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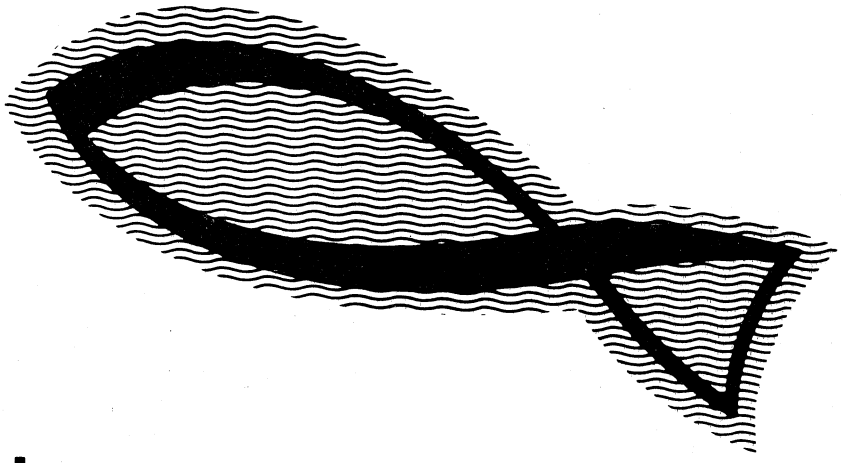

by

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SCIENCE AND FISHERIES MANAGEMENT

The W.J.M. Menzies Memorial Lecture delivered at the Annual Course of the Institute of Fisheries Management at the University of East Anglia, Norwich, on 16 September, 1975.

by

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It is a great honour and a pleasure for me to be invited to give the Menzies Memorial Lecture, firstly because we are commemorating a great man whom we all admired and secondly because I regarded him as a personal friend. I first met Menzies in 1936 in Copenhagen where we were both attending a meeting of the International Council for the Exploration of the Sea. He was the senior British representative on the former Salmon and Trout Committee and I was a young student at the University in Oslo. I had been working on salmon scales and I had some fruitful discussions with him on the subject.

After the War, on his retirement from the Civil Service, we saw more and more of him at scientific and other meetings where his influence was felt over a wide range of subjects. I had the pleasure of spending an afternoon with him in Fredericton, New Brunswick shortly before he died and a very pleasant afternoon it was.

Much of what we know of the natural history of Scottish salmon is derived from Menzies' painstaking researches over a long period and, indeed, his reports on the movements of salmon along the Scottish coast[1], together with those of the late Knut Dahl[2] and his collaborators gave us new light on the problems of movements of salmon in the sea.

In recent years <u>management</u> has been a fashionable word. Almost everything we do, as human beings, is managed in some way or other. There are those who think that management is a new technique but they forget that since the dawn of history men have managed their lives, albeit not too well, but nevertheless manage them they did.

I have always been surprised when I read historical documents as to how much "management" was exercised in former times over fisheries and fish stocks in many parts of the world and what a good knowledge our predecessors of long ago had of the biology of fish species. Whilst I know members of the Institute of Fisheries Management are interested in fish and fishing in the more limited use of those terms there is much to be learned from what happened in the case of the oyster fisheries in former times. The story as regards the Irish oyster has been recorded[3].

In many parts of Europe the flat oyster (Ostrea edulis) is indigenous and far back in historical time it provided oysters for local populations, so much so that kitchen middens in many coastal areas contain a high proportion of oyster shells. With the development of human populations oysters became items for trade and in most cases the intensity of fishing increased to well above the former subsistence levels and consequently stocks deteriorated. Those concerned with the oyster stocks, whether they were landowners or Governments, local chieftains, or municipal authorities, then put restrictions on the capture of oysters by way of close seasons, size limits, establishment of sanctuary areas and so on. All these restrictive measures were aimed at conserving the stocks, albeit by making fishing operations inefficient. This was a primitive form of management based on conclusions drawn from observations made by our less well endowed predecessors as far as science was concerned.

