INTERNATIONAL COUNCIL FOR
THE EXPLORATION OF THE SEA

C.M. 1986/G : 50
Demersal Fish Committee

Digitalization sponsored
by Thünen-Institut

THE ANALYSIS OF THE GROWTH OF TURBOT BY BACK CALCULATION OF OTOLITHS

by

P.I. van Leeuwen and A.D. Rijnsdorp.
Netherlands Institute for Fishery Investigations
P.O. Box 68, 1970 AB IJmuiden
The Netherlands.

INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

C.M. 1986/G:50
Demersal Fish Committee

THE ANALYSIS OF THE GROWTH OF TURBOT BY BACKCALCULATION OF OTOLITHS

by

P.I. van Leeuwen and A.D. Rijnsdorp

Netherlands Institute
for Fishery Investigations
P.O.Box 68, 1970 AB IJmuiden
The Netherlands

Abstract

The growth of turbot in the southern and central North Sea has been studied by backcalculation of the otoliths. The age determination and backcalculations using burnt otoliths has been validated by showing that only one ring is laid down annualy between April and July, and that the backcalculated length of 1- and 2-year old turbot corresponded to the length observed in young fish surveys.

The seasonal growth of 3, 4, 5 and 6 year old turbot was studied by estimating the length increment after the formation of the last annulus. Maximal growth rates in these age groups of 2.0 - 2.6 cm per month occured during the summer. The growth rate decreased in autumn and virtually stopped in winter.

Introduction

During the routine age determination of burned otoliths of turbot and brill doubts were raised about the accuracy because of the sometimes very wide 1st annual ring observed. The otoliths are normally cut through the nucleus before age determination, but it is possible that the cut does not always go through the nucleus. In these cases the 1st annual ring will be missed and the age of the fish will be underestimated by one year. One possibility to validate the age reading of individual fish is to backcalculate the length at which the first annulus is formed and comparing this backcalculated length with the length of 1-year old fish in sea. The backcalculation technique assumes that the otolith grows isometrically with bodysize and that the rings in the otolith are true annuli.

In this paper the backcalculation technique will be described and its main results presented. Besides a validation of the ageing, the annual and seasonal growth will be analysed and discussed.

Material and methods

Market sampling data

The data used in this study were collected in 1983 and 1984. Figure 1 summarizes the number and origin of the samples analysed. Each fish sample was randomly selected in the main fishmarkets in the Netherlands and consisted of 10 individual fish of each of the four market categories. At the laboratory the otoliths were taken and the weight (10 gram), length (mm), sex and maturity stage recorded.

Fish surveys

Length distributions and otoliths were collected during two routine survey programs: the Demersal Young Fish Survey (DYFS) and a Beach Sampling Program (BSP). In the DYFS about 200 15 minutes hauls are made with a 6 meter shrimp trawl and beam trawl in the shallow coastal areas along the continental coast of the Netherlands, Federal Republic of Germany and Denmark as far north as the Skagerak. The bulk of the hauls are made in water with a depth of 3 - 20 meters. In addition the estuarine areas are surveyed with a total of about 150 hauls. The DYFS is carried out in spring (April-May) and in autumn (September-October) (for details see van Beek et al. 1980). The beach sampling program was carried out along the Netherlands coast between 5200 and 5300 North. With favourable conditions four stations were sampled each month with a 2 meter beam trawl towed by a rubber dingy. Haulduration was 10 minutes. At each station 5 hauls were taken at depths of 1, 2, 3, 5 and 7 meter. In addition pushnet hauls were taken in the surfzone at a depth of approximately 50 cm. The pushnet hauls are particulary directed for 0-group turbot and brill which live in the surfzone along the beach. The 1-group turbot live in slightly deeper water (Riley et al.1981) which is completely covered by the DYFS.

Otolith preparation

Untreated turbot otoliths appeared to be very difficult to read. Preparation of the otolith by breaking, polishing the bigger part so as to get a cut through the nucleus and burning them improved the readability of the pattern of rings considerably. (Christensen 1964,Jones 1972 and Weber 1979). The symmetrical otolith was used for age reading in about 75%, the asymmetrical in the other 25%.

Backcalculation

The burned otoliths were mounted in plasticine and were read with a binocular. The pattern of light and dark rings was drawn using a drawing mirror at a magnification of 15x. The dark band is assumed to represent the annual ring or annulus. Only the outer tips of the annuli were drawn so the maximum diameter of each annulus could be measured from the drawing with a ruler with a precision of 0.5 mm. The measurements were all taken using a single axis which formed the main axis of growth of the otolith as illustrated in figure 2.

In this paper we will call the white zone 'opaque' and the dark zone 'hyaline'. Within the opaque zone in general some small dark bands can be observed which are seldom visible around the complete otolith. These small dark bands smoothly turn into the hyaline zone without a distinct borderline. The border between the hyaline and the opaque zone is sharp and distinct. We have therefore used this most distinct border as time mark in the otolith (Fig.2).

The terminology of opaque and hyaline zones is in accordance with the general usage (Blacker 1974). The opaque zone represents the dense part in the otolith formed in the main growing season and the hyaline zone represents the transparent part formed in the other part of the year. Whether the opaque zone can be seen as light or dark band in the otolith is completely dependent on the illumination and preparartion.

The length at the time when the annulus is completed is backcalculated according the following equation:

$$BLx = ((OLx-1/2.OL1) / (OLt-1/2.OL1)) * Lt$$

BLx = backcalculated fish length at time x
OL1 = width of 1st annulus
OLx = width of xth annulus
OLt = width of total otolith
Lt = fishlength at time t
The different variables are explained in figure 2.

Results

In order to check whether the rings in the otolith of turbot are true annuli the type of edge of the otolith (opaque or hyaline) was studied in each month of the year. Figure 3 shows that a hyaline edge only occurs in one period of the year between March and August with a peak in May and June. Therefore we can conclude that the observed rings are true annuli. The formation of the annulus starts in March and already in April more than 50% of the turbot has started to form their annulus. In June the first fish with a completely formed annulus can be observed. In July already more than 50% of the turbot has finished annulus formation. On average the annulus is formed in a period of about three months. Because we have used the border between the hyaline and the opaque zone as time mark for backcalculation the backcalculated length represents the length in the beginning of July.

