B. Sammelberichte und Referate.

The assessment of age and growth in Fish.

A short account of the development of present methods and main literature on the subject.

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With 6 text-figures.

The question of finding reliable methods for a safe determination of the age of fishes has long occupied biologists, and rightly. The fact is, that a chain of problems as well of a biological as a practical kind are for their solution depending of a sure knowledge of the age of fishes. What the power of determining the age of any tree or bush is to the forester and plant-physiologist, the methods of determining the age of fish are to the fishery-officer and biologist.

There are 3 classes of problems, which may be said to be intimately connected with a reliable notion of the age of fishes viz: the Race-problems, the questions of growth and rate of growth and finally the questions of the composition of the fish stock as regards age and the influence of fishery on the duration of life among fishes.

The importance of the problems is sufficient to explain all the energy and the amount of work, which after the institution of systematical fishery investigations by different nations, has been spent on the determination of age in fishes. An immense amount of work has really been done, and there are not very many living fishery-biologists, who have not contributed more or less to the solution of the question of the age of fishes.

As regards fresh waters it was possible to gain some experience on age and rate of growth in fish which were subject to culture. As soon, however, as the question of the age of „wild“ or free-living fish was raised, the experience of the culturist proved insufficient, and would even lead to quite erroneous conclusions.

In the sea the fry of the year of some fish could be observed, along the shore, and while it stayed there a rough estimate of the growth of the fry could be formed. In many places the fishermen had in this way also formed an estimate or judgement on later growth.

This system of judgement Professor G. O. Sars endeavoured to follow up during his renowned investigations on the cod in Lofoten during the 60^{ties} and 70^{ties} of the latter century.

He tried to begin with the fry of year of the cod, and describe its growth during a summer by measuring a number of individuals. Next year he tried to recognise the yearling fry, study their habitat and measure their growth during summer. Thus he endeavoured to follow the growth for several consecutive years and in this way he thought to obtain a safe notion of the age and growth of the cod. Later experience has amply proved the inadequacy of the method.

A marked advance was obtained in the year 1892 by the Danish biologist Dr. C. G. Johs. Petersen (*Fiskenes biologiske Forhold i Holbæk Fjord 1890—91. Beretning fra den danske biologiske station I. 1892*) whose later reports also contain important supplements to his method.

He showed, that when a large number of individuals of a species were measured and the material obtained was graphically arranged according to the frequency of different size-units, one or several groups were always formed around certain sizes, that were more frequent than others. These size-groups were, as regards the smaller sizes generally well separated. As regards larger fish, these groups tended more and more to amalgamate, and when the fish reached size peculiar to maturity the amalgamation of all groups into one was totally accomplished. These groups were with certain reservations by Dr. Petersen considered as representing different year-classes. Later experience has largely confirmed the correctness of this interpretation, although the method in many cases has proved insufficient and even misleading.

An immense amount of work has in most European countries been done in order to accomplish an age-assessment in fish by means of Petersen's method, and a great deal of important knowledge has really been gained.

Experience however proved that only the first 2—3 year-classes of a species as a rule were recognizable by means of the method.

The method in fact rests on the supposition, that the start in size which the fry of one year possesses compared to the fry resulting from next years spawning, that this start in size is retained also during subsequent years.

To a certain extent this holds good, where the spawning season is short, and where growth is uniform. But experience shows, that a long spawning season, unequal growth in different years and different localities, besides active and passive migrations, combine to blot out the „annual groups“ in most species after the lapse of very few years. After the lapse of even one year the single individuals of a year-group could not in all cases be recognized as belonging to a certain group and after a lapse of few years a recognition of the year-classes even as groups became almost impossible.¹⁾

In the year 1899 Dr. Johannes Reibisch published a paper. (*Eizahl bei Pl. platessa und die Altersbestimmung dieser Form aus den Otholithen. Wissenschaftl. Meeresuntersuch, N. F., Bd. IV, Abt. Kiel, Berlin 1899*), in which he demonstrated that the otoliths of the plaice evidently could be employed for a determination of the age of individual fish, the formation of bony substance in these organs being periodic corresponding to summer and winter.

About the same time Dr. C. Hoffbauer published a paper (*Die Altersbestimmung des Karpfens an seiner Schuppe, Allgemeine Fischereizeitung*

¹⁾ I omit mentioning the endeavours which have been made to study growth by means of marking fish. As generally fish of advanced age only can be marked, the method may only be applied as a means of control of other methods, and cannot go very far towards the exact assessment of age.

1898, Nr. 19) where he showed that the age of the common carp could be determined by means of an examination of its scales. The effects of the seasons of the year left certain traces in the structure of the scale, traces which plainly might be read off under the microscope.

