SCRS/1984/040 Col.Vol.Sci.Pap. ICCAT, 22: 185-193 (1985)

VARIATION IN MEAN LENGTHS OF MODAL SIZE GROUPS OF BLUEFIN TUNA IN THE WESTERN ATLANTIC

S. Nichols
NMFS, Southeast Fisheries Center

SUMMARY

Variations in mean lengths of modal groups were found in USA rod and reel, Canadian purse seine, and USA purse seine size frequency data. These variations appear to originate from events prior to first recruitment, and can be modeled as variation in von Bertalanffy's t_o parameter among cohorts. Particularly aberrant t_o values occurred for the 1977-1980 year classes, which have been estimated to have been very weak, suggesting that mean lengths of juveniles might prove to be indices of recruitment strength.

RESUME

Des variations de la taille moyenne des groupes modaux ont été observées dans les données de fréquence de taille de la pêche américaine à la canne et moulinet, des senneurs canadiens et des senneurs américains. Ces variations auraient une origine antérieure au premier recrutement, et peuvent être portées en modèle en tant que variation du paramètre t_o de von Bertalanffy entre cohortes. Des valeurs de t_o particulièrement aberrantes ont été obtenues pour les classes annuelles de 1977-80, que l'on estime très médiocres, ce qui suggère que la taille moyenne des juvéniles pourrait s'avérer être un indice de l'importance du recrutement.

RESUMEN

En los datos de frecuencias de talla de las pesquerías estadounidenses de caña-liña y cerco y pesquería canadiense de cerco, se encontraron variaciones en la media de talla de los grupos modales. Estas variaciones parecen tener su origen antes del primer reclutamiento y pueden ser modeladas como la variación en el parámetro t_o de von Bertalanffy, entre cohortes. Se observaron valores de t_o especialmente aberrantes en las clases anuales del periodo 1977-1980 - estimadas como muy débiles - que sugieren que la media de talla de los juveniles podría resultar ser un índice de la fuerza del reclutamiento.

INTRODUCTION

Examination of size frequency data from the USA rod and reel fishery for juvenile bluefin revealed an unexpected year to year variability among mean lengths of modal groups (Nichols 1984). Upon inspection, all modal groups appeared to progress in length as predicted by the Parrack and Phares growth curve (Parrack and Phares 1979), but some cohorts remained offset from their predicted length at age, suggesting that events in the early (pre-recruit) life history were responsible for the variation in mean lengths. These variations were modelled as variations in von Bertalanffy's t_0 parameter among cohorts (Nichols 1984).

This paper explores the variation among mean lengths of modal groups more fully. The rod and reel data were subjected to modal analysis to establish (more rigorously than by simple inspection) that the changes in mean lengths do indeed indicate a fluctuation in the t_0 growth parameter. Length frequency data for the USA and Canadian purse seine fisheries were examined, and similar t_0 variation were found in those data, also. Separate t_0's for each year class were estimated using both rod and reel and purse seine data. A similarity exists between the temporal changes of t_0 and of stock sizes of age 1 fish estimated by virtual population analysis (VPA), suggesting that mean size of age 1 fish in the rod and reel fishery might prove to be an index of recruitment strength.

METHODS

Size frequency data for the USA rod and reel fishery were used as described by Nichols (1984). Purse seine length frequencies were obtained from the ICCAT data base. For purse seine data, only length frequency samples identified to a single month, and with length intervals no larger than 1 inch were used.

Mean sizes of the modal groups in the rod and reel data were determined by the method of Macdonald and Pitcher (1979), using the computer program NORM/SEP made available by NMFS's Northwest Fisheries Center. Modal sizes in June, July and August were determined separately. Date of capture within those months was ignored. Only the first 2 modes (age 1 and 2) could be extracted consistently from the data; a third mode could be determined occasionally.

The procedure used by Nichols (1984) to determine t_0 for each cohort was used here. Trial t_0 values from -0.5 to -1.5 years in 0.01 year increments were used, along with $L_\infty = 313$ cm and $K = 0.0903$ per year from the Parrack-Phares growth curve, to determine predicted values of length at time of capture for each year class. A 1 May birthdate was assumed. For the rod and reel data, day of capture was available, and was used for calculating predicted length. For purse seine data, mid-month capture was assumed. Upper and lower bounds for any year class at any time of capture were taken to be the predicted lengths at $\pm \frac{1}{2}$ year from the time of capture. (These bounds are different for each trial t_0 value.) Fish within these bounds are assumed to be members of the year class in question. The t_0 minimizing the expression

$$\frac{1}{N} \sum^{N} (\text{observed length - predicted length})^2 \qquad (1)$$

(where N is the number of fish assumed to be members of the year class) was taken as the best estimate t_0 for that year class. Note that the mean square rather than the sum of squares is minimized. This is necessary because N changes as t_0 is changed. Expression (1) therefore may not change smoothly as t_0 is changed. In practice, however, the "roughness" of expression (1) with small changes in t_0 is trivial near the minimum.

