TECHNOLOGICAL ECONOMICS OF THE MANAGEMENT OF GAME FISHERIES WITH PARTICULAR REFERENCE TO THE DEVELOPMENT OF SCOTTISH TROUT WATERS

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A.J. Hails

Department of Management Science and Technology Studies,
University of Stirling,
SCOTLAND.

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ABSTRACT

In 1971 the government White Paper on game angling in Scotland stated that there existed a great need to make more waters available to the resident population and to visitors in Scotland. In order to bring about this development a complete re-organisation of angling was suggested including the evolution of a new body to organise trout angling in Scotland, the Scottish Anglers' Trust (SAT). This thesis examines these statements in very broad terms and, from a study of the angling industry in Scotland, it is apparent that there is in fact considerable evidence of under utilisation of many waters. However further analysis of the industry reveals that there is some excess demand over supply for certain types of water, namely well managed fisheries intended for intensive utilisation by anglers. There is therefore some need for development of more waters.

From a detailed discussion and analysis of the demand for game angling in Scotland it is thought that locational factors will be important in determining sales: thus the SAT and indeed the private entrepreneur, in locating a new fishery which is intended for intensive angling, must take account of the population distribution and competitive forces around any potential site.

A thorough examination of the management of game fisheries reveals that the costs of running an intensively fished water are likely to be quite considerable and there is a need for the careful assessment of management techniques to ensure that management is carried out in a technologically-economic manner.

The government intend that the SAT will be a financially self-sufficient body after an initial three year period of Exchequer support. From a detailed study of the role of the SAT the following points emerge: it is envisaged that some difficulties in the acquisition of waters may be encountered; running costs of the SAT will be high and it is not clear that the self-sufficiency objective can be satisfied. However it may be possible for the SAT to stimulate some government intervention to assist with the acquisition of waters, and, some financial support by the government, if this is found necessary, may be justified if the impact of the holiday angler on the local economy could be investigated further by the SAT.

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CHAPTER 1

GAME ANGLING IN SCOTLAND - PAST AND PRESENT

1.1 HISTORICAL BACKGROUND

Angling is undeniably one of the most ancient amusements on record. The earliest record of the sport dates back to 2000 years BC and since then it has been recorded on Egyptian remains and by the earliest Greek and Roman historians. In more recent times Blakey (1854) asserts that Britain has played a leading part in introducing rod-fishing to many areas of the world. In 1854 he wrote that, with reference to the Anglo Saxons, "in their diversified migrations, a fishing rod is now almost as necessary an appendage to the outfit as the rifle or pistol". He describes Scotland as almost unique in Europe with regard to its fishing waters, both loch and river, which abound with salmon, sea trout and trout and reports that the country permits "a comparatively open and free field for angling" such that it is possible to fish almost any water in the country without interference.

In his writings Blakey refers only to game angling (angling for salmon, sea trout and trout) and although this is still the most important form of angling in Scotland there are other forms of angling which are carried out in Scotland including coarse fishing (e.g. for pike, perch) and sea fishing. Both coarse and sea angling are of much greater importance in England than in Scotland although game angling is carried out in England. However because of the paucity of good game waters it tends to be a more expensive activity in England, while in Scotland it is still within the reach of the average person. This is particularly true of trout angling and it is with this form of angling that this thesis is mainly concerned.

1.2 PRESENT SITUATION

The angling situation in Scotland today is very different to that described by Blakey: fishing is no longer comparatively free and open for game fishing although this is still true of much coarse fishing in the country. Legally the situation has not changed since Blakey's writings: the right to fish for trout and coarse fish still belongs to the riparian owners of rivers and lochs (except in the Tweed which is a special case) and their permission must be sought before the angler can legally fish the water. With salmon and sea trout the fishing rights are also private but, as a separate heritable estate, may be owned separately from the land which adjoins it. Originally salmon and sea trout rights belonged to the Crown but over the years the rights have been awarded to subjects as rewards or payments for services rendered. Thereafter the right becomes a separate heritable estate. However while the acquisition of rights has not changed since Blakey's writings anglers must now seek permission from the owners and in addition pay a permit fee for the privilege to fish most game waters.

Blakey reported an increasing interest in angling during the 1800's, quoting the increase in rod and tackle makers and sellers in London from only 6 or 7 in the early years of the 19th century to between 40 and 50 by the middle of the century. The number today is nearer 150. This increase in interest reflects the dramatic change in life styles over the last 150 years. In the early 19th century 3 out of 10 people lived in urban communities, by the mid-19th century, once the effects of the industrial revolution had been realised, this number increased considerably until by the 20th century it has reached 8 out of 10. Associated with this increased urbanisation, since the inter-war years, has been the greater affluence of the communities bringing about the increase in car ownership such that populations have become very much e mobile. These changes, along with the increase in leisure time, e led to an increased demand for almost all outdoor activities. e angling has therefore, for the reasons discussed, seen a conside- le increase in interest over the last 150 years.

Rather more is known today of the actual numbers involved in game gling as a result of several studies on recreation demand. The most prehensive study on angling was that carried out by the National inion Polls in 1970. Their results indicated that 7% of the popula- on of 12 years and over took part in angling in the year of the udy involving 2.79 million people. Although it is rather difficult calculate how many carried out each of the three different types of gling since some anglers took part in more than one, it seems that proximately 53%, 34% and 13% went coarse, sea and game angling spectively. Unfortunately the study was carried out in England and les only and, since the pattern of angling is rather different, it unfair to assume that the situation would be the same in Scotland. U.K. study carried out by the British Travel Association (1967) cated that approximately 5% of the population (16 and over) went e and game fishing. Two studies carried out by Duffield and (1970, 1971) in Lanarkshire and Greater Edinburgh on recreation in the area indicated that on average, 5% of the population over years took part in angling during the year of the study. This gure included both coarse and game angling but since the former is such minor importance in Scotland it would seem fair to assume that majority of the 5% were game anglers. All the studies would pear to be of the same order of magnitude and it is a fair assumption at in Scotland 4-5% of the adult population takes part in game angling. number of young people involved (i.e. less than 16 years) has ver been assessed. Duffield and Owen's survey indicated that almost more mobile. These changes, along with the increase in leisure time, here led to an increased demand for almost all outdoor activities. Game angling has therefore, for the reasons discussed, seen a considerable increase in interest over the last 150 years.

Rather more is known today of the actual numbers involved in game angling as a result of several studies on recreation demand. The most comprehensive study on angling was that carried out by the National Opinion Polls in 1970. Their results indicated that 7% of the population of 12 years and over took part in angling in the year of the study involving 2.79 million people. Although it is rather difficult to calculate how many carried out each of the three different types of angling since some anglers took part in more than one, it seems that approximately 53%, 34% and 13% went coarse, sea and game angling respectively. Unfortunately the study was carried out in England and Wales only and, since the pattern of angling is rather different, it is unfair to assume that the situation would be the same in Scotland. A U.K. study carried out by the British Travel Association (1967) indicated that approximately 5% of the population (16 and over) went coarse and game fishing. Two studies carried out by Duffield and Owen (1970, 1971) in Lanarkshire and Greater Edinburgh on recreation within the area indicated that on average, 5% of the population over 16 years took part in angling during the year of the study. This figure included both coarse and game angling but since the former is of such minor importance in Scotland it would seem fair to assume that the majority of the 5% were game anglers. All the studies would appear to be of the same order of magnitude and it is a fair assumption that in Scotland 4-5% of the adult population takes part in game angling. The number of young people involved (i.e. less than 16 years) has never been assessed. Duffield and Owen's survey indicated that almost

25% of the population in the survey area was under 15 and therefore the number of juvenile anglers may be quite considerable. These workers also investigated socio-economic characteristics of the participants which are of some general interest at this stage. Very briefly, they found that, as one might expect angling is very much a male dominated activity with over 80% of the participants being male; secondly it appeals to all income and socio-economic groups and to all age groups; thirdly 5-9% only of all anglers belong to clubs or associations; fourthly over 70% of anglers have access to a motor vehicle; fifthly in the two areas it is the fourth or fifth most popular outdoor activity.

At present angling is made available to anglers by several different groups. Firstly, there are the riparian owners or private fisheries some of which open their waters to the general public on payment of a permit fee, while others, in possession of the higher quality waters, lease stretches to a limited number of individuals usually at a very high cost (such stretches are usually good salmon waters). There are fisheries which are leased or owned by hotels which offer angling as an added attraction to their guests (usually at no extra cost to the individuals), many also offering day permits to casual anglers. There are also clubs and associations, the former usually leasing a water, quite often at a fairly nominal rate, for the use of the members and the latter often being an amalgamation of clubs which leases several waters for the use of their members. Both are organised purely for the benefit of their members and costs to the members are minimised. In some cases day permits are sold to visitors the income from this often greatly contributing to funds.

The actual number of waters available to the public is not known exactly but by far the most comprehensive guide is that produced by the Scottish Tourist Board. The guide (which is entitled "Scotland for Fishing" and costs 30p) is revised annually and gives information on permit purchase, cost, fish species available and other relevant information. Over 650 rivers and lochs are listed in the booklet covering the whole of Scotland. As a comparison the coarse fishing guide produced by the same organisation lists a total of 80 waters where coarse fishing may be obtained, reflecting the lack of interest in this activity in Scotland (it is however thought that coarse fishing is on the increase, particularly from English and foreign visitors).

Angling is organised for anglers in Scotland by several different groups. All are concerned with the promotion of angling interests and the protection of angling waters in Scotland and it would seem from the stated objectives and aims of the organisations that there is considerable duplication of effort. The Salmon and Trout Association is a British organisation whose principal aims are to protect and improve salmon and trout fisheries of the U.K.; to act as a watchdog for game fisheries interests; to advise ministers and public authorities on matters which affect salmon and trout fisheries and fishing and to help organise opposition to harmful proposals relating to water. The organisation publishes one of the main game fishing periodicals, the Salmon and Trout Magazine, which is produced both for its members and the general public. This is perhaps the biggest organisation with a stated interest in Scottish matters. The National Anglers Council whose executive is made up of representatives from coarse fishing (the National Federation of Anglers), game fishing (the Salmon and Trout Association) and sea fishing (National Federation of Sea Anglers) is obviously the organisation representing the angling interest in its widest, national sense but it is only concerned with matters pertaining to England and Wales although it does control the British register for record sizes of all fish species caught in British waters. The Anglers' Co-operative Association is an organisation concerned primarily with the promotion and protection of angling aims and interests and is devoted to fighting water pollution. It provides a useful information service for its members. The aim of the Scottish Anglers Association is to promote the aims of Scottish anglers and to encourage the formation of angling clubs and associations. Again they are concerned with the avoidance of water pollution and are prepared to bring pressure to bear upon polluters. Finally there is the Scottish National Angling Clubs Association. Membership of this organisation is confined to clubs (with a minimum of 25 members) which have been constituted for at least 5 years. While the organisation is concerned with the promotion of angling and also with consultations with government bodies on any matters pertaining to angling, in particular trout angling, it is also concerned with the organisation of competitive angling both at a club level and also at the international level. To this end it is affiliated to the international Fly Fishing Association which organises the matches between Scotland, England, Ireland and Wales.

The above list of organisations concerned with angling in Scotland is by no means exhaustive and it is clear that there is some duplication of effort as a result. Almost all the organisations are small with limited manpower and resources and there is a need for either a co-ordinating body or alternatively a complete re-organisation of the control of angling interests in Scotland.

1.3 CURRENT CHANGES IN THE ORGANISATION OF TROUT ANGLING IN SCOTLAND

Over the last few years there have been government commissioned reports and a government White Paper on angling in Scotland, finally culminating in a new Act in 1976. Although these changes will be discussed in greater depth later it is important to state at this stage that the proposed changes are likely to completely change the organisation of angling in Scotland.

According to the White Paper on angling (H.M.S.O., 1971) "trout fishing is particularly popular in Scotland. It is a pastime enjoyed by many people from all walks of life. As there is no public right of fishing in Scottish rivers there is only a limited number of waters where trout anglers in general can fish; and there is a great need to make more waters available to the Scottish public and for visitors". The Paper suggests a complete reorganisation of angling in Scotland including the formation of a new body, the Scottish Anglers' Trust, with responsibility for the development of trout angling in Scotland. It is intended that this new body will improve the availability and quality of trout waters available to anglers, both local and visitor.

1.4 CONCLUSIONS

This introductory chapter has briefly described the change in angling interests over the years and has described in more detail the current angling situation in Scotland from the information available.

The new proposed angling system for Scotland has been briefly discussed here because of its potential far-reaching effects on Scottish angling and it is discussed in greater depth in Chapter 2.

Basically angling as a sport, in common with most recreational activities has been increasing over the last 100 years and continues to increase today. In Scotland brown trout angling is recognized as the sport of the angler of moderate means and it is with this particular aspect of angling with which this thesis is mainly concerned although it is impossible to consider this type of fishing in isolation from salmon, sea trout and coarse fishing.

At present trout angling is not well organised in Scotland although it is thought to be of importance for both recreational purposes and for the tourist industry. The organisation of trout angling lags behind other countries where the sport is equally important and the new legislation represents an attempt to rationalise the whole system.

Finally it is apparent from the discussion of angling in this chapter that there is a paucity of information on many aspects of the angling industry. There is some information on the number of anglers involved from the work of Duffield and Owen and others but little on the current state of angling waters with regard to number, situation and utilisation, or on the development potential of waters with regard to initial investments, annual running costs or potential return on any such investment in the industry. Such questions must be of relevance to any group which is organising angling in Scotland such as the Scottish Anglers' Trust and also the private investor.

It is necessary therefore to determine where in Scotland there is a need for development as suggested by this White Paper and this requires some knowledge at least of the factors which are important in determining demand for angling. Such knowledge would permit a more informed selection of waters for development. It would also be necessary to know something of the likely costs which will be incurred in both the management and general running of fisheries, in order to decide whether development of a particular water is potentially a financially viable proposition (this must be true irrespective of the financial objectives of the developer although the interpretation of 'financially viable' will vary depending upon the overall objectives of the developer). It should be clear now that any decision makers, in angling, if they are to meaningfully answer these questions and make the correct policy decisions will have to adopt an inter-disciplinary approach rather than aiming for either biological or economic optima. Neither optimum will determine the best strategy: what is required is a technological economic approach which will permit the fusion of the many aspects of micro-economics which are relevant to the problem with the technology of fisheries management. The validity of this statement will become apparent in the chapters which follow.

The aim in the remainder of this thesis is to put this approach into practice in answering these questions which are so pertinent with the current development of trout angling in Scotland. Chapter 2 discusses in detail the recent developments in trout angling organisation. In the next section, Chapters 3 and 4 set the economic perspective with firstly, a detailed discussion on the current angling industry its size, pricing strategy and other related information from a questionnaire survey carried out in Central Scotland angling waters. Secondly, in Chapter 4, some of the data from Chapter 3 on permit sales and related information is utilised in an attempt to identify the factors which are important in the determination of sales. Although a predictive model may not be successfully developed with such cross-sectional data, any information on the variables which determine permit sales, their relationship with the dependent variable and relative importance would be of considerable value in the development of trout angling. In Section 3, Chapter 5 very briefly sets the biological perspective with a discussion on the biology of trout fisheries. Section 4 goes on to consider the biology and economics of trout angling. Chapter 6 gives a detailed discussion of the more common management methods in trout fisheries considering both the biological and economic objectives of fisheries management which lead to the overall management strategy; Chapter 7 goes on to consider the costs involved in running a trout fishery, including the management costs discussed in Chapter 6 along with all the other costs involved. Reference is made to three case studies to facilitate this assessment. Finally, in Section 5, the findings of the previous chapters are brought together in Chapter 8 with a discussion of the potential for development of trout angling in Scotland discussing this in the context of the White Paper.

CHAPTER 2

GAME ANGLING IN SCOTLAND - THE FUTURE

2.1 INTRODUCTION

In Chapter 1 the recent discussions on game angling in Scotland were mentioned and the importance of these changes with regard to the development of angling highlighted. This is discussed in detail in the latter part of this chapter. The first section very briefly describes trout angling and the laws which related to it at the start of this study since this is of general relevance to the thesis and of particular relevance to the latter part of this chapter.

2.2 TROUT ANGLING AND THE LAW

There have been several acts passed since the turn of the century concerning trout fishing. In 1902 an act was passed which made it illegal to fish for or have possession of trout during the close season (H.M.S.O.,1902). This was an attempt to protect stocks of trout during the breeding season, the close season extending from 7th October until the 14th March. This legislation came some 35 years after similar legislation for salmon stocks. It is also illegal, by the Trout (Scotland) Act of 1933 to purchase or sell trout under 8" at any time, or, between 1st September and 31st March irrespective of size. Many fisheries impose their own size limits during the season but these are not dictated by the law. The setting of the 8" limit for buying or selling trout in season is partly to protect trout populations in that it encourages anglers to leave trout until after they are likely to have reached spawning age. However it has also been imposed to protect the salmon populations: it is illegal to take salmon parr or smolts and since they are similar in appearance to young trout the 8" limit discourages the removal of what may in fact be young salmon rather than young trout.

Until very recently illegal fishing for trout was a civil offence (illegal fishing for salmon has been a statutory offence since 1951) requiring the proprietor of the water to go through the laborious process of taking out an interdict against the individual. This process has made the protection of waters very difficult.

2.3 RECENT CHANGES IN TROUT ANGLING IN SCOTLAND

On the 12th March 1962, a committee on Scottish salmon and trout fisheries was appointed "to review the law relating to salmon and trout fisheries in Scotland, including the Tweed, and its operation with special reference to the constitution, powers and functions of District Boards, and the responsibilities of the Secretary of State, and to consider in the light of current scientific knowledge the extent to which fishing for salmon and trout by any method, whether in inland waters or in the sea should be regulated, and to recommend such changes in the law as might be thought desirable" (H.M.S.O, 1965). The committee was chaired by Lord Hunter and subsequently known as the Hunter Committee.

The first report of the Hunter committee in 1963 dealt exclusively with the subject of drift-net fishing for salmon in the sea, but their second report, although discussing salmon fishing in detail, devoted considerable time and thought to trout angling.

Although the second report (H.M.S.O., 1965) states that there is a great lack of information on the state of trout angling in Scotland the committee still regard it as of major importance to the angler of moderate means. They state that "the actual and potential demand for angling is very large and the objective should therefore be to provide in all parts of Scotland ample brown trout angling available to the public at a price within the means of the ordinary angler together with some higher quality fishing which would often be more expensive". This statement is the central theme of the recent changes in trout angling in Scotland and, the suggestion that there is a large potential demand for angling which can only be satisfied by the development and improvement of more waters forms the basis of this thesis. Accordingly, the proposed changes are discussed in some detail in the remainder of this chapter so that the implications of the changes may be discussed in full.