Since these papers appeared, a number of investigators have endeavoured to test and develop these methods, which both, on closer analysis, prove to rest on the fact, that the growth of fishes is periodical according to the seasons of the year, and that this periodicity leaves certain traces which can be recognized in the whole of their osseous system or osseous formations. In this way the number of seasonal periods may be read off.

Some investigators have used the otoliths. Others have employed certain bones, as gill-covers, scapula, vertebrae or neural processes. Others again have preferred to use the scales.

But the choice of the organ for age-determination may now be considered as being a question of an entirely practical kind, a question to be answered for each species. We employ the organ which most easily and cheaply can be procured, and which permits of the surest and quickest work.

In most cases this holds good for the scales. But where these are partly or wholly absent or on account of their structure are difficult to read or, as is the case in some species, are not all formed at the same time and thus present certain difficulties, certain bones are employed with advantage. And the choice of such bones must be made according to circumstances.

In the following pages I will shortly review the results which, as regards methods, have been obtained by examining different species or groups of species. At the same time the main literature will be mentioned.

Pleuronectidae.

Among flatfish the important species, the plaice, has been principally the subject of age and growth-studies.

Since Reibisch in 1899 published the first paper on the assessment of age by means of the otoliths, quite a number of scientists have examined this species.

The first man who tried to employ the method on a large scale was Professor Heincke of Helgoland. He deserves also credit for having contributed towards the general recognition of the possibilities of the method. In this respect I may refer to his papers in „Beteiligung Deutschlands an der Internationalen Meeresforschung, I. und II. Jahresbericht“, where on the one hand he demonstrates how the seasonal changes perceptibly affect the structure of nearly all the bones of the fish and on the other hand by means of large analyses gives clear examples of the applicability of the method.

The method has now, as regards the plaice, been employed on a very large scale and thousands of plaice have been examined as to age during the investigations of most North Sea countries.

On the one hand a reliable age assessment by means of the otoliths has proved possible, at least up to certain ages. As regards older fish the otoliths become too little transparent and the annual rings too close for an absolutely safe reading. In these cases the broad flat bones of the head and shoulder girdle are good subjects and give safer results.

Only very few other pleuronectid fish have been subject to examination as to age and in literature only a few specimens have been mentioned and their scales figured.

From personal experience the present writer knows the scales of Pl. Microcephalus to be excellent for an analysis of age and I have by their aid analysed large samples.

In regard to Halibut (*Hippoglossus vulgaris*) I have by examination found the winterings of the otoliths very plain, especially when examined perfectly fresh.

Fig. 1. Otoliths and bones of plaice of different age (from Heincke).

Also a few other species have been cursorily examined, and the probability is, that the age of most pleuronectids will prove ascertainable by means of otoliths, bones, or scales.

The literature on the age of plaice has during the many investigations of late years accumulated greatly and the following list only refers to the earliest and most important works from different regions.

Baltic and Danish Waters.

Johansen, A. C., Contribution to the biology of the plaice, with special regard to the Danish plaice fishery. II.—IV. Meddelelser fra Kom. for Havundersogelser Serie Fiskeri, Bd. II, Nr. 5, Bd. III, No. 4 and 5. Revue d. ges. Hydrobiol. u. Hydrogr. Bd. II. H. 4 u. 5.

German Bight.

Heincke, F., Die Arbeiten der Kgl. Biolog. Station auf Helgoland im Interesse der Internationalen Meeresforschung 1903—04. Deutsche Wissenschaftl. Komm. f. d. Internation. Meeresforschung. Jahresbericht I u. II. (Also see paper mentioned under Gadidae.)

Heincke, Fr. und H. Henking, Über Schollen und Schollenfischerei in der südöstlichen Nordsee. From, Die Beteiligung Deutschlands an der Internation. Meeresforschung. IV./V. Jahresbericht 1907.

Mayer, Herman Nik., See paper mentioned under Gadidae.

Southern North Sea.

Wallace, William, Preliminary investigations on the age and growth-rate of Plaice. Internation. Inv. of Marine Biol. Association, Report I, 1902—1903.

Wallace, William, Age and growth-rate of plaice in the southern North Sea as determined by the investigation of otoliths. Ibid., Report II, pt. I, 1904—05.

Arctic.

Atkinson, George T., Notes on a Fishing voyage to the Barents Sea in August 1907. Journ. of Mar. Biol. Ass. Plymouth, Vol. VIII, No. 2, May 1908.

Gadidae.