RESULTS

Lengths at capture vs. time for the USA rod and reel fishery are shown in Fig. 1, along with boundaries (i.e., $\pm$ 1/2 year) between cohorts established by the Parrack-Phares growth curve (t_0 = -0.96): From 1975-1977, the modal groups appear as expected, near the center of the "channels" for each cohort. For the 1977-1980 cohorts, the largest 1/4 to 1/3 of each modal group extends into the size range expected for the next older cohort. The amount of offset for each cohort is about the same from year to year relative to the boundaries, suggesting that growth in this post-recruit stage of life is the same as predicted by the Parrack-Phares curve.

Estimates of mean size for the first two modal groups (Table 1) were used to verify that post-recruitment growth remains as predicted by Parrack and Phares (1979). Monthly mean lengths at age 2 were plotted against mean lengths at age 1, along with the "Walford line" predicting length at age i+1 from length at age i base on the Parrack-Phares equation (Fig. 2). The points follow the Parrack-Phares line, with no systematic departures indicative of post-recruit growth differences.

Length vs. time data from the USA and Canadian juvenile purse seine fisheries were plotted in the same format as the rod and reel data (Figs. 3, 4). Purse seine catches extend into older age groups than the rod and reel data, so the modal structure is not always as obvious, but the general patterns of modes near the values predicted by the Parrack-Phares curve for the early years, and modes offset upwards since 1978 are present in both the USA and Canadian purse seine length frequencies.

Values of t_0 each year class were estimated from the rod and reel data only, and from rod and reel and purse seine data combined (Fig. 5).

Changing t_0 among cohorts will produce gaps and overlaps of cohort boundaries if a $\pm$ 1/2 year rule if followed in estimating age from length. (In fact, the extent of the gaps and overlaps produced by the t_0's in Fig. 5 are usually small compared to the range of lengths for $\pm$ 1/2 year and rarely include many fish in either the rod and reel or purse seine samples.) The simplest solution is to "split the difference" by averaging t_0's from neighboring pairs of cohorts to establish length boundaries between cohorts for estimating ages. Boundaries using the t_0's from the combined data and this "split the difference" rule alleviate the problem of splitting modal groups in the rod and reel samples (Fig. 6), and for the combined rod and reel and purse seine length frequencies (Fig. 7).

DISCUSSION

Existence of real variation in mean length of modal groups is established by its simultaneous occurance in the separately sampled rod and reel, Canadian purse seine, and USA purse seine fisheries. Agreement between observed annual progression of modal lengths and the Walford line from the Parrack-Phares growth curve demostrates that the phenomenon is not due to a change in growth pattern after recruitment, and thus is likely determined during the pre-recruit phase.

Several sources of error may affect t_0 estimation. By necessity, each measured fish is treated as if it were a random, independent selection from the stock. This "assumption" may be particularly inappropriate for recent purse seine samples, where much of the quota can be met with capture from a small number of schools. Estimates based solely on purse seine data may be less reliable than estimates based on rod and reel data, because the purse seine samples were often dominated by older juveniles (age 3-5), for which obvious modes are not as clear. Several choices for fitting procedures might be considered; I chose probably the simplest. Particularly for the rod and reel data, the modes are so obvious that even eye-fit curves would probably suffice. Even the largest discrepancy between t_0 from rod and reel only and from the combined data (1979 year class) is too small to make much difference in assigning fish to age classes.

There is a general similarity between year to year variation in the t_0 estimates and estimates of recruitment strength made by virtual population analysis (Fig. 8, data from Powers et al. 1983), suggesting that variations in the t_0 parameter might be an indicator of variation in year class strength. Plotting the t_0 estimate vs. VPA recruitment estimate (Fig. 9) suggests that the relationship may be strongest below some threshold value of recruitment, although the "smoothing" of recruitment fluctuation generated by the ageing procedure used for VPA and sole reliance on purse seine data prior to 1975 might obscure any relationship in the early years. Estimation of t_0 can be accomplished quite effectively using only age 1 fish from the rod and reel data (Fig. 10), so if t_0 variation does prove to index recruitment strength, evaluation can be made soon after recruitment.

At least three possible causes for the particularly aberrant t_0's for the 1977-1980 years classes can be considered:

(1) increased growth during the pre-recruit phase, perhaps related to reduced competition associated with low pre-recruit abundance

(2) a shift in time of (sucessful) spawning

(3) survival of only those potential recruits from very early in the spawning season.