In the backcalculation we assume a direct proportionality of the size of the otolith and that of the fish. Figure 4 shows that their indeed exists a linear relationship between length of the otolith and length of the fish, although the functional regression line does not go through the origin. The relations do not differ between male and female turbot (Table 2).

The results of the backcalculations are presented in table 3 and in figure 5. The mean backcalculated length of 1 and 2-year old turbot can now be compared with the length frequency distributions from the young fish surveys carried out along the continental coast of the North Sea. In figure 6 we see that in July the first individuals of the newly born 0-group are found in the very shallow water along the beach. These 0-group turbot were mainly caught with the pushnet in the surfzone. In the subsequent months these 0-group turbot grows to a length between 4 and 10 cm and move to somewhat deeper water. Here they are caught in the DYFS. The disappearance of the turbot bigger than 6 cm in November and December from the beachzone is probably due to the movement of these bigger 0-groups to deeper water. In April-May the now 1-year old turbot can be recognised in the length distributions along the beach (BSP) as well as in the deeper water (DYFS). The growth of the 1-year olds can be followed in the length distributions of the DYFS were in autumn they have reached a mean length of about 20 cm. As 2-year olds in spring they have a mean length of about 24 cm and in autumn it seems that they pass the marketable size limit of 30 cm.

The backcalculated length represents the length reached between June and July when the 1st annulus is formed. In figure 7 the distribution of backcalculated lengths at the time of annulus formation (June-July) is compared with the length distribution of turbot in April-May (DYFS). and nicely corresponds to the length distributions in the surveys. Also a correspondance exists between the backcalculated lengths and survey length distribution of 2-year old turbot.

The backcalculation of fishlength opens the possibility to study the seasonality in somatic growth. The length increment between the moment of the formation of the last annulus to the present length gives us an estimate of the growth during the present growing season. The estimated growth after the last annulus is shown in figure 8 for four age-groups. Growth rate is fastest from June to October-November. From December up to April turbot nearly shows any growth in length. The mean length increment in May, June and July was calculated assuming that fish which had not yet completed their annulus had a length-increment of zero. The mean growth rate therefore will be slightly underestimated in these month because the growth of the early turbot is reduced by the zero growth of the later ones. These fish probably grow in length that will be reflected in the otolith by the growth of the hyaline zone. The average growth rate between July and November in cm per month is 1.75 cm, 1.25 cm, 1.0 cm and 0.75 cm for respectively agegroup 3, 4, 5 and 6. The growth in length of 3, 4 and 5 year olds is maximal between July and August at respectively 2.6 cm, 2.0 cm and 2.2 cm per month. A striking feature in the seasonal growth curve is the temporarily decrease in growth in September-October.

Discussion

The assumption of a direct proportionality between fishlength and otolith length does not hold completely, because the functional regression line between fishlength and otolith length does not go through the origin. Inspection of the data points in figure 4 shows that as the turbot becomes bigger the length of the otolith does not increase in the same proportion as the length of the fish but lags behind. This results in a slight increase in the slope of the regression line and an increase in the negative intercept of the Y-axis. If we look to the growth pattern of the otoliths of older turbot it appears that the form of the otolith changes slightly due to an disproportional increase of the thickness of the otolith as the fish become older. We therefore conclude that the negative intercept of the regression line of fishlength and otolithlength is caused by deviation from isometric growth in bigger turbot. For the turbot in which this deviation of a strict isometry occurs the backcalculated lengths will be slightly overestimated.

The observation that each year only one ring is formed and the close, although not complete correspondence between the distribution of backcalculated length at age 1 and 2 and the length distribution of these agegroups in the young fish surveys, validates the age determination and indicate that the backcalculation of the first annulus can be applied to correct the age determination in case of a very wide 1st annual ring.

A more precise comparison of the frequency distribution of backcalculated lengths and observed length in the young fish surveys shows that the backcalculated length distribution is shifted over about 2 cm to a bigger length in the 1- and 2-year olds. The annulus in the otolith is formed in July, whereas the young fish surveys were carried out in April-May. The shift in the length distributions reflects the growth in May and June, although the difference of 2 cm in the 1-group is more than could be expected from the monthly growth rate of 0.5 cm as observed by Jones (1973). The somewhat higher variance in the backcalculated lengths probably indicates the variance due to inaccuracies in the technique. Part of this extra variance stems from the use of only one half of the asymmetrical otoliths. Lucio (1986) showed that the asymmetrical otoliths gave a sligthly biased result in using only half of the otolith, but an unbiassed result when the total diameter was measured. In our study 25% of the otoliths used for backcalculation were asymmetric.

The growth rate of North Sea turbot as observed in this study from backcalculations corresponds to the results of Mengi (1963) and Jones (1974). The slightly larger lengths at age data presented by Rae (1972) are probably due to the ageing technique, which was not always consistent in burning the otoliths before age determination, leading to an underestimation of the age of the fish. The growth rate of female North Sea turbot reported by Weber (1979) corresponds to the one obtained in our study, but that of male was much higher. The occurence of 1 year old males in the commercial landings of the Federal Republic of Germany (minimum landing size, 30 cm) might indicate that in part of the age determinations the generally small 1st annulus has been overlooked so part of the turbot has been aged 1 year too young.

The maximal growth rate of 3, 4 and 5 year old turbot in the North Sea during summer (2.0 - 2.6 cm per month) is of the same magnitude as the maximal growth rate in fish cultivation experiments (Purdom et al. 1972, Iglesias et al. 1985). However, on an annual basis the growth rate in fish cultivaltion is higher. This is caused by the decreasing growth rate in sea in autumn and winter, which does not occur to the same extent during cultivation.