The first attempts at determining the age of gadoid fish by means of studying their bony structures were made by Stuart Thompson in Plymouth, who endeavoured to show the periodic growth of different gadoids by studying their scales (1902—1904).

Also other investigators as Prof. Heincke, Helgoland, Mayer, *ibidem*, Cunningham, and also the present writer tried to employ the otoliths, vertebræ or other osseous structures for an age-assessment.

In 1905 a danish student of biology Mr. Lunn attempted a study of the scales of the cod, at the instigation of Dr. Damas, of the fisheries laboratory in Bergen. As Mr. Lunn had to discontinue his promising work, Dr. Damas took up the work on a large scale, and during subsequent years treated an immense material comprising cod, haddock, saithe and whiting, collected under the direction of Dr. Hjort of Bergen.

With certain limitations the scales as a rule proved an excellent means of determining the age of these fish, and certainly in most cases are far superior to any other organ taken from the osseous system. They are easy of treatment, easily and cheaply accessible and possess the advantage, that even fish in the market may be examined with hardly any cost. The slime covering the skin is rubbed away with a knife, the necessary sample of scales scraped of, put in a small envelope and dried for subsequent examination.

The treatment is practically the same as later mentioned under Herring scales.

The scales are, as regards the four species mentioned, built on the same system, and resemble each other very much in all species.

The adjoined figure, taken from Damas, illustrates the structure.

Around the original first plate of the scale, there runs a system of concentric lamina or broken crests, joined by radial bars. These crests are numerous and far apart in summer and few and close in winter. The periods of growth are thus easily recognizable.

The scales of the Pollack have also been studied and figured by Stuart Thompson, and they are quite similar to those of the other species. Large analyses of this species have however apparently not yet been effected.

Analysis of age in gadidæ on a large scale has mainly been undertaken by Dr. Damas during Norwegian and International fishery work.

The main literature relating to the subject is the following:

Fig. 2. Scale of *gadus virens*
(from Damas).

Thompson, Stuart, The periodic growth of scales in Gadidæ as an index of age. Journ. of Mar. Biol. Association, Plymouth, Vol. VI, No. 3, 1902 (preliminary note) and Vol. VII, No. 1, 1904 (in extenso).

Heincke, J. F., Appendix E. General Report on the work of the period July 1902—July 1904. Rapports et Procès Verbaux de la Conseil perm. p. l'exploration de la mer, 1905, Vol. III.

Cunningham, Zones of growth in the skeletal structures of Gadidæ and Pleuronectidæ. 23 ann. Rept. Fishery Board for Scotland, 1905.

Dahl, Knut, Undersøgelser over Nyttens af Torske ud klækning i Østlandske Fjorde. Bil. II, tab. E, Aarsberetning vedk. Norges Fisherier, 1906, 1^{te} Hefte.

Mayer, Herman, Nic., Beiträge zur Altersbestimmung der Fische. Wissenschaftl. Meeresuntersuch. 1906, N. F., Bd. VIII, Abt. Helgoland, Heft 1.

Hjort, Johan, Some Results of the international Ocean Researches. Scottish oceanogr. lab. 1908.

Damas, Desiré, Contribution à la biologie des gadides. Rapports et Procès Verbaux de la cons. perm. p. l'expl. de la mer. 1909, Vol. X.

Clupeidæ.

Of fish belonging to the Herring tribe only the common herring and sprat have been made the subject of age assessments.¹⁾ Especially the norwegian

¹⁾ A few individuals of the common shad have occasionally been examined and the otoliths show yearnings. Author has had the opportunity of examining the scales of a specimen. Yearnings are present resembling those of the herring.

fisheries investigations have spent a great deal of work in developing methods for a determination of age in these species.

In 1902 Dr. Jenkins of Kiel endeavoured to analyse the age of the herring by means of the otoliths. In the years 1904—1906 cand. Hj. Broek studied herring races for the Norwegian Fishery Board. During the latter part of his work he entered upon question of age-assessments, and showed by means of a parallel analysis of otoliths and scales, that the latter were well suited for a determination of age.

In 1907 the present author published an extensive work on the scales of the Herring, and during later years the age of the sprat has also been studied in the same way by Mr. Oscar Sund of the fisheries laboratory, Bergen.

Fig. 3. Herring scale (from Dahl).

Analyses of herring on a very large scale have also during late years been made in Norway by the present author.

Vertebrae as well as otoliths of these clupeid fish are suited for age assessment, also opercula and other flat bones are good; but none of these, (especially not the vertebrae and otoliths), give so sure results or are so easily and quickly treated and read off as the scales.

The structure and form of these is represented in the accompanying figure, where the transparent narrow winterings and the broad dark summer zones are obvious.