These possibilities are not mutually exclusive. The magnitudes of the maximum t_0 shifts (3-4 months) argue against (2) and (3) as likely sole causes. Larvae were observed in icthyoplankton samples in the Gulf of Mexico in 1977 and 1978 during the normal spawning season (April-June). Larvae were not detected in February-March Gulf of Mexico samples in 1980 (Richards, McGowan and Ortner 1982), although survival from non-peak spawning from outside the Gulf cannot be dismissed. The most aberrant t_0's and the lowest estimates of recruitment from VPA coincide with heaviest exploitation of presumed spawning concentrations in the Gulf of Mexico. However, the sudden rebound of t_0 to near previous levels for the 1981 year class precedes the reduction in exploitation in the Gulf of Mexico by one year.

REFERENCES

Macdonald, P.D.M. and Pitcher, T.J. 1979. Age groups from size-frequency data: a versatile and efficient method of analyzing distribution mixtures. J. Fish. Res. Bd. Canada 36:987-1001.

Nichols, S. 1984. An examination of USA rod and reel juvenile bluefin tuna catch per unit effort. SCR/83/62.

Parrack, M.L. and Phares, P.L. 1979. Aspects of growth of Atlantic bluefin tuna determined from mark-recapture data. SCRS/78/37.

Powers, J.E., Conser, R.J. and Parrack, M.L. 1983. An assessment of Atlantic bluefin tuna resources. SCRS/82/66.

Richards, W.J., McGowan, M.F., and Ortner, J.A. 1982. Summary of Gulf of Mexico icthyoplankton research 1977-1982 with bluefin tuna population estimates and preliminary analysis of larval bluefin distribution and icthyoplankton assemblages. NMFS Southeast Fisheries Center, Miami Laboratory Reference Document.

Table 1. Mean lengths of age 1 and 2 modal groups for June, July and August, from the USA rod and reel size frequency samples.

AGE	JUNE 1	JUNE 2	JULY 1	JULY 2	AUGUST 1	AUGUST 2
YEAR						
1975	52.7	75.0	56.6	79.9	62.3	80.9
1976	55.9	77.7	57.9	79.2	-	-
1977	57.7	77.3	57.5	76.8	-	-
1978	-	76.6	62.1	81.8	66.7	83.9
1979	61.2	81.3	64.2	84.2	67.5	87.0
1980	62.4	83.5	63.9	86.4	66.0	91.0
1981	-	82.0	61.7	84.3	67.0	85.2
1982	55.8	78.0	57.8	81.4	-	-
1983	51.4	76.6	56.3	80.9	62.4	79.6

Figure 1. Length vs. time of capture for USA rod and reel samples. A value of 1 indicate 5-9 fish; 2: 10-14 fish, ..., X: > 50 fish. ● indicates 1-4 fish. Diagonal lines are established by the Parrack-Phares (1979) growth curve, ± 1/2 year, and are tentatively the boundaries between year classes for determining age from length.