These restrictive measures, the only managerial processes these people knew, were insufficient, save in a few cases, to maintain the stocks and frequently the owners of the beds would then restock from other beds less affected by over-fishing. Even then with the lack of oysters for restocking from natural beds, or their excessive price, some new form of activity was sought to rectify the position and researches were made into the possibility of rearing the oyster artificially to a certain stage for restocking purposes. This has proved successful and it appears that suitable oyster beds can now be managed properly and the oysters farmed, rather than merely fished. In a few years' time I have no doubt that oysters farmed and managed on scientific lines will be common again.I hope, as Sam Weller in Dickens' novel says "Oysters and poverty go together".

Oysters are sedentary creatures and apart from their larval stages remain in the same spot all their lives. I have digressed from the main theme of my talk but as I have already said the oyster is an excellent subject for scientific management.

About 150 years ago salmon were mainly exploited in the estuaries and rivers and very little fishing was done in the open sea. There were, of course, exceptions to this rule. For example, at Carrick-a-rede on the northern coast of Ireland a net was used even

before 1790 in the open sea some distances outside the mouths of the adjacent rivers.[4.] However it was not until early in the last century that bag nets and other open sea nets were first used. Until open sea nets of various kinds were used the unit for management was the river system, including its estuary, and whilst conflicting interests might make for difficulty in some river systems nevertheless something well worthwhile could be done to "manage" the fishery based on observations made over a period of time. A very good example of what could be done in this regard is given in Gilbert's book on the River Wye.[5.] By abolishing the freshwater nets those interested in the Wye were able, with other controls, to manage the fisheries so that the river became one of the world's greatest salmon angling waters.

Most of this was done without the benefit of science, in the usual sense we would use the term today but Hutton's famous series of papers[6.] emphasised the quality of the fishing in the Wye down the years. In case I give the impression that no other owners managed their fisheries please let me say at this stage this is far from true but I use the Wye as an indication of what can be done. Incidentally, the Wye is a good example of management to a plan. The object of those concerned with the Wye and, in particular, John Hotchkiss, the pioneer worker on the river, was to provide quality angling and they succeeded very well. They could, of course, have opted to develop the tidal water net fishery but that would have necessitated different tactics.

As soon, however, as salmon were exploited on route to their home river the possibilities of effective management by the owners of the fisheries in one river system were reduced and management had to be extended to cover much larger areas, which called for, if not national, at least widespread application of regulations to safeguard the fisheries against over-exploitation. This is where the State came in to control the siting, number, construction, and conditions of operation of such engines as bag nets, stake nets and later drift nets in the open sea. Only the State could manage the fisheries in the widest sense but this was done, I am afraid, not so much on scientific grounds, although scientific research has helped, but rather on empirical grounds.

Tagging experiments in the thirties indicated that some salmon were intercepted in the coastal waters of countries other than the home country but the proportions involved may not have been large. For example, Dahl and his collaborators [7.] have indicated in their valuable papers the capture of salmon tagged in Norway in Swedish rivers, presumably the home waters of the fish concerned.

However from the mid-sixties fishing for salmon in Greenlandic coastal waters and also offshore on the high seas developed and this, and a later similar development in areas off the Norwegian coast, posed further difficulties as regards the scientific management of salmon stocks.

Scientific investigations of many kinds have indicated the extent of exploitation of salmon well away from home waters and since the problem is an international one, it was necessary to extend management to the international sphere. The International Council for the Exploration of the Sea, in conjunction with the International Commission for the North-West Atlantic Fisheries (ICNAF) set up a working group, known as the ICES/ICNAF Working Party on North Atlantic salmon, which investigated the problems involved and produced a number of valuable reports.[8.] An intensive international scheme of tagging and other experiments was undertaken in order to provide a firm scientific base for international action.

Two international bodies are concerned with the conservation of the fish stocks of the North Atlantic, namely ICNAF referred to earlier and the North East Atlantic Fisheries Commission (NEAFC).

ICNAF's regulations, as regards the North-East Atlantic have

a. Established the quantity of salmon which can be taken in the coastal waters of Greenland at a maximum of 1,100 tons per annum at present and

b. Provided for a ban on high seas fishing for salmon as from 1 January 1976.

