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A GROWTH MODEL FOR *NEPHROPS NORVEGICUS* FROM BISCAY BAY IN FUNCTION OF PERIODICITY OF MOULT

by

Gérard CONAN

CM 1975/K : 10

SUMMARY.

Size frequency distributions, proportion of soft individuals and proportion of berried females were sampled in *Nephrops* commercial landings from Biscay Bay between April 1970 and April 1971. Age classes II to V yield most of captures. During fishable life span male and female Norway lobsters would moult in Spring ; in Autumn all males and age II females would moult again. Females become mature at end of age II and spawn there on every year, skipping Autumn moult while incubating. Von Bertalanffy curves were fitted to data of modal or mean carapace sizes referred to age at Spring and Autumn moult ; regression equations are $L = 116.91(1-e^{-0.077(t+0.438)})$ for males and $L = 56.04(1-e^{-0.1785(t+0.435)})$ for females, where L is carapace length in mm and t age in years. Regression equations for weight in grams versus carapace size in mm are $W = .00039\ L^{3.18}$ for males and $W = .00081\ L^{2.97}$ for females. A computer model simulates variation of mean size and mean weight growth rates in function of relative increase in size at moult and periodicity in rate of moulting.

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A growth model for *Nephrops norvegicus* from Biscay Bay in function of periodicity of moult+

by

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Usual methods for estimating growth are unsuccessfull when applied to Norway lobster ; individuals are not directly ageable and progression through time of modes in the size frequency distributions is not readily interpretable. Present work deals with a growth model based on interpretation of life cycle of Nephrops.

MATERIAL AND METHODS.

From April 1970 to April 1971, size frequency distributions were sampled twice a month from nothern Biscay Bay boat landings, randomly selected at harbour "Le Guilvinec". Number of soft individuals and berried females were recorded for each .5 mm size class.

A Fortran program was written for computing, printing and plotting relative size frequency distributions resulting from stratified samples regrouped over any selected time period. Component age groups were separated from total size frequency distributions by Hasselblad's technique (1966) as programmed by Tomlinson (1970). Von Bertalanffy's equations were ajusted by least square regression without linear transformation (Tomlinson and Abramson, 1961).

RESULTS.

Regression of Weight versus carapace size yielded the equations $\mathrm{Log}_e\ W = -3.407 + 3.184\ L$, for the males, and $\mathrm{Log}_e\ W = -3.093 + 2.973\ L$ for the females (weight is grams, length in millimeters). Differences significant at 95% level were found between sexes by F test both for slope and position of regression lines.

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Seasonal variations of sex ratio and proportion of berried females are presented in Fig.1. During July, August and September a well marked peak period in the proportion of berried females is reached (up to 75%) ; it is likely that reproduction period is sharply defined and thus distinct age groups should exist within the population. Proportion of females, as shown by sex ratio, decreased in catch along with disappearance of berried individuals and stabilized around 35% from October to December.

Size frequency distributions were regrouped in wide time sequences corresponding to described seasonal variations (Fig.2). During July and August a very high, nearly constant, proportion of berried females is present in all size classes. From September to November smaller size classes are recruited ; in smaller size classes proportion of berried females is small or null. During Winter months distributions are unimodal. They correspond to the recently recruited size classes ; very few berried females are caught. From February to April large size classes of females reappear ; these females are no longer berried.

Seasonal variations of the proportion of "soft" individuals are presented in Fig. 1. Classifying in category "soft" permits a quick diagnosis for individuals in intermolt stages D_4, E, A_1, A_2, B_1, B_2 (Drach, 1939 ; Drach and Tchernigovtzeff, 1967). 3 maxima were reached by the proportions of soft individuals among males and among females ; these peaks are likely to correspond to periods of high moulting activity. During April, May and June 1970 (Fig.2), and later during February, March and April 1971, all size classes of both sexes seem to be uniformly affected by moulting; while during September, October and November 1970 all size classes of males, but only smaller, recently recruited, size classes of females, contain individuals in the state of moulting.

For analysing the size frequency distributions, it was taken into account that during moult periods, each age group yields two subdistributions : one is produced by individuals in premoult stages C, D, E, which have not yet grown, the other by individuals in postmolt stages A and B which have already grown in size. Number of components in sampled distributions is thus variable ; the modes may double in number during molt periods, or even be fully concealed when the distance between means of subdistributions is slight compared with their standard deviations.

Equations for relative increase in size at moult (Thomas, 1965) were used in order to estimate the number of moults which separated successive modal or mean sizes during intermoult periods. Starting from smallest detectable modal size, hypotheses using 1, 2, 3 and 4 moult increments were tested

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for reaching next mean sizes of component subgroups in the S.F. distributions of Fig.3. Expected size frequency distributions were adjusted to the observed ones by Hasselblad's technique. Best fit solutions suggest that the first two subgroup mean sizes are separated by two moults in the size frequency distributions of the males, and by one in the size frequency distributions of the females. Results of size frequency distribution analysis are presented in table 1.

SYNTHESIS

- Life cycle.

Two periods of moult per year are likely to exist, one in Spring, the other in Autumn. In this case 2 Spring moults would be represented in Fig. 1 ; a cycle of 3 molts per year is unlikely since distances between mean sizes of age groups would not be explainable.

Best interpretation would be that 4 age groups yield most of the catch of *Nephrops*. Young individuals are recruited in Autumn at a mean size of 21 mm ; 4 years later males reach 45 mm by means of 2 moults a year, and would possibly there on moult less frequently, at the same age females reach 39 mm after moulting twice the first year, and from then on only once every Spring.

About 9 months after recruitment, most of females would spawn ; they would remain in berry until the next Spring[1], thus skipping Autumn moult, but would become progressively unavailable to trawl fishery at end of Summer[2]; next they would reapper in catch in early Spring, after hatching of brood and would moult and spawn again before end of Summer[3, 4].

- Growth interpretation.

In order to evaluate parameters of von Bertalanffy growth equations, each estimated modal or mean size in a cohort was referred to the age at start of the moult period which had originated it. For non recruited age groups size frequency data from Hillis (1972) were used ; smallest mode in these distributions is at 4 mm carapace length corresponding to 12 mm total length

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1) Figueiredo and Thomas (1967) indicate that period of berry is of six to seven months ; in Portuguese waters spawning is in August, hatching in February.

2) Rice and Chapman (1971) found that berried females show tendency for burrowing, thus being less easily caught by trawl.

3) Thomas (1964) shows, on basis of ovary maturity that 90% of females spawn annually in Scottish waters.

4) Figueiredo and Barraca (1963) state that shortly after spawning a new set of eggs begins to develop in ovaries of berried females so that spawning will again take place in ensuing summer.

(O'Riordan, 1964) ; compared with mean size of first post larval stage this is 3.5 mm less than indicated by Figueiredo and Thomas (1967) after Santucci (1926) and 1 mm more than indicated by Jorgensen (1925) ; Poulsen (1946) estimated that pelagic larval stages last 2 to 3 weeks, thus the 4 mm mode was attributed to age group 0 born during preceeding Spring. The set of data taken from Hillis and the one collected from Biscay Bay, were fitted together by trial and error, using least square analysis ; in the trial time lags of 0 and one year were ascribed between the two sets, the no time lag hypothesis was finally retained for both sexes. *Nephrops* would be recruited at age II, and their growth equations would be $L = 116.91\ (1 - e^{-0.077\ (t\ +\ 0.438)})$ for the males or $L = 56.04\ (1 - e^{-0.1785\ (t\ +\ 0.435)})$ for the females. In strict acceptance these curves should only be used for finding out mean individual sizes reached at each moult period ; in between these time points growth is either null during intermoult periods, or is a function of instantaneous rate of moulting and mean relative increase in size at moult during moult periods.

