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On the Growth of Eels in the IJsselmeer

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LARGE numbers of eels (*Anguilla vulgaris* TURT) have been able to thrive in the IJsselmeer, the freshwater lake created by the enclosure of the Zuiderzee, and fair catches of this valuable fish have been made there. For efficient management of the fishery, however, it is necessary to have as accurate information as possible about the growth of the eels, and the results of an investigation made to obtain this information are recorded here. As the great majority of the eels in the lake are males, this paper deals mainly with the growth of male eels.

Many studies of eel growth in various localities have already been made (e.g., RASMUSSEN, 1952; RAHN, 1955) and nearly all of them utilized the annual rings in otoliths or scales (or both together). In our studies we have used the annual rings in the otoliths. Small otoliths were dipped in creosote and examined by reflected light. Larger otoliths were first placed on a piece of hard rubber and polished with a wet, soft stone. The otoliths of more than 12,000 eels have been examined in this way and many others have been measured during the course of the investigation.

In order to obtain good samples of the eel population in the lake, we used a small-meshed trawl made of sarran, with which it was possible to catch elvers and eels of all sizes, and in our opinion the size distribution in the samples was a fair representation of the composition of the stock.

We fished with this trawl during the course of several summers. All the eels caught were measured and length-frequency tables were drawn up for each summer; these show the modal lengths of the youngest year-classes very distinctly. A comparison of length-frequencies for successive summers shows immediately the gradual shift of the mode. By this simple method we have already learned a good deal about the growth of the youngest stages (cf. Table 1). When studying this table, one must remember that eels are still growing a little in September and October; accordingly the lengths at the end of a summer lie in fact between those we observed in September

Table 1

The length-frequency of eels which entered the IJsselmeer as elvers in 1952, expressed as percentages of the total catch of eels with the small-meshed trawl. The figures in the first column refer to elvers only

cm.	1952				1953			1954			
	6–V %	17–VI %	22–VII %	4–IX %	26–VI %	23–VII %	22–IX %	2–VI %	8–VII %	3–VIII %	14–IX %
6	36·2	0·9	–	–	–	–	–	–	–	–	–
7	**60·5**	16·5	3·5	–	–	–	–	–	–	–	–
8	3·3	**18·6**	13·1	0·9	–	–	–	–	–	–	–
9	–	1·9	**14·7**	4·1	1·8	–	–	–	–	–	–
10	–	1·2	5·7	12·5	6·8	–	–	–	–	–	–
11	–	–	1·4	**15·8**	11·4	2·5	–	–	–	–	–
12	–	–	–	13·9	**15·9**	4·7	6·0	–	–	–	–
13	–	–	–	9·3	12·3	8·0	6·4	4·1	–	–	–
14	–	–	–	4·5	9·1	11·2	7·1	4·5	–	–	–
15	–	–	–	3·5	4·7	**11·8**	8·2	7·1	3·6	5·8	–
16	–	–	–	–	5·4	8·6	**10·8**	8·7	6·2	6·2	–
17	–	–	–	–	4·5	6·5	7·2	**11·3**	9·4	6·6	5·5
18	–	–	–	–	2·1	5·4	7·2	10·0	**10·8**	8·5	5·3
19	–	–	–	–	–	5·7	5·5	9·5	9·2	**9·0**	5·5
20	–	–	–	–	–	5·5	3·8	6·7	8·2	8·5	5·5
21	–	–	–	–	–	3·8	2·3	5·2	6·5	7·0	**6·1**
22	–	–	–	–	–	3·5	2·3	3·7	4·4	5·9	5·6
23	–	–	–	–	–	3·1	2·6	4·1	4·6	3·1	5·5
24	–	–	–	–	–	2·6	2·0	3·4	2·7	3·1	3·7
25	–	–	–	–	–	–	–	3·1	2·7	2·4	3·8
26	–	–	–	–	–	–	–	2·9	2·1	1·7	3·2
27	–	–	–	–	–	–	–	2·1	2·1	1·3	2·0

and June. Over several years the average initial growth appears to be almost the same for corresponding year-classes. In normal summers growth is about 4–5 cm., but during the exceptionally cold summer of 1956, growth was considerably less.

The table also shows that eels of the same age-group have different growth-rates; some grow slowly, about 2 cm. in a summer, others rather fast, at least 8 cm. This results in an increase of the frequency range, which involves the gradual suppression of the mode itself; in most cases this occurs after only two summers. The growth of the 1952 group of elvers could be followed for three summers, owing to the very large number of elvers which entered the lake in that year. Further, it appears that the length-frequency curves themselves are fairly symmetrical.