NEAFC's regulations as regards the North-East Atlantic have

a. Established sanctuary areas off Norway, around Great Britain and Ireland and Iceland in which salmon fishing of all kinds is prohibited outside national fishing limits;

b. Fixed a close season for fishing on the high seas for salmon fishing by all methods from 1 July one year to 4 May the year following; and

c. Established size limits etc. for salmon taken in the open fishing season (5 May to 30 June) for the high seas fishery.

The international management of the salmon fisheries is based on sound scientific principles but also had to take into account political and national considerations. We all would, of course, like to see a complete ban on fishing for salmon on their feeding grounds but that has not proved possible. The United Nations Law of the Sea Conference which is to be re-convened next year will certainly have before it the question of the salmon which must loom large in the eyes of many people in countries which have important stocks of salmon.

From the middle of last century many people interested in salmon were keen to undertake artificial propagation and hatcheries were established to provide unfed fry for suitable waters. Operations of this kind were conducted on the basis that artificial propagation was highly efficient, whereas natural spawning was inefficient. Many of us had doubts as to the so-called ineffectiveness of
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natural spawning and Junes and King in their classical experiments indicated a high degree of success in fertilisation under natural conditions. Despite this many fishery owners and others continued to plant out unfed fry in great numbers, the criterion of success being the number of unfed fry planted out. It cannot be said too frequently that the success of artificial propagation must be judged on the extra number of adult fish produced and not on the number of young planted in the river.

In recent years more and more attention has been paid to the production of viable smolts and we now have accurate assessments of the survival rates from fish reared artificially to the smolt stage in many areas.

What we do lack, however, in most cases is a clear indication of the economics of smolt rearing, such as had recently been given
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by Piggins and Lawrie in a recent report of the Salmon Research Trust of Ireland Inc. which is jointly sponsored by Arthur Guinness & Son and Co. Ltd., and the Minister for Agriculture and Fisheries for

Ireland. Such information must be available if we are to manage our fisheries in the wider sense of that term.

Apart from artificial propagation there are, of course, many other ways of assisting in the maintenance and development of salmon fisheries. This was recognised a long time ago by our predecessors who did much to facilitate the passage of salmon over obstacles, both natural and artificial. Early fish passes were in the main used to provide for the ascent of salmon over man-made obstacles, such as mill dams, but sometimes small natural obstructions were eased by relatively simple methods.

The early fish passes usually consisted of a series of shallow pools arranged on an incline with a notch or V to allow the fish to swim, sometimes to jump, from pool to pool. Where passes were built to provide a means of access over impassable natural falls new grounds were opened up to salmon and in some cases new fisheries were established. A classical case of this is provided at Ballisodare, Co Sligo.[11.] There in 1851 an engineer of the Irish Office of Public Works, who had made a study of the habits of salmon, erected three passes to provide facilities for the ascent of fish over what were then impassable falls. The lowest of these falls at Ballisodare itself prevented salmon from entering the river but soon after their construction and stocking of the river with a small number of adult salmon and some unfed fry a fine stock of salmon was developed. In a few years the maximum annual catch by nets below the falls had reached 11,000, with annual catches of 6,000-7,000 fish not uncommon.

Of course it is not always possible to open up new ground in this way, but simple investigations will show whether fish passes are needed at obstacles of all kinds. An assessment of the spawning potential above an obstacle is, of course, highly desirable before incurring the expense of erecting a fish pass.

In recent years the traditional fish pass, consisting of a series of shallow pools, often with a notch or V of some kind to facilitiate the swimming of the fish, has been superceded by other forms of fish pass, designed on scientific lines. Some of these, such as the two fish passes on the River Erne, are still pool passes but they have scientifically designed submerged oxifices, the object being to