- Computer simulation of growth :

A model was designed for retracing age group growth in mean size and mean weight. Size frequency distribution is first calculated, and then converted to a weight distribution by applying weight-lenght relationship to median sizes of size classes ; ultimately weighted averages of size and weight distributions yield the estimates of mean size and mean weight. The model is applied independently to each sex.

Initial size frequencies at recruitment, f(L), are assumed to be normally distributed. Distribution mean is calculated by applying von Bertalanffy equation to the age at moult preceeding recruitment ; standard deviation σ is obtained by Hasselblad's technique from youngest fully recruited age group in the catch. f(L) is divided into 14 size intervals equal to $\sigma/2$; a discreet distribution F(L) is substituted by integrating f(L) over each interval.

$$F\ (L_m) = \int_{L_m - \sigma/4}^{L_m + \sigma/4} f(L)\,dL$$

L_m is the median size of $m^{th.}$ interval, $1 < m < 14$

Mean relative increase in size r is calculated for each moult period as ratio of mean individual sizes ($\overline{L}_n$, $\overline{L}_{n-1}$) reached at end of present and preceeding moult periods. Mean individual sizes are calculated from von Bertalanffy equation.

$$r = \overline{L}_n / \overline{L}_{n-1}$$

Proportion P_τ of individuals having moulted at time τ of a moult period is estimated by integrating instantaneous relative rate of moulting ρ (t) from t_o start of moult period, up to τ (fig. 4).

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$$P_\tau = \int_o^\tau (t).dt$$

$\rho(t)$ is derived from S(t), proportion of "soft" individuals in age group. If $\rho(t)$ represents the proportion of individuals in an age group reaching stage D_4 (starting to be soft) and $\rho'(t)$ the proportion of individuals reaching B_2 (finishing to be soft), while Θ is the average time during which an individual remains soft, then $\rho'(t) = \rho(t - \Theta)$. At time τ :

$$S(t) = \int_{\tau-\Theta}^{\tau} \rho(t)dt$$

$\rho(t)$ is assumed to fit a normal curve, thus S(t) is defined by 3 parameters T (time at which greatest proportion of individuals reach D_4), σ' the standard deviation of $\rho(t)$ and Θ. An algorithm based on a polynomial approximation of the normal equation is used for modeling numerically S(t) ; T,σ' and Θ are estimated by least square fitting of S(t) to time sequence of proportions of soft individuals observed during a moult period. The sum of squares is minimized by simple iteration process.

Lets define frequency of non moulted individuals remaining in size class L_m :

$$F(L_m).(1-P_\tau)$$

and frequency of individuals having moulted and grown from L_m to $(L_m.r)$:

$$F(L_m).P_\tau$$

then mean size at time τ is :

$$\bar{L}_\tau = (\sum_{m=1}^{m=14} F(L_m).(I-P_\tau).L_m) + (\sum_{m=1}^{m=14} F(L_m).P_\tau.L_m.r)$$

Mean weight is calculated by applying weight length relationship in each size class

$$\bar{W}_\tau = (\sum_{m=1}^{m=14} F(L_m).(I-P_\tau).aL^b{}_m) + (\sum_{m=1}^{m=14} F(L_m).P_\tau.a.(L_m.r)^b)$$

Mean size growth curves obtained by this method simulate quite well observed modal sizes at age (fig. 6). However goodness of fit decreases towards older age groups which might obey to a different rythm of moulting. Mean weight growth curves can easily be integrated piece wise in a yield model by numerical methods (Ricker, 1958). For many crustacean species proportion of soft individuals in population is known to follow regular time variations ; the

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present model could possibly be adapted to other species either for modeling growth or for predicting proportion of individuals in soft, premoult or post-moult conditions in the captures.

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Table 1.

Interpretation of progression of modal sizes during sampling period.

Males

April 1970	(1)			27		33		39			47		53
May	(1)			27		33(5)	37(4)		41(4)	45(5)			53
June	(1)			27	31(4)	33(3)				45		49	
July				27		33		39		45			
August				27		35		39		45			
September	(1)	21		27		35		39		45		49	
October	(1)		23								45(3)		51
November	(1)		23		31		37				45		51
December			23		31								55
February 71	(1)		25		31					45			
March	(1)		23		29			39		45			
April	(1)		23	27	31	35		39		45			

Females

April 1970	(1)			27(4)	29(3)	33	37	41		
May	(1)			27(4)	29(3)	35(4,3)				
June	(1)			27(4)	29(3)	35	39			
July				25(2)	29(2)	33	39(4)	41(3)	45	49
August				27(2)	31(2)	35(2)	39(2)			
September	(1)	21		25(2)		33(2)	37(2)			49
October	(1)		23	25(2)						
November	(1)		23		31(2)					
December			23	25(2)						
February 71	(1)		23	25(2)	31(4,3)					
March	(1)		23	27(4,3)	31					
April	(1)			25(4)	31	33(3)	37(3)	41		
				27(3)		35(4)				

Berried females are not readily available to fishery at end of Autumn and in Winter.

(1) Months during which "soft" individuals were found in the catch.
(2) Modal sizes in size frequency distributions of "soft" individuals.
(3) Modal sizes in size frequency distributions of berried females.
(4) Modal sizes of individuals in premoult stages.
(5) Modal sizes of individuals in postmoult stages.