The main suggestions put forward by the Hunter Committee, to achieve their objective, include statutory protection for fisheries, a licensing system for anglers, introduction of area boards to administer all fishing (i.e. salmon, sea trout, trout and coarse fish) and the founding of the Scottish Anglers' Trust, an organisation to be run by anglers for anglers with the specific aim of developing trout angling. This report by the Hunter Committee formed the basis of the government White Paper on 'Salmon and Freshwater Fisheries in Scotland' (H.M.S.O., 1971). In general the Paper accepted and further reinforced the view of the Hunter Committee.

The major points in the White Paper with regard to changes in trout angling in Scotland are described in the paragraphs which follow and this is followed by a discussion of the financial implications of the changes as seen by both the Government and the Hunter Committee.

<u>Statutory protection</u>

It has often been stated that the main factor which has prevented the development of trout fishing in Scotland has been the difficulty of preventing unauthorised fishing on Scottish waters. The recommendation from the Hunter Committee was therefore that poaching should become a statutory offence involving fines and imprisonment for repeated offenders. The Government have however concluded that protection should not be afforded to all proprietors as suggested by the Hunter Report: they have decided that only those waters which co-operate and open their waters to the public on a satisfactory basis (as judged by the Area Boards) will be protected. (However since protection will be given on an area basis (e.g. catchment area or part of catchment area) rather than an individual water, some waters closed to the public, or not meeting the requirements of the Secretary of State, may still gain protection. This is essentially because of the difficulties of legislating for rivers which are divided up into many fishing 'stretches' or beats run by different proprietors.)

<u>Licenses</u>

Most countries where rod fishing is popular have a licensing system and Scotland is almost unique in having, to date, no such system. The advantages of a licensing system are that (a) it provides a revenue which contributes towards the cost of improvement of waters; (b) it permits identification of anglers and in so doing makes control of anglers considerably easier; (c) it permits the collection of statistics on anglers and may make the collection of statistics on anglers' catches easier. The report recommends the introduction of annual licences for all anglers, the details of which would be laid down at a later date. The licences would not, of course, give the angler the right to fish any water in the country, permission would still have to be obtained from the owner who would still be able to charge a permit fee for the right to fish on his water.

Area Boards

At the moment the trout fishing in Scotland is not adequately organised: the organisations involved at present have already been discussed in Chapter 1. To rectify this the White Paper has suggested a new pattern of local administration requiring the division of Scotland into 14 area boards. Administration of salmon fishing has been through the Salmon Fishery District Boards and the success of these has varied considerably in different areas of the country. The paper suggested that these should be discontinued and the area boards introduced to take their place although with additional responsibility for trout fishing. The main functions of the board which are of relevance to trout fishing should include:

(i) Regulation and management of fisheries, including control of netting in brown trout waters; imposition of close season and powers to change this, subject to local conditions; control of artificial introductions of eggs and fish to waters.

(ii) Fishery protection and the operation of a fishery warden service.

(iii) Maintenance of a register of all protected waters.

(iv) Issue of fishery licenses.

(v) Levying of a fishery rate. This will be based on the valuation of trout fisheries carried out by the district assessors.

(vi) Liaison with tourist organisations and the Scottish Anglers' Trust.

(vii) Representation of the fishery interest.

The membership of the board should include representatives of the salmon and trout fisheries in the area and, to ensure that other interests in the affairs of rivers or lochs are not ignored and that independent views are expressed, there should be other non-fishery members also. It is envisaged that the area boards should become financially self-sufficient after an initial period of Exchequer support, their income coming from salmon and brown trout rates, rod licences and salmon net licences. The total anticipated revenue from these sources was not discussed by the White Paper but the Hunter Report quoted figures in the region of £140,000 from rates and £125,000 - £175,000 from licences although these are clearly estimates from the limited information available to the committee. Part of this money will go to the area boards but part will also be redistributed to the Scottish Anglers' Trust.

Scottish Anglers' Trust (SAT)

The SAT is seen as an organisation run by anglers for anglers. Its objectives would be generally to develop angling in Scotland, in particular brown trout fishing. Obviously it would take over most, if not all, of the responsibilities of the many organisations already in existence in Scotland, some of which have been described. The SAT would seek to acquire waters for the use of its members, manage these acquired waters and also collect statistics from its waters which would assist in management policies. Of the three functions only the first requires further explanation.

The White Paper gives the following three methods of acquiring waters:

1. Local angling clubs may wish to affiliate to the Trust making their waters available to members of the Trust;

2. Proprietors may be willing to hand over their waters for the Trust to administer and manage, thereby relieving themselves of any responsibility whilst still obtaining protection;

3. The Trust, once established, could purchase or lease waters on its own.

In order to fish waters under the control of the SAT, anglers would have to pay an annual subscription to the Trust (50p-100p per year was suggested) although certain waters which were expensive to manage or provided extra services (e.g. boats and outboards) may have additional charges.

Financially it is intended that the SAT, after initial Exchequer support, should become self-supporting with an income from the anglers' subscriptions, permits for non-members, additional charges to members for 'expensive' waters, and a share of the anglers' licence fees collected by the Area Boards. Anglers' subscriptions will of course depend upon the success of the SAT in acquiring and managing desirable waters and, in laying down only three methods of acquisition, the Paper has rejected two of the proposals put forward by the Hunter Report: firstly that control of waters owned by public bodies should be handed over to the SAT and secondly that unregistered waters should be registered in the name of the SAT and controlled by them for their members. (The Hunter Committee recommended that all waters ought to be registered, similarly all waters were to be protected.) Both of these methods gave the Trust a good chance of acquiring a large number of waters early on in its development which would, of course, improve the Trust's chances of attracting a large membership and securing financial self-sufficiency.

The methods of acquisition put forward by the Government are less promising. With the first suggestion it is difficult to see the advantage to be gained from affiliating to the SAT. Protection would be available to a club without affiliation and, while affiliation may mean some assistance with management, it also means that the water is open to the members of the SAT. The club thus runs the risk of heavy angling pressure, the loss of visitor permits which many clubs sell, for the benefit of the possibility of assistance from the SAT with management. The second method of acquisition is equally likely to be unfruitful in that it seems likely that proprietors who are willing to behave in the manner suggested will have already leased their water to a local angling group. The number of waters which will be acquired in this way is therefore likely to be small. The third method has similar problems in that areas where there is a demand for angling waters are likely to have few waters available for lease at a reasonable price since clubs will have already taken over available ones. If the more expensive trout waters are to be bought or leased then it is clearly going to be a costly activity for the SAT. In this situation the Trust needs the waters to attract membership but needs the membership in order to raise funds for the acquisition of waters.

It is therefore difficult to visualize a self-sufficient Trust appearing after three years. The chances of success of the Hunter Report suggestions were very much higher in that a large number of waters could have been acquired within a short space of time. The Government by retaining the waters in public ownership and by avoiding the takeover of unregistered waters have made it very difficult for the Trust to acquire a substantial number of waters and have therefore made the success of the Trust open to some doubt.

One of the more general criticisms of the White Paper (and this is also true of the Hunter Report) is the lack of any quantitative discussion on the financial viability of the proposed angling system. It is recognized that there is a need to make more waters available to the public, both local and tourist, at a reasonable price, to satisfy the local and tourist demand for angling. The importance of the sport to the country is recognized: "It too, therefore (brown trout angling) makes a valuable contribution to the Scottish economy and is one of the basic attractions to visitors to many of the remoter areas" (H.M.S.O., 1971). However nothing further is mentioned on the number of waters envisaged, the size of the local and visitor demand or the actual or estimated contribution to the economy of the activity. Furthermore, in the financial aspects of the actual running of the new system, irrespective of its magnitude or impact, there is very little discussion. In the Hunter Report there is mention of the potential annual income from licence sales, salmon and trout rates, and government grants in the first years. In the government report there is mention only of the government grants to be made to the Area Boards and the SAT in the first three years of their existence. The potential income from government grants (as estimated by the Government) and from rates and licence sales (as estimated by the Hunter Report) are shown in Table 2.1. The potential income from anglers (other than membership fees) is not estimated here. Clearly there will be charges to non-members wishing to fish SAT waters as well as some additional charges to members for some waters.

TABLE 2.1

Potential Income of Area Boards and SAT

Item	£'s Year 1	£'s Year 2	£'s Year 3	£'s Year 4
Government grant	150,000	125,000	100,000	0
Licences	200,000	200,000	200,000	200,000
SAT Subscriptions	10,000	10,000	10,000	10,000*
Rates	134,000	134,000	134,000	134,000
Total	494,000	469,000	444,000	344,000

*see p.23

The total in year 1 is certainly an over-estimate in that it will take more than one year to levy rates on trout fisheries since these have never been done before and it is also likely to take more than a year to realise the income quoted for licences and SAT subscriptions. The Hunter Report estimated that there would be in the region of 75,000 to 100,000 licences sold annually raising in the region of ca. £200,000 annually. Using the Duffield and Owen (1971) figures of the angling population this amounts to only 30-40% of the angling population and may well be a serious underestimate of the actual sales.

It is difficult to make any comment on the adequacy of this income without some knowledge of the potential financial requirements of the Area Boards and the Scottish Anglers' Trust. Neither the Hunter Report nor the Government made any attempt to assess the likely annual costs of the two organisations if they are to fulfil their functions. The costs for both must include, in general terms, buildings for offices, labour, management materials, office running costs, vehicles etc. Without any attempt to quantify these it is impossible to comment upon the vaiability of the new proposed system.

At this stage it is instructive to consider the Irish angling situation because in many respects it is similar to the proposed Scottish system, and, in particular to the proposed SAT which will control trout angling.

2.4 THE IRISH ANGLING SITUATION

Angling in Ireland is similar in many respects to Scotland: many hotels own or rent fisheries for the use of their guests; many private fisheries exist which are of variable quality; an organisation exists which is similar in function to a large extent to the proposed SAT. This organisation is the Inland Fisheries Trust Incorporated (IFT) which was established in 1950.

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The function of the IFT is to run and develop brown trout, coarse and sea angling in Ireland for the benefit of the anglers. They have a large staff covering both administrative and scientific personnel and their expertise in the field of fisheries management is well documented.

For their annual income they rely heavily on government grants and to a very much lesser extent on members' subscriptions (members may fish all of the many IFT waters free of charge, or at a very low cost, membership in 1975 costing £2 per year, non-members having to pay £1 per day permit). For example in 1975, state grants amounted to £430,000 while income from subscriptions, donations and permits amounted to £20,905. This reliance upon state grants is not however regarded as a desirable situation by the IFT: "Council is very conscious of the growing imbalance between the government's subvention to the Trust and contribution from anglers - the primary beneficiaries of our work" (IFT, 1971-72). It would seem therefore that while they would not expect to become financially self-sufficient they would hope to reduce the gross imbalance between government funds and anglers contributions. One possible explanation for the low membership recorded by the IFT is that their waters are not evenly distributed over the country and in some areas well removed from IFT waters, anglers are unlikely to subscribe for the privilege of fishing on the Trust's waters only very irregularly.

Membership of the IFT (this is of course similar to the membership of the proposed SAT) in Ireland is about 6,000, this amounting to a very small proportion of the population of the country (ca. 0.2%). The proportion of the population which takes part in angling is not known but if it is assumed that it is the same proportion as in Britain then membership amounts to only ca. 4% of the angling population.

Annual expenditure amounts to ca. £500,000 per year. The figures for 1975 (IFT 1975-76) for example, amounted to £503,866 including £433,325 on brown trout fisheries, £65,503 on coarse fisheries and £5,038 on sea angling. Salaries for all employees, including 160 full-time and 20-30 casual employees, amounts to about 75% of the total annual outlay. The expenditure for 1975 is shown in some detail in Table 2.2

TABLE 2.2

Expenditure of the IFT in 1975

Item of Expenditure	Cost in £'s	% of total
Fish food	15,586	3
Management Materials	27,731	5
Salaries	376,289	74
Vehicles	31,116	6
Travel & Subsistence	15,856	3
Rent & Rates	3,045	1
Insurance	5,194	1
Stationery Post, Telephone, Advertising, Bank Charges	10,969	2
Depreciation*	24,329	5
Miscellaneous	943	<1
Total**	511,268	

* Depreciation is of Fixed Assets other than property (i.e. excluding buildings and fish farm. It includes vehicles, boats, outboards, other equipment).

** This does not include alterations in expenditure due to opening and closing stocks of fish.

It is worthy of note that these figures, as already stated, cover brown trout, coarse and sea fishing. However the emphasis is very strongly on brown trout which accounted for 86% of the annual expenditure in 1975.

There are two major points which emerge from this discussion of the Irish situation which are of great relevance to the changes in the Scottish system. Firstly it is likely that membership of the SAT could well be disappointingly low. No estimate of Trust membership was indicated by the Hunter Report or by the Government. Given the findings of the Irish Trust and the fact that the control of waters could well be rather restricted for reasons already discussed a low membership may be expected. If it is similar to the Irish experiences (i.e. 0.2% of total population) then membership may well be as low as 10,000.

Secondly, it is clear that the costs of running the new Trust are likely to be on a parallel with the Irish costs. (There will of course be the additional costs of running the boards but further discussions will relate entirely to the SAT since trout angling is the main interest in this study.) Once the government grants are terminated it may seem unlikely, given the Irish experiences, that the income to the Trust will be sufficient to meet the costs. However, this assumes that the SAT is to be organised along similar lines to the IFT and since no definitive statements of the overall objectives of the SAT have been made by the government the assumption that angler income will be similar to Irish figures may well be unrealistic. There is therefore a need for most detailed discussion on the role of the SAT before any assessment of the financial implications of the proposals can be made.

2.5 THE SALMON AND FRESHWATER FISHERIES (SCOTLAND) ACT, 1976

Since the publication of the White Paper which reported the government's intended course of action there were no further developments until the end of 1975 and early 1976. At the end of 1975 the Freshwater and Salmon Fisheries (Scotland) Bill was presented to Parliament. This Bill contained the machinery necessary to bring about statutory protection for fisheries, in accordance with the pronouncements in the White Paper; to empower the warden service to carry out their supervisory role; to set the penalties for offences against fishery enactments and finally to affirm that Exchequer contributions towards organisations developing freshwater fisheries will be forthcoming, the amount to be determined by the Secretary of State for Scotland. The Bill, after minor amendments, became an Act in June 1976 and goes some way towards implementing the White Paper.

In a statement of the principles behind the Bill the government stated that the Bill is seen as a first step towards improving trout fisheries. It has been done in the spirit of the White Paper and it is felt that although many of the recommendations have not been implemented e.g. the area boards and the licensing system, they are accepted as realistic recommendations which may eventually be implemented. The Scottish Anglers' Trust is supported in theory by the Government and they see a great advantage in the existence of such a body in the context of the Bill. Although not explicitly mentioned in the Bill it is none the less implied in certain sections that such an organisation should come into being. From the government debates on the Bill it is clear that a large number of M.P's and fishing organisations regard this very much as a first step towards implementing the useful and practical suggestions of the White Paper.

2.6 THE FUTURE FOR SCOTTISH FRESHWATER ANGLING

It is fairly evident from the latest developments that the future of Scottish angling is still uncertain. What is certain however is that changes will be taking place which will promote the development of more waters. It is unlikely that this present Parliament will provide any further legislation on the subject through lack of Parliamentary time (D. Canavan, M.P., pers. comm.). What does seem more likely is that the Scottish Assembly, when it comes into operation, will devote time to implementing more of the White Paper recommendations, especially since there is likely to be more effective representation from the many angling organisations and individuals in Scotland, who are openly concerned about the shortcomings of the Act.

Given the number of years which it has taken for the current advances it is difficult to project a final date for further legislation but it does seem, from current opinion, that further developments along the lines of this White Paper are very likely.

2.7 CONCLUSIONS

It is apparent that while some aspects of the proposed system such as the licensing system, statutory protection etc. are clearly necessary and can only be of benefit to anglers and organisers of angling, other aspects are of less certain success. For example, the acquisition of waters by the SAT may be a problem and this is necessary to ensure a good membership of the Trust.

Financially the SAT has unknown requirements but it has been asserted that the Irish figures of expenditure present a good yardstick. After a more detailed examination of the angling situation in Scotland and the role of the SAT in the chapters which follow it will be possible to assess in more detail the financial implications of the new proposals.

SECTION 2 THE ECONOMIC PERSPECTIVE

CHAPTER 3

THE QUESTIONNAIRE

3.1 INTRODUCTION

In Chapter 1 the general aims of the project were outlined indicating the need for information on the angling industry, its size, pricing strategy, and other related information. Unfortunately the game angling industry is rather diverse in nature and as a result information on the individual firms within the industry is not readily available from any single source. It is the case also that, unlike many industries, many of the firms do not retain records of their sales etc. so that for the majority of firms time series data are not available. It seemed therefore that in order to make some assessment of the industry the only recourse was to approach the firms individually requesting relevant information for the season just finishing (1973 season) since it was assumed that all firms would keep fairly complete records of their sales etc. for the current season.

3.2 METHODS

Before pursuing this any further a preliminary requirement was to ascertain whether a reliable and comprehensive list of fishing waters and their controlling bodies was available. Various lists of angling waters/bodies are retained by national angling bodies but since these are largely advisory/consultative bodies their lists are likely to be far from comprehensive. The most comprehensive list located is that produced by the Scottish Tourist Board entitled "Scotland for Fishing - A comprehensive guide to angling facilities". The list, produced in booklet form, is updated annually and provides information on the waters available for game angling, the cost and types of permit available, the species of fish which are likely to be caught and the source of permits. The information supplied is collected from the controlling bodies of the waters including private individuals, public bodies, hotels, clubs and associations. The guide has been published annually for over 20 years and the publishers have expressed confidence in its comprehensiveness (Scottish Tourist Board, pers. comm.).

It would have been interesting to have covered the angling waters in the whole of Scotland but, because of the very large number of waters involved, this would have necessitated a survey with all the attendant complications surrounding random sampling. Instead it was decided to limit the area to the North, as far as Perthshire and Angus and, to the South as far as Ayrshire, Lanarkshire and Selkirk (see Fig. 3.1). With this restriction it would be quite possible to carry out a full census of known waters rather than a survey.

