.52 \log L$. The length exponent is >4 and similar to the value of 4.295 for herring in this research. Ehrlich et al. (1976) also presented a similar standard length-dry weight relation for Firth of Clyde herring larvae ($\log W = -5.7052 + 4.5710 \log L$) as well as a relationship of $\log W = -4.3043 + 3.9155 \log L$ for larvae of plaice, *Pleuronectes platessa*. Stepien (1976) reported a standard length-dry weight relationship for larval sea bream, *Archosargus rhomboidalis*, of $\log W = -0.5144 + 4.2816 \log L$, and Lasker et al. (1970) reported a standard length-dry weight relationship for northern anchovy larvae, *Engraulis mordax*, of $\log W = -3.8205 + 3.3237 \log L$.

It is acknowledged that variables such as temperature and feeding conditions can influence growth and complicate length-weight relations. These factors may have contributed to some variability in the present study. However, it is felt that these influences were minimized by the experimental feeding levels and temperatures which were within ranges for adequate growth and survival, and any changes in length or weight were most likely mitigated together causing little effect on the form of the length-weight relation. This is supported in studies of haddock larvae (Laurence 1974) where condition factors were similar and randomly associated with prey concentrations >0.5 organisms/ml.

The use of larval length-weight relations for extrapolation may result in some underestimation or overestimation at the smallest and/or largest sizes due to changes in growth rates for yolk-sac or metamorphosing larvae. Farris (1959) suggested that growth rates of larval marine fishes could be separated into three different phases; the first two prior to yolk absorption and the third following. Zweifel and Lasker (1976) presented a mathematical interpretation of larval growth with age defined by the Laird-Gompertz growth function. They noticed two growth cycles; one extending from hatching to yolk absorption and the other following yolk absorption. This variability in the small sizes is probably not inherent in the data of this study because larvae were not included until yolk was absorbed and active feeding had commenced. Some variability may be present in the upper range of sizes in these length-weight relations. In some cases data for larger larvae are not as extensive as for smaller larvae. Also, the majority of the largest individuals for each species were either undergoing or had completed metamorphosis where changes in growth rates of length or weight might cause allometry. Zweifel and Lasker (1976) briefly considered the length-weight relation in terms of a modified Gompertz-type relation and noted overestimation problems in extrapolation at the largest sizes.

Length-weight relations have merit, but their usefulness is greatly enhanced when combined with other studies, particularly those on age. Length-weight by itself does not necessarily imply rate of change because of the potential influence the environment may have on changing growth with time. However, when correlated with age and compensated for change in rate due to biotic and abiotic influences, length-weight studies can be an important component in estimating growth, survival, and population production.

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EFFECT OF THERMAL INCREASES OF SHORT DURATION ON SURVIVAL OF *EUPHAUSIA PACIFICA*

Euphausiids are an important source of food for many valuable species of fish including herring, cod, pollock, and salmon. Cooney (1971) reported that *Euphausia pacifica* was the most abundant species associated with the diffuse scattering layer at all locations in Puget Sound, Wash. He found that during the day euphausiids are most abundant between depths of 50 and 100 m and that at night most of the population migrates into the upper 50 m. Cooney's findings indicate that great numbers of euphausiids could be drawn through