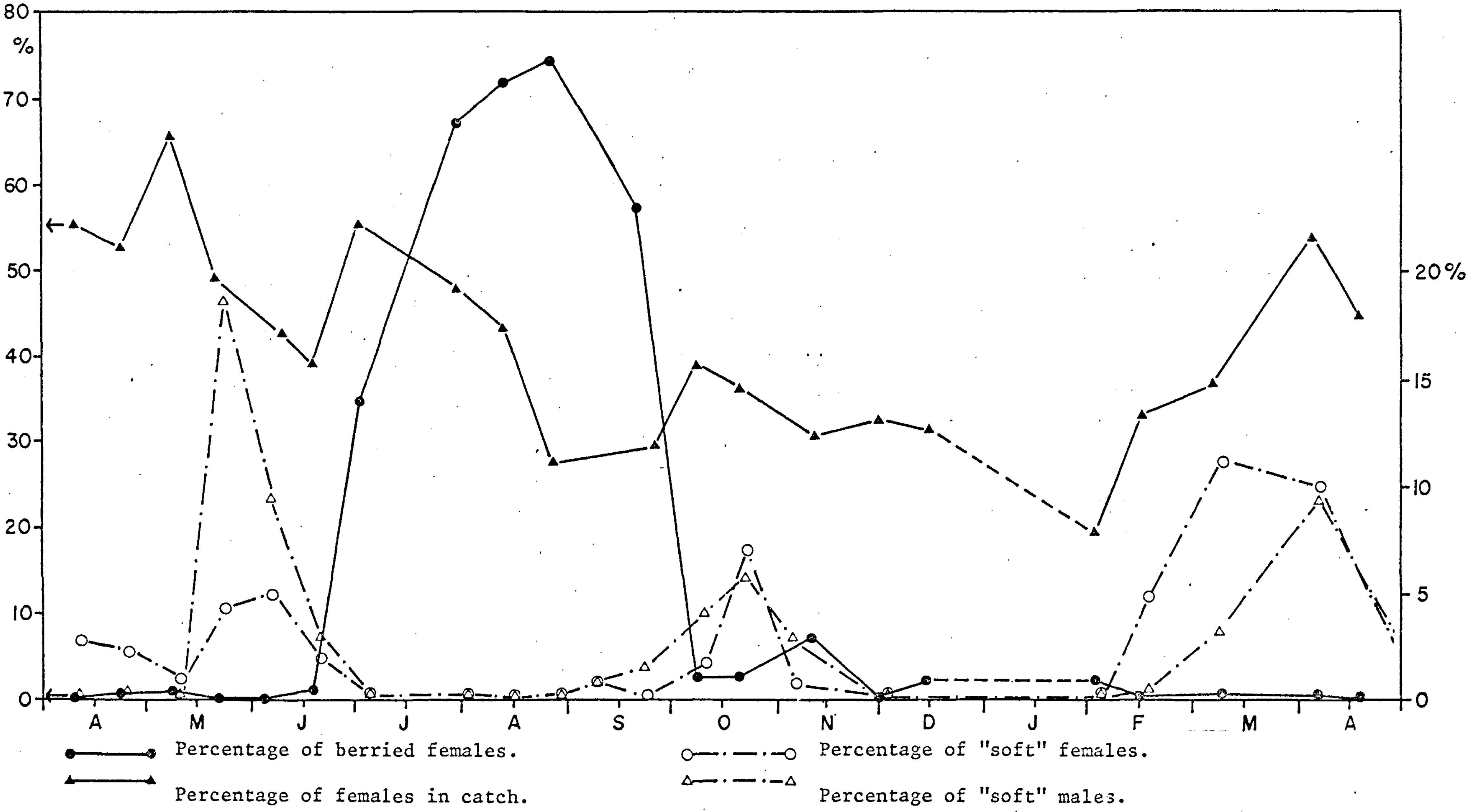
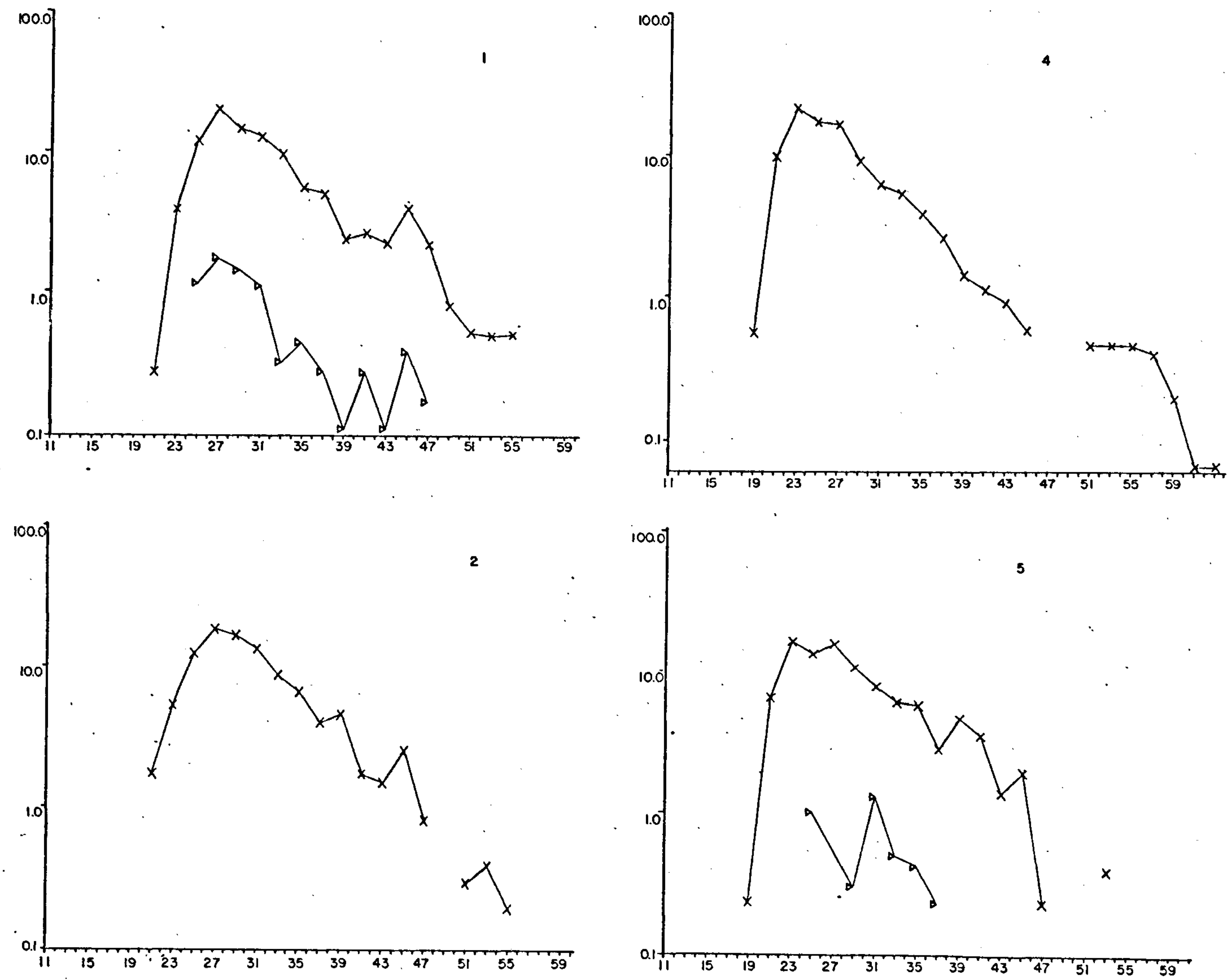


Fig. 1 Seasonal variations of parameters in catch during sampling period.



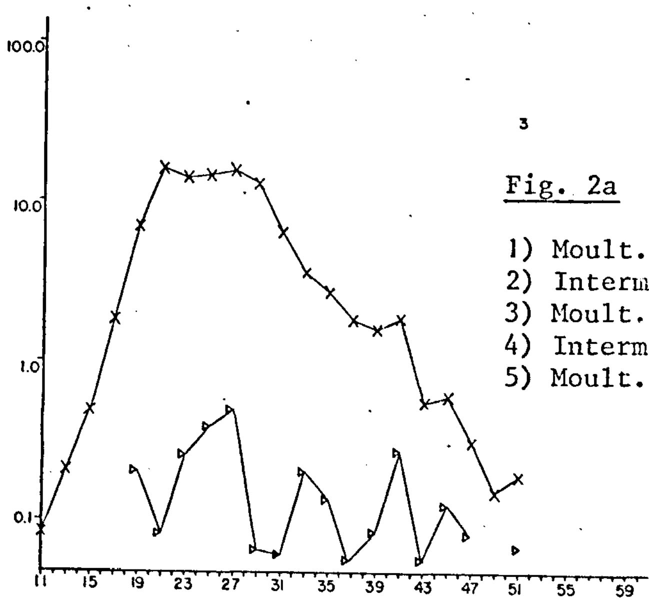


Fig. 2a Polygons for size frequencies regrouped over moult and intermoult periods. Males.