There were two possible ways of obtaining the necessary information from the waters: by interviewing the relevant bodies or by sending a mail questionnaire to them. The advantages of using the interview technique are that a higher response rate can be expected and also that more complex questions can be asked since an interviewer is present to assist with any problems of interpretation. Although the latter is not of much importance to the present study, since the information required is exclusively of a factual nature and unlikely to present any interpretative problems, the former is of more relevance to the study since for the purposes of demand analysis and prediction it is necessary to have, as near as is possible, a complete return from the geographical area under study. However the disadvantage of the interview technique is that it is very costly in time and manpower and because of this it would be necessary to reduce considerably the study area or resort to a survey of the area rather than a census. The mailed questionnaire

FIG. 3.1 The census area for the questionnaire showing the distribution of waters within it.

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overcomes the financial problem since it costs very little to produce and send but its over-riding problem is the response rate which is reputed by many sources to be typically rather low. The problem with a low response rate is partly the small sample size which results but of greater importance is the possibility of a biased response - to quote Oppenheim (1972) "non-response is not a random process". However Oppenheim quotes figures which indicate that although response rates from respondents with no particular interest in the subject may be only 40% or lower, the response rate from respondents who have some interest in the subject may be as high as 80%. With the present study one could then hope for figures around this latter size since the questionnaire would only be sent to individuals or groups actually involved in a fishery.

The chances of an acceptable response rate can be improved by including with the questionnaire a stamped, self-addressed envelope. According to the literature (e.g. Moser and Kalton, 1971) this offers a good incentive for respondents to reply since most individuals would avoid wasting a stamp but would feel it was basically dishonest to remove the stamp for another use.

On balance it was decided that although more risky than the interview method the mail questionnaire was the more appropriate technique for the information required. Since the data was of a factual nature the questions were of the pre-coded rather than free-response type, this being easier for both the respondent and the analyst.

As stated earlier, the questionnaire was designed largely to gather information on the pricing and permit sales of firms in the fishing industry and this information was derived from questions 3, 4, and 5 but it was decided to include other questions on ownership (question 1), some aspects of water quality and evidence of management (questions 7, 8, 9 and 11) and other questions of general interest (see Fig. 3.2). In order to explain the purpose of the questionnaire and to assure respondents that any information would be treated confidentially a covering letter was sent along with the questionnaire (see Appendix 1).

It is always recommended in questionnaire surveys that a pilot study first be carried out before the main survey to ensure that the questions are clear to respondents. Unfortunately due to time restrictions it was not possible to carry out a pilot study but a pre-test was carried out instead. Three fisheries in the locality were visited personally and the owners asked to answer the questions and discuss any problems they encountered with interpretation. No problems were apparent however and the questionnaire was sent out unaltered.

3.3 RESULTS AND DISCUSSION

The first mailing, including an introductory letter, the questionnaire(s) and a stamped, addressed envelope was sent out on the 20th November 1973. Questionnaires were sent out to 125 water bodies including 214 actual fishing waters (it is quite common to find more than one water controlled by the same body). The distribution of these waters is shown in Fig. 3.1.

The first return resulted in a rather poor response with 42 of the bodies surveyed returning completed questionnaires. This represents a return of 34% and included 62 individual waters. It was felt that part of the reason for the low response was due to the fact that (a) not all water bodies had completed their end of season returns at the time of receiving the questionnaire and (b) that some of the clubs and associations required a committee meeting to authorize the release of the information requested. Both of these factors

Please answer all questions on the basis of this season's information.

<u>If you control more than one fishing water please fill in one questionnaire for each fishing water</u>.

1. What is the name of the fishing water? ______

2. Is the fishing water:-
   - i owned by the permit issuing body? Answer yes or no ______
   - ii leased from a private landowner? Answer yes or no ______
   - iii leased from a public landowner? (e.g. Forestry Commission, Council) Answer yes or no ______
   - iv any other, please state ______
   - v don't know? Answer yes or no ______

3. What is the total number of permits you have sold this season?

4. Please list below the total number of each type of permit you have sold this season and their respective prices.

Type of permit	Number sold this season	Price of permit
Half-day		
Day		
Juvenile (Day)		
Boat (Day)		
Week		
Fortnight		
Month		
Season		
Juvenile (Season)		
Any other, please state		

5. If you issue permits <u>other than</u> day permits e.g. week, month, season etc. is it possible to calculate from your records how often such permits have been used while valid?

   Answer yes or no ______

6. (a) If boat fishing is permitted, how many boats do you have? ______

   (b) How many rods per boat are permitted? ______

N.B. In each Questionnaire, if a Club, will you please indicate in 4 above, membership number and cost and number man-days fished in 1973 Season.

7. (a) Do you record all anglers' catches? Answer yes or no ______

   (b) If "yes" what is the total catch this season for the species of fish listed below?

Species	Total number caught
Brown trout	
Rainbow trout	
Salmon	
Sea trout	
Coarse fish	

8. (a) Do you record the weights of fish caught? Answer yes or no ______

   (b) If "yes" what was the total weight and/or average weight of fish caught for each species?

Species	Total weight caught	Average weight of each fish caught
Brown trout		
Rainbow trout		
Salmon		
Sea trout		
Coarse fish		

9. What is the size limit and bag limit for fish, if any?

Species	Size limit	Bag limit
Brown trout		
Rainbow trout		
Salmon		
Sea trout		
Coarse fish		

10. How many days were cancelled this season due to adverse weather conditions ______

11. (a) How many full-time supervisors (bailiff, keeper) of the water do you have?
    How many hours per week does he/do they work in total? ______ hours

    (b) How many part-time supervisors of the water do you have? ______
    How many hours per week does he/do they work in total? ______ hours

12. (a) How many days this season did you work at full capacity and have to refuse some anglers permits? ______ days

    (b) Were the days:
    - mainly Saturdays/Sundays? Answer yes or no ______
    - mainly public holidays? Answer yes or no ______
    - mainly week days? Answer yes or no ______
    - mixtures of above? Answer yes or no ______

FIG.3.2 The Questionnaire

became apparent from explanatory letters sent by some respondents.

The first reminder was sent out on the 18th January 1974 and included a new covering letter (see Appendix 1), the questionnaire and a self-addressed envelope. The return from this was 36 water bodies covering 58 waters constituting a return of 25% of bodies surveyed. A final reminder, again including a new covering letter (see Appendix 1), the questionnaire and self-addressed envlope, was sent out on the 22nd of February 1974 and this brought in a further 12 bodies covering 22 waters constituting a return of 10%.

At the end of the exercise a total of 90 water bodies had replied giving a response of 72% and including 142 waters. Of these replies two were incorrectly completed and unsuitable for analysis. A further ten replies were from hotels where fishing was only permitted to hotel guests, the price included in the hotel fees or where permits were being issued on behalf of another fishing body which administered the water and retained all records. It was decided to delete these fisheries from the census altogether. The gross returns and corrected returns are shown in Table 3.1.

TABLE 3.1

The Questionnaire Returns

	Initial	1st Return	2nd Return	3rd Return	Total	%
Water Bodies	125	42	36	12	90	72
Waters	214	62	58	22	142	66
Water Bodies*	115	32	31	10	78	68
Waters*	198	57	50	17	124	63

* Excluding useless replies + 10 hotels

If one considers 68% as a return rate (it would seem reasonable to consider the water body as the unit rather than the individual waters since the questionnaire was in fact sent to the water controlling body) then this would seem a satisfactory return for analysis. Furthermore it is fair to assume that the figure of 68% probably underestimates the true return since not all of the hotels surveyed replied and if one can assume that these bodies are no different from the hotels which did reply then some of these will be non-permit issuing bodies and ought to be deleted from the survey.

At the end of the survey the data from the questionnaires was coded and transferred to computer cards for preliminary analysis (this raw data is recorded in Appendix 2). Before discussing the actual findings of the survey it is first necessary to examine the returns for any biases. Since approximately 30% of the bodies did not reply it is essential to consider whether the replies received were in any way different from those not returned and therefore not truly representative of the firms in the industry. This may be assessed in several ways:-

(i) By comparing the first, second and third replies.

(ii) By comparing the proportion of permit issuing body types (club, association, hotel, private and public) surveyed to the proportion of types replying.

(iii) Assuming (ii) shows a significant difference then by comparing the turnover figures of the different water body types.

(i) It is often the case that where reminders are sent the returns from the initial circulation are different from subsequent returns from the reminders. Frequently it is noted that the final returns from reminders are poorer in quality reflecting perhaps the lack of interest of the respondent. It is sometimes found (Moser and Kalton, 1971) that in fact the final returns may be a guide to the sort of answers one could expect from the non-respondents. A comparison of first, second and third replies may therefore bring out any differences between the three groups of respondents and allow correction of this bias in the data should it exist.

A qualitative comparison without involving a quantitative assessment made it clear that in fact questionnaires were satisfactorily completed in the vast majority of cases with no differences between the three returns obvious. The last returns were not therefore of poorer quality in this sense. However it would seem reasonable to suggest that the fisheries with the higher turnover rates and therefore probably more concerned with divulging such information would be less inclined to reply. According to the theory one might expect more of this type of fishery to appear in the later returns than the earlier returns. To investigate this the annual turnover figures were grouped into suitable size classes within the three groups and a chi-squared analysis carried out. The table of figures used is shown in Appendix 3, the chi-squared value obtained being 3.45. This value proved to be not significant showing that there was in fact no differences in turnover figures between the three returns and thus financial status did not seem to affect the return.

(ii) One might expect that since a wide range of water controlling bodies were surveyed including angling clubs, associations, hotels, private and public bodies, some groups may have been more inclined to reply than others. For example it would be reasonable to suggest that of all the groups the public bodies would be the most likely to reply while with the other groups there may be many reasons why the water bodies would be less inclined to complete the questionnaire, the most important reason being fear of competition. Table 3.2 shows the percentages of each group surveyed compared with the percentages of the groups replying.

The chi-squared value obtained was 1.31 which with four degrees of freedom represents an insignificant chi-square. In other words there is no significant difference between the proportion of each group sent and the proportion replying.

TABLE 3.2

The returns from different groups compared with the number surveyed

	Club	Association	Private	Public	Hotel
% Sent	23.2	25.6	20.8	13.6	16.8
% Replied	23.9	25.0	18.2	17.1	15.9

It would seem therefore from the foregoing analyses that the returns from the questionnaire can be accepted as representative of the bodies surveyed. At this stage then it is possible to analyse the returns further to make some general statements about the industry.

The total income in 1973 from the waters which replied amounted to £101,328. [£47,827 from the 61 lochs and £53,501 from the 63 rivers.] Accepting that this is a random sample of the 211 waters surveyed the total income for the year from the geographical area studied would be ca. £175,000. The 211 waters represent 38% of the total number of waters cited in the 'Scotland for Fishing' Guide (excluding Orkney, Shetland and the Hebrides) and if one extrapolates from this to calculate a total Scotland figure then the income for the year may be in the range £0.3 - £0.5m. This does of course assume that the area surveyed was representative of the Scottish waters and given that the area selected included the most populous area of Scotland as well as the less densely populated areas this may indeed be an unfair assumption. However the figure does give the order of magnitude of the figure for Scottish permit fisheries. This figure does not include the private fisheries which are normally leased on a seasonal basis to a very small number of anglers. Most of the good salmon stretches on Scottish rivers are leased in this way at very high cost to the anglers. Mills (1971) quotes a figure of £40,000 being paid for a stretch of the Dee. Clearly, were these exclusive fisheries included the figure would be greatly inflated but these fisheries do cater for a minority of wealthy anglers and cannot be considered as permit fisheries and as such are really a case apart from the fisheries surveyed. Also not included are the fishing holidays widely advertised in angling papers which offer a 'package deal' with the cost including accommodation, board and fishing on certain waters. This was briefly mentioned earlier in the chapter when discussing the returns from hotels surveyed. It must be emphasized also that while the figure of £0.3 - £0.5m reflects the income to the 'popular' fisheries it in no way reflects the total income generated by these fishing waters in Scotland.

From the data collected it is apparent that the revenue from permit sales varies widely from a few pounds to several thousands. This is shown in Table 3.3 where the waters are grouped according to income. Hotels have been eliminated from this assessment since the interpretation of income and viability is irrelevant with regard to hotels.

TABLE 3.3

Income Groups of the Waters

Income Range £'s	Lochs		Rivers		Bodies	
	No.	%	No.	%	No.	%
1 - 499	48	79	39	62	43	55
500 - 999	4	7	10	16	15	19
1000 - 1999	4	7	9	14	9	12
2000 - 2999	2	3	3	5	7	9
3000 +	3	5	2	3	4	5

From the table it is apparent that there are few firms running either single or multiple waters which are likely to be viable economic businesses. A viable business is here interpreted as one which will be sufficient to produce a living for one person. Most of the bodies have an annual turnover of less than £500 which clearly does not constitute a viable business. This is not to say that the return on the investment in the fishery is not acceptable since nothing is known of the investment in such fisheries, which could, in fact, be very small.

From the figures it is apparent that only about 8% of the waters or 14% of the bodies have high enough income figures to potentially give an individual a living although again nothing is known of the capital investment involved in these fisheries. An assessment of the types of costs involved from the answers to some of the other questions (e.g. supervision, boat ownership, water ownership) could be made but such assessment would only be qualitative and quantitatively these factors could vary tremendously from water to water.

At this stage then, the conclusion is that the income of the fisheries is very variable with a large number of the fisheries having small incomes and a small number with large incomes. The income of lochs and rivers is investigated further in the discussion of permit sales and permit price.

In the design of question 4, since it was known beforehand that many different types of permit were sold, an attempt was made to include all possibilities rather than to leave the question open: this was done largely to aid later analyses. It was also evident from an early stage that it would be difficult to standardise the permit sales for comparative purposes. In other words it would be difficult to equate the season, weekly, day etc. permits which the waters sold. An attempt was made to overcome this problem with the inclusion of question 5. If a reasonable number of positive answers to this question were received then it would be possible to assess how often, on average, the different types of ticket were used while valid. This would then allow a standardisation of both sales and prices using the day ticket and price as the standard unit. Unfortunately not one positive answer was obtained from the returns and as a result it became necessary to standardise on the basis of price for the different types of ticket. For example where a water issued both day tickets and season tickets, the prices of both were used as a guide to their respective values to the holder. Thus if a season ticket cost ten times the day ticket one could assume that the season would be used on at least ten occasions by the holder in order to get value for his money. Thus for all fisheries which sold day tickets and other non-day tickets it was possible to calculate total day ticket sales by converting, on the basis of price, the non-day tickets to the standard day ticket. However some fisheries, whilst selling season tickets did not sell day tickets and in these cases conversions of the type mentioned above were obviously not possible. To overcome this problem price based conversion factors were calculated for season tickets from a range of fisheries for which the data was available. From these conversion figures an average conversion factor was calculated for season tickets (see Appendix 4). For fisheries which did not issue day tickets these conversion figures were used to calculate the standard day ticket sales. While this method of assessing standard day sales may seem rather innaccurate Gibson (1975) has shown that for one fishery the estimated usage of season tickets, on the basis of price comparison with day tickets, was close to the actual usage. The error was ca. 20% (that is, usage was 20% more than estimated) and, when it is remembered that for a majority of the fisheries season tickets form only a part of total sales (only ten fisheries sold exclusively season tickets) resultant innaccuracies are not likely to be too serious. The results of the calculations are shown in Figs. 3.3 and 3.4. The first graph indicates that although both lochs and rivers have a high percentage of waters in the lowest price range the rivers have a much higher proportion than the lochs. The lochs have almost as many (44%) in the next two ranges as they have in the first while the rivers have only about one quarter in the next two ranges. This difference probably reflects the higher costs associated with the running of boat fisheries where boats and possibly outboards have to be

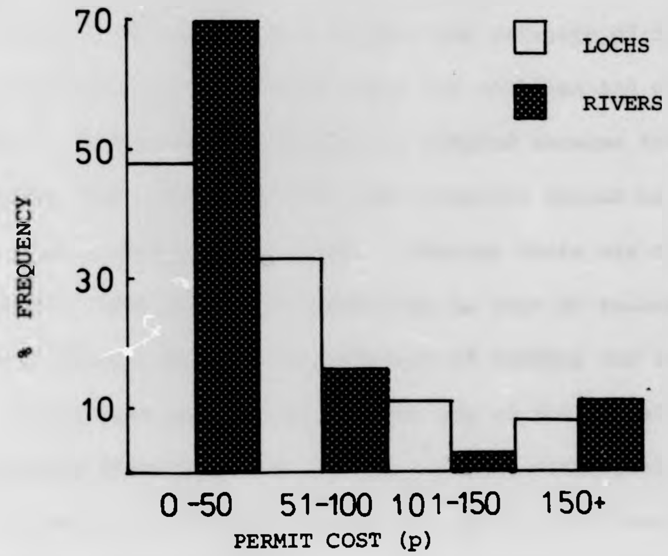

FIG. 3.3 Permit Price Range for Lochs and Rivers

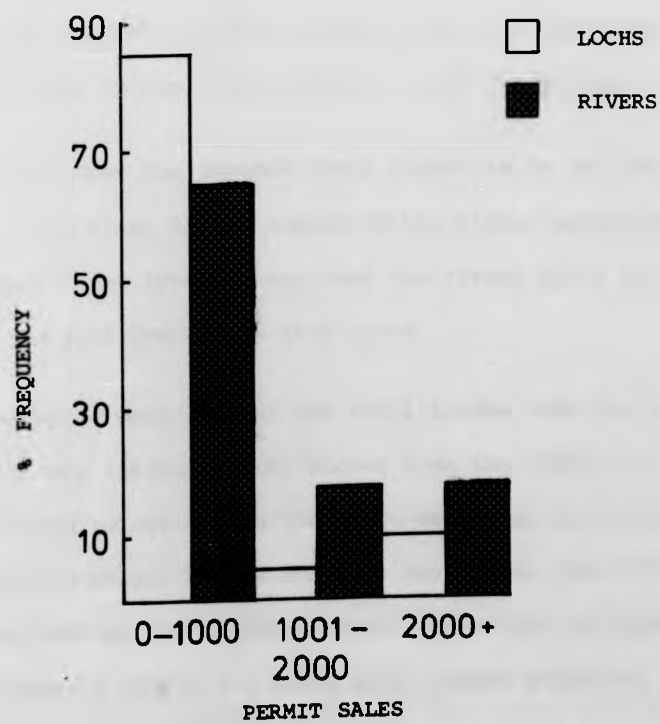

FIG. 3.4 The Range of Permit Sales for Lochs and Rivers

maintained and replaced from time to time.