As regards the herring the large scales on the fore part of the side of the body are the best for examination.

If they cannot be examined fresh, the samples ought to be kept in small

envelopes (for each individual) and dried in a suitable temperature. Upon examination they ought to be softened on a glass slip in a drop of glycerine and water, cleared and looked over in water with a weak lens. For old fish it is advisable to control the readings under a thin coverglass and with more powerful magnification.

Preparations may be mounted either imbedded in glycerine-gelatine sterilised with carbolic acid or the scales may simply be glued on a gummed glass slip or mounted dry between two glass slips. The sample may also be left lying on the slips with a drop of glycerine, and they will thus keep for more than a year.

The main literature is:

- Jenkins, J. T.**, Altersbestimmung durch Otolithen bei Clupeiden. Wissenschaftl. Meeresuntersuch. 1902, N. F., Bd. VI, (Abt. Kiel).
Dahl, Knut, The Scales of the Herring as a means of determining age, growth and migration. Report on Norw. Fishery and Marine Investigations 1907, Vol. II, No. 6.

(A preliminary account of his subsequent work on the same subject has been given by the same author in the Review of the results of Norwegian Fishery and Mar. Investigations 1900—1909 by Dr. Hjort, heading the some report, now just being published in toto.)

- Broch, Hjalmar**, Norwegische Heeringsuntersuchungen während der Jahre 1904—1906. Bergens Museums Aarbog 1908, Nr. 1.
Schneider, Guido, Die Clupeiden der Ostsee. Nr. 5 im Bericht Über die Tätigkeit der Komm. C₁ in der Periode Februar 1903—Juli 1907. Rapports et Procès Verbaux, Cons. Perm. pour l'expl. de la mer, Vol. IX, Kjøbenhavn 1908.
Hjort, Johan, Circular to members of committee A. Conseil Perm. pour l'expl. de la mer. Procès Verbaux 1908, Vol. XI.
Sund, Oscar, The Sprat. Review of Norw. F. and Mar. Invest. Report on Norwegian Fishery and Marine Investigations, Vol. II, Nr. 1.

Salmonidæ and other Freshwater-fish.

The study of scales of freshwaterfish was first taken up by Dr. Hoffbauer, as previously mentioned. In his first and subsequent works he mainly dealt with the age and growth of the common carp. However he has also cursorily dealt with the scales of some other species of carp besides pike and a few others, and shown their scales to possess periodic growth.

In Scotland the Salmon has been studied since 1904 by Mr. H. W. Johnston who in several papers has dealt with its scales as indicative of age, growth and breeding habit. Mr. Johnston's results have also been popularised by Mr. Calderwood, and a sportsman, Mr. J. A. Hutton, has in a lecture on the subject added some of his own observations to Mr. Johnston's.

In Norway the present author has since 1906 studied Salmon scales on a large scale. Also trout and other salmonidæ have been included in this investigation and an assessment of their age has proved possible. The results will shortly be published.

The scales of the salmon, consist as the adjoined figure shows of an elliptical plate, provided with a system of concentric ridges, which increase in number, as the fish grows.

In the posterior, exposed part of the scale these ridges are absent. These ridges become during winter few in number, are weaker and lie closer together. In certain parts of the scale, especially dorsal and ventral parts, the ridges during winter become even broken or irregular.

The central part of the scale presents the slow growth of the parr or smolt before leaving the river. The consequent broad annual belts represent the consequent enormous growth of the fish during the stay in the sea.

Also the spawning process seems to leave certain traces in the scale of the salmon, by means of which the number of spawning periods can be ascertained. This feature however probably needs further confirmation.

Fig. 4. Scale of Salmon (from Hutton).

Also in the vertebræ the neural processes and the flat bones of the head and shoulder girdle the traces of the periodic growth of the fish are plainly visible, but in these large bones the traces of early growth in the river are necessarily blotted out in large fish. The scales are best for examination. They are easily and cheaply acquired (they may even be taken from the living fish) and present all facilities for easy examination. Scales from large fish had better be examined dry. Small scales must as a rule be examined in water or glycerine and water, as they are apt to curl up, when dry.

The scales of the trout are on very much the same system as those of the salmon; so are also the scales of the mountain char of which I have examined some samples.

During later years hundreds of trout samples have been examined by the present author as a comparative material to salmon scales, and I may say, that the determination of age in trout apparently present no insurmountable diffi-

culties. As mentioned before, the whole material will shortly be published. The appended diagram shows in an elementary form the main results of a comparison of the growth of the salmon, sea trout and slow growing brook trout, as ascertained by the present writer's investigations in Norway.¹⁾

A great number of trout from different localities, lakes and rivers, have also been examined and their growth varies between that of the sea trout and brook trout, growth being very different in different places.