1) Moult. May 8 - June 18 1970.
2) Intermoult, egg bearing. July 2 - August 27 1970.
3) Moult. September 7 - November 11 1970.
4) Intermoult. November 30 1970 - February 1 1971.
5) Moult. February 15 - April 19 1971.

Ordinate : % frequencies Abscissa : carapace length in mm. X : total ▲ : soft

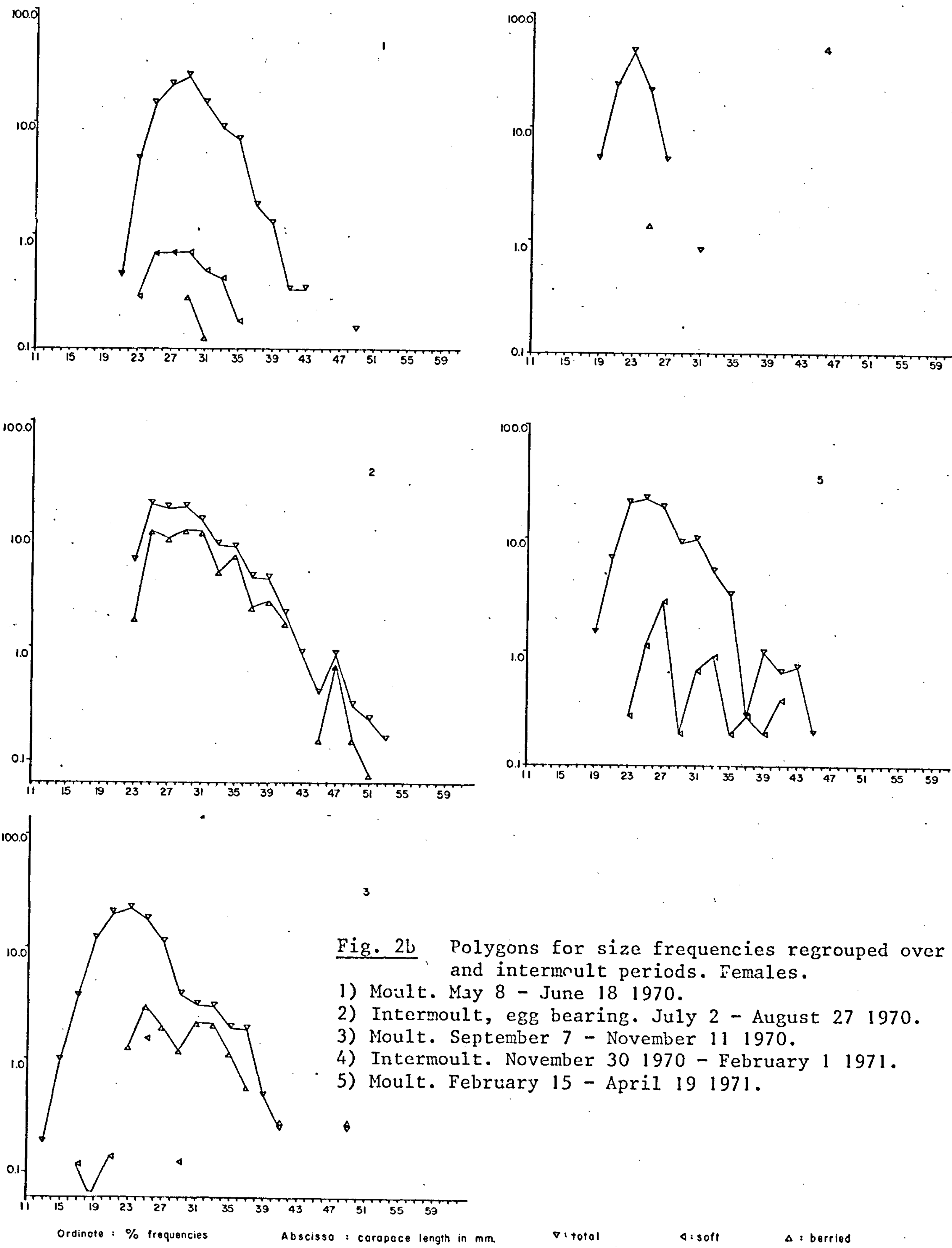


Fig. 2b Polygons for size frequencies regrouped over moult and intermoult periods. Females.

1) Moult. May 8 - June 18 1970.
2) Intermoult, egg bearing. July 2 - August 27 1970.
3) Moult. September 7 - November 11 1970.
4) Intermoult. November 30 1970 - February 1 1971.
5) Moult. February 15 - April 19 1971.