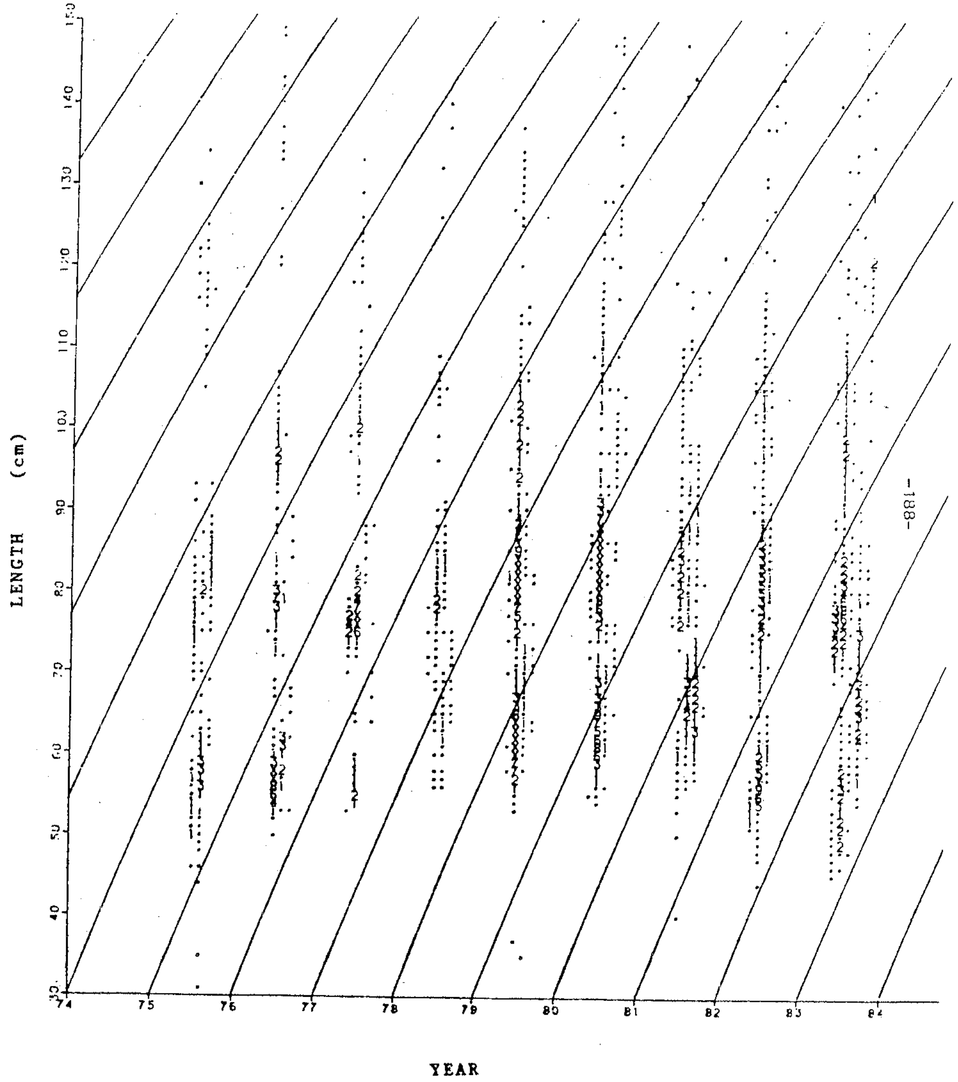

Figure 2. Mean length of age 2 fish vs. mean length age 1 fish for individual cohorts in June, July, and August. The diagonal line is the "Walford line" established by L_{∞} and K parameters determined by Parrack and Phares (1979).

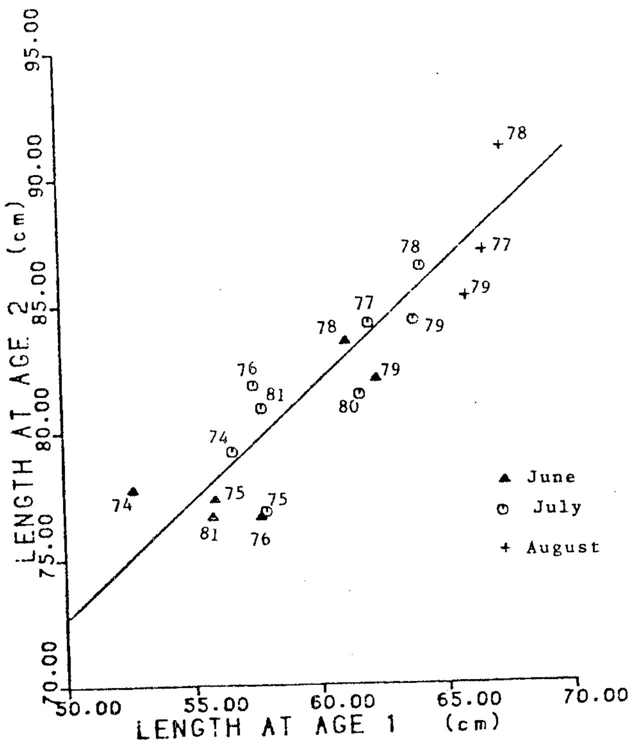

Figure 3. Length vs. time of capture for the Canadian purse seine data. Value of 1 indicate 10-19 fish 2: 20-29 fish, ..., X: ≥100 fish. ● indicates 1-9 fish. Diagonal boundaries are established by Parrack-Phares growth curve.