The length distribution of 1 year old turbot in the fish surveys do not differ from the distributions observed in the eastern North Sea in the beginning of this century (Johansen 1915) and from the distribution observed on the English East coast in the seventies (Jones 1972), so the growth rate of juvenile turbot has not increased as in North Sea plaice (Bannister 1978) and sole (de Veen 1978).

References

Bannister, R.C.A. 1978. Changes in plaice stocks and plaice fisheries in the North Sea. Rapp.P.-v.Reun.Cons.int.Explor.Mer 172: 86-101.

van Beek, F., R. Boddeke, R. de Clerc, G. Rauck and J.F de Veen, 1980. Young fish and brown shrimp surveys along the continental coast of the North Sea in 1978. Annales Biologique 35: 298-306.

Blacker, R.W. 1974. Recent advances in otolith studies.in Harden Jones, R. (edit) Sea Fisheries Research. Elek Science. London: 67-90.

Christensen, J.M., 1964. Burning of otolits,a technique for age determination of soles and other fish. J.Cons.perm.int.Explor.Mer 29:73-81.

Iglesias, J., M. Olmedo, J.J. Otero, J.B. Peleterio and M.R. Solorzano. 1985. On growing of turbot, Scophthalmus maximus L. in the Ria de Vigo (NW Spain). ICES C.M. 1985/F:35.

Johansen, A. C., 1915. Fuenfter Bericht ueber die Pleuronectiden in der Ostsee. Rap. P.-v.Reun. Cons. perm.int.Explor.Mer 22:1-104.

Jones, A., 1973. The ecology of young turbot, Scophthalmus maximus at Borth, Cardiganshire, Wales. J.Fish.Biol.5:367-383.

Jones, A., 1974. Sexual maturity, fecundity and growth of the turbot Scophthalmus maximus L. J.Mar.biol.Ass.UK. 54:109-125.

Lucio, P. 1986. On the methodology of length backcalculation from otoliths in flatfish, with particular reference to brill. ICES C.M. 1986/G:52.

Mengi, T., 1963. Ueber das Wachstum des Steinbutts (Scophthalmus maximus L.) in der Nordsee. Ber.dt.wiss.Komm.Meeresforsch 17:119-132.

Purdom,C.E., Jones,A. and Lincoln,R.F., 1972. Cultivation trials with Turbot (Scophthalmus maximus). Aquaculture, 1:213-230.

Rae, B.B. and Devlin, S.D.E., 1972. The Turbot, its Fishery and Biology in the Scottish Area. Marine Research 1: 1-27.

Riley,J.D., Symonds,D.J. and Woolner,L., 1981. On the factors influencing the distribution of 0-Group Demersal Fish in coastal Waters. Rapp.P.-v.Reun.Cons.int.Explor.Mer, 178: 223-228.

de Veen, J.F. 1978. Changes in North Sea sole stocks (Solea solea L.). Rapp.P.-v.Reun.Cons.int.Explor.Mer,172:124-136.

Weber,W., 1979. On the turbot stock in the North Sea. ICES C.M. 1979/G:12.

Table 1. The type of the edge of the otoliths of North Sea turbot (opaque or hyaline) in each month in 1983.

Month	Total number	Opaque-i	(%)	Hyaline	(%)	Opaquei+l	(%)
JAN	73	73	(100)				
FEB	103	103	(100)				
MAR	96	88	(91.7)	8	(8.3)		
APR	190	76	(40.0)	114	(60.0)		
MAY	171	27	(15.8)	143	(83.6)	1	(0.6)
JUN	56	4	(7.1)	46	(82.1)	6	(10.7)
JUL	198	3	(1.5)	69	(34.8)	126	(63.6)
AUG	105			9	(8.6)	96	(91.4)
SEP	115			2	(1.7)	113	(98.3)
OCT	104					104	(100)
NOV	102					102	(100)
DEC	59					59	(100)

Table 2. Regression coefficients and approximate confidence limits of the functional regression between fishlength and otolithlength for male, female and sexes combined.
Y = u + v.X with Y = fishlength and X = otolithlength

	u	95%c.l.	v	95%c.l.	R	N
males	-1.79	-0.70/-2.88	1.19	1.14/1.23	0.978	135
females	-1.17	0.84/-3.17	1.23	1.18/1.28	0.954	219
Total	-2.39	-1.37/-3.41	1.25	1.22/1.28	0.974	371

Table 3. Mean backcalculated length at age and standard deviation for turbot male and female in 1983 and 1984.

AGE	MALES N	MALES Length	MALES SD	FEMALES N	FEMALES Length	FEMALES SD
Year: 1983						
1	391	9.8	2.5	969	10.7	3.1
2	369	23.3	3.8	959	24.7	4.4
3	223	32.7	3.8	811	36.4	4.6
4	123	37.8	3.5	575	43.9	4.5
5	91	40.9	3.7	414	48.9	4.3
6	68	42.9	2.9	327	53.2	4.3
7	40	44.7	3.5	197	56.3	4.0
8	24	45.6	2.9	101	58.3	4.4
9	13	46.9	3.6	62	60.1	4.0
10	10	47.9	3.7	39	61.2	3.9
11	5	47.5	4.8	26	63.0	3.9
12	3	46.1	4.5	22	64.7	4.1
13	2	46.5	7.1	11	66.3	3.8
14	2	48.5	7.1	9	66.5	2.4
15	1	43.5		4	68.0	1.0
Year: 1984						
1	346	11.0	2.9	952	10.8	2.7
2	315	25.8	3.7	898	26.1	3.9
3	130	34.8	3.3	695	38.0	4.1
4	49	39.2	3.2	467	45.1	4.1
5	25	41.7	3.6	304	50.0	4.2
6	17	43.4	3.7	219	54.0	4.2
7	15	44.7	3.9	175	57.5	4.1
8	8	46.9	5.6	111	59.5	3.9
9	5	49.5	8.2	57	61.2	4.0
10	3	50.5	11.3	35	63.2	3.9
11	2	45.0	2.1	23	66.0	4.2
12	1	44.5		12	65.4	3.0
13				6	65.8	2.9
14				4	67.0	1.7
15				4	67.8	1.5