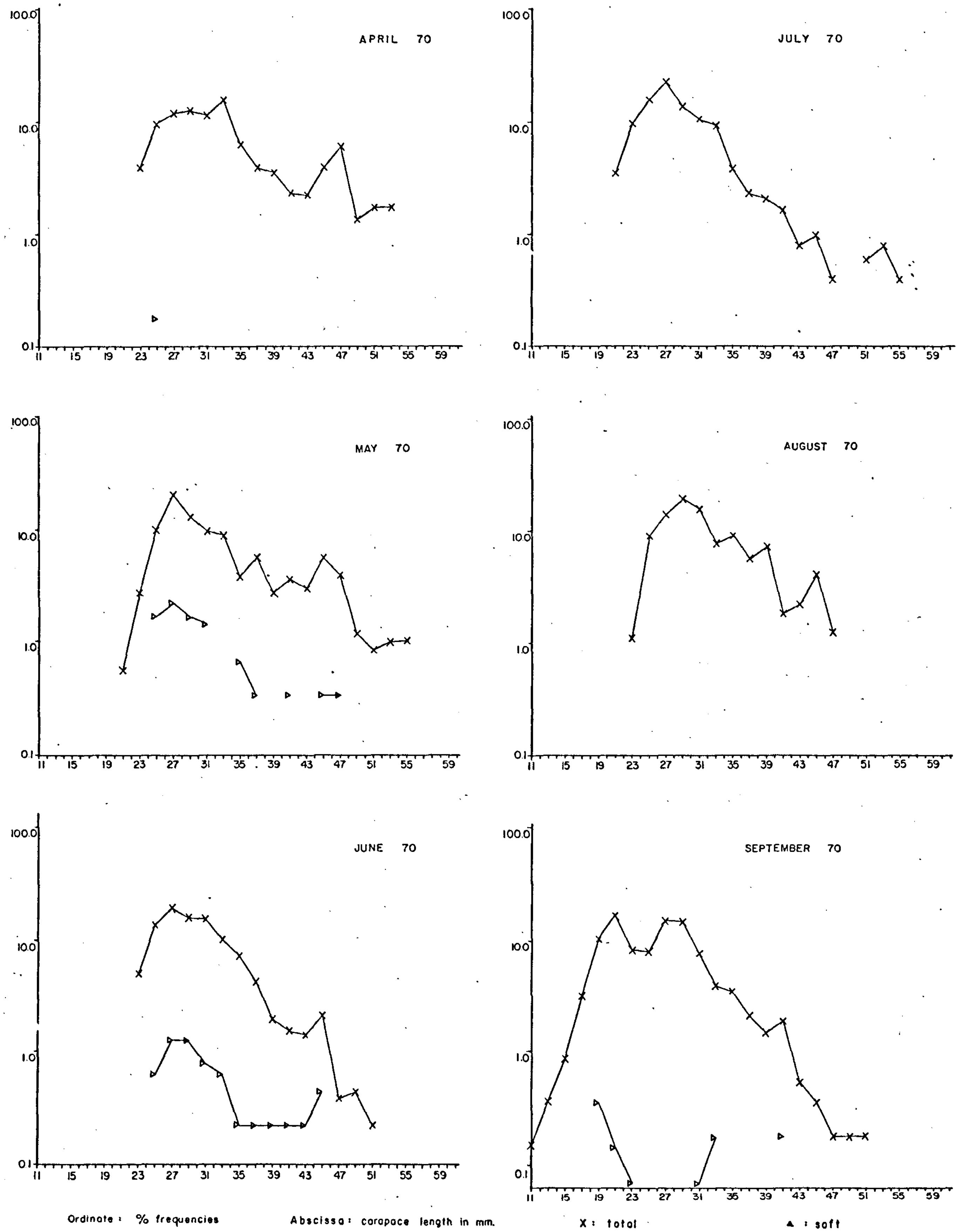


Fig. 3 Polygons for monthly regrouped size frequencies.
3a Males.

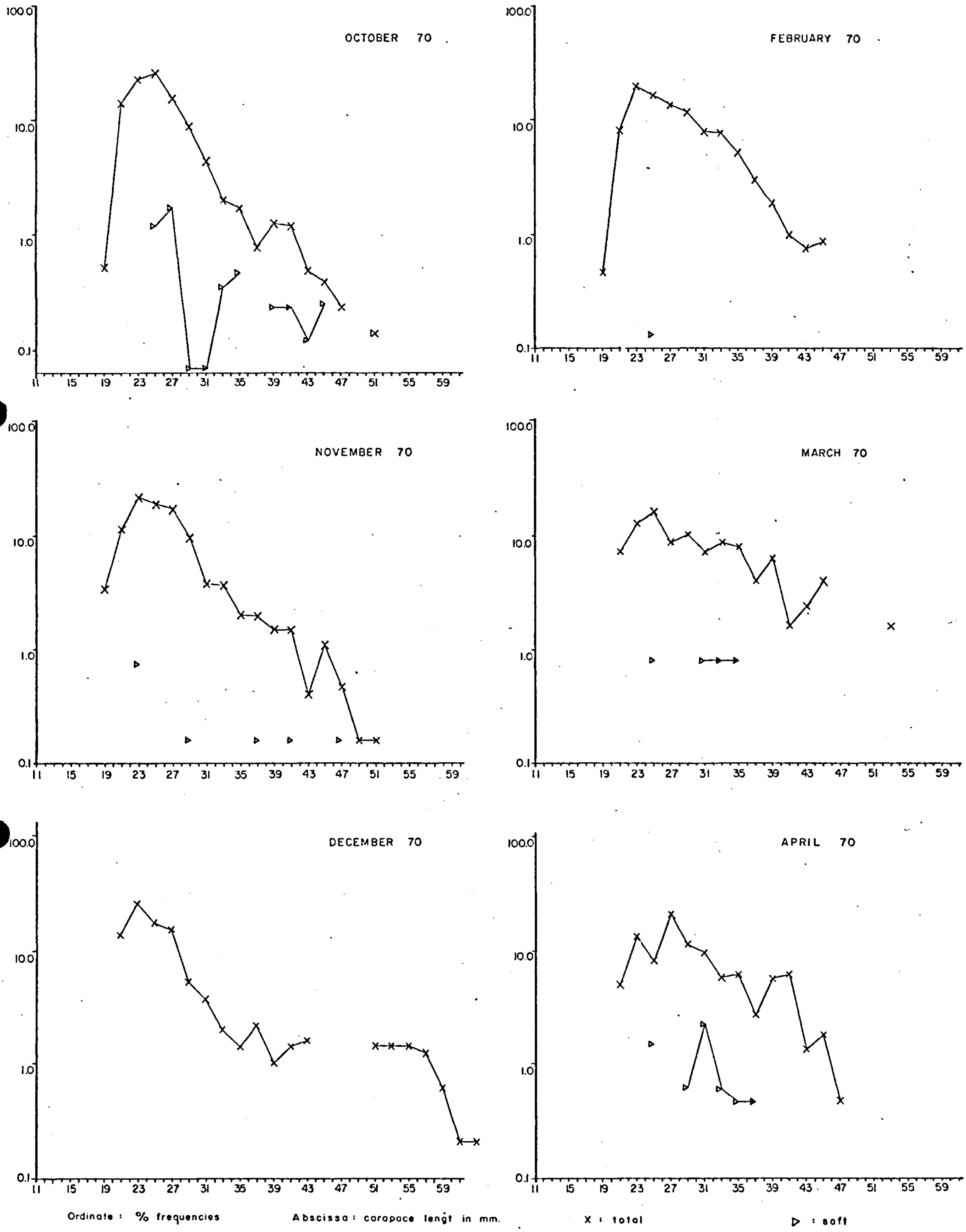


Fig. 3 Polygons for monthly regrouped size frequencies.
3b Males.