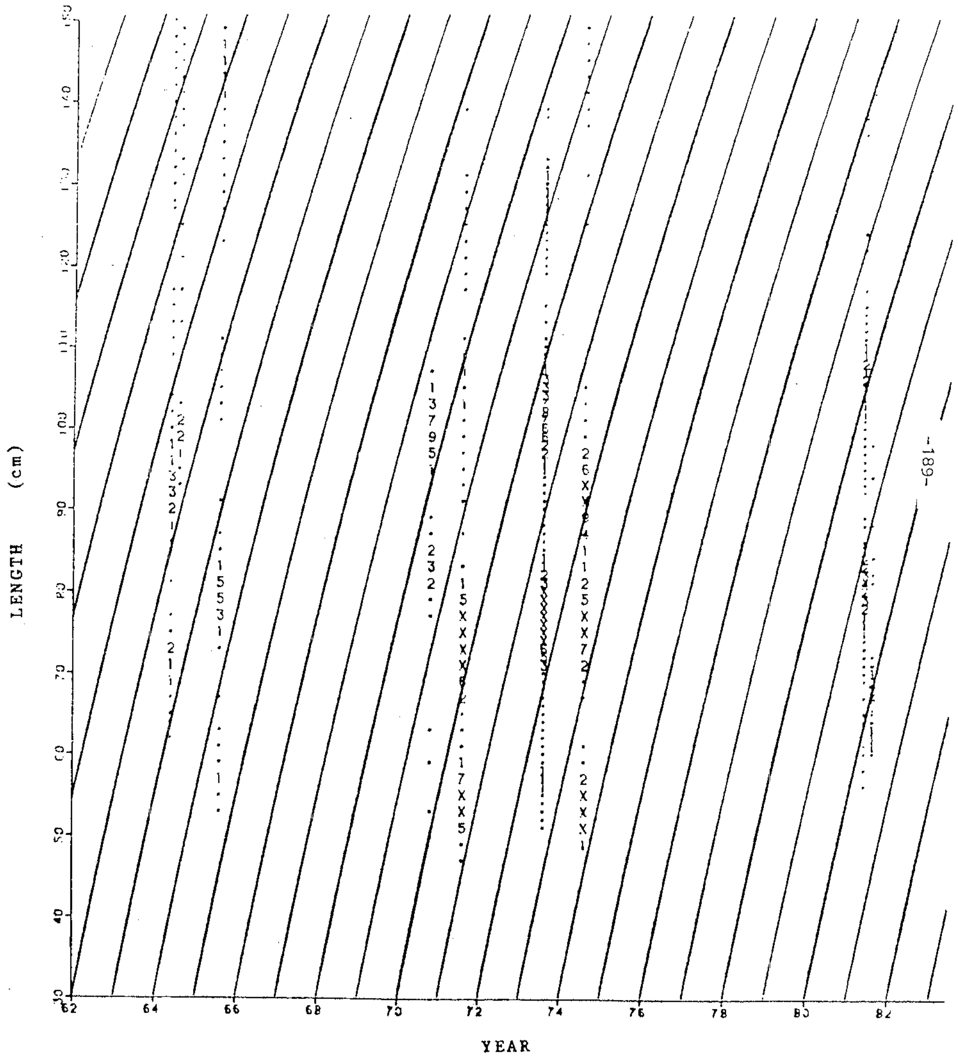

Figure 4. Length vs. time of capture for the USA purse seine data. Value of 1 indicate 10-19 fish 2: 20-29 fish, ..., X: >100 fish. ● indicates 1-9 fish. Diagonal boundaries are established by Parrack-Phares growth curve. (Samples are also available for the isolated year 1962.)

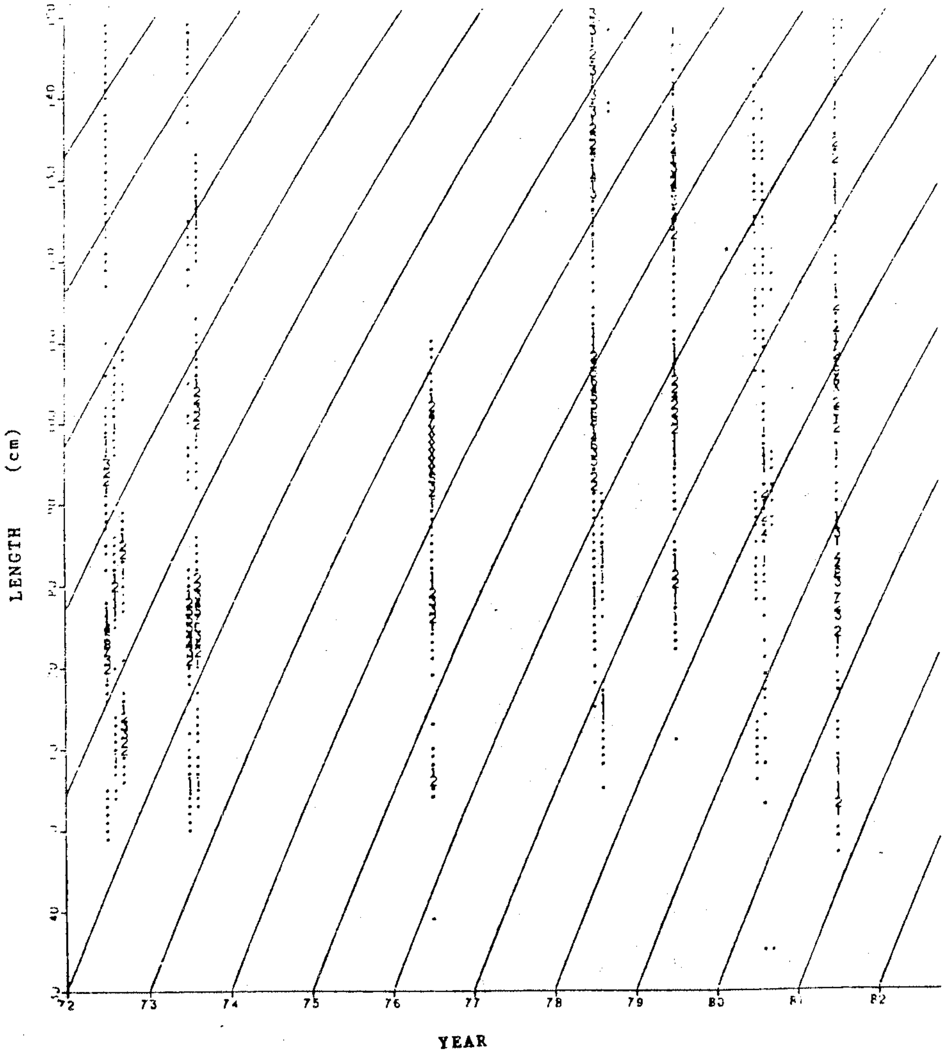

Figure 5. Values of t_0 estimated from the rod and reel data only (+), and from the rod and reel and purse seine data combined (⊕).