provide improved facilities for the fish to swim from pool to pool. Unfortunately pool passes require a great deal of space, which is often not available in many places. The Borland fish lift and the Denil fish pass have considerable advantage over the traditional pool pass in that if constructed at the same time as a dam they can be fitted into the design of the dam thus eliminating expense as well as requiring less space. Generally also the water requirements of these passes are smaller than a pool pass. Both the Borland and Denil fish passes were designed on scientific principles and they have proved themselves to be effective. The earliest pass of the Borland fish lift design in Ireland was built on the dam at Leixlip on the River Liffey and since its construction has been responsible for passing up many hundreds of salmon to the main spawning grounds which would otherwise have been unoccupied by salmon. A Borland type fish pass has now been provided at the Ardnacrusha dam on the River Shannon to bring salmon from the tail race into the long head race and to enable them to enter fresh water. Observations had shown previously that few salmon entering the tail race dropped downstream to enter the main River Shannon and consequently stock was lost each year. As the Shannon hydro-electric scheme when it was completed in 1929 was the largest on any Atlantic salmon river our knowledge of the effects of such a scheme on salmon stocks was small. If we knew then what we know now a fish pass could have been included in the dam itself at reasonable expense.

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In recent years considerable attention has been given to the environment for salmon and, in particular, for the construction of holding ponds for angling purposes and, indeed, for more general purposes. Most of this work has been done on a rather hit and miss basis but here I think careful attention to detail will have highly beneficial results. Unfortunately, this type of work requires a great deal of labour and today costs are almost prohibitive.

In parts of North America the use of artificial spawning channels has been given much attention in recent years, particularly with Pacific species of salmon. However because of the difference in habits between the Atlantic salmon and the various species of Pacific salmon there would seem to be less advantage to use artificial spawning channels for Atlantic salmon than for their Pacific counterparts.

In connection with the assessment of the exact effect of the Greenland fishery on the stocks of salmon in home rivers work on both sides of the Atlantic has indicated that, on the basis of biochemical differences, there are a number of distinct geographical "races" of salmon. Information of this kind has an important bearing on management inasmuch as each race is probably in "equilibrium" with its surroundings. The introduction of outside stock may not be an advantage and it may well be harmful in producing a mixed bag of genes. Information from Ireland suggests, for example, that ova imported from Canada and reared to the smolt stage gave very few, if any, returns of adult fish. From the point of view of economics alone work of this kind may well be useless in any case, for which reason in Ireland we have now ceased to import salmon ova from abroad for restocking purposes. Incidentally, there are difficulties in rearing Icelandic ova because they are generally very small in size compared with native ova and, therefore, cause difficulties in the normal hatcheries in use in Great Britain and Ireland.

Statistics are the life blood of fisheries management and in recent years steps have been taken in most countries to improve their quality. Unfortunately salmon anglers are often loath to give details of their catches for a variety of reasons, none of which impress me. What we require are catch per unit effort figures over long series of years and general information is not enough as can be readily shown.

But catch statistics, important as they are in themselves provide information on only one facet of stocks. Climatic and other conditions greatly affect the catchability of salmon so that even with similar runs catches may vary over a wide range. In recent years much attention has been devoted to the design and operation of fish counting devices of all kinds, some of them quite sophisticated in character. I do not propose to discuss them here because most of them are well known. Whilst considerable success has already been achieved in counting salmon in cases where the fish can be concentrated into a narrow channel we still need an accurate method of counting salmon moving in wide channels and indeed, this is to my mind one of the really pressing problems of salmon management today.

Counting of descending salmon smolts under present conditions requires

rather elaborate and expensive installations and this again is a field in which considerable research is necessary to see if simpler arrangments can be effective.

Whilst on the subject of statistics I should perhaps refer to some difficulties in their interpretation which have arisen in the case of Irish stocks. In the late sixties, as a result of the examination of material from the salmon of a number of rivers but particularly from the River Foyle, I concluded that since about 1965 the grilse in Irish rivers had increased in average weight so that a high proportion were well in excess of the weight limit used to distinguish "salmon" from "grilse". At one time the Irish limit was 7 lb. but in the sixties it was 8lbs. Now as regards the Foyle I found in one year that using the 8 lb. limit the ratio of "grilse" to "salmon" was 60:40, whereas if one examined a representative collection of scales the ratio was 93:7. This discrepancy, as I have shown in a series of papers[13], arose from the fact that in recent years the grilse in the River Foyle have a very high average weight and a high proportion of them weighed 8 lbs. and upwards, with an occasional genuine grilse of 14 lb. Now had we examined the weight range on a time scale we would, on the basis of the results of scale reading earlier, have concluded that we had a substantial number of small summer fish, that is to say fish which have spent more than two but less than three years feeding in the sea. A phenomenon of this kind could partly, if not wholly, explain the apparent increase in salmon in other areas as well. I am informed that in 1969 at least a similar phenomenon was observed in relation to Scottish salmon.