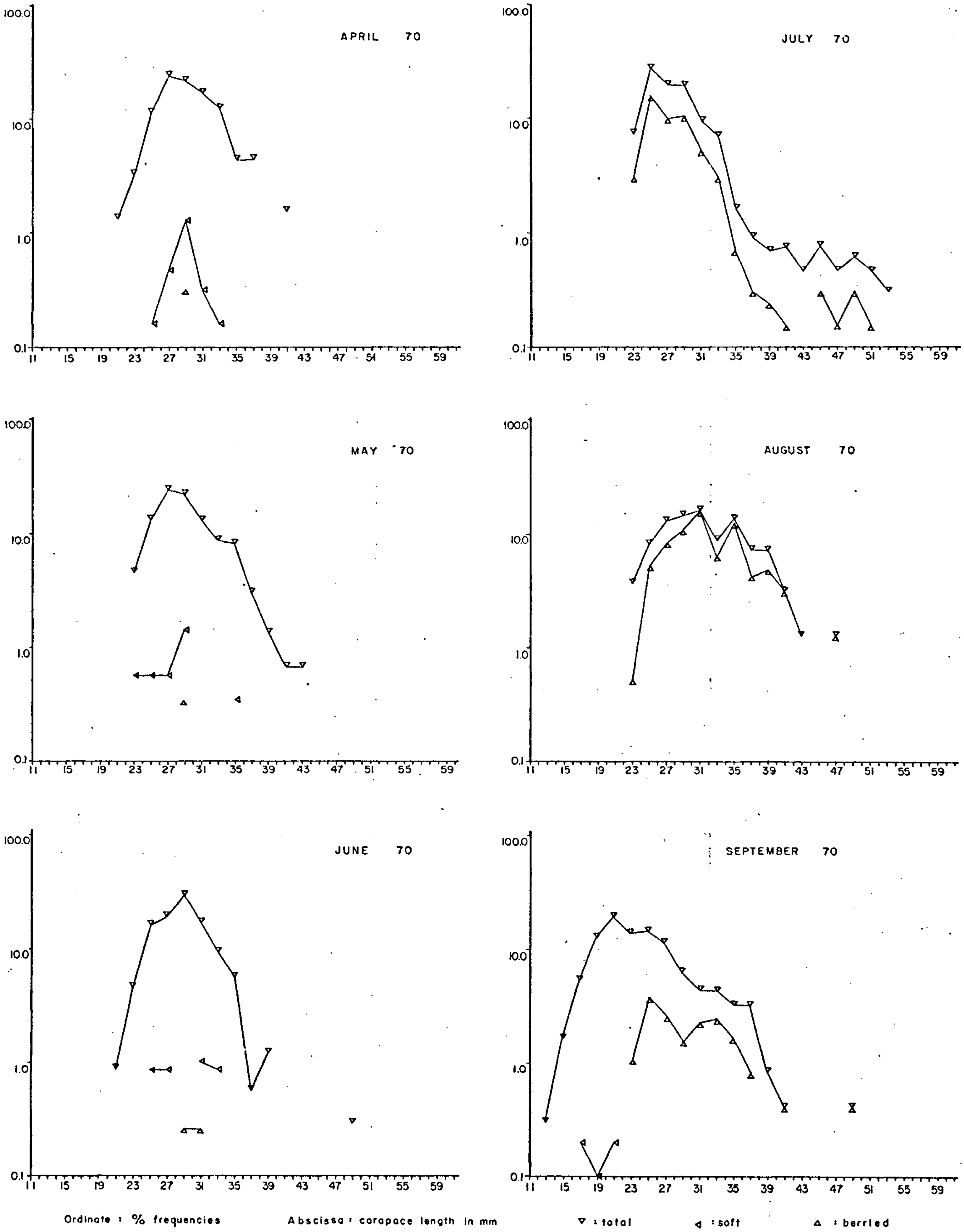


Fig. 3 Polygons for monthly regrouped size frequencies.
3c Females.

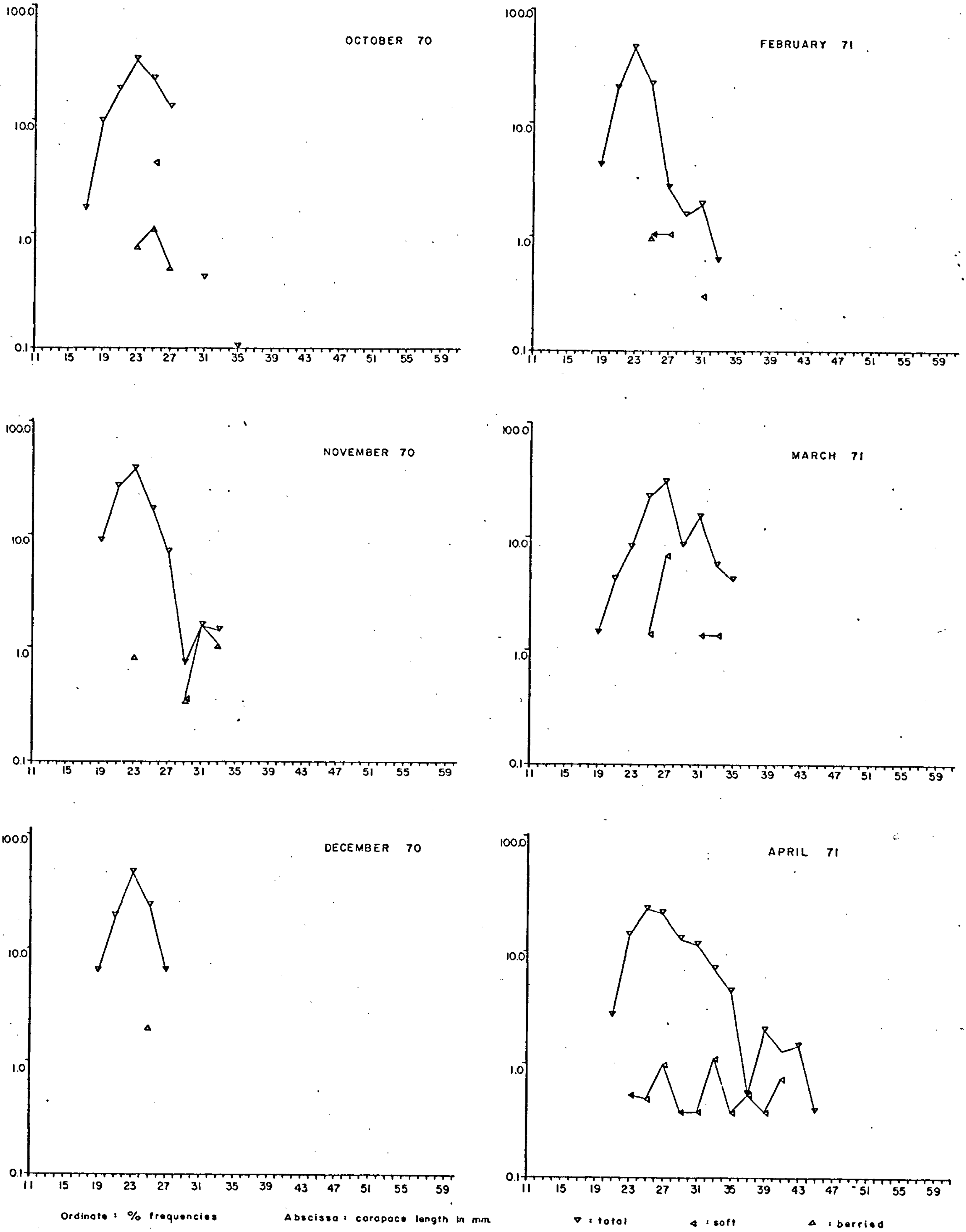


Fig. 3 Polygons for monthly regrouped size frequencies.
3d Females.