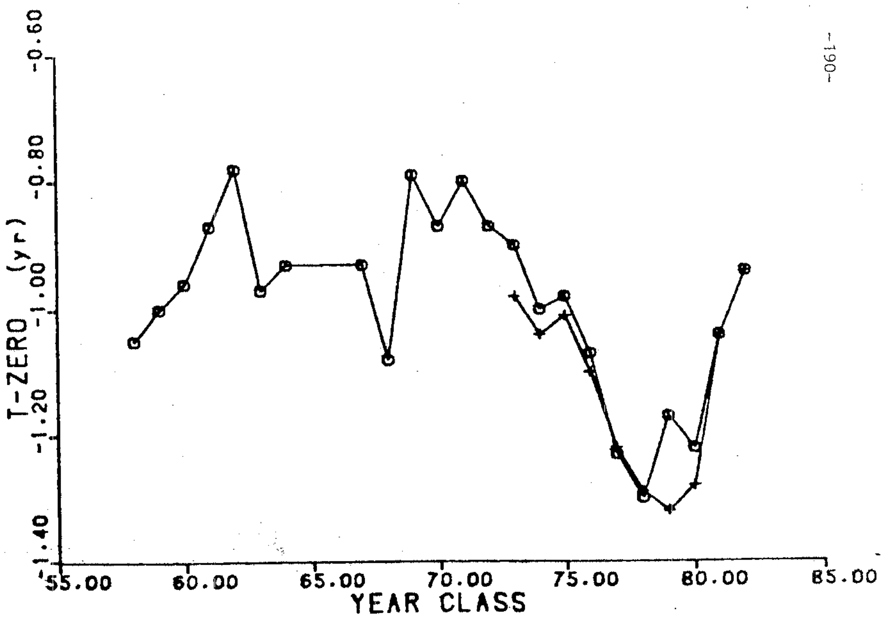

Figure 6. Length vs. time of capture from USA rod and reel samples, as in Fig. 1. Diagonals are now the adjusted boundaries between year classes establish by the Parrack-Phares L_∞ and K, the variable t_0's from the combined data, and the "split the difference" rule for eliminating gaps and overlaps.