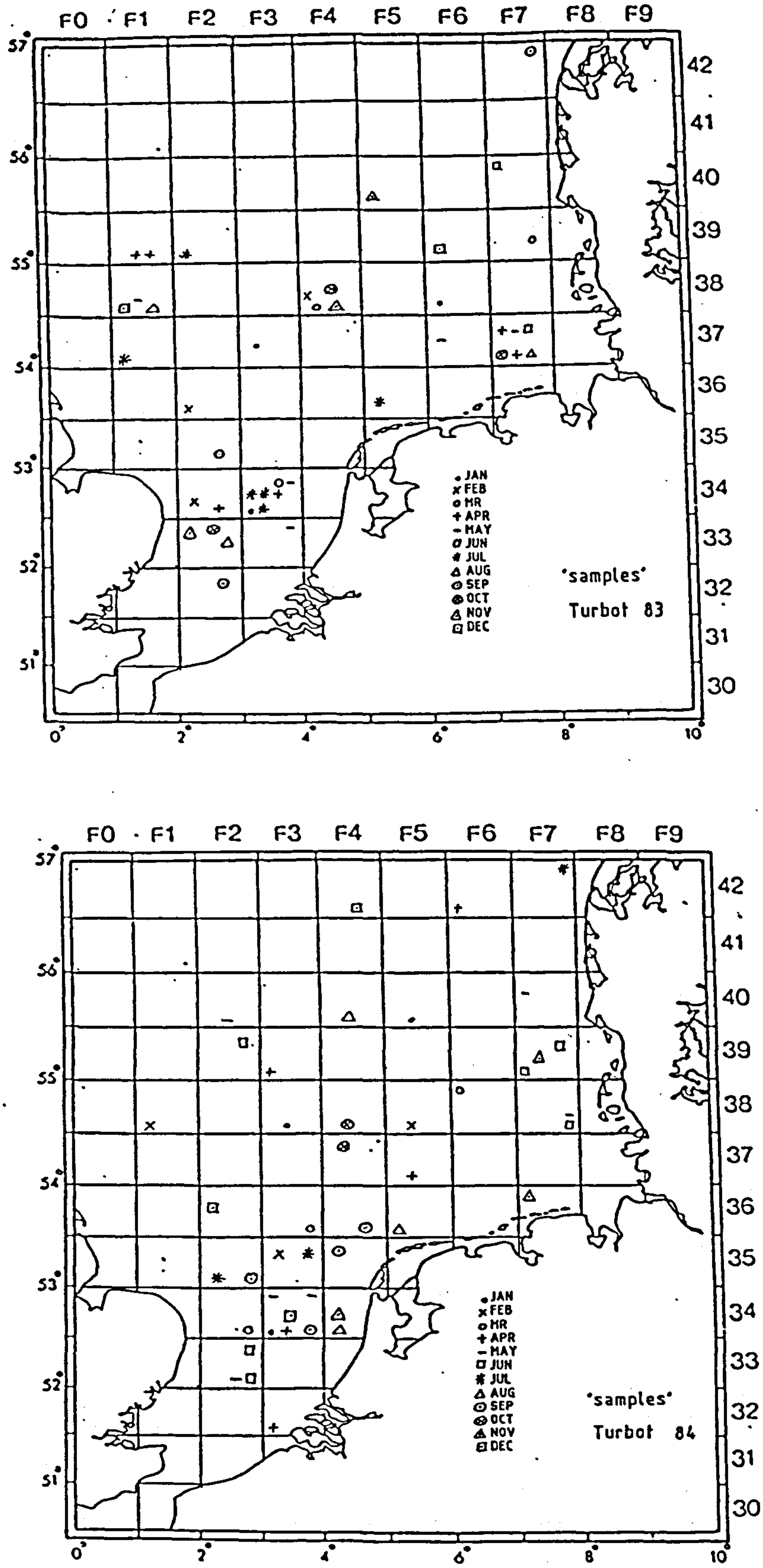


Figure 1. The origin of turbot samples in 1983 and 1984

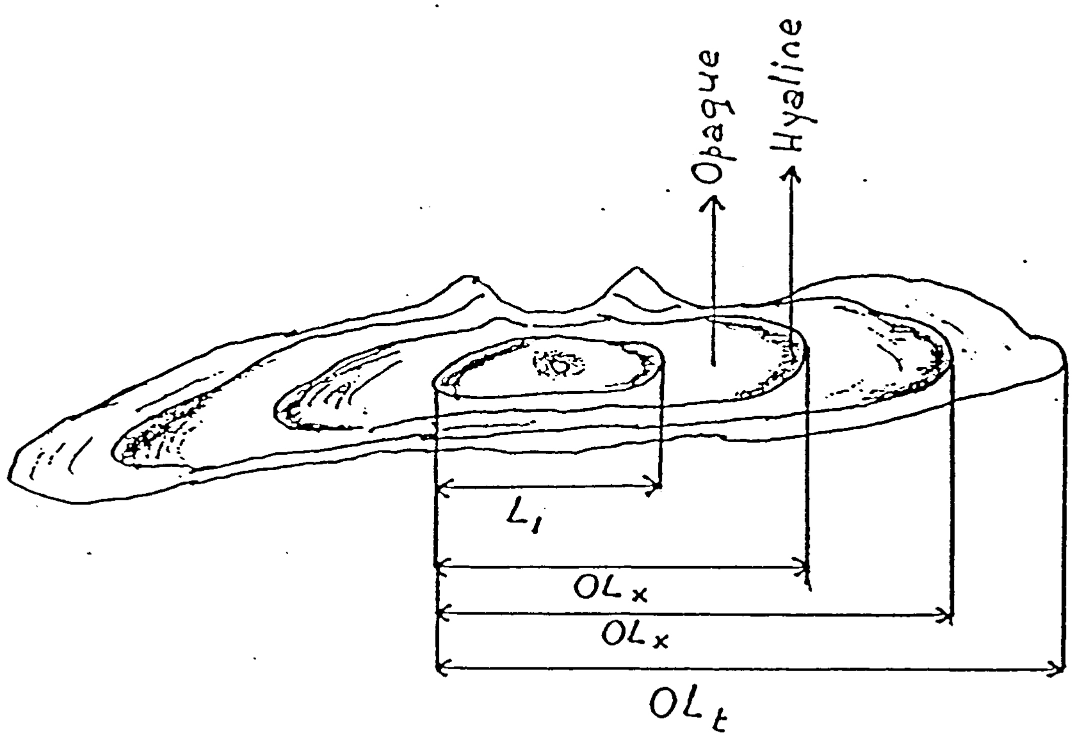


Figure 2. Section of a turbot otolith with an indication of the measures taken for the backcalculation (see text).