I have devoted considerable time to the salmon as that is a species very much in all our minds today because of its vulnerability to overfishing, especially on the high seas and in Greenland but I feel I must mention one other matter. If I was appointed Managing Director of a Company to manufacture say, furniture, I would naturally expect my Board to set out its objectives - the type of furniture to be produced and so on - perhaps on somewhat general lines. Likewise I feel that when we consider managing salmon fisheries the objectives should be set out clearly. For example do we want the fishery managed mainly in the interest of the angler

or have we a more general interest in both angling and commercial (netting) activities, because our actions will be governed largely by our objective. Unfortunately our objectives are seldom set out as clearly as I think they should be.

Scientific investigations on salmon have been very extensive in the past twenty-five to thirty years but much less attention has been given to the sea trout, which is a sporting fish of considerable importance to some areas. Although I know that sea trout are taken by nets in some places, for example, off East Anglia and they are taken, at least the larger ones, as a by-product of commercial salmon fishing in many areas, nevertheless their exploitation commercially seems to be on a much lower level than is the case with salmon, at least as far as Great Britain and Ireland is concerned. For this reason sea trout stocks would appear to me to be an excellent subject for management on a scientific basis in the interest of angling. However before we can manage sea trout stocks scientifically we must know a lot more about the biology of this species.

Menzies was the first in these islands to examine systematically the scales of sea trout and in 1919 he published a paper on the sea trout of the River Forth. However he was more concerned with the salmon and it was fortunate that Menzies should have become acquainted with the late G.H. Nall in 1923. As explained in Menzies' book Sea trout and trout[14], published in 1936, Nall became a voluntary research worker with the then Fishery Board for Scotland and as a result he produced a magnificent series of papers on sea trout of Scottish rivers. Later he did some work on Irish sea trout, as well, all of which he mentioned in his now well-known book The life of the sea trout[15].

There is, however, some evidence that there are wide variations in, for example, the average size of the different age groups of sea trout and of the composition of the smolt runs. This point first came to my knowledge when I was examining the scales of sea trout from some Irish rivers, which had been the subject of Nall's earlier work. Now the material used by Nall was still available in the Fisheries Laboratory in Dublin so I re-read the scales used by Nall in his earlier work and I found that my results were in complete agreement with his. I concluded then that there were real differences between the results obtained by Nall and mine relating to later years

as I have already indicated in a review paper I published in 1963[16], in which I gave a brief account of the works done on Irish sea trout up to that time. Incidentally, in a chapter in Jock Scott's Sea Trout Fishing[17], published in 1969 I gave details of later work as well. For these reasons I think a re-appraisal of the life history of sea trout would be well-worth while at the present moment, not only in Ireland but in Great Britain, the area with which most of us are concerned.

Tagging of sea trout has not been given the same degree of attention as that for salmon, although the work done by officers of the Ministry of Agriculture, Fisheries and Food in relation to the Coquet and East Anglian stocks has given very interesting results in relation to the possible management of the species.

Sea trout vary very much in character from place to place but little work has been done on whether the characteristics we find in any one place are genetic in character or not. Some work albeit limited in scope, has been done in Ireland on the rearing of ova of sea trout from the large Ems River (Sweden) fish and their planting out in Irish rivers. The results, for what they are worth would seem to indicate that the introduced fish were little different in average size from the native Irish fish but more work is certainly needed on these lines before we can be certain.

Another point which requires investigation is the question of the return of small sea trout to the water. I know of several fisheries where this is done as part of the management programme in the belief that the fish will later reach large dimensions.