Further information on growth was obtained by examination of the otoliths. In the typical eel otolith, reflected light enables us to see a dark centre surrounded by two narrow, opaque, whitish rings, which have been formed during the *Leptocephalus* stage in the Atlantic Ocean.

Opaque bands surrounding these two rings may be seen, which were formed during the period spent in fresh water. Each band is surrounded by a narrow zone, which appears dark, while the bands themselves appear white or greyish. When we compare the otoliths of eels caught over a period

Table 2

Length-frequency of male silver eels from the IJsselmeer

Length cm.	Frequency %
29	0·4
30	0·8
31	2·6
32	4·6
33	8·2
34	10·4
35	13·0
36	14·2
37	13·8
38	10·3
39	9·1
40	5·6
41	3·1
42	1·9
43	0·6

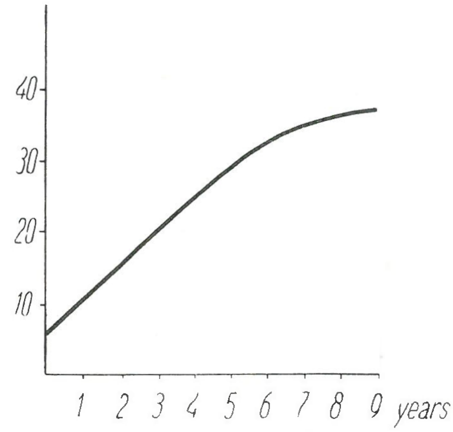

Figure 1. The average growth of male eels in the IJsselmeer.

of time, we notice that the bands lie close to the edge of the growing otolith and follow its extension during the summer, while the small dark zones are formed in winter. Hence it is obvious that each band represents a period of summer growth.

At the end of a summer, when all the eels caught with a sarran trawl had been measured, their otoliths were examined and the number of bands noted, together with the length of the eel, which gave us the ages of each centimetre group. From these data the relative length-frequencies of certain age-groups in the stock were then easily calculated and the growth deduced from the differences between them.

When these figures were compared with those deduced from the modes, it was clear that there was close agreement. This confirms the value of otoliths for determining the age of eels.

The possibility was considered of calculating the growth from the breadth of the otolith bands. The edges of these bands are not sharp, however, and estimates based on their dimensions can lead to serious errors. For this reason the method was discarded.

In general, our results are in agreement with those of Dr. B. Havinga (1945), who studied the otoliths of the older eels in the IJsselmeer. The two series of data have been combined with what is known about the normal length-distribution of silver eels, the final stage of every eel (Table 2). These data form the basis for Figure 1, which illustrates the average growth of eels, and for Table 3, which shows the gradual change in the length-frequency distribution of the 1952 group of elvers in successive years. From our figures we conclude that at least eight summers on an average must elapse before an elver in the IJsselmeer becomes a silver eel, provided that the summers are normal.

With regard to the fairly symmetrical length-frequency distribution of the male silver eels, in which a mode occurs at about 36 cm., one gets a

Table 3

Computed length-frequency distribution of eels of the 1952 elver group. The figures for the first 4 periods are deduced from otolith readings. Those for the last 4 periods are derived from the average growth (Fig. 1) and the length-frequency of silver eels (Table 2)

Length cm.	Years I	II	III	IV	V	VI	VII	VIII
8	2							
9	9							
10	28							
11	31½							
12	23	5						
13	5	11						
14	1	14	3					
15	.	17	3	.				
16	.	21	5	.				
17		13	10	½				
18		10	11	½				
19		6	12	1				
20		3	13	4				
21		1	12	8	.			
22			11	10	1			
23			9	12	3			
24			5	14	5			
25			4	14	8	1		
26			2	13	11	2	.	
27				10	13	3	1	
28				7	13½	6	2	.
29				3	13	9	3	1
30				1	11	12	5	2
31				.	8	13	8	3
32					5	13	11	5
33					3	12	12½	8
34					2	10	13	10
35					1	7	12½	13
36						5	11	14½
37						4	8	14
38						3	5	10
39						2	3	8
40						1	2	5
41							1	3
42								2
43								1

strong impression that the incidence of the silver stage occurs on attaining a certain length. This would imply, in view of the very different growth-rates, that individuals reach the silver stage at different ages. At first sight, then, the symmetry of their length-frequency distribution appears to be incomprehensible, since it must be governed by the different strengths of the various year-groups. The problem becomes clear, however, when the fact is recognized that any batch of eels of any length will, in the course of time, grow to form a group of silver eels with a length-frequency distribution