It is interesting to note here that in setting prices the fishery manager/owner often behaves as a discriminating monopolist in that a variable price is charged depending upon the category of consumer. Thus many fisheries offer reduced rates for children and old age pensioners. It may be that prices are reduced because these are low income groups thus suggesting that the fisheries should be considered as public rather than private goods. However there are other possible explanations. Thus juvenile tickets may be sold at reduced rates (a) because children are not as efficient at fishing and therefore less costly; (b) because they do not receive any of the social benefits present at some fisheries (e.g. social use of a clubhouse); (c) because the seller regards this as an investment, encouraging young anglers to fish at a price they can afford in anticipation of their patronage of the fishery as adults. Old age pensioner charges may be reduced simply because the old age pensioners can patronise the fishery during the week when the fisheries are less busy, and, if prices were not reduced, then this sector of the market would be lost altogether.

Fig. 3.4 shows the imputed total ticket sales for both lochs and rivers. It is clear that a significantly higher proportion of the lochs appear in the lowest group than the rivers while more rivers appear in the last two groups than lochs.

It was noted earlier that the total income from the lochs (61 in number) was very similar to the income from the rivers (63 in number). This would seem to agree with the afore-mentioned findings since although the lochs, on average, charge more per day ticket, the rivers compensate for this by selling, on average, more tickets than the lochs. This is clearly seen in Table 3.4 which shows ticket sales for lochs and rivers.

TABLE 3.4

Ticket Sales for Lochs and Rivers

Ticket Ranges	Lochs No.	Lochs %	Rivers No.	Rivers %
0 - 499	40	66	25	40
500 - 999	12	20	16	25
1000 - 1999	3	5	11	17
2000 - 2999	3	5	5	8
3000 +	3	5	6	10

It is suggested by the results presented at this stage that there is a large number of fisheries which have low annual sales, low priced tickets and low annual incomes. It appears that many fisheries may be under-utilised and this is substantiated by the results of question 12. This question requested information on the number of days worked at full capacity and the results indicated that while 20 lochs reported working at least one day at full capacity only 6 rivers worked at capacity on any occasion during the season. The lochs concerned were all boat fisheries and the high number in comparison to the rivers may simply reflect the limitation of boats in many instances rather than the limitations of water capacity (this is deduced from the answers to question 6 which indicated that some of these waters have few boats available). However, overall, 23% of the waters reported reaching capacity on at least one occasion and 65% of these reported reaching capacity on less then 20 occasions throughout the season. (Over 50% of the waters reported that their capacity days were at the week-ends!) Neither does it seem that many fisheries lose a substantial amount of time through inclement weather. From the results of question 10 in Table 3.5 it is clear that more lochs than rivers are affected by the weather, this no doubt the result of the dangers of using boats in open water in windy weather.

TABLE 3.5

The Incidence of Water Closures (shown as a percentage)

	Lochs	Rivers
Some Closures	28	11
No Closures	72	89

It does seem therefore, from all these considerations that there is a large number of lochs and rivers with low sales; low priced permits; low annual income and evidence of under-fishing.

The remainder of this chapter presents the results and discussion of the questions relating to water quality and management and other questions of general interest.

Question 2 assessed the ownership of the fishing waters and the results of this are shown in Table 3.6.

TABLE 3.6

Water Ownership

Ownership	Loch		River		Total	
	No.	%	No.	%	No.	%
Owned by P.I. body	31	50.8	18	28.6	49	39.5
Leased - Private Landowner	10	16.4	36	37.1	46	37.1
Leased - Public Landowner	18	29.5	6	9.5	24	19.4
Any other	2	3.3	1	1.6	3	2.4
Don't Know	0	0	2	3.2	2	1.6

From the table it is clear that about half of the lochs are owned by the permit issuing bodies while half are leased from a public or private landowner. The high number leased from the latter as compared with the rivers reflects the public ownership of water supplies for human consumption which, if not run as a fishery by the water supply boards, are generally let to local angling bodies. A much smaller percentage of the rivers are owned by the permit issuing bodies, the waters, in general leased from a private landowner. Overall approximately 40% of the waters were owned while the majority of the remainder were leased from private landowners.

Question 6 investigated the extent of boat ownership by the waters. The results shown in Table 3.7 indicate that as one might expect the rivers are predominantly bank fisheries while the lochs are predominantly boat fisheries although 38% of the latter were exclusively bank fisheries.

TABLE 3.7

Boat Ownership

	Lochs		Rivers	
	No.	%	No.	%
Boats available	38	62	2	3
Boats not available	23	38	61	97

The following section considers the results of questions 7, 8, 9 and 11, questions designed largely to gather some information on the management and quality of the waters. There are many management criteria which could have been considered, the ones finally selected were chosen not necessarily because they were considered the most relevant but rather because they were relatively unambiguous questionnaires to ask and answer. Questions 7 and 8 asked the water bodies if they recorded the numbers and weight of fish caught. Biologically the recording of at least one of these is essential for the efficient management of the fish population. The importance of such records is more fully considered in Chapter 6. The results of the question are shown in Table 3.8. From the figures it is apparent that a much higher proportion of lochs (46%) keep records than rivers (21%). For both lochs and rivers, where records are maintained, the majority keep records of both the number and weight of catch: only 5 waters (4%) maintain records only of the number of fish caught and no waters reported

TABLE 3.8

The Incidence and Extent of Record Keeping

Record	Lochs No.	Lochs %	Rivers No.	Rivers %	Both No.	Both %
Number and weight	23	38	13	21	36	29
Number only	5	8	0	0	5	4
Weight only	0	0	0	0	0	0
Neither	33	54	50	79	83	67

recording only the weight of catch. The explanation of the difference between the figures for lochs and rivers lies most probably in the field of pure practicability since it is far easier, especially where boat fisheries are concerned, to have all anglers at some focal point where it hardly inconveniences them at all to record their catch. With rivers, on the other hand, where access to the water may be from several points and there is no need for anglers to collect at some central point it is much more of an inconvenience to anglers to record their catch before leaving. This finding does not indicate that the lochs are necessarily better managed than the rivers but it does indicate that a larger number of lochs have available to them the information required for management.

Further information on what may be loosely termed management of the waters was obtained from question 9 which asked whether or not waters imposed size and bag limits on the catch (i.e. minimum size limit and maximum catch/angler). Size and bag limits are often used to control the exploitation of the fish population (this is considered in greater detail in Chapter 6). Table 3.9 shows the response to this question. The table indicates that a majority of lochs and rivers impose a size limit on brown trout while few impose size and bag limits (no waters imposed only bag limits). Almost all of these waters work to an 8" or 9" limit. The selection of these limits may be to ensure that trout reach spawning age before being exploited, although it would be fair to say that the size of spawning fish varies more than the 8" - 9" limit would suggest. Another possible explanation is that the size limit reflects the size limit for the sale of brown trout which is set by law at 8". This limit is partly to protect the breeding population of trout but also, in part, to help with the protection of salmon parr and smolts. This has already been discussed in Chapter 2.

TABLE 3.9

The Incidence of Size and Bag Limits

	Lochs		Rivers	
	No.	%	No.	%
Size Limit	47	77	44	70
Size and Bag Limit	10	16	3	5

The conclusion then, is that the size limits, rather than reflecting the management practices of a water, more probably reflect the legal size limit for the sale of fish which is largely imposed for the protection of the salmon population although it may in some waters reflect an attempt to ensure that a majority of trout spawn once before becoming exploitable.

Question 11 assessed the extent of water supervision. It should be remembered that with rivers where salmon are present some supervision may take place from water bailiffs or river watchers from the Salmon Fishery District Boards. Such boards are made up of and supported financially by the proprietors of salmon rivers within the district. This type of supervision is not included in the assessment of supervision in question 11. The results from the question are summarized in Tables 3.10, 3.11 and 3.12 From the figures it is apparent that approximately half the lochs and rivers have some supervision, the latter having a slightly higher proportion than the former.

TABLE 3.10

Supervision of Waters

	Lochs No.	Lochs %	Rivers No.	Rivers %
Supervision	32	52	30	48
No Supervision	29	48	33	52

TABLE 3.11

Type of Supervision Recorded

	Lochs No.	Lochs %	Rivers No.	Rivers %
Full-time	6	19	15	50
Part-time	23	72	14	47
Both	3	9	1	3

TABLE 3.12

Total and Average Hours Supervision

	Loch	River
Total hours supervision per week	517	843
Mean hours supervision per week	16.2	28.1

From Table 3.12, however a much higher proportion of the rivers employ a full-time supervisor while the majority of the lochs rely on the services of part-time staff. The last Table reflects the effects of this showing that the rivers have a much higher number of hours of supervision/week than the lochs. This, with the additional supervision from the Salmon District Fishery Boards, would suggest that rivers are better supervised than the lochs. Several lochs did however record 'informal' supervision, carried out on a voluntary basis by members of clubs and associations. The extent of this cannot unfortunately be determined from the questionnaire but where it does occur it is most likely to be supervision of conduct of anglers on the water rather than management of the water.

There are several explanations for the relatively small amount of supervision of waters. The first explanation was alluded to in Chapter 2: up until 1976, poaching of trout remained a statutory offence and, as a result most trout waters felt relatively unprotected from poachers. Some fisheries have stated that this is the main reason that waters have not been developed: to many fishery owners there seems little point in employing supervisors to manage waters and watch over anglers when the water is not adequately protected by land from poachers. This may explain why rivers are supervised more than lochs since the rivers have salmon as well as trout to protect and salmon poaching is a statutory offence.

A second possible explanation revolves around the financial aspects of supervision. If a supervisor were employed to manage a water rather than to police it, and the water detectably improved through his efforts to such an extent that improved ticket sales were effected then it would quite possibly be worth the investment in supervision. However this assumes that there is a demand in the area of the fishery such that sales could be improved. If this seems unlikely then development is not likely to take place.

Finally there are many fisheries which have been in the hands of land owners for many years and it may simply be a lack of interest in their part in the fishery which has stifled development.

Any one or a combination of these factors may help to explain the poor supervision of a majority of lochs and rivers.

3.4 <u>CONCLUSIONS</u>

There are four major conclusions from this questionnaire which may be summarised as follows:

1. There are many fisheries with small annual ticket sales.
2. There are many fisheries with low priced permits.
3. There are many fisheries with excess capacity.
4. There is a fairly low incidence of supervision and little evidence of management interest in a majority of fisheries.

In view of the statements in Chapters 1 and 2 indicating that there is a need to make available more trout fisheries and further develop existing ones these findings are rather surprising. It has become necessary therefore to investigate further permit sales in an attempt to find out if sales are low in many fisheries because

(a) the fishery is not located in the right place. This may be true if the location of consumers and competing fisheries are important factors affecting sales;

(b) the fishery is not patronised because it is not a 'good' trout fishery. Conclusion 4 suggests that many fisheries are not actively managed and, in some cases this may lead to a poor trout fishery;

(c) the fishery is not patronised because of lack of interest of the owners. It is true that all fisheries in the questionnaire advertise their existence in the 'Scotland for Fishing' guide and this in itself may reflect some interest in the fishery. However it may be that many owners go no further than this and are not really concerned with actively promoting their fishery. Some fisheries, for example, make it very difficult for anglers to fish their water by supplying only one private address from which permits may be obtained and this address is not always close to the actual fishery.

Any one or a combination of these factors may explain the low ticket sales in many waters. Clearly if trout fishing is to be developed in Scotland then some attempt must be made to investigate the angling industry in much greater detail. The private investor, in general, wants to maximise his profits from any investment in trout fishing. He therefore requires to know where to put his fishery, what kind of fishery to develop, how much to spend on development and how many anglers he can expect at a given permit cost. The Scottish Anglers' Trust, or similar public investor, requires similar information although their objectives may be very different.

There is therefore a need for much greater information on the trout angling industry in Scotland and this is the subject of the following chapters.

CHAPTER 4

THE DEMAND FOR GAME ANGLING

4.1 INTRODUCTION

In Chapter 3 a general discussion on the angling industry in the study area was possible from a preliminary analysis of the questionnaire data. In this chapter the data on permit sales, in conjunction with locational information on the fisheries, will be utilised in an attempt to investigate which factors are important in determining sales and how these factors affect sales. In the first instance it will be necessary to discuss the economic background of any such analysis and then, later, to go on to discuss and test a relevant analytical method for the particular problem.

4.2 ECONOMIC BACKGROUND

Classical demand analysis describes how a consumer behaves in allocating his income. It is assumed by economic theory that a consumer buys a good because it gives him utility. The first unit of a good gives a certain amount of utility, but, with each additional unit, while total utility increases, marginal utility (marginal utility equals the additional utility obtained from one extra unit of a good) falls. This is the Law of Diminishing Marginal Utility. The rational consumer allocates his income to the differently priced goods such that he maximises his total utility. This is done by selecting items with the greatest marginal utility/price until the point of equality is reached or if this ratio is still lower than others when consumption is reduced to zero, by reducing consumption to zero. This therefore will determine how much of his income a consumer would allocate to the variety of goods available to him and would of course

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Thus economic theory clearly indicates the variables which are important in determining the demand for a particular good. From this brief discussion of consumer behaviour it is obvious that the price of a good, the price of other goods, the income of the consumer and the quality of a good are important variables. (Often in traditional theory it is assumed that the product is homogenous and that the decision of the consumer to buy a particular type of good is made largely on the basis of price. However in the majority of cases differentiation of the product, either real or imagined, exists. Differentiation of a product class exists where any significant basis for separating the goods of one seller from those of another can be identified. This differentiation may take many forms: differences in location of the sellers; quality of the product; quality of service; reputation etc.) Quality is therefore most likely to be an important variable in the decision making processes and this behaviour of the rational consumer. However although traditional theory has this to offer the analyst it does not provide a mathematical form which the demand relationship should take. It does not even state whether the function is linear or non-linear. To find the correct form is usually a matter of trial and error, taking what appears the most realistic formulation for the data available.

4.3 THE MODEL

A suitable functional form is suggested by the model described by Cochrane (1974). The derivation of this model is based upon assumptions about consumer behaviour dealt with in a probabilistic theoretical manner. Cochrane's model determines trip distribution where:

$$T_{ij} = \frac{O_i A_j e^{-\lambda c_{ij}}}{\sum_j A_j e^{-\lambda c_{ij}}}$$

where T_{ij} = Number of trips from a particular i (e.g. a town) to a particular j (a site);

O_i = Number of trips from the same i to any j;

A_j = Attractiveness of the particular j;

$e^{-\lambda c_{ij}}$ = Total cost to consumer of travelling to the particular j (λ = an empirically derived constant)

$\sum_j A_j e^{-\lambda c_{ij}}$ = Sum of the attractiveness × cost (to consumers at the particular i) of all other j's.

An interpretation of Cochrane's model is that sales at a particular site will be a function of the size of the market (O_i) × the market share which a site j can command. The market share is determined by the formula

$$\frac{A_j e^{-\lambda c_{ij}}}{\sum_j A_j e^{-\lambda c_{ij}}}$$

that is, the quality and price of the site divided by what may be described as the average price of alternative sites weighted by the quality.

This functional form has been shown to be appropriate in other studies (e.g. Black, 1966) and in the absence of any other a priori evidence on functional form, the form suggested by the model is used here, viz.

$$T_{ij} = O_i^{\beta_1} \left[\frac{A_j^{\beta_2} \; P_{ij}^{\beta_3}}{C_j^{\beta_4}} \right] e^{\beta_{o+u}}$$

where P_{ij} = Total cost to the consumer of travelling to the particular j.

C_j = Competition variable measured as the sum of the attractiveness × cost (to consumers at the particular i) of all other j's.

The formula of the model which was applied to the data was:

$$\text{Log } T_{ij} = \beta_0 + \beta_1 \text{ Log } O_i + \beta_2 \text{ Log } A_j + \beta_3 \text{ Log } P_{ij} - \beta_4 \text{ Log } C_j$$

Thus instead of constraining the coefficients of the model to unity as did Cochrane they will be derived using a multiple regression analysis.

The variables described in this formula are briefly discussed below before going on to discuss how the variables were quantified from the data available.

Price Variable

The price variable in common with Cochrane's model is taken to include both payment for the commodity and also the expenses the consumer incurs in travelling to the selling point. In other words it includes the total cost to the consumer. Direct payments are obviously the same for all consumers but the travelling costs incurred must depend on the distance the consumer is travelling. Empirically the relationship between visit rates per unit population and distance is consistent and well documented (e.g. Smith, 1970; Smith and Kavanagh, 1969; Jamieson, 1970) - the relationship is a negative, exponential one. This requires further discussion. Travelling costs may be divided into two components: travel cost and time cost. The former, quite logically is related to distance in a linear fashion (assuming that only variable costs for private transport are considered). Time costs must be a function of the amount of time spent travelling (again this can be assumed to be linear if the effects of traffic congestion and motorway travel are counted as negligible) and the value which an individual consumer places on his time. It has already been stated that the visit rates are known to have a negative exponential relationship with distance and it is possible to explain this on the basis of travel time cost. The fact that visit rates fall very sharply over distance simply reflects the notion of opportunity cost. The consumer only has a limited amount of time to set aside for travelling to a site. If a consumer sets out on a day fishing trip (this in fact accounts for the majority of fishing trips) then the longer the consumer spends in travelling the shorter his actual fishing time will be. Thus the cost per unit fishing time increases with increasing travel time. In effect then, the greater the foregone fishing opportunities associated with increasing travel time means a higher cost per unit time of fishing to the angler. However visit rates do not drop to zero but become very small as distance increases. This may be accounted for in two ways. Firstly there will be individual consumer differences such that although the majority are unwilling to travel more than a certain distance there will always be some anglers who will travel further for a variety of reasons. Added to these individuals are the small number of week-end travellers who are likely to devote more time to travelling than the day traveller and also the dual purpose visitor who may be in the area on business, visiting relatives etc.

<u>Prices of related goods</u>

It would be wrong to assume that the prices of all other goods will affect the demand for a particular good since the cross elasticities of demand for many products will be zero (i.e. the effect on demand for good A of a price change in good B is zero). Only the prices of complements and substitutes should therefore be considered. Thus the prices of other fisheries within the market area of fishery A must be included since any change in the price of these competing fisheries might be expected to cause a change in demand for angling at fishery A.

Changes in the prices of complements such as fishing tackle may also affect demand for angling and, with time series data this could well be included as a relevant variable. However since cross-sectional data is used here this variable can be eliminated.