Fig. 5. Comparison of growth in salmon, sea trout and brook trout (K. Dahl).

The method thus evidently presents facilities for penetrating very far into the old question of different races or local and growth varieties of the salmonidae. The main literature relating to the subject is:

- Hoffbauer, C.**, Die Altersbestimmung des Karpfens an seiner Schuppe. Allg. Fischereizeitg. 1898, Nr. 19.
Hoffbauer, C., Weitere Beiträge zur Alters- und Wachstumsbestimmung der Fische, spez. des Karpfens. Jahresbericht d. teichwirtschaftl. Versuchsstation zu Trachenberg. Schles. Fischereiverein 1900—1901.
Hoffbauer, C., Untersuchungsergebnisse über Alters- und Wachstums-erkennung nach der Schuppe. Verh. d. internat. Fischereikongresses, Wien 1905.

¹⁾ The diagram is based on rough averages from different localities.

- Johnston, H. W.**, The Scales of Tay Salmon as indicative of age, growth and spawning habit. 23 Rept. of Fishery Board for Scotland 1904, Pt. II, App. II.
- Johnston, H. W.**, The Scales of Salmon. 25 ann. Rept. of Fishery Board for Scotland 1906, Pl. II, App. II.
- Johnston, H. W.**, The Scales of Salmon. 26 ann. Rept. of Fishery Board for Scotland 1907. Pt. II, App. III.
- Calderwood, W. L.**, The life of the Salmon. London 1908.
- Hutton, J. Arthur**, Salmon Scales as indicative of the life history of the fish. Manchester 1909.

The Eel.

As early as in 1873 Boudelot in treating the scales of osseous fishes suggested that the concentric stripes or zone in the scale of the common eel corresponded to periods of growth. Like many other suggestions of the kind which are to be met with in the works of earlier ichthyologists on different fish, the thought contained has passed almost unnoticed until the work of Hoffbauer and Reibisch, as before mentioned, brought the question of a possible age assessment into general notice.

In Denmark Mr. K. J. Gemzøe during the years 1905 and 1906 took up the work of studying the scales of the eel on a large plan.

In recent years Dr. Guido Schneider also made some investigations on the matter in Swedish waters. Besides the scales he also studied the structure of the vertebrae to some extent.

The outcome of the studies of these two authors is, that scales as well as vertebrae to a certain extent are suited for an age assessment.

The scales of which a representation is given in the adjoined figure, are composed of elliptical or roundish plates of chalk and these plates are arranged in concentric zones of growth, parted by open concentric channels corresponding to the periods of stagnation. The number of these zones of growth correspond to the annual seasons and augment in number corresponding to the size of the fish.

By counting the number of annual rings the age of the fish may be estimated after the scale has been formed.

The method has however one drawback. The scales are not formed from the

Fig. 6. Scale of Eel (from Gemzøe).

beginning of the life of the eel. When the young eels have passed the leptocephalus stage and arrive on the coasts of Denmark as glass-eels, their age is unknown. They may be one or two years.

Gemzøe has shown that the first scales appear on both sides of the lateral line on the middle part of the body in front of the anus. The scales on the other parts of the body are formed in subsequent years.

By measuring the young eels Gemzøe has fixed the average age for the formation of the oldest scales to the 3rd summer after immigration. He proposes the following formula for age assessment after immigration: Number of annual rings in the scale $+ 2$.

Dr. Schneider has shown that the ossification of the vertebræ may take place even from the first year after immigration and that the relation between number of annual rings in vertebræ and scales seems to show that the scales are not always formed in the third summer after immigration, but apparently may take place earlier or later in a few cases.

The main drawbacks of the method are thus:

- 1) Difference in age of scales on different part of the body,
- 2) Variation in age at formation of first scales,
- 3) Uncertainty as to age of glass-eels on immigration.

The method is thus only with certain reservations applicable. It must be applied with considerable care and forethought and the results will only be approximately correct.

The literature is:

Boudelot, Recherches sur la structure et le développement des écailles des poissons osseux. Arch. de Zool. exp. et gen. 1873, Tome II.

Gemzøe, K. J., Om Aalens Alder og Vækst. Beretning til Landbrugs ministeriet fra den danske biologiske Station 1906, XIV.

Schneider, Guido, Über das Wachstum der Aale (*anguilla vulg.*) in den Gewässern Schwedens. Publications de Circonstance Nr. 46. Conseil perm. internat. l'exploration de la mer. Kjöbenhavn Mars 1909.