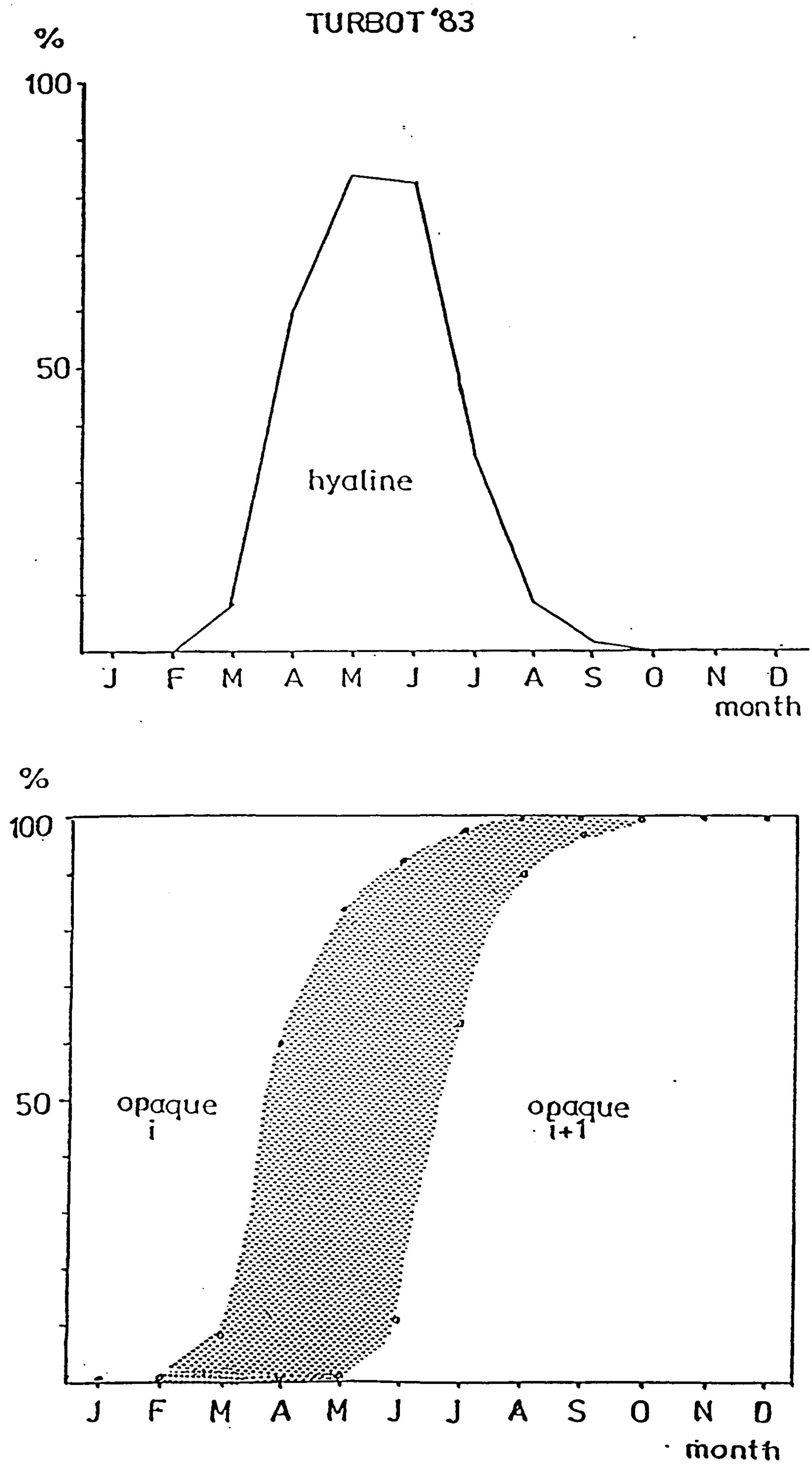
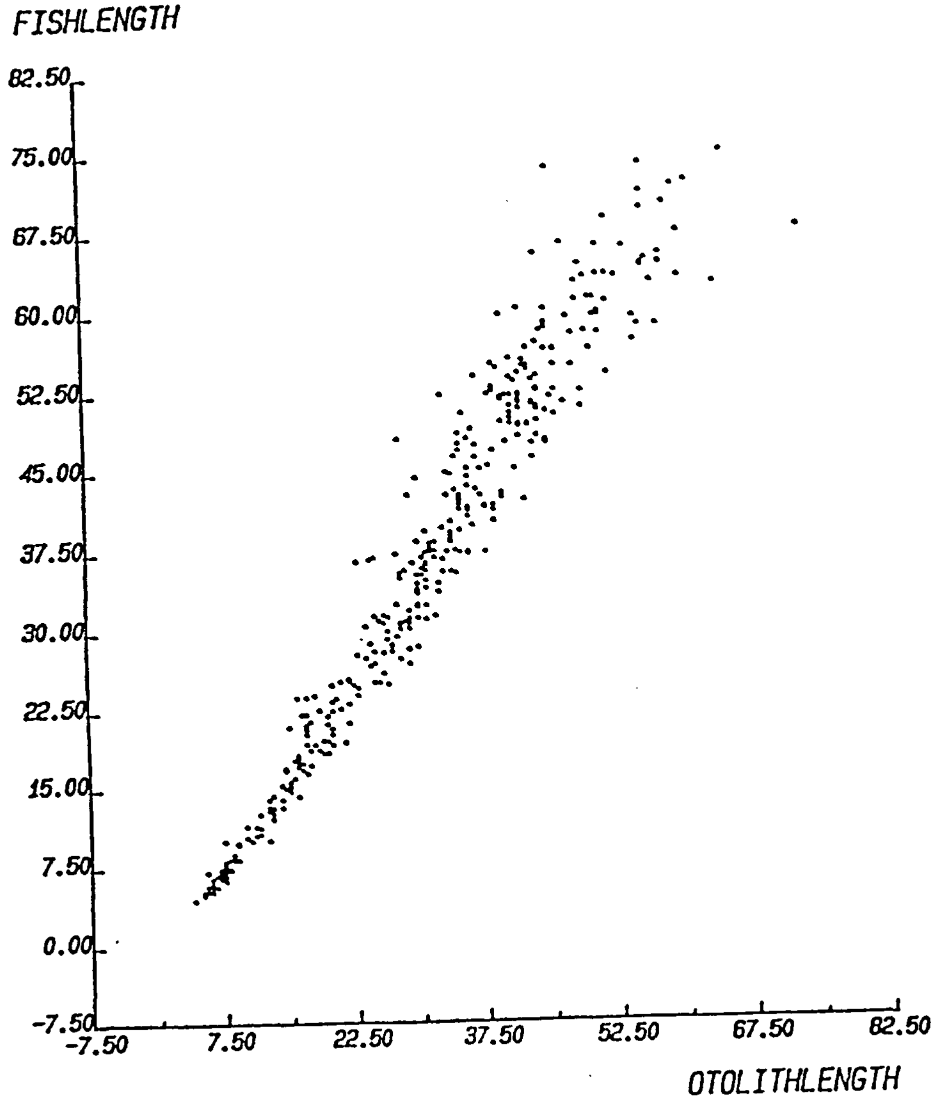