The prices of other fishing sites within the market area only partly takes account of the competitive forces around a fishery: competition in terms of quality as well as price must be assessed. There are presumably other activities which may be substitutes for angling (e.g. perhaps shooting or boating) but there is unfortunately no information available which would permit the selection of likely substitutes.

Quality

It should be expected that, all other things being equal, the better the quality of a site the greater will be the demand at that site. How may the anglers' subjective notion of quality be assessed? Obviously there are many parameters of quality which may be listed as relevant to the decision making processes of the angler. Perhaps the most obvious parameter would be the potential number and size of catch since this may seem to be the main purpose of any fishing trip. However Moeller and Engelken (1972), working in the U.S.A., found that irrespective of the age of fishermen interviewed, characteristics of the environment such as natural beauty, privacy and water quality were ranked as most important by fishermen while size and number of catch were ranked only as important (number being of greater importance to younger rather than older fisherman). Facilities available at the site such as toilets, rest rooms were rated as least important by all but were of more importance to older rather than younger fishermen. Similarly Voss Bark, (1974), working in Britain, reports that anglers are very much concerned with the aesthetic quality of the site and also with features of the catch. Discussing the artificially stocked fisheries he reports that anglers must be able to catch fish but not too easily and that the chance of catching a 'monster' trout is valuable.

Both of these papers would suggest therefore that there is unlikely to be one quality parameter which adequately reflects the consumers' notion of quality, particularly since there is evidence that the important characteristics may well vary between different age groups. The solution would be to use a composite variable but, of course, an initial requirement would be an accurate assessment of the range of characteristics ranked as important by anglers in the study area. Since this would be a time consuming task a more feasible alternative is to select a quality parameter which can be readily assessed for all fisheries which is thought to be of some relevance in the decision making processes of the angler.

Numbers of consumers

In assessing this variable account must be taken of the suspected market area and the population within this area: the number of consumers must be a function of the population within a given radius of the selling point.

4.4 DATA PREPARATION

4.4.1 INTRODUCTION

Although 124 fisheries replied to the questionnaire reported in Chapter 3 not all of these fisheries were, in practice, available for use in the model: for those fisheries on the southern boundary of the study area no information was available on the number and location of competitors or on population statistics since assessment of these parameters extended into England. From the remaining fisheries, 58 were selected using random number tables and used in the analysis.

4.4.2 QUANTIFYING THE VARIABLES

The form of the variables in the model has already been described earlier in the chapter but the translation of the raw data from the questionnaire into the variables has yet to be discussed.

Permit sales

It was mentioned in Chapter 3 that from the return of the questionnaires it was apparent that a variety of permit types were sold and a method was described for standardising the permit types (p.36). It is this standardised figure which is used as the dependent variable.

Population

The basic requirement for this variable is a realistic assessment of market area. On the basis of work done by Duffield and Owen (1970, 71) it is thought that anglers travel, on average, 19 miles (38 mile round trip) to get to their fishery. If it is assumed that angler travel is normally distributed about this mean then it would seem necessary to use a market area of twice this distance around the fishery in order to adequately define the market area. However from some more detailed work by Jamieson (1970) and from the present study a market area of

20 miles can be justified. From the work of Jamieson on Loch Carron and Loch Lomond in 1970 it has been calculated that average journeys were 16 miles and 10 miles respectively. The number of consumers travelling 20 miles or less amounted to 80% and 97% respectively. From the present study an analysis of Loch Carron sales in 1972 confirm these figures showing little variation from Jamieson's results with an average journey of 15 miles and 85% of the consumers travelling from within a 20 mile radius. These results would therefore suggest that a market area of 20 miles may be a realistic assessment. However, the fisheries considered are not in high tourist areas and, in such areas, the situation described may not always be true. For example, Loch Vennacher, in 1973, relied on tourists for approximately 25% of its sales (unfortunately a breakdown of the sales figures was not available). Thus the market area may not be quite so small for those fisheries in the most popular tourist areas. However in the absence of any further information on such fisheries, the market area of 20 miles is used in the model. The population distribution in the area was obtained from the 'Scotland population distribution map' (Caird and Diamond, 1965). The map referred to the 1961 census and although apparently out of date for the current study, Jamieson (1970) has calculated that although there are isolated exceptions (e.g. the new towns) the differences between population distribution in 1961 and 1970 are insignificant and it has been assumed that this situation is still true in 1975.

<u>Price</u>

This includes both permit cost, the method of standardising this to cost per day already described in Chapter 3, and travel cost. The cost of travel was calculated at 3p/mile (this figure was quoted by the Automobile Association as the cost of running an average car in

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Autumn 1974) and the total cost of a return journey assessed. The travel cost was estimated by considering the average travel cost of populations within a 20 mile 'radius' of the fishery. Since a grid system was used (i.e. instead of defining radii around each fishery to estimate the parameters a grid system was superimposed on the map and the first set of squares around the square containing the fishery considered as radius 1 and so on; each square corresponds to four square miles) it is clear that the distance will be slightly more for those populations within squares diagonally opposed rather than vertically or horizontally opposed to the fishery. This could lead to fairly serious errors if populations proved to be unequally distributed around some fisheries while not around others. In order to assess the severity of this problem ten fisheries were randomly selected and, by eye, it was determined whether main populations were horizontally or vertically opposed to the fishery. However it was found that within each fishery main populations were fairly randomly distributed on this basis and this problem of the grid system has therefore been ignored. The cost for each 'radius' was therefore the population of the radius times the cost per trip, the calculation of the cost per trip is shown in Table 4.1.

TABLE 4.1

Cost per Trip in Each Radius

'Radius'	Miles (Return)	Cost @ 3p/mile
1	4	12
2	12	36
3	20	60
4	28	74
5	36	108

The costs calculated in this way were then summed and divided by the total population to give an average trip cost. This may seem slightly obscure since it represents the average cost if every person makes the trip. However the assumption was made earlier that approximately 5% of the population makes angling trips and that the 5% is evenly distributed throughout the sample area.

Quality

Quality was discussed at some length earlier in the chapter and it was suggested that the quality parameters which may be considered as important factors in determining demand were both wide ranging and difficult to measure objectively. From the questionnaire, information was available on the number of hours of supervision per week at each fishery and this could be a useful reflection on the extent of management of the water. Unfortunately this information was only available for those waters which replied and therefore not available for many of the competitors. Since the competition variable includes a quality parameter this clearly makes this factor unsuitable.

From the fishing guide it was apparent that the ease with which anglers could obtain permits for the fisheries was very variable. Some fisheries, for example, sold permits actually on the site while at the other extreme some quote only one private address from which permits could be obtained. From the various possibilities a scoring system was developed as follows:

Availability	Score
On site	5
Several shops/hotel	4
1 shop/hotel	3
Several private addresses	2
1 private address	7

While this may seem to be a rather obscure measurement of quality the work of Moeller and Engelken already discussed on page 52 suggests that these types of assessment may be just as relevant to the angler as immediately obvious parameters on catch etc. Their work would suggest that any one parameter may not be quite so useful as a composite variable reflecting several of the characteristics of a site which anglers' regard as important. However, as stated, this would require specialist knowledge of anglers' attitudes and, in the absence of this, the variable chosen seems as relevant as any other conveniently available parameter and is likely to be one factor which affects the decisions of the angler.

Competition

This variable as outlined in the introduction reflects not only the number of competitors and their respective prices but also the quality of the competing fisheries. If the market area is 20 miles around a fishery then realistically the effective competitive area should be 40 miles around a fishery. However in order to reduce the amount of time to collect the data an area of 30 miles around the fishery was defined as the competitive area.

The price of the permits was calculated in the manner already described under price. Travel cost was estimated not for the population within 20 miles of the competitor but rather for the populations whose custom was being competed for by the two fisheries. In other words the relevant populations are those in the overlapping market areas of the fishery and competitor. This is illustrated in Fig. 4.1.

However so far the variable does not reflect the proximity of the competitors to the fishery. One would expect that, all other things being equal, the closer the competitor to the fishery then the more effective will be the competition. The proximity was assessed by

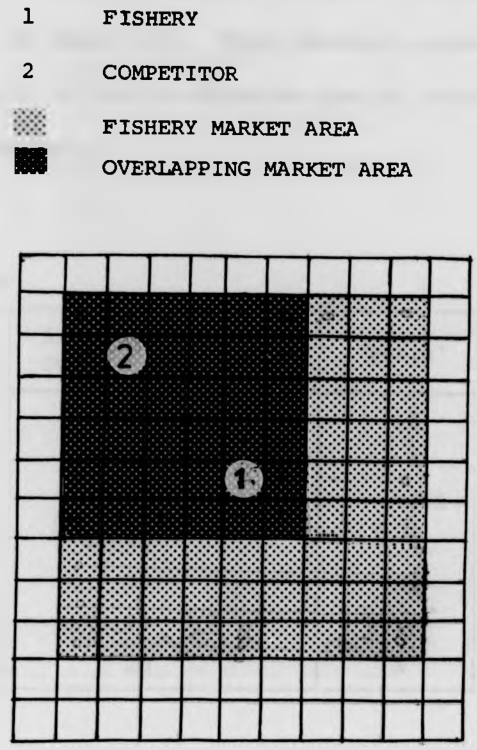

FIG. 4.1 Overlapping Market Areas

creating a scale of proximity which reflected the average number of common squares between a competitor and the fishery. This gave the scoring system recorded in Table 4.2. This proximity score was then added to the quality score to give a composite quality score based on both availability and proximity.

TABLE 4.2

Proximity Scoring System

Radius in which Competitor Situated	Average Number of Common Squares	'Score'
1	81	5
2	68	4
3	56	3.5
4	45	3
5	35	2.5
6	24	1.5
7	16	1

Similarly one would expect that the smaller the number of people in the shared area then the greater the competition between the two areas. The population weighting was obtained simply by assessing the number of people in the shared area on a 1-4 scale by eye (this was done largely because of time restrictions) and the competition variable for each competitor weighted by this figure.

Finally the composite competition figure obtained for each competitor were summed for each fishery to give a total competition variable for each fishery, reflecting the number, quality, price and proximity of competitors and also the number of shared consumers. The formulation of this composite variable is summarized in the figure below:

$$\sum_j \left[\frac{A_j \, P_{ij}}{Popln} \right]$$

where A_j = Availability + proximity

P_{ij} = Price

Popln = Total population in 'shared' area

4.4.3 TESTING THE MODEL

The results of the multiple linear regression analysis are shown below:

$$Log\ T_{ij} = 1.93 + 0.16\ Log\ O_i + 1.16\ Log\ A_j - 0.98\ Log\ P_{ij} - 0.35\ Log\ C_j$$

* (t-statistic) (1.73) (4.13) (-2.10) (-1.12)

** $F = 9.44$

$R^2 = 0.4$

* At 5% significance $t = 2.00$ (df = 53)

** At 5% significance $F = 2.52$ (df = 4,53)

Care must be taken in the interpretation of the signs of the t-statistic and coefficients for the price variable: since this involves a negative exponential function this has the effect of reversing the true signs in the regression. Thus from standard economic theory a negative price coefficient would be expected and this would appear as a positive coefficient in the regression.

There are several problems which may arise with this type of multiple regression analysis which ought to be considered before any detailed analysis of the results should be done. Of particular relevance here are multicollinearity, errors in variables and specification errors.

Multicollinearity

If multicollinearity between the explanatory variables exists then the values of the coefficients as determined by the analysis cannot be used with any confidence as the true estimates. Carrying out single correlations between the independent variables can identify simple cases of multicollinearity (obviously this will not identify any cases involving more than two variables). The coefficients of single correlations between the explanatory variables (including also correlations with the dependent variable) are shown in Table 4.3 and it is clear that no high correlations are in evidence. However it must be remembered that any correlation between the explanatory variables makes the t-statistics smaller and thus less significant than they otherwise would have been. This may help therefore to explain the lack of significance in some variables.

TABLE 4.3

Single Correlation Coefficients of All Variables

	(P_{ij}) Price	(Components of Price) Travel	Permit	(A_j) Quality	(O_i) Population	(C_j) Competition
Price (Travel + Permit)	X	X	X	X	X	X
Travel	X	X	X	X	X	X
Permit	X	X	X	X	X	X
Quality	-0.21	0.04	-0.22	X	X	X
Population	-0.07	0.001	-0.07	0.11	X	X
Competition	0.29	-0.08	0.31	-0.14	-0.29	X
Sales	-0.36	-0.09	-0.35	0.54	0.26	-0.32

Errors in variable estimation

Errors in variable estimation cause biases in the results. It is inevitably difficult to say in which direction the bias occurs but the fact that it does occur, particularly in the present analysis since so many of the variables were only indirectly assessed, may help to explain anomalies in the variables.

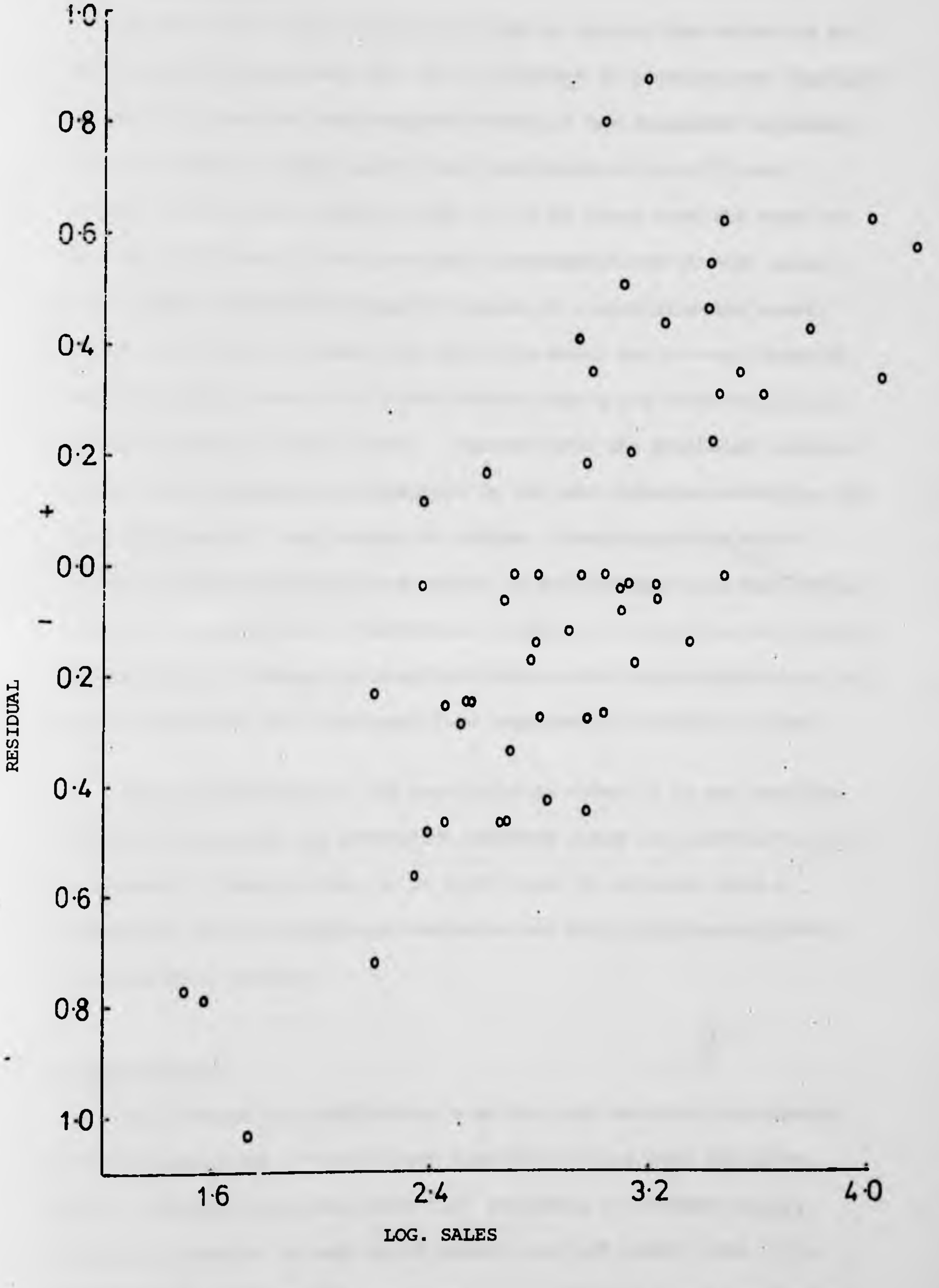

FIG. 4.2 Observed Sales Against Residual

Specification error

Specification error exists when one or more of the variables has the wrong functional form and may be detected by plotting the residuals between the observed and predicted values of the dependent variable: if a particular pattern exists then specification error exists. Figure 4.2 shows the residual plot and it is clear that the equation is over-predicting at low sales and under-predicting at high sales, such biased predictions being the result of a specification error. In an attempt to eliminate this error the model was re-run, changing each variable in turn to a linear rather than a log form, the final run involving all linear forms. However from the graphical presentation of the residuals (see Appendix 5) the specification error has not been eliminated. Any attempt to further investigate this error could be a time consuming task and it is not possible with the limitations of both time and econometrical expertise to continue the investigation further although it does have interesting implications from the point of view of the functional form suggested by Cochrane's model.

With the presence of the specification error it is not possible to use the equation for predictive purposes since any predictions will be biased but despite this it is still valid to continue with a discussion of the independent variables and their relationship with the dependent variable.

Price Variable

The reversal of coefficients sign for this variable has already been discussed and it can be seen from the results that the price coefficient has taken the wrong sign according to economic theory. Since the variable is made up of travel cost and permit cost it is important to consider the separate relationships of these components with the dependent variable. From Table 4.3 it is clear that the permit cost component is largely responsible for the positive relationship. Travel cost also has a positive relationship but, at the level of correlation it is more realistic to interpret this as a sign of no correlation between the two variables. The positive sign of the price component may possibly be explained by the hypothesis that the price value, in part, reflects the quality of the good in that it must reflect the cost of management of the fishery. Pricing for the well managed fisheries may also be high because angling is a private good for which exclusion is technically difficult and therefore costly. Therefore for the more managed fishery not only will prices reflect the cost of management they will also reflect the cost of policing since such fisheries will clearly be very attractive to poachers. It might reasonably be supposed that the quality parameter ought to correlate highly with price as a result of this but from Table 4.3 this is not the case. This does not however indicate that the explanation is invalid, rather it may be interpreted as further corroboration of the aforementioned discussion on the problems of quality estimation. A parameter like fish catch, for example, especially in an artificial fishery, may more realistically reflect the management cost of a fishery which will be reflected in its price.