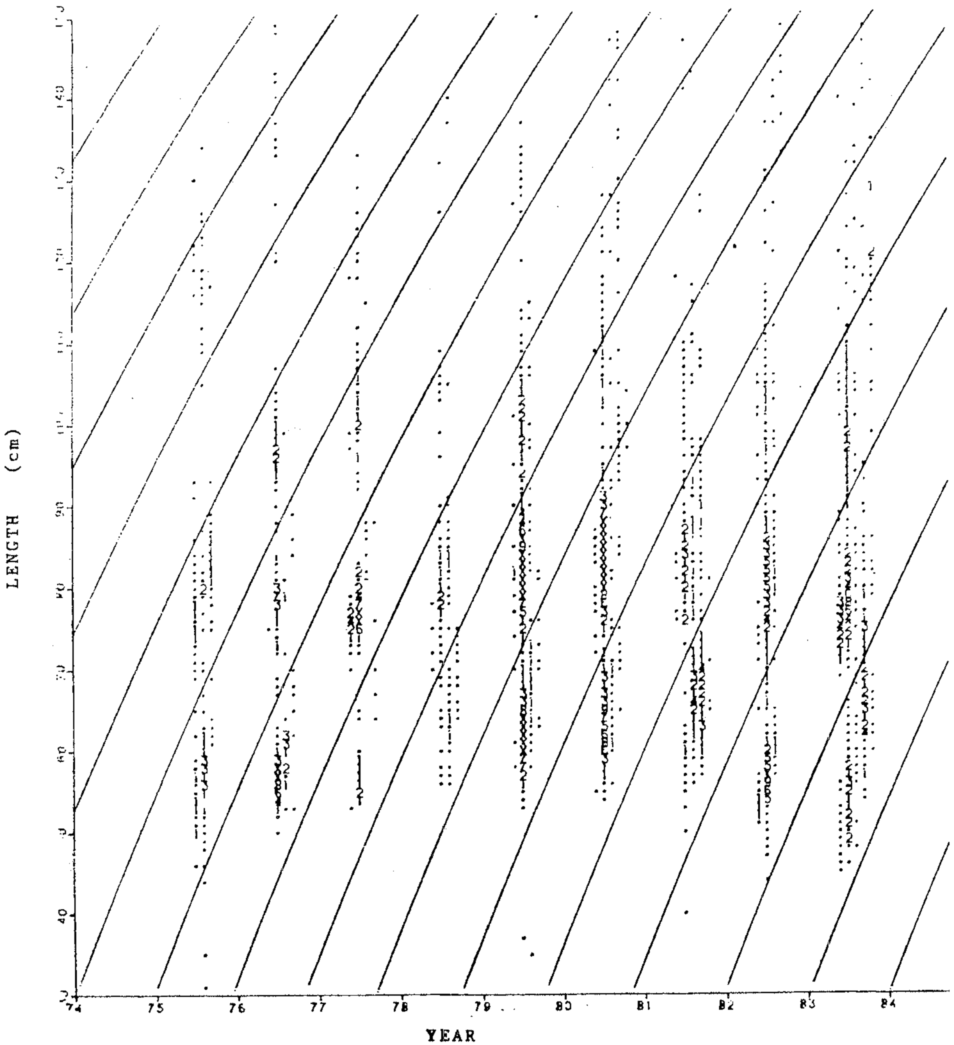

Figure 7. Length vs. time of capture from USA rod and reel, and Canadian and USA purse seine data combined. Diagonals are now the adjusted boundaries between cohorts, as in Fig. 6. (Includes 1962 US purse seine samples not shown in Fig. 4.)

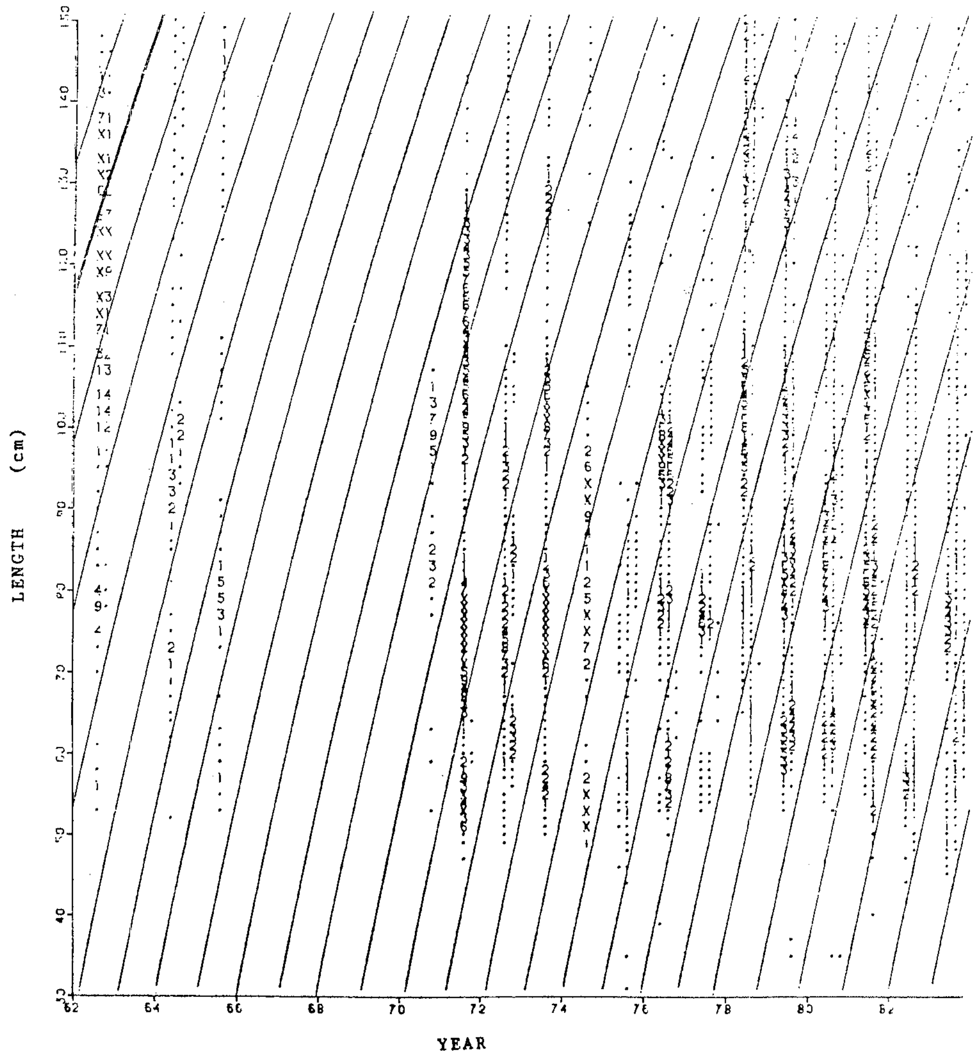

Figure 8. Estimates of age 1 stock sizes for the Western Atlantic, from Powers *et al*. 1983.