Figure 3. Monthly occurence of the hyaline edge in turbot otoliths sampled in 1983.



NORTH SEA TURBOT: Fishlength against length of the otolith

Figure 4. Relation between fish-length and otolith-length in North Sea turbot (sexes combined).

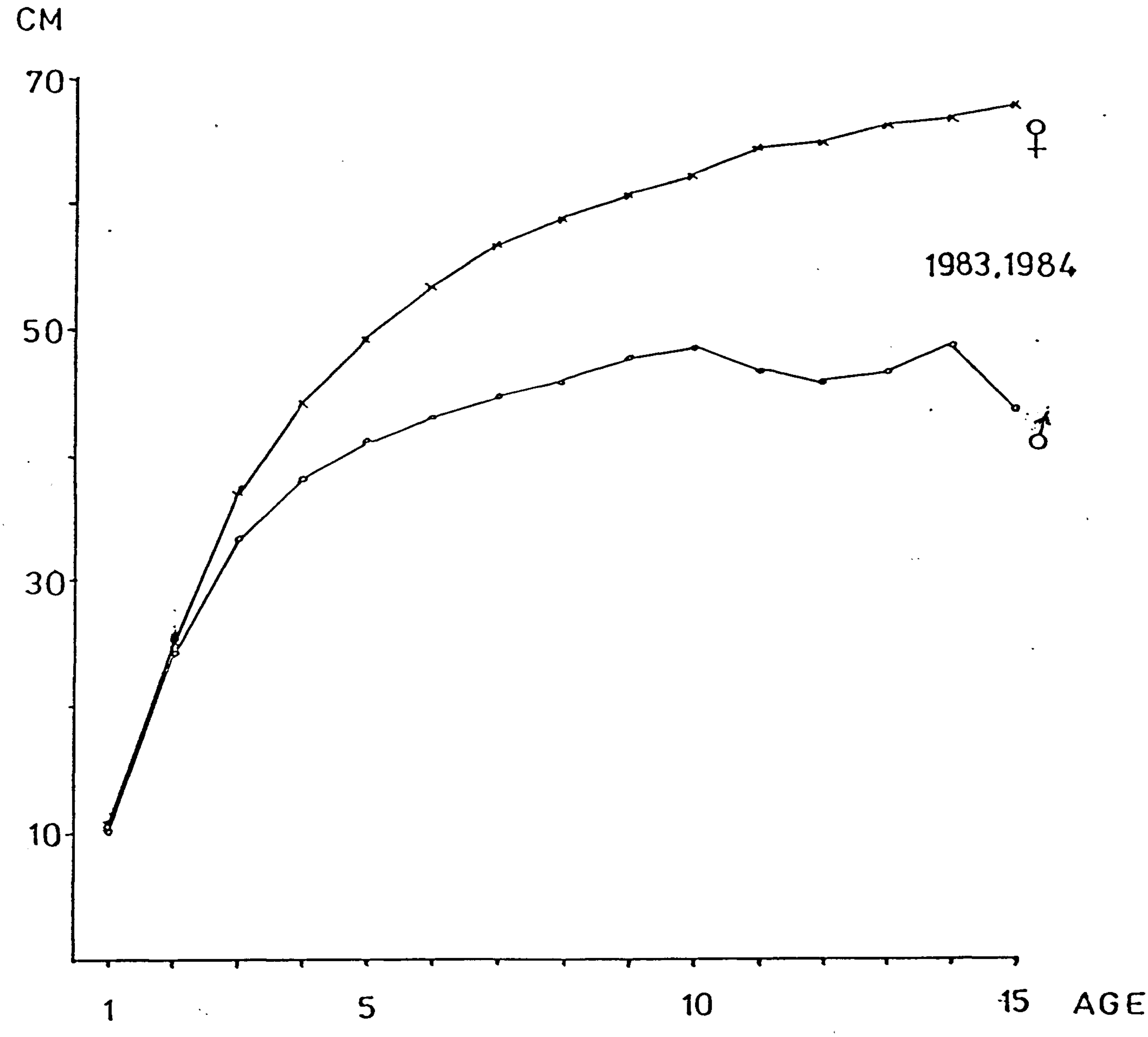


Figure 5. Growthcurve of male and female turbot as obtained by backcalculation of otolith collected in 1983 and 1984.