The lack of correlation between travel cost and the dependent variable is harder to explain since both the theoretical and empirical evidence suggest that travel cost ought to take a negative sign. It may be therefore that the method of assessment of travel cost is at fault. It has already been mentioned that the grid system used in the analysis introduces innaccuracies and this may have resulted in a poor assessment of travel cost.

Quality Variable

The coefficient for this variable was both positive and significant suggesting that ticket availability may have an important effect on site selection. It is difficult to determine the causal direction of the relationship: an important possibility is that high demand could lead to the improvement of ticket availability. However Jamieson (1970) reported 'comments and suggestions' from a questionnaire sent to anglers and one of the suggestions frequently made was that permits should be more easily obtainable. It would seem therefore that this is very likely to be a factor which affects the anglers' selection of waters.

Population Variable

Although this variable took the predicted sign in the analysis, significance was not achieved. Thus the prediction that the population around a fishery will be an important factor in the determination of sales is not substantiated statistically. From the earlier discussions this seems rather surprising and there are two possible explanations of the results. Firstly, errors in estimation of the variable may have resulted from (a) difficulties in accurately assessing population from the population map and (b) from changes in the distribution of population since the map was printed. Secondly, it may be the case that the less populated areas, particularly towards the highlands, may benefit from the transient tourist populations and this ought to be taken into account in assessing population.

Competition Variable

The coefficient of this variable was not significant suggesting that the earlier prediction of the effect of competition on sales was incorrect. However it is believed that the composite competition variable may not be adequately representing competition. Considering the number of elements which made up this variable it is rather difficult to hazard a guess at the reason for this.

4.5 THE DEMAND FOR ANGLING - CONCLUSIONS

It is unfortunate that the model of angling demand cannot be used for predictive purposes since this would have been useful in the determination of specific waters for development. However in studies where cross-sectional data is utilised for economic analysis it is usually found that the results do not yield as significant results as data from time series studies. It is also important to remember that there was a considerable amount of raw data manipulation required in order to reduce the data to a standardised form: this can only have exacerbated the data accuracy problem. Despite these shortcomings of the analysis, the regression was significant ($p < 0.01$) and the discussion of the explanatory variables and their relationship with the dependent variable is of value for planners in game angling.

From the analysis and discussion it is believed that the availability and price of tickets are important with regard to sales. Also although locational factors could not be substantiated as important factors the prediction is still that they will be of importance in determining sales. Thus it may be suggested that in order to maximise sales the fishery selected would be in a situation where the population within a 20 mile radius was quite high, where competition within a 30 mile radius was minimised and where the management of the water was quite intense, the price of the ticket reflecting this. (Management in this context is taken to include the entire process of running the fishery as a business.) It would be important too to have tickets available at the site for anglers thus reducing the effort involved in purchasing a permit.

It is important to emphasise that this chapter has been specifically concerned with an investigation of the factors affecting permit sales: the intention was not to develop a demand model for angling per se. Therefore although some interesting questions have arisen from the application of the gravity model these have not been investigated further. Some of the avenues which might be explored by other workers include the following. Firstly, the problem of errors in the estimation of variables merits further investigation: the data utilised in the analysis was difficult to use directly and it was necessary therefore to use, for example, scales and other indirect methods in quantifying the variables from the available data. Improvements in the estimation of the variables could well improve the significance of the model. Secondly, the problem of specification error has been identified in this analysis and, since it has not been encountered by other workers applying the basic model to different kinds of problems, it would be interesting to investigate the reason for its existence in this analysis on game angling. Thirdly, it is felt that the collection of the data for three of the four variables could have been greatly facilitated by the use of a computer. Population, travel cost and competition data were obtained by manual extraction from the grid system previously described. This method presented no opportunity for manipulation of the parameters which were assessed. For example, it would have been interesting to alter the market area: using manual techniques this would have necessitated a complete re-assessment of the data from the grid, whereas if the grid had been stored in a computer, the extraction of the new variables would have been very much easier. Use of the computer for the assessment of the variables would therefore present more opportunity for the manipulation of the variables with possible improvements in the overall significance of the model as a result.

4.6 DEVELOPMENT OF ANGLING

What follows now is a more general discussion on the development of angling in Scotland based on the deliberations of the last two chapters.

It seems likely from the discussions in this chapter that many of the Highland fisheries, where competition is heavy (there are over 10,000 lochs north of the Highland boundary fault (Campbell, 1967a) and many of these are open to anglers for fishing) and where resident population is low (transient tourist populations may be important in some areas to compensate for this) will have low sales. This is substantiated by the findings from the questionnaire. Many lowland fisheries however, also have low sales. These include fisheries in the south of Scotland where, in many instances, similar conditions of fairly heavy competition and low population prevail and also fisheries in the central belt of Scotland. In these latter areas population is generally high and competition moderate. The important factor here may well be the differences in quality of the fisheries.

There is a clear indication from the questionnaire that most of the fisheries with a high turnover reach capacity sales regularly throughout the season while the majority of the more 'casual' fisheries never reach capacity. This would suggest therefore that there is an excess demand over supply for a particular type of fishery and that sales at low turnover fisheries could be increased by a concomitant improvement in quality where the fishery concerned is in a 'good' location with regard to population and competition. At the present level of advertising and general interest there would appear to be an excess of supply over demand for the low turnover type of fishery and without a change in advertising or similar effort there seems little chance of these fisheries improving sales unless they can change to

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In order that a fishery may increase its sales it is necessary for it to improve its quality and since this will mean, in most cases, improved management of the fishery, relatively substantial sums of money may be required, particularly since the questionnaire has indicated that for a majority of waters very small amounts of capital are normally involved. It is therefore necessary to consider the potential costs of development in much greater detail since this must be of relevance to any fishery irrespective of its overall objectives.

It would be of great value if it were possible to project the effect on demand of changes in the explanatory variables discussed earlier. It would be feasible in such circumstances to predict that if a fishery in a known location were to improve its quality by investing £X it would increase its income by £Y. Such an analytical technique would permit the determination of where and how fisheries ought to be developed depending upon the objectives of the investor. This, of course, represents the optimum situation and, in practice, it will not be possible to quantify at this level. However it will still be possible to consider potential costs in detail and then discuss, in general terms, the potential for development of Scottish waters. This is the subject matter of the chapters which follow.

SECTION 3 THE BIOLOGICAL PERSPECTIVE

CHAPTER 5 THE BIOLOGY OF TROUT FISHERIES

CHAPTER 5

THE BIOLOGY OF TROUT FISHERIES

5.1 INTRODUCTION

Before going on to a discussion of development of water and associated costs it is essential to set the biological perspective with a discussion on the basic biology of trout fisheries.

The exploitable 'game' fish which exist in Scottish waters belong to a single family, the Salmonidae. Members of this family which are exploited to any appreciable extent as game fish in Scottish lochs and rivers include the salmon, Salmo salar (L.); the sea trout, Salmo trutta (L.); the brown trout, Salmo trutta fario (L.); the rainbow trout, Salmo gairdneri (Richardson) and the American brook trout, Salvelinus fontinalis (Mitchill).

Only the non-migratory species will be considered in any detail here and therefore although salmon and sea trout are discussed in relation to their interaction with the non-migratory species, they are not considered in any depth.

Of the non-migratory species only the brown trout is indigenous to Scotland and, as a species, it has been described as the 'poor man's' game fish since trout angling tends in general to be much less expensive than salmon or sea trout angling. Although self-sustaining populations of rainbow trout and brook trout are known to exist in Scotland they are very few in number (Maitland 1972) and therefore the first section of this chapter relates almost entirely to the natural brown trout fisheries in both still and running waters. This section considers in general terms the important factors in the natural environment with regard to trout production. An understanding of these factors is vital for the effective management of trout fisheries, the subject matter of the next chapter.

5.2 THE NATURAL ENVIRONMENT OF THE TROUT

What follows now is a discussion of the environmental requirements of the natural trout fishery with a view to highlighting the numbers of interacting variables which must be considered and identifying the difficulties of running such a fishery.

Fig. 5.1 shows a fairly simplified diagram of the main interrelationships of the trout environment and is relevant for both still and running waters. In running waters the brown trout dominates in conditions where there is typically a steep gradient and thus fast flowing water, a largely rocky or stony substratum, a high oxygen concentration due largely to the flow rate and relatively low temperature of the water all the year round. The areas where these conditions are likely to be met are in the mountain and moorland areas of Scotland.

Trout are still found, in varying densities, in rivers with a lesser gradient, often in hilly rather than mountainous areas. Here the flow rate is rather slower, the substratum often rocky or stony in some places while muddy or silty in others. This latter type of substratum gives rise to often extensive plant growth which in turn offers a food source to a variety of invertebrate organisms as well as shelter for the trout. However this kind of environment, although offering shelter and a potential food source in the invertebrates to the trout, offers a suitable habitat to other fish species and as a result trout tend not to be the dominant species here. Cyprinids, pike and perch, collectively termed coarse fish by the game angler, prefer habitats with a muddy substratum since they spawn on aquatic plants associated with muddy areas of river beds. The relative proportion of rocky to muddy areas in a river will determine to a large extent the importance of brown trout in relation to other non-migratory species.

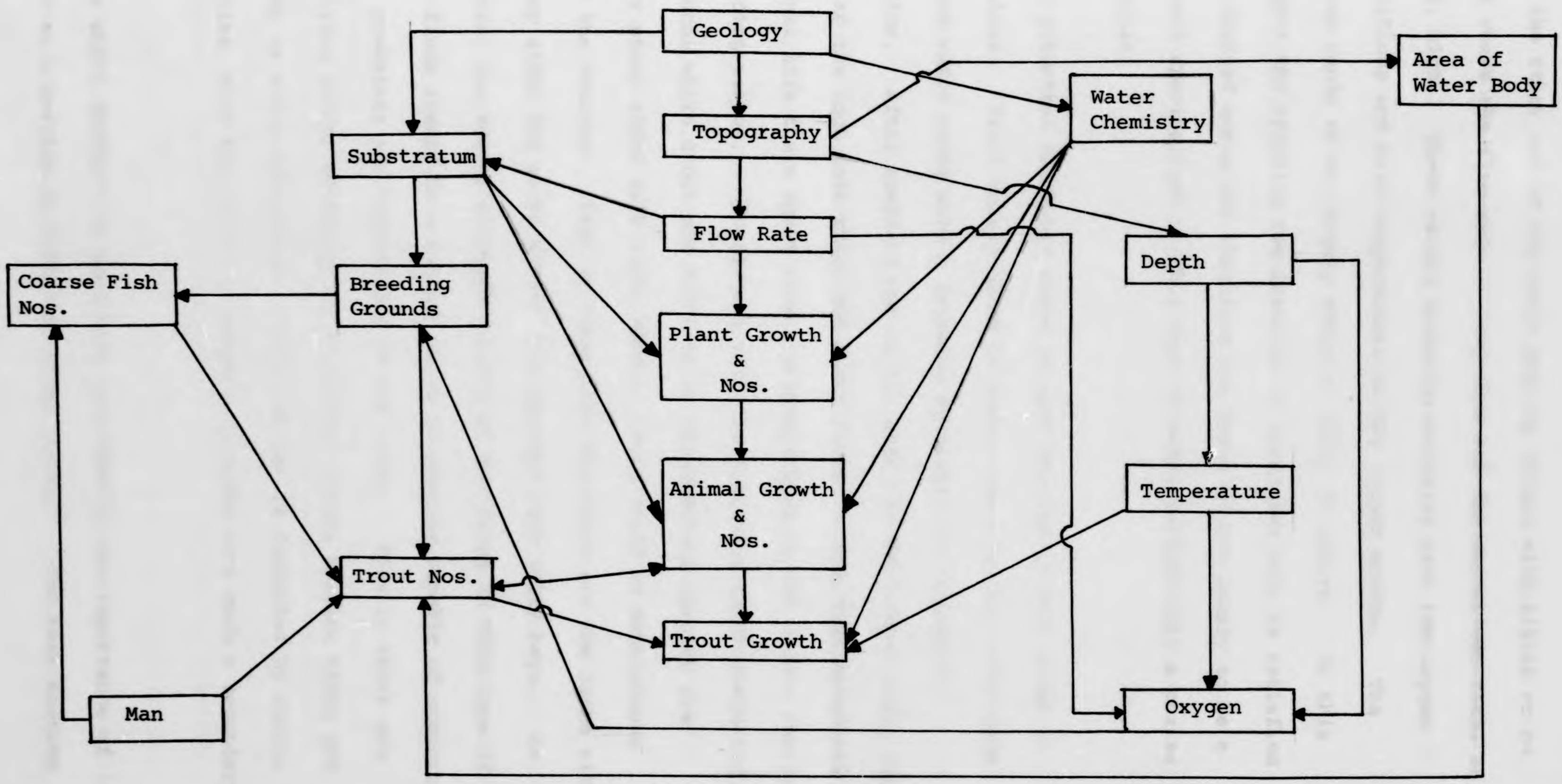

FIG. 5.1 The main inter-relationships of the trout environment.
N.B. Man is considered here as a predator of fish rather than as a manager of the trout environment.

At the other end of the scale are the rivers with little or no gradient where the flow rate is very slow and the deposition rate, as a result, high. These waters characteristically have low oxygen concentrations and high temperatures in the summer months. The substratum tends to be largely muddy or silty in nature. In this environment the breeding requirements of trout may only be satisfied in very limited areas and therefore the trout is not likely to be a significant species here. This type of water is typically a coarse fish habitat.

The situation described above is very similar to that found in still waters. Trout rarely breed in lochs requiring the conditions of flowing water along with a suitable substrate for successful propagation. After spending one or two years in the rivers trout may migrate to the loch into which the river flows. They then spend all their adult life there apart from a movement back to the rivers during the breeding season. Consistent with the typically trout dominated river, lochs where trout are found to be the dominant species are generally steep sided with rocky shores, often found in mountainous parts of the country. Next in importance for trout are the lochs with less steep sides and rocky shores interspersed with silty bays. As with rivers, the trout, although capable of surviving in this type of habitat, finds itself in a habitat which is equally capable of supporting both predators and competitors of the trout. Finally there are the low-lying lochs, generally in cultivated areas, shallow sided and with muddy or silty substratum. This habitat is dominated by coarse fish species, with the trout, if present, playing very much a secondary role.

This short section has described very briefly the importance of the trout as a species in different water 'types'. The next section goes on to consider in more detail some of the variables depicted in Fig. 5.1 discussing their relevance with regard to trout survival, growth etc., and identifying why the trout is found in varying numbers in the different habitat types described.

5.3 FOOD ORGANISMS

Trout are thought to be entirely carnivorous, feeding largely by sight using the cues of shape and movement for prey selection. It is said that the trout exploits suitable organisms which are both easily seen and captured rather than those which are inconspicuous.

The main food items in lochs and rivers are those animals which live either permanently (such as molluscs and crustaceans) or for at least part of the life cycle (such as the nymphal stages of various insect species) on the river or loch bottom. Trout are also known to exploit terrestrial invertebrates which accidentally fall into the water from the bank vegetation, but this is of secondary importance as a food source. These are the main food items of trout up to a size of 30-40 cm in length (at this size a trout is likely to be four or five years old). It is believed that trout larger than this size are mainly piscivorous exploiting such vertebrates as minnows, sticklebacks etc. (For example, Hunt & Jones (1972b) found that sticklebacks alone accounted for almost 48% of the diet of trout over 40 cm in length).

From various pieces of both qualitative and quantitative work on river and loch bottoms it is concluded that trout food is both more abundant and more varied in stony areas than in muddy or silty areas. The existence of aquatic plants in either area greatly enhances this abundance and variability as well as offering shelter for the trout populations and aerating the water as a result of photosynthesis. The animal and plant communities which become established in water bodies can be very variable depending upon the physical, biological and chemical characteristics of the habitat. Thus with plants, factors such as topography, nutrient content, pH, water temperature, water depth will affect the type and extent of plant growth. With animals similar factors are important and, in addition, the presence of vegetation is relevant since this provides an important substrate on which animals may live.

Of the flowering plants three different groups may be identified including (a) emergent species which are rooted in mud under water but with the erect aerial leaves above water; (b) submerged species which have roots and shoots under water although in some species the flowering shoots may be extended above water; (c) floating leaved species which are rooted in mud under water with long, flexible stems under water also, the leaves and flowers floating on the surface of the water. There are also some floating leaved species which float freely at the water surface without roots in the substrate.

Of the non-flowering plants there are three categories which are of importance to trout including the algae; the mosses and liverworts and finally the ferns and horsetails.

Plants and animals are found in association with one another in fresh-water environments. Frost and Brown (1967) give some useful associations showing the vegetation of lochs and rivers in relation to topography. Some illustrative examples of this are shown in Table 5.1.

Not all plants and animals are of benefit to trout populations but there are certain species which are particularly useful in trout waters. These animal and associated plant species are well documented (Frost and Brown, 1967; Birch, 1972; Macer-Wright, 1973). A brief list of those species which are known to be of value to trout waters is shown in Table 5.2.

TABLE 5.1

Vegetation and Fauna of Lakes in Relation to Topography
(From Frost & Brown 1967)

Substratum and Depth	Vegetation	Commoner Inv. associated with vegetation	Commoner Inverts. associated with substratum
1. Shallow			
Rocky: Rock face	Algal felt Water moss	Midge larvae Mites	Freshwater limpet Snails
Stones & boulders	Water Lobelia Lakewort Quillwort	Midge larvae Mayfly nymphs Snails Worms	Mayfly nymphs Stonefly nymphs Caddis larvae Snails Shrimps Leeches Midge larvae
Sandy	None	None	Mayfly nymph Pea Mussel
Silt mainly with few stones	Common reed Reed mace Bullrush Sedge	Mayfly nymphs Dragonfly nymphs Alderfly larvae Caddis larvae Limpets Beetles Snails	Mayfly nymphs Alderfly larvae Water boatmen Pea mussel Water slater
2. Deeper (illuminated)			
Silt	Potamogeton Pondweed Canadian Pondweed Water milfoil Stonewort	Mayfly nymphs Caddis larvae Pea mussel Mites	Midge larvae Mayfly nymphs Water moss Aquatic worms
3. Deeper Still (No illum.)	None	None	Midge larvae Pea mussel Aquatic worms
Silt & Mud only			
Open water	Flating algae	Water fleas Phantom larvae	

TABLE 5.2

Useful Plant & Animal Species in Trout Waters

Rivers: Animals	Rivers: Plants	Lochs: Animals	Lochs: Plants
Midge larvae	Water buttercup	Midge larvae	Water buttercup
Mayfly nymphs	Water milfoil	Mayfly nymphs	Water lobelia
Shrimps	Water celery	Snails	Quillwort
Snails	Water parsnip	Shrimps	Stonewort
Caddis larvae	Water violet	Worms	Starwort
Blackly larvae	Mare's tail		Mare's tail
	Starwort		Rushes
			Sedges
			Pondweed

It must be remembered at this stage that in many lochs there are three zones which can be identified and only one of these is a major feeding area for the majority of trout. The first is the littoral zone of inshore area. This extends out to a depth of about 3m and since light penetration is good rooted plants can grow here. The next zone is the limnetic or offshore zone. Here there is still light penetration but the water is too deep for any rooted vegetation. The last zone is known as the profundel zone. This lies beneath the limnetic zone and here there is no light penetration. Clearly the littoral zone will be the richest part of the loch and provide much of the feeding for trout. It is the size of this area therefore which is of importance in assessing the quality of a loch for trout feeding.