Apart from the fact that damage may be done to the fish little is known as to whether this practice is beneficial or not. No amount of argument can substitute for knowledge. It is true that whilst whitling or finnock, which have spent less than a full year in the sea are quite small, will grow to larger sizes if returned unharmed to the water we know nothing as to why some sea trout return to the rivers on the first occasion after as little as 3 to 4 months sea feeding and why others remain at sea for one or more years. I am afraid that consideration of the average weights may also be deceptive, as I know from at least one case on an Irish river where

the practice of returning small sea trout was practised.

Many years ago the late Rowland Southern was intrigued by the great variation in the size reached by trout in Irish waters and he started in the twenties his researches into the reasons why generally in acid water the fish were small whereas in limestone waters they were large.[18] After exhaustive examination of representative collections of scales of brown trout from many Irish waters he came to the conclusion that acid water trout grew slowly and died young, whereas limestone trout grew rapidly and lived to ripe old ages. He showed that young trout from acid waters transferred to limestone waters grew rapidly and took on the characteristics of the limestone trout so the question was not entirely or mainly a genetical one. This was an important finding from the management point of view and, at least as regards Ireland indicated that it was no use stocking acid waters with outside stocks, rather, the stock should be reduced.

In recent years the Irish Specimen Fish Committee has collected, as a by-product of its work, sets of scales, length measurements and weights of specimen brown trout weighing 10 lbs and upwards. Examination of this material has indicated firstly that these specimen fish generally have grown rapidly and, secondly in most cases there has been a change (increase) in growth rate at a time when most fish would have been expected to slow down in growth. I have postulated that this change in growth rate is due to a change in feeding habits, the adoption of a fish eating habit.

Twomey has also shown that the addition of nutrients and limestone results in the temporary increase in the growth rate of brown trout in certain neutral or acid waters but the effect is comparatively shortlived and it is expensive.[19]

Of course many stocks of brown trout live within a closed system so that management on a rational basis is more easy of achievement than with salmon and sea trout. In many of the more important artificial fisheries for both brown trout and rainbow trout careful monitoring of the stocks is possible, both as regards the growth of the stocks and the catch. Indeed statistics relating to the numbers and weight of the catch provide the basic raw materials for management in such cases.

I have said nothing so far about the fisheries for coarse fish not because I believe them to be unimportant; on the contrary I think they are very important from the recreational point of view. Scientific research on coarse fish in Great Britain and Ireland was, until the last war, on a very restricted scale. Hartley's well-known paper[20] was published only after the war and at that time it constituted one of the few scientific papers on coarse fish in these islands. Since then a series of valuable papers have emanated from a number of authors but even today there are many gaps in many coarse fish species. Gradually, however, a fund of knowledge is being built up which will in the end provide us with sound scientific basis for management of these important fisheries.

One field of work which has not been given the attention it deserves in my opinion, is the relationship between species of freshwater fishes, and in particular, the question of predation and competition between species. Clearly in small enclosed waters we cannot expect to have first-class brown trout fishing and first-class pike fishing but it would be useful to know the interaction of other species one on another. This brings me to the question of introductions of exotic species from abroad. There are many anglers who believe that we should import all kinds of freshwater fishes in the general belief that the angling must be improved thereby. Unfortunately introduction of exotic species has not been an unmixed blessing and careful consideration must be given to each case on its merits. It is no good saying fish can be restricted in their distribution. Once in a country it is difficult, if not impossible, to restrict a species to one river, or part of a river system. The end result may be stocks of an unwanted fish over a wide area.

The question of weed control in many waters is of extreme importance and the new techniques being developed have important consequences for the fishery manager. I have left to the end the question of disease. The advent of UDN disease from the mid-sixties produced an interest in fish diseases in these islands. In the beginning a number of persons claimed to have identified the causative organism but it is obvious that these claims were wrong, although it was not so obvious at the time. The difficulty was that no one knew what was the bacterial floral pattern of normal salmon and trout and the isolation of a

particular organism from affected fish was obviously not evidence that this was the organism causing the disease. Some workers were obviously misled by the presence of myxobacteria which seems to be ever present in affected as well as unaffected fish. The premature release of information, which turned out to be completely inaccurate, was certainly harmful and gave rise to difficulties of a political nature. The origin of the disease and of the causative organism are still unknown, although we do know a considerable amount about its effects which seem, at least as regards Ireland to be very much on the wane. Control of disease and its eradication is an important element in management and we are fortunate that a number of organisations are working actively in this field at present.