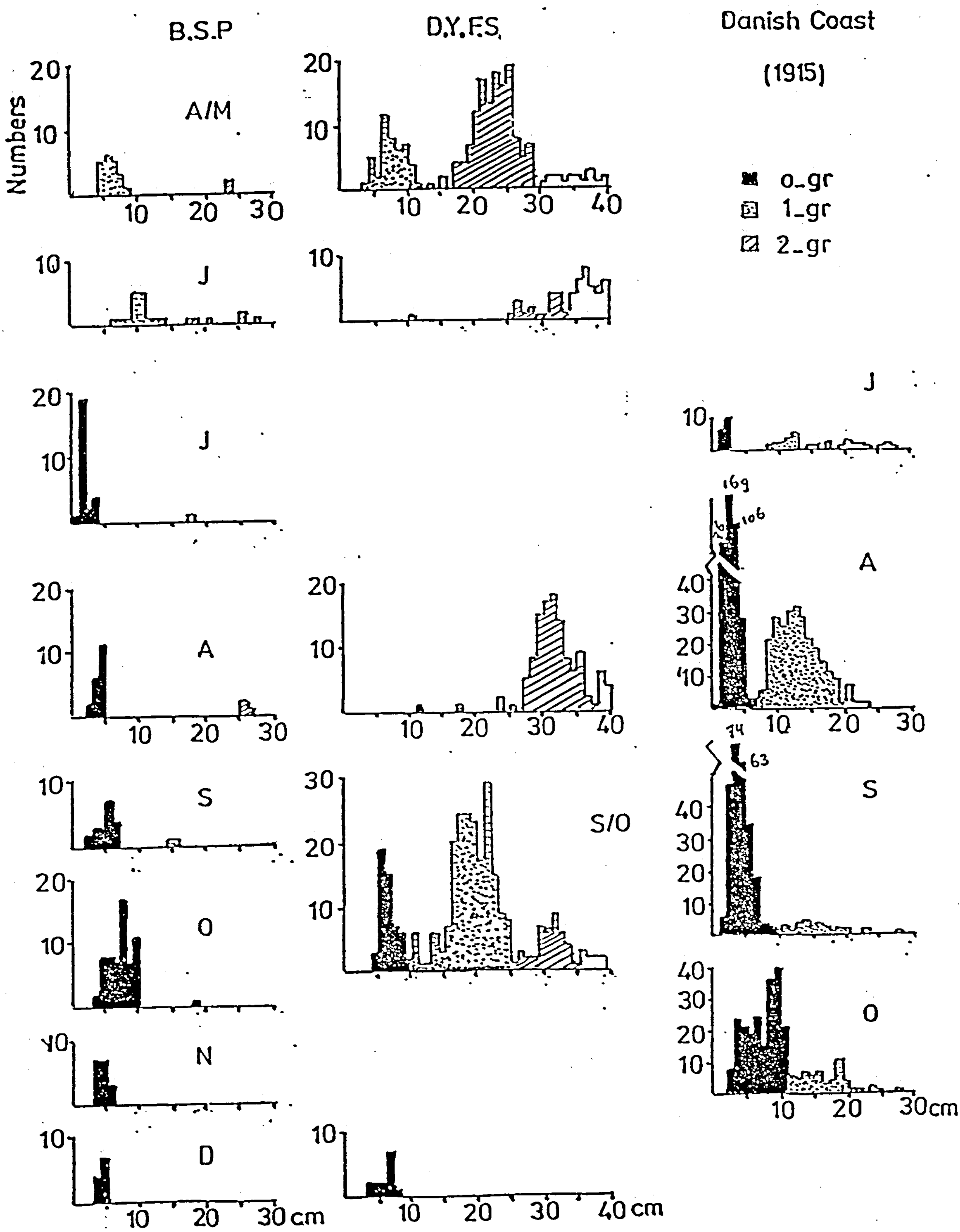


Figure 6. Lengthdistribution of turbot caught in the Beach Sampling Program (BSP), and the Demersal Young Fish Survey (DYFS) in different month between 1975 and 1985. The present length distributions are compared to those collected in the beginning of the century (Johansen 1915).