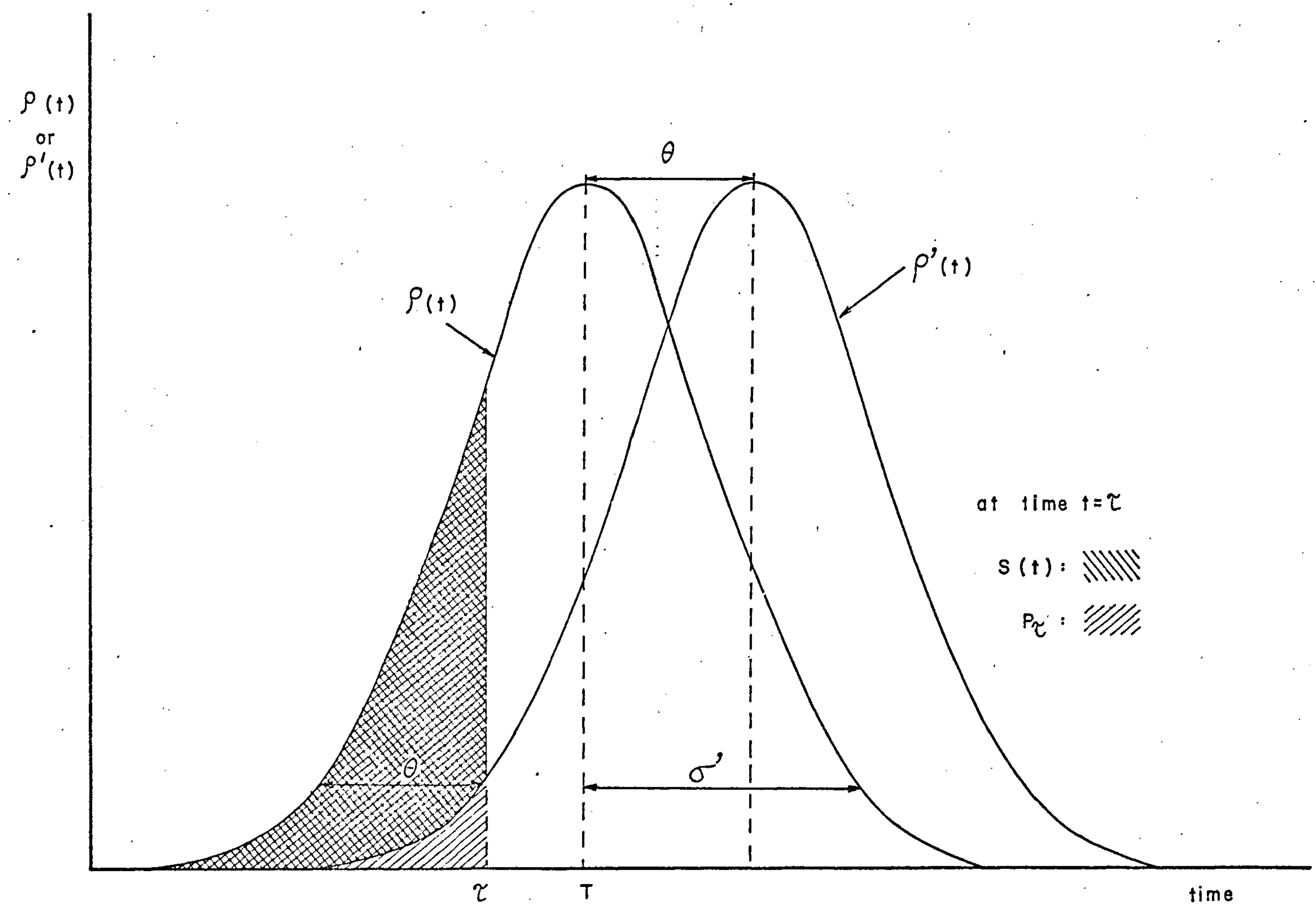


Fig. 4 Graphical representation of S(t), proportion of "soft" individuals, and of P_{τ} , proportion of individuals having moulted at time τ.
ρ (t): instantaneous relative rate of initiation of moulting.
ρ'(t): instantaneous relative rate of termination of moulting.

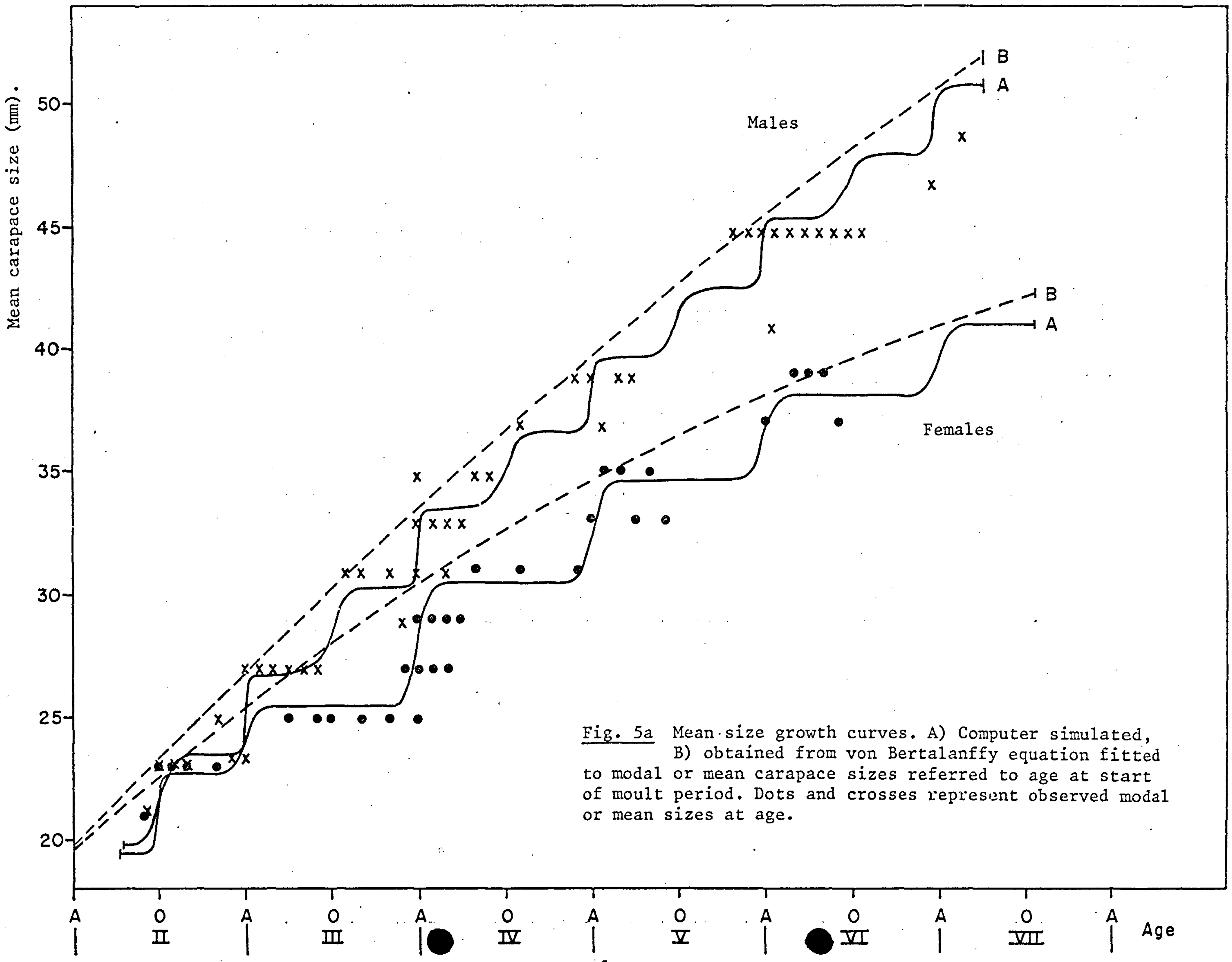


Fig. 5a Mean size growth curves. A) Computer simulated, B) obtained from von Bertalanffy equation fitted to modal or mean carapace sizes referred to age at start of moult period. Dots and crosses represent observed modal or mean sizes at age.