5.4 TEMPERATURE AND OXYGEN REQUIREMENTS

Brown trout can survive in water temperatures up to 22-25°C. Above 25°C total mortality is almost assured and above 22°C some mortalities are to be expected unless the water is oxygen saturated. Since the percent saturation is inversely related to temperature this situation is not likely to prevail in the natural environment.

Maximum growth of trout takes place between 7°C and 19°C although this does vary to some extent between age groups. At temperatures exceeding 20°C, although trout may survive for some time growth is negligible and similarly although trout can survive in temperatures near the freezing point of water growth again is very poor.

Egg development requires rather specialised conditions for success. Thus although adult trout can survive in temperatures up to 22°C in muddy or silty substrates egg development under these conditions would not take place. The optimal temperature range for egg development is from 7°-12°C.

5.5 WATER CHEMISTRY

The chemistry of the water is directly determined by the geology of the area and to varying extents by the activities, both industrial and agricultural around the water body. Productivity of waters is difficult to discuss briefly in quantitative terms because of the number of variables involved but generalising it can be said that hard alkaline waters (that is those waters with a high calcium carbonate content) are more productive than soft acidic waters. It is suspected that above a level of hardness of about 60 ppm of calcium the growth rate of trout is maximal and that below this level the growth rate is less than maximal. The effect of hard water on growth is largely through the trout food organisms rather than directly through the trout thus in hard waters a greater standing crop of invertebrates is found than in soft acid waters.

Unfortunately other variables are involved in productivity which may obscure the effect of water hardness. For example it was stated earlier in the discussion on water types that in lowland waters which are generally hard waters trout are often not the dominant species due to competition and predation by other fish species and it may only be where this is controlled and where adequate spawning facilities are available that the full effect of the water quality on the trout quality may be realised. The waters where trout are found to be the dominant species are often in soft water areas where growth rates are not likely to be very good. In addition to this water productivity problem in these areas there is often over-population as a result of excellent spawning facilities. The combination of these two factors often leads to a stunted population of trout small in size and large in number. This situation is unfortunately true of many of the Scottish highland lochs.

5.6 COMPETITION

There are two types of competition which must be considered: intraspecific competition and interspecific competition.

Interspecific Competition

Trout are known to be strongly territorial animals. This territoriality begins as the young fry start to feed. At this stage a territory represents a rather small area in which the fry feeds and from which it will attempt to exclude other fry. As the trout grows the size of the territory which is defended also grows. Thus, fry in Black Brows Breck (Frost and Brown, 1967) defended areas of about 4" × 4" while 9" trout in the same water defended areas of about 4 yd × 4 yd. It has been found however that large, older trout will not exclude young trout from their territories so that several age groups will live in one place. Thus territoriality, which occurs in both lochs and rivers, serves to disperse trout of the same age throughout a water body. This suggests that there is a maximum number of trout of any one age which will survive and grow in a given area of water (this does of course assume that excess trout can move away and this is more likely to be true of rivers than of lochs).

This territoriality would appear to result from competition for a place to live and/or competition for a food supply. From experiments in aquaria it seems just the presence of larger fry depresses the growth of smaller fry even when abundant food is present, Allen (1951) has shown that in stretches of the Horokiwi River growth was slowest where trout were most dense and the average density of bottom fauna was lowest where trout density was highest. This suggests that the two elements of competition, for food and space, are in operation with trout.

Competition for space may take place during the breeding season in situations where there is a limited area of suitable gravel beds for spawning. In such situations it is not unusual for a female trout to disturb a redd (breeding site) in order to lay her own eggs.

<u>Interspecific Competition</u>

Competition from other fish species can again be readily divided into competition for space and competition for food.

(a) Competition for space. This competition may be for both living space and for breeding space. Competition for living space may take place between trout and salmon (strictly speaking these are not separate species but for the purposes of this discussion they may be considered as such) particularly in the younger stages: young trout are in fact more aggressive than young salmon (at this stage they look very alike) and tend to drive salmon away from the better territories. Competition for breeding space is only likely to take place between salmon, sea trout and brown trout since they spawn at the same time of year and require similar types of gravel for successful reproduction. There is however no competition between trout and any other fish species such as pike, perch or cyprinids since neither their spawning times nor their breeding site requirements coincide.

(b) Competition for food. This takes place on a much wider scale although it is rather difficult to quantify the effect on the trout populations. A brief discussion on the species involved and the degree of competition suspected is given below.

Trout, salmon and sea trout: since all three have largely the same diet, competition for food must be suspected.

Trout and perch (*Perca fluviatilis*). There is considerable overlap in food organisms between these two species (Thorpe, 1974) except that perch tend not to take surface organisms while trout do.

From Thorpe's analysis of stomach contents of trout and perch in Loch Leven it is clear that although their intake of different food organisms varies over the year there are certain months when particular food species are predominantly taken by both species. It is evident also that perch have a lower conversion efficiency than trout (3% as opposed to 10%) and as a result consume approximately twice the amount of food as trout of the same size. It should be added however, that the presence of perch can have a beneficial effect on the trout population since trout have been found to feed extensively on perch fry. In Loch Leven Thorpe found that in July, August and September perch fry made up 40%, 58% and 42% of the daily intake of the trout (this of course would be a very seasonal component of the diet). Despite this potential contribution however the view is sometimes expressed that the overall effect on a trout population of a large perch population is detrimental, particularly where food may be limiting.

Trout and pike (Esox lucius). Young pike, in the first few months of life, are likely to compete with trout since they have certain food items in common such as various crustaceans and larval aquatic insects. Large pike and large trout, both of which are largely piscivorous, may compete for perch, minnows and sticklebacks but since the number of predators is likely to be small and the number of prey items large this is not likely to be very serious.

Trout and grayling (Thymmalus thymallus). Although not a common species in Scottish waters, grayling are found in considerable numbers in certain localities. Not much is known of the degree of competition between the two species but it is thought that where shrimps and caddis larvae form an important part of the diet, competition may be significant.

Trout and eels (Anguilla anguilla). It has been established from the analysis of stomach contents that the eel should be regarded as a competitor for food with trout since their food items coincide quite closely. Work by Thomas (1962) indicated that in a comparison between salmon parr, trout and eels the only clear cut differences between the three species was that while terrestrial organisms formed 12% of the diet of trout and 3% of the salmon parr diet they were not present at all in the eel's diet, the species being exclusively a benthic feeder. Overlaps of diet did occur particularly with the insect groups and to a lesser extent with the molluscan groups. A further factor of importance is that eels are thought to spend 8-12 years in fresh water and therefore each individual must affect several generations of trout. Despite these findings Thomas does not regard the eel as serious competitor with trout since the eel's food consumption is much reduced in winter, the time at which food is most likely to be limiting. However this viewpoint is not held by individuals involved in management who still regard the eel as a fairly serious competitor.

5.7 PREDATION

The predators of trout include other fish, birds and mammals.

Fish species. Eels are frequently regarded as predators of trout but there seems little evidence to support this contention. Indirect contrary evidence is presented by Burnett (1968) who reported considerable improvement in yearling trout numbers in a New Zealand stream when eels had been removed. This improvement was a result of increase of survival of raw ova to fingerlings. Burnett concludes from this that eels are both predators and competitor of trout, although he supplies no direct evidence of predation. Direct contrary evidence is presented by Thomas (1962) who found that although fish made up anything from 15-40% of the eel diet the main prey species was the minnow and on no occasion was any Salmonid found as a prey item.

The real predation in trout waters comes from the presence of pike. As already stated the pike is known to eat invertebrates in the first few months of life. Since they grow so fast, by the Autumn of their first year (the pike's year begins in April - May with spawning taking place February to April) they are big enough to predate upon Autumn trout fingerlings. From this age onwards pike are piscivorous and it is reckoned by the Inland Fisheries Trust in Ireland, who have carried out extensive work on pike, that they require to eat 5-7 times their body weight of fish in a year just to maintain weight. In order to grow this figure must be nearer 10 times body weight (this figure is similar to the requirements of trout). It is also apparent from analysis of the stomach contents of pike that individuals from 1¼ lb - 3½ lb (from 17" - 21", 2, 3, or 4 year olds) contained trout ranging in size from 6" - 12" while older pike tended to select trout in the 11" - 14" range. It has been reported that pike have a preference for trout over perch and cyprinids (Frost and Brown, 1967) but this does not seem to be true in all waters. One water where perch are very numerous trout are not exploited heavily by pike while perch appear to make up the bulk of the diet (A. Potter, pers. comm.). However irrespective of the pike's preferences it is in most cases generally accepted that where the species is present in large numbers they should in most cases be regarded as a serious predator of trout stocks.

Birds. The main predators in Scotland are the Cormorant, which reputedly eats its own weight of fish per day, the Heron which, along with the Cormorant is regarded as a fairly serious predator and the Goosander, which is quoted as a problem although the extent of predation by this species is not known.

Mammals. These include the water shrew and brown rat which will predate upon young trout and the otter and mink which will take adult trout. The distribution of the last two is rather local but where present they can be serious predators. Man could also be included here although he is not really a natural predator in the strictest sense any longer.

5.8 BREEDING REQUIREMENTS

Brown trout first spawn at age 3-4 years in most British waters. During the summer months the eggs and sperm begin to develop in mature female and male trout, maximum gonad size is reached in October and November and it is usually in November to December that the fish are ready to spawn. Trout can only successfully spawn in running water and trout in lochs usually move up into feeder burns in order to spawn.

In rivers trout often move up the main river into the tributaries to spawn. It is well documented that spawning sites have certain characteristics with regard to water velocity, gradient, depth and quality, including size, shape and quantity of gravel. The trout spawns in redds which are areas of gravel where the eggs are deposited in pockets. The gravel requirements are fairly precise: from the work of Beausang (1963) and Stuart (1953) the following are the requirements of a good spawning site:

Local gradient	:	1:50
Water depth	:	6 - 18"
Gravel depth	:	12"
Gravel size	:	Max. size 3-4" with 85% 2"
		60% 1"
		45% ½"
		25% ¼"

The effect of these components is to give a fairly consolidated mass which is permeable to water. Where fine silt is present the beds become firmly consolidated and because the female must excavate a 'nest' where eggs are deposited such a consolidated bed is unsuitable. The place normally chosen for a redd is at the tail of a pool where the water is not too deep and where the current is not too fast. This type of situation ensures that a current of water travels through the gravel ensuring that the eggs are kept free from silt and that they have a constant supply of oxygen.

The incubation period for eggs is very temperature dependent but in average Scottish waters it may be about 14 weeks. Thus eggs laid in mid-November will be hatching in February to March.

5.9 EFFECTS OF EXPLOITATION ON NATURAL TROUT POPULATION

The natural predators of trout have already been discussed in this chapter but one predator, man, has only been briefly mentioned:

trout fishing by rod and line can no longer be considered a natural form of predation as it once may have been, and it is therefore considered separately here. Natural sport fisheries, like sheep or cattle farms must be exploited in a controlled manner in order that they may continue as a source of fish. The fishery manager aims for a balanced situation where the fish removed by anglers are being adequately replaced by the natural reproduction of trout. Millichamp (1974) describes the ideal population of fish, from the point of view of the self-sustaining fishery, with the aid of pyramid structures. The pyramid represents layers of increasing sizes of trout and, in a well balanced fishery should look like the pyramid in Fig. 5.2.

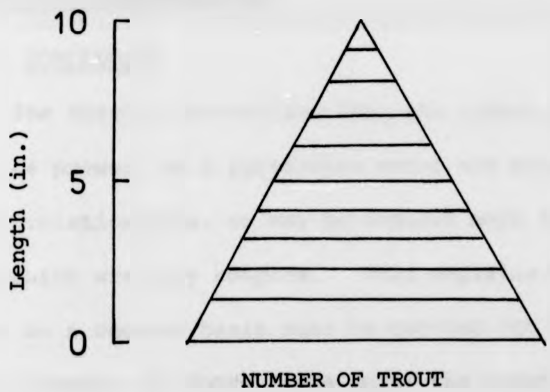

FIG. 5.2 Pyramid Structure Depicting an Ideal Fish Population (From Millichamp, 1974)

Thus there are large numbers of small trout and small numbers of large trout without any 'bulges' in any particular size class. Numbers decline as the fish become larger due to predation and natural mortality. Losses of the largest fish will be heavy due to the exploitation of these fish by anglers. Anglers, even if no size limit has been set, will tend to return the smaller trout concentrating on those trout at the top of the pyramid. Clearly if exploitation is heavy, leaving fewer of the larger fish which will thus become harder to catch then anglers may start exploiting the smaller fish. In situations such as this anglers may begin to heavily exploit the younger spawning fish (normally fish will begin to spawn when 7"-8" although this does vary from water to water). Clearly this may lead to a drastic removal of spawners which would adversely affect the fish population in the following years. For this reason size limits and bag limits (number of fish in catch) are often used in the management of sport fisheries. The effect of exploitation on fish populations can therefore be a complex matter and the use of bag and size limits in controlling exploitation will be discussed in more detail in Chapter 6.

5.10 CONCLUSION

The factors controlling both the number and sizes of trout which will be present in a particular water are many and varied, the inter-relationships, as may be deduced both from Fig. 5.1 and the discussion are very complex. This explains why the exploitation of trout on a regular basis must be carried out in a controlled manner. These methods of control come under the general heading of fisheries management and this is a fairly well developed field today. Clearly it is technically and practically a difficult subject area since the fishery manager is attempting to manipulate what is known to be a very complex situation. The more commonly used management methods are discussed in some detail in Chapter 6.

SECTION 4 THE BIOLOGY AND ECONOMICS OF TROUT ANGLING

SECTION 4 THE BIOLOGY AND ECONOMICS OF TROUT ANGLING

CHAPTER 6 THE MANAGEMENT OF TROUT FISHERIES

CHAPTER 7 THE COST OF RUNNING A FISHERY

CHAPTER 6

THE MANAGEMENT OF TROUT FISHERIES

6.1 INTRODUCTION

In this chapter some of the more commonly used management methods on Scottish lochs are discussed in some detail in an attempt to accomplish two things. Firstly, it is hoped to determine the criteria the manager ought to use in selecting different management methods. This discussion is set against a background of economic theory which, although of limited practical assistance in fisheries management, forms an interesting basis for discussion of management methods. Secondly, this chapter sets out to determine the magnitude of costs involved in management methods, including labour and material costs: in developing Scottish trout fisheries it is clearly necessary to have some indication of the likely management costs both in the initial development and in the annual running of fisheries.

The objectives of management may be broadly divided into three groups: angler satisfaction, biological objectives and economic objectives. Angler satisfaction objectives are dictated by the collective expectations of the anglers and, from the work of Moeller and Engelken (1972) which has already been discussed, although characteristics of the site were most important the characteristics of the catch were also of some relevance. While the former are of no relevance in this chapter the latter define the angler satisfaction objectives which may be summarized as: to produce a satisfactory number, size and quality of trout which will be available to anglers. The biological objectives revolve around the biologically efficient exploitation of the trout. These may be summarized as: to remove annually the largest proportion of the weight of trout which a river or loch produces, (this is more fully discussed on p135); to have a majority of trout reproduce at least once before capture (this has been discussed in Chapter 5). The economic objectives must be to ensure that satisfaction of the angler and biological objectives are carried out in an economical manner. Essentially therefore, in general terms, the fishery manager aims at satisfying the required number of anglers subject to the constraining effects of the biological and economic objectives: it is thus a question of determining the optimum strategy.

The management decisions which must be taken within the fishery are the same as those for any firm and may conveniently be divided up into four distinct groups. These include product decisions, price decisions, quantity decisions and technological decisions. Product decisions are concerned with the specification of goods to be produced and the assessments of the costs of production; price decisions are simply concerned with the setting of prices for goods produced; quantity decisions determine how much of the good should be produced and, finally, technological decisions determine the methods to be used in implementing the product and quantity decisions. These decisions are subject to the constraining effects of the main objectives of management.

For a fishery the technological decisions revolve largely around the many documented methods of manipulating the trout environment to produce the desired product. It is this aspect of management which forms the subject matter of this chapter. The determination of the optimum strategy here, subject to the various objectives outlined, could be greatly assisted by the field of micro-economics which discusses the optimum production strategy of firms. If the management methods are considered as the resource inputs to the production process and the desired fish quality as the product output then it is clear that to alter the output the firm can either vary the resource inputs or alter the production method by altering the relative amounts of each resource input (it is to be expected that the more efficient the production technique the greater will be the output). The problem for the manager is to determine the most efficient combination of resources to supply the required quantity of product. The most efficient combination will be that which either maximises product with a given cost outlay or minimises cost for a given amount of product. From the utility approach to production theory it has been shown that in order to maximise product with a given cost outlay, resources should be combined in such a way that the marginal physical product (this is defined as the change in total product which results from a unit increase in the quantity of the resources used per unit time) per £'s worth of one resource equals the marginal physical product of each other resource used. This therefore allows the determination of the precise combination of resources which the firm should use.

This analytical method is, in theory, of great value to the fishery manager in determining his technological economic optimum production method from the many techniques available. Some of the most widely used fishery management techniques which are to be discussed in this chapter are shown in Fig. 6.1 and it is clear from this diagram that there are many inter-relationships between the components of management making any rational decision on resource choice very difficult. However it becomes obvious from a study of management data that while this approach is of theoretical interest to the manager it is of very limited practical value simply because the data on the effects of different combinations of resources on output is not available. Any quantitative data on management at best tends to relate to the effects of varying one resource while keeping all others constant and assessing the effect of this on total product output. Economic theory does however have some useful generalizations from this approach: the Law of Diminishing Returns states that if the inputs of all other resources are held constant while equal increments/unit time of one resource are added, total product will increase up until a certain point and thereafter output increases are likely to become progressively smaller.