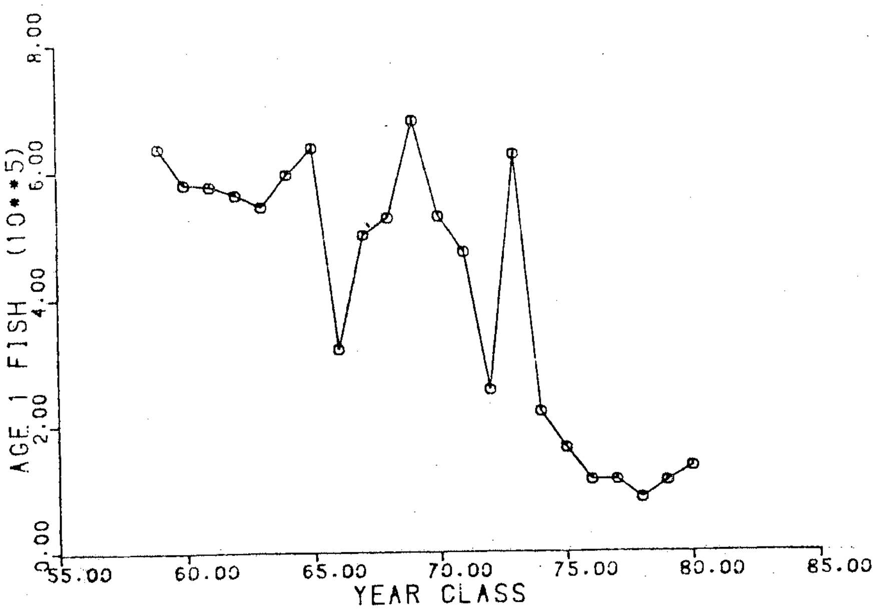

Figure 9. Estimated t_0 vs. age 1 stock size.

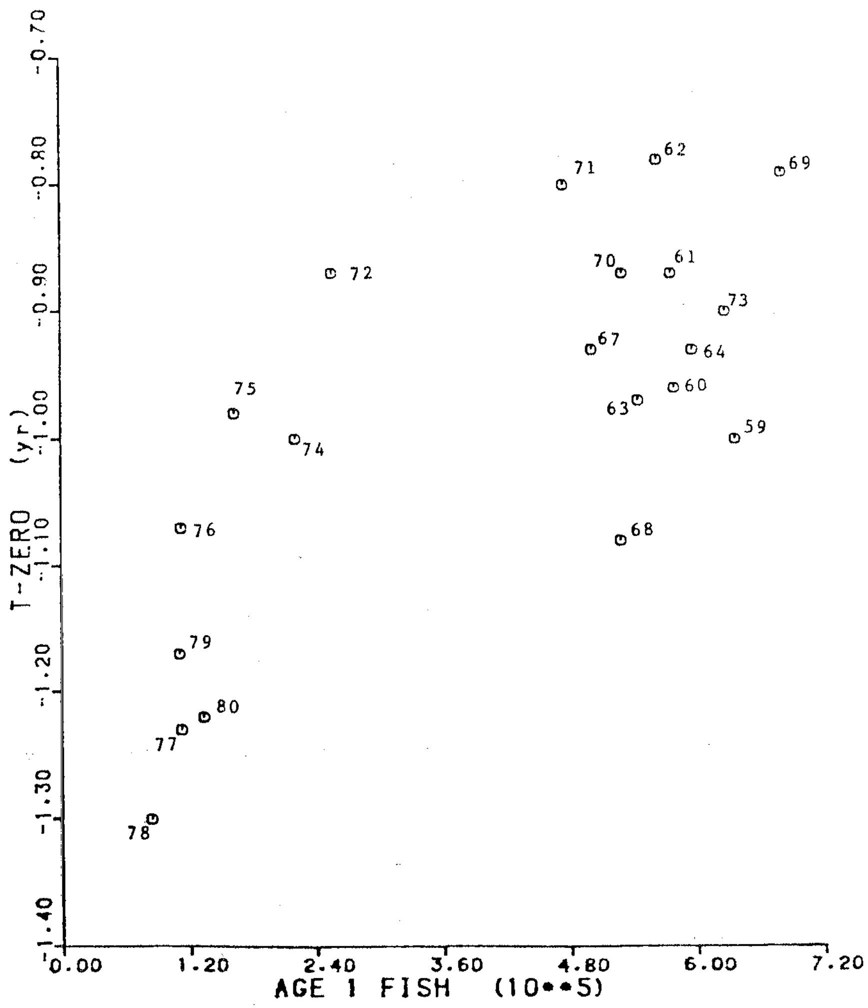

Figure 10. t_0 estimated from all available rod and reel data vs. t_0 estimated only from age 1 rod and reel data.