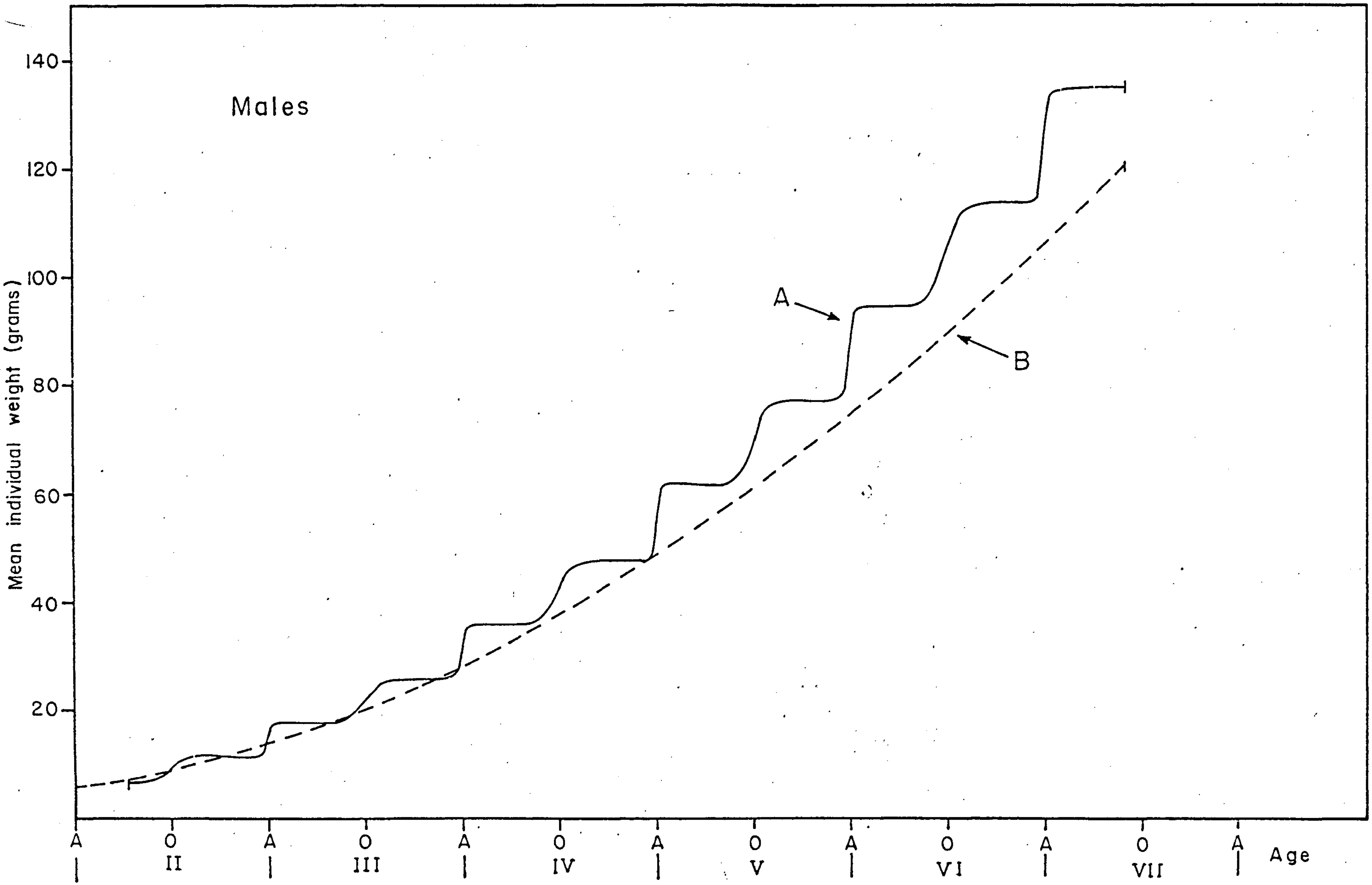


Fig. 5b Male mean weight growth curve

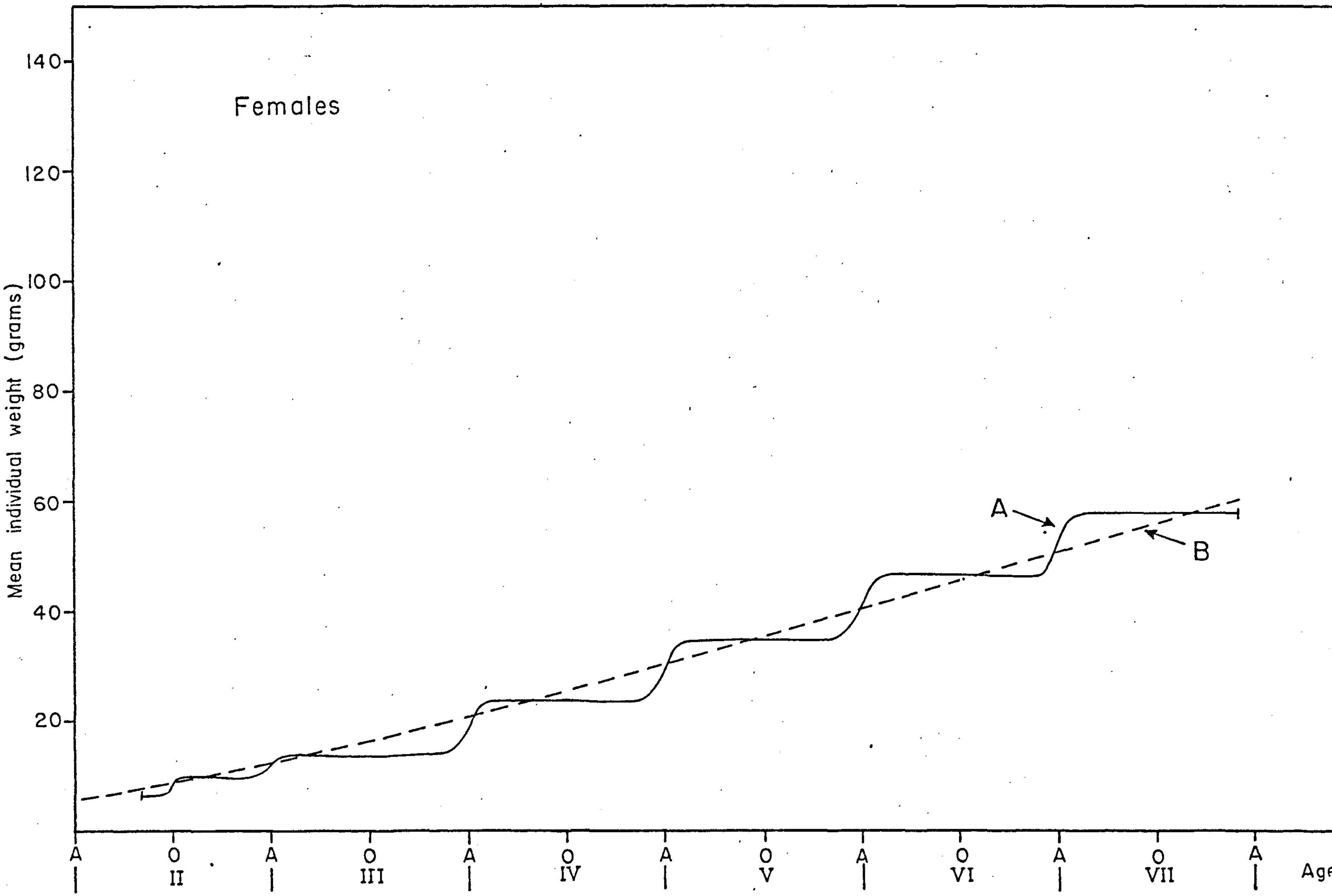


Fig. 5c Female mean weight growth curve.