Now that artificial propagation is being pursued actively in many areas scientific control at each station is essential. Recently in Ireland, for example, a virulent form of furunculosis has been identified, which does not seem to be of real consequence in wild stocks but is causing mortality in reared stocks.

Due to the interference by MAN proper management of fish stocks and fisheries is now vitally necessary and will become more so in the future and when I say management I use the term to cover activities by the small individual fishery owner, the larger owners, the Public Corporations and the other organisations concerned at local and national level with fisheries.

It gives me great pleasure to pay tribute to W.J.M. Menzies, who did so much in his time to foster an interest in science in relation to the management of salmon and trout fisheries. Those of us who knew him regretted his passing. I regarded him as a friend, as one of the giants in his field, whose love of fishing knew no bounds and even when infirmity struck him continued to fish and enjoy it.

REFERENCES

1. Knut Dahl and Sven Sømme (1936) Experiments in salmon marking in Norway, 1935. Skr. norske Vidensk Acad. 1935, No. 12; also for years 1936 to 1940. Ibid. 1937. Vol., 1938, No. 4 and 1941, No. 10.

2. Fisheries, Scotland Salmon Fish. 1937 (No. 1); 1938 (No. 1) and 1938 (No. VII).

3. Proc. Roy. Irish Acad. 62.C.7 (1962).

4. Jour. Roy. Soc. Antig. Ire. 88, 57-65 (1958)

5. H.A. Gilbert, The tale of a Wye fisherman, Methuen, London, 1929.

6. J. Arthur Hutton published annual reports on Wye salmon in the Salmon and Trout Mag. from 1913. (No. 5) to 1949 (No. 123).

7. Apart from the experiments referred to at 2 above. L. Rosseland has conducted tagging experiments in Norway over a long period of years giving similar results.

8. Co-operative Research. Rep (Sec. A.) No. 8 (1967), No. 12 (1909), No. 24 (1971) and No. 35 (1973) published by Int. Council Explor. Sea. (ICES), Copenhagen.

9. J.W. Jones and G.M. King, Proc. Zool. Soc. Land. 119, 33-38 and 120, 317-323 (1950).

10. D.J. Piggins and J. Lawrie. Costs of production of artificially reared salmon smolts. Rep. Foyle Fish, Comm. (1974). App. I. pp. 40-45.

11. Sci. Proc. R. Dublin Soc. 22 (No. 31). 1940

12. S. O'Meallain. Fish pass at Leixlip Dam. River Liffey development. Jour. Dept. Agric. Dublin 48 (1951).

My former colleague, Mr. C. McGrath, has also dealt with many of the engineering problems relating to freshwater fisheries in a paper "Inland Fisheries and the Engineer" (Trans. Inst. Civil Eng. Ireland 82 (1950). pp. 51-59.

13. See Rebs. Foyle Fish. Comm. 16 to 24 for details.

14. Arnold, London, 1936. Menzies' paper on the sea trout of the River Forth was published in Fisheries Scotland, Salmon Fish. 1919 (No. 1), June, 1920.

15. Seeley, Service, London, 1930.

16. Sci. Proc. R. Dublin Soc. Ser A.I. No. 10 (1902)

17. Sea Trout Fisheries, Seeley, Service, London, 1969, Chapter 18, pp. 193-203.

18. R. Southern Salmon and Trout Mag. Nos. 67, 68 and 69 (1932).

19. Eileen Twomey, Fertilisation of some acid or bog lakes in Ireland. Rep. Sea and Inland Fish, Ire (1950). App. 27. pp 90-104.

20. D.H.T. Hartley. The natural history of some British freshwater fishes. Proc. Zool. Soc. London 117. 129-206.