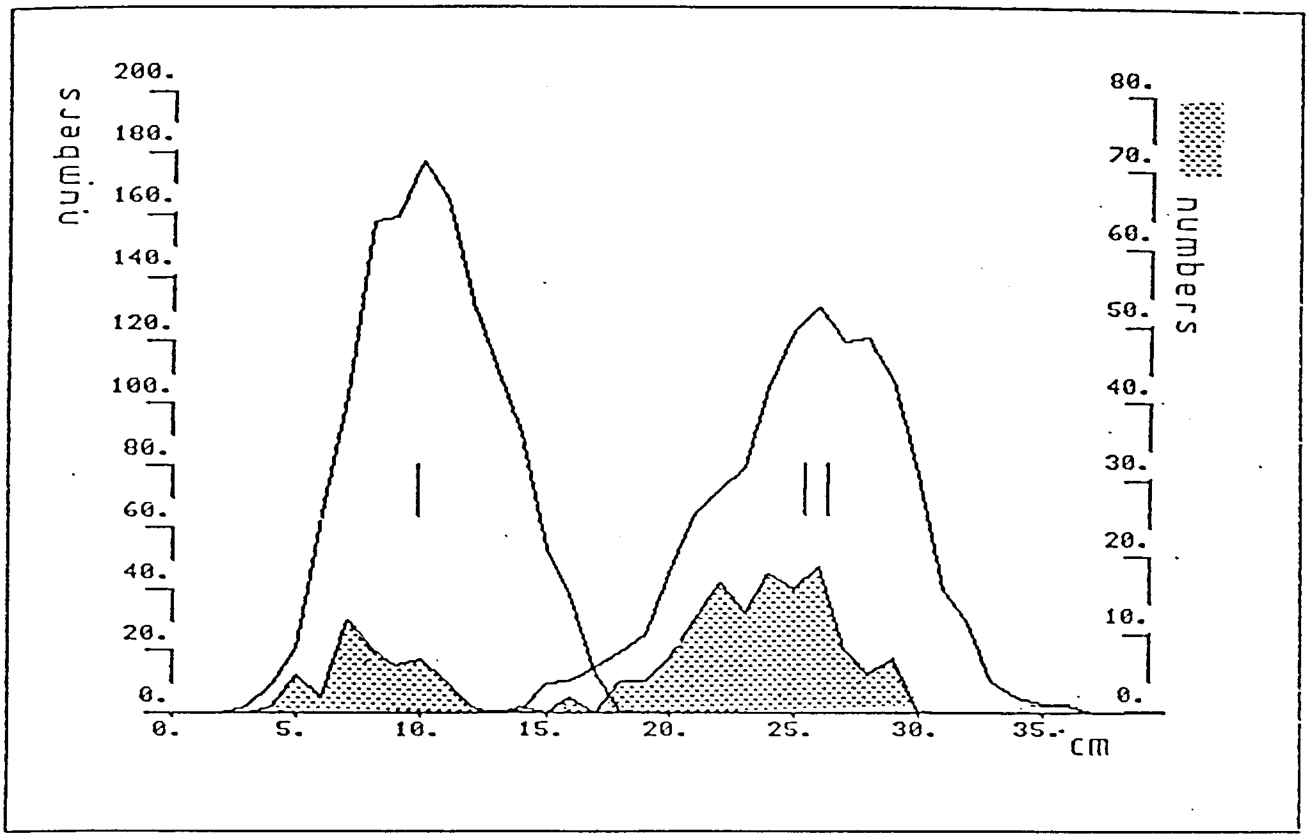


Figure 7. Comparison of the lengthdistribution of backcalculated lengths of 1- and 2-year old turbot with the length-distribution in the DYFS in April-May (shaded).

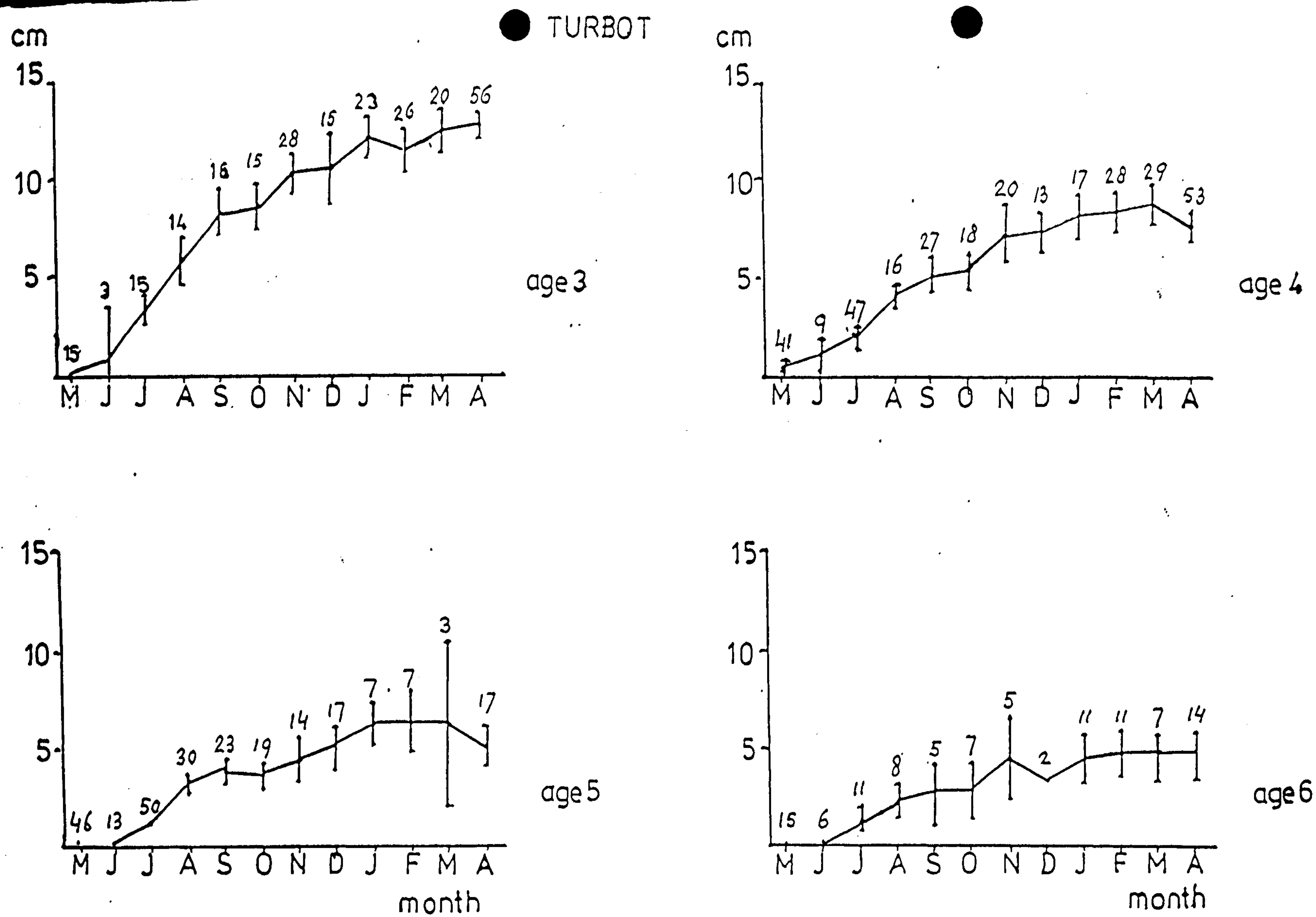


Figure 8. Monthly increase in length of 3, 4, 5 and 6 year old turbot as obtained by backcalculation. Vertical bars indicate the standard deviation. Numbers indicate the number of observations in each month.