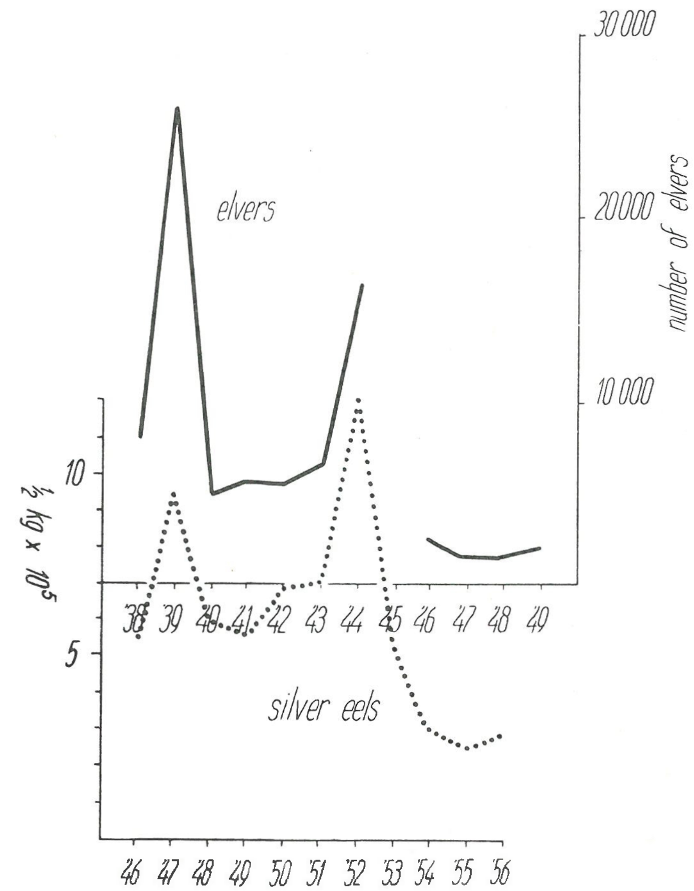

Figure 2. Comparison of elver catches with silver-eel catches 9 summers later.

which is symmetrical, although it contains eels of different ages. To investigate this point, we examined a series of otoliths from 590 silver eels caught in one night during the 1956 season. The results are shown in Table 4. Fortunately for this study, elver migration was on a small scale in all years from 1946 to 1950 (cf. Figure 2), so that the strengths of the respective silver-eel year-classes may be considered as almost equal. Table 4 shows that in the silver stage, the eels with 8 annual rings in their otoliths predominate, which again is in agreement with our previous assumption. For the sake of completeness, the length-frequency distribution of these 8-ring eels was compared with that of the whole batch, and no significant difference was found.

Next we tried to correlate the annual production of silver eels with the number of immigrant elvers. We have a rough idea of the latter quantity, because during the elver seasons from 1938 onward, elvers have been fished

Table 4

The age distribution of a batch of silver eels of normal length distribution, caught on 31. August 1956

Number of annual rings in otolith	Frequency %	Number of annual rings in otolith	Frequency %
4	0·6	9	9·1
5	9·3	10	5·2
6	17·0	11	1·7
7	19·8	12	0·7
8	36·0	13	0·4
		14	0·2

every two hours throughout the night with the same dip-net at the same spot near a sluice where the elvers congregate and try to get into the lake. The elvers caught are counted, and their numbers are taken to represent the strength of the elver migration.

No correlation was found between silver-eel catch and elver migration eight summers earlier, but there was a good correlation for an interval of nine summers (Figure 2). We must therefore conclude that, on an average, nine summers elapse between elver and silver-eel stage. As the majority of the silver-eel otoliths show only 8 bands, however, we must conclude that eels generally grow for eight summers and become silvery in the ninth; that is to say, the food taken in this summer is not used for growth, but is transformed into fat, as a store of energy for their tremendous journey back to the breeding grounds.

Summary

1) An investigation has been carried out on the growth of eels, chiefly males, in the IJsselmeer.

2) The eels show very different growth-rates; this gives rise to a broad, fairly symmetrical length-frequency distribution in every year-class (Table 3).

3) In the early stages, the average growth-rate in a normal summer is about 4 to 5 cm.; in later stages it diminishes (Figure 2).

4) The average length of the male silver eel is about 36 cm.

5) In general, a male eel grows for eight summers after the elver stage and becomes silvery in the ninth.

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