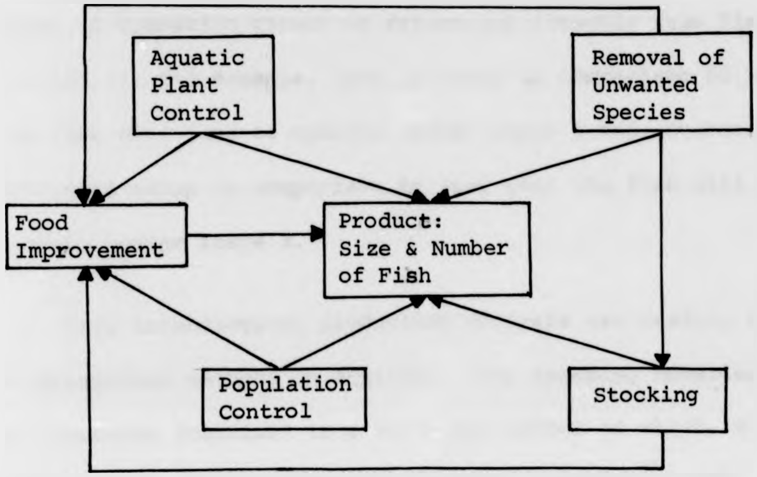

FIG. 6.1 The Inter-Relationships of Selected Management Techniques

The implications of this for the manager are quite important and merit further discussion. A quantitative example is used to develop this relationship. The example (from Leftwich, 1960) involves two resources, land and labour. The unit of land remains constant and the effect of incremental units of labour on total production is assessed and recorded numerically in Table 6.1 and graphically in Figs. 6.2 and 6.3. The total product curve provides information on the amount of product which is obtained per unit of land while the average product curve gives information on the efficiency of labour, or, the amount of product/unit of labour for the different ratios. In stage 1 of the graphs both total product (TP) and average product (AP) curves are increasing indicating increases in the efficiency of labour. In stage 2 the efficiency of labour decreases but at a diminishing rate while in stage 3 the efficiency of labour decreases at an increasing rate. Thus the technological optimum strategy must lie in the combination of resources found in stage 2. However cost should also be considered since it is the technological - economic optimum strategy which is really most relevant. The actual point of operation cannot be determined directly from Figs 6.2 and 6.3 but if, for example, land is cheap in comparison to labour then the firm will tend to operate nearer stage 1 and, conversely, if labour is cheap in comparison to land then the firm will tend to operate nearer stage 3.

This technological production analysis can readily be applied to management methods on angling. For example, consider the addition of limestone (calcium) to a loch, the effect of which is to ultimately improve fish growth thereby producing a desirable 'good'. The analysis suggests that, if the water body is kept constant while equal increments of lime are added, then the product will increase up to a certain point and then decrease. This is in fact precisely what happens in practice. If the assumption is made that calcium is in short supply in a water then increments of calcium are known to bring about improvements in fish growth resulting in more and more fish attaining the desired size. At a certain point however, increases in limestone cease to have any effect on growth. This is thought to happen because of the existence of some other factor which has become limiting, e.g. the intrinsic rate of growth of fish or changes in quantities of other minerals in limestone apart from calcium. Further additions after this point may result in a reduction in growth because of the adverse effects of excess quantities of calcium and other minerals. For economic reasons however it is unlikely that this point would ever be attained in practice.

TABLE 6.1

The Effects of Incremental Units of Labour on Total Production and Average Production

Land	Labour	(TP) Total Product (Labour)	(AP) Average Product (Labour)	
1	1	3	3	Stage I
1	2	7	$3\frac{1}{2}$	
1	3	12	4	
1	4	16	4	Stage II
1	5	19	$3\frac{3}{4}$	
1	6	21	$3\frac{1}{2}$	
1	7	22	3	
1	8	22	$2\frac{3}{4}$	Stage III
1	9	21	$2\frac{1}{3}$	
1	10	15	$1\frac{1}{2}$	

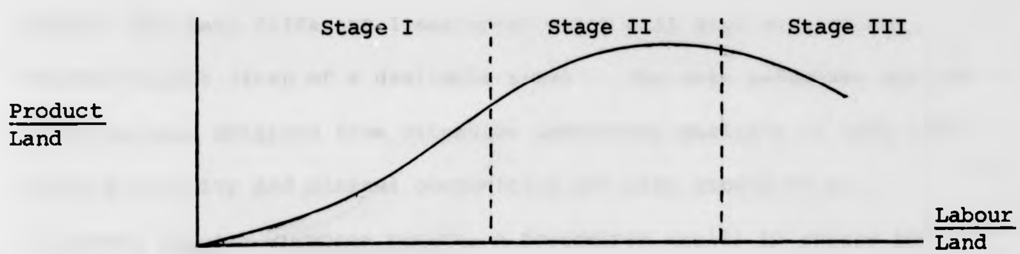

FIG. 6.2 The Total Product Curve

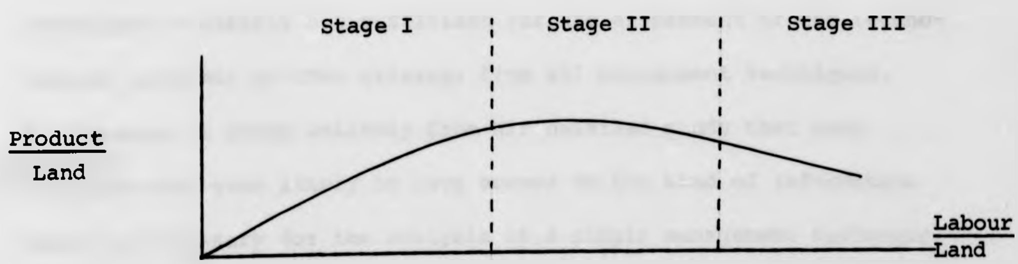

Fig. 6.3 The Average Product Curve

Owen (1976) has carried out an investigation on the effectiveness of liming in acid-water lochs and has amassed the kind of information required by the analysis discussed. His analysis in fact went further than that suggested above since the aim was to optimize productivity of waters given the variability in calcium and other mineral content of the many commercially available limestones and the constraints of all mineral levels, finance, application rates etc. Owen used linear programming methods to optimize the solution. This analytical method is of great relevance to fisheries management but it requires very detailed data since it is necessary to accurately set all the constraints. This analysis is therefore very similar to the first analysis described where there are many combinations of resource inputs (the many different limestones) which will give rise to the desired output (fish of a desirable size). The data necessary for the analysis were obtained from extensive laboratory analysis of both limestone solubility and mineral composition and also growth of an indicator species (Lymnaea pergra, a freshwater snail) to assess the productivity of limestones. However even this amount of data, although useful for the analysis of liming as a single management technique is clearly not sufficient for the assessment of the technological economic optimum strategy from all management techniques. Furthermore it seems unlikely from his detailed study that many fisheries are ever likely to have access to the kind of information which is necessary for the analysis of a single management technique, firstly because the fishery manager is not likely to be in a position to carry out controlled investigations himself and secondly because even if more detailed studies were carried out it is difficult to say how applicable results would be to the general situation. In many instances detailed scientific data will be pertinent to, at worst, a specific water and, at best, to a water 'type', rather than being of more general relevance.

In conclusion it would appear that while economics has provided the theoretical framework for optimizing management strategy, technical limitations make it impossible to utilise these methods. This is, of course, of very little use to the fishery manager who still has to make management decisions. The method which is to be followed in the remainder of this chapter represents an attempt to assess management methods in much the same way as the fishery manager, in practice, must do. The method quite simply involves selecting where possible, examples of management which involve varying the inputs of one resource (i.e. one management method) whilst keeping all other inputs constant and determining product output as a result. The increase in product output is then translated, where possible, into economic terms so that the costs of inputs can be compared with the increase in value of the output, allowing an assessment of the technological economic efficiency of the management practice. Thus the trial and error methods of the fishery manager and often the fisheries biologist will be assessed in order to determine the cost-effectiveness of the method. The results obtained will not determine any optimum management strategy for any particular method nor is it intended to be of any specific relevance to any Scottish water. It is rather, an attempt to follow the lines of analysis which could be carried out by the fishery manager and, at the same time, investigate the magnitude of costs, including both labour and materials of the more commonly used management techniques.

Before embarking upon a discussion of the selected management methods and their associated costs and benefits there are several points of information on the general structure of the discussion.

Firstly, at this point in the thesis, lochs only are discussed: rivers have been included in earlier stages of the analysis of game angling, but, in order to narrow down the focus of the thesis, rivers have now been eliminated from the discussion.

Secondly where technical details are being discussed it has been difficult to decide whether to use metric or imperial units since the field of fisheries management is still very much in a stage of transition. Because the basic unit, the acre, is still in common usage it is retained here. Most other units are given in metric. However, when quoting other authors, the original units have been retained and many are in imperial units.

Thirdly, for ease of understanding and cross reference, each method is discussed under the following headings:

INTRODUCTION: This describes why the management technique is necessary and, briefly, what effect it has.

METHODS: This describes the more common methods employed to effect the management technique.

COSTS: This describes the costs of the best methods (best from the point of view of technical efficiency). The costs are assessed for a 100 acre loch in order to assist in the assessment of capital and running costs of management. All costs are taken at mid-1975 prices and labour is costed assuming an annual salary of £2500, this being the salary for agricultural workers in mid-1975.

EFFECTIVENESS: This section assesses in financial terms the effectiveness of the management method and compares this with the costs assessed in the previous section.

CONCLUSION: This briefly summarizes the findings on the cost-effectiveness of the management technique.

6.2 FOOD IMPROVEMENT

6.2.1 INTRODUCTION

From an earlier chapter on natural fisheries it was apparent that one can distinguish between different 'types' of fisheries depending on their chemical, physical and biological conditions. Such differences can lead to considerable variation in the weight and number of fish produced by the water. This is perhaps best illustrated by reference to Frost and Brown's data on the comparative sizes of trout from different 'types' of lochs and rivers (Frost and Brown, 1967). Some illustrative examples are shown in Table 6.2.

TABLE 6.2

Growth of Trout in Rivers, as shown by their length at the end of their third year, in Relation to Topography, Food Supply and Water

	Topographical category	Potential food supply for trout	Soft Water (< 150 ppm $CaCO_3$)	Length (in)	Hard Water (> 150 ppm $CaCO_3$)	Length (in)
Rivers	Stable, eroded	good	R. Liffey (Kings R.)	6.6	R. Liffey (Straddan)	9.6
			Upper River Dart	7.0	(Rye Water)	11.3
Lochs	More shallow water than deep:					
	Littoral stony	good	Granabhat L.	8.6	L. Derg	11.6
		poor	L. Atorick	7.0	Malham Tarn	11.2
	Littoral very weedy	very good	Boisdale L.	9.3	L. Glore	12.1
			L. Leven	11.1	L. Rea	13.8

Thus it would appear that, although there are clearly other factors which will affect trout production, the variation in the above water characteristics would seem to account for quite large differences in the growth of fish. (The differences between soft water and hard water lochs and rivers are statistically significant: using a t-test, $p < 0.01$.) With a size limit of, for example, 9" (23 cm) the waters with soft water and without a very good potential food supply have, in the main, populations which are unlikely to be catchable until their 3+ or 4+ year, while those waters which have hard water will have takeable fish in their 2+ year. Clearly the earlier the population becomes exploitable the better since more time spent in the fishery results in higher natural mortality: this is an inefficient usage of naturally produced trout food.

One of the aims of management must be therefore to improve the potential food supply of fishery such that fish growth rates are improved. For example, if by careful management it was possible to improve Loch Atorick (see Table 6.2) to Loch Granabhat standard or Loch Granabhat to Loch Derg standard then a substantial improvement in the biological efficiency of the fishery would have been brought about. It does not seem unreasonable to aim to improve a poor fishery such that an increase in growth of 2-3" in the 3+ fish is effected.

6.2.2 METHOD OF IMPROVEMENT

More specifically, what can be done to improve the potential trout food supply of a fishery? From the literature it is apparent that the establishment of useful animal and plant communities and the chemical improvement of the waters through the addition of fertilisers have been successfully implemented in various waters. In many cases carrying out one improvement without the other is not likely to be successful, thus stocking with suitable plant or animal species is not likely to be successful if the chemical composition of the water is not suitable for the successful establishment of the species. Similarly, any attempt to establish certain animal species which are important trout food items without the existence of suitable plant communities for their protection, feeding or breeding substrate is likely to fail. In the short term this may be successful but the ultimate aim must be to establish a self-sustaining population.

Animal and plant species

There are two criteria which may be used for the selection of appropriate animal and plant species. The first is that the species must be of some value as a trout food source either directly or indirectly. Thus an animal species is of direct value if it is exploited as a food item by trout and the plant species which harbours this animal becomes of indirect value to the fishery. The second criterion is that the species must be of value to the fly fisherman. Fly fishing, which is the most common method on managed waters, may be of two types: wet fly and dry fly. With the former the intention is both to resemble the size and shape of the food organism and also to simulate the movement of the organism by 'working' the flies. Frequently the wet fly is designed to resemble the nymphal stages of the insect species. With the latter an attempt is made to exactly reproduce the natural fly species which the trout are known to feed on. In Scotland the most popular method is wet fly fishing largely because conditions in either loch or river are rarely calm enough for the use of dry fly. It is therefore important to encourage the establishment of the correct species for the local conditions. Thus if a water is well sheltered and often has calm days then dry fly fishing may be preferred. In this instance there must be careful selection of animal species which are winged for part of their life cycle and which are exploited by the trout. Appropriate plant species must also be selected, since these may provide a feeding or breeding substrate for useful animals. These have already been discussed in Chapter 5 where brief lists of useful species for lochs are given along with some indication of preferred substrate and water depth.

According to Campbell (1967a), most waters, even poor Highland lochs have a fair abundance of small food organisms and also the seasonally available species such as the mayfly nymphs and midge larvae. However, with such waters, it is often the very important permanently available larger species such as shrimps and snails which are lacking. These types of animals fundamental to the production of large numbers of large trout and are often very important over winter when surface animals are not available and insect larvae are too small to be taken. Campbell also states however, that many attempts to introduce such species have failed largely because of heavy predation by fish and he suggests that some measures should be adopted to protect at least some of the population from predation until the population becomes established. Wire-netting enclosures which are fish-proof are suitable for this. To assist the colonisation of snails Birch (1972) suggests the use of earthenware drain pipes to assist the colonisation of snails while the plant life is becoming established. These pipes, placed in the shallows, offer a suitable breeding substrate, cover and a suitable surface for algal growth which is a source of food.

Both plant and animal species may be collected from other sites where they are abundant and transported to the fishery. For example Birch suggests that shrimps and snails may be collected from other waters with the use of faggots. These are bundles of branches which are staked into the ground where the animals are known to be abundant. They may be removed after a few days with their fauna and transported to the fishery. While this latter method, and indeed any such collection method, is very economical requiring only manpower, there is some risk of importing disease carrying specimens. For example the shrimp is the intermediate host of a fish parasite, Acanthocephalus, which may, in certain circumstances, have serious effects on trout populations (Awachi 1965). There is however little alternative with many species since commercial suppliers do not exist although it is possible to buy shrimps and snails from commercial suppliers (which perhaps reflects their importance to fisheries).

In determining stocking densities of animals it must be remembered that natural densities may be very high. Pyefinch (1960) quotes figures of 100,000,000 - 200,000,000 insects emerging in a three acre loch, similarly Frost and Brown reporting on some work carried out in the Highlands assert that populations of gammarus may be in the region of 5 million per acre in an average trout water, while Macan (1974) reports figures of just less than 1 million per acre in a tarn. Whatever the food item being considered therefore the densities occurring naturally can be exceptionally high. When considering stocking numbers it would not of course be necessary to stock at this level but a relatively high number must be stocked and enclosed to give the population a chance to become established such that a high density is eventually produced. A density of 5,000 - 10,000 per acre is advised by one supplier (Welham Park Fish Hatchery) although it is said by this supplier that few fisheries actually stock at this density.

The establishment of desirable plant species is rather difficult to assess. Most of the suitable plant species are available commercially but unfortunately tend to be very expensive because suppliers have largely developed in response to a demand from the owners of garden ponds and indoor aquaria. At one small fishery this problem was overcome by removing plants from other water bodies and transplanting them (J Howman, pers. comm.). At this fishery 50% of a loch perimeter of 1,500 yards was covered with marginals and a substantial amount of submerged species planted, the entire operation requiring 50 man hours of labour.

Chemical Improvement

The addition of fertilisers has been carried out on waters, both still and running for many years and is a well established management practice. From Table 6.2 it is apparent that the level of calcium in the water is an important factor determining the rate of fish growth. Any fertilisers added to the water tend to have therefore a high calcium content, although they also often contain quantities of phosphorous nitrogen and potassium in varying amounts. The effect of these is largely indirect acting through the food chain.

Fertilization experiments on poor Highland lochs were carried out by Morgan (1966) and over a period of six years the effects on the bottom fauna and fish were monitored. The amount of fertiliser added is shown in Table 6.3 and the results of the addition in Table 6.4. The addition of the fertilisers over the two year period raised the calcium level of the water (a six acre loch) from 1.0 mg/l to 12 mg/l. The results of this are clear from the table indicating the effect on both the growth of the bottom fauna and the trout population. It is clear from their figures of bottom fauna over the years 1957 - 60 that, as one might expect, the effects do disappear after some time making re-treatment necessary on a regular basis. The frequency of this will depend upon the individual characteristics of the waters (e.g. rainfall, throughput of water etc.).

TABLE 6.3

Chemical Additions to the Six-acre Loch (from Morgan, 1966)

1954	1955
½ ton/acre Lime 200 lbs/acre NPK	112 lbs/acre $NaNO_3$ 336 lbs/acre NPK

TABLE 6.4

Effects of Chemicals on Trout and Bottom Fauna
(From Morgan 1966)

	May 1954	May 1956	May 1957	May 1958	May 1959	May 1960
Fish weight 2+	2.4	5.2	4.9			
(oz) 3+	4.2	7.4	8.0			
Fish length 2+	15	25	24			
cm 3+	23	27	28			
Bottom Fauna						
Nos/M^2	500	3500	4750	4000	4250	1250
g/M^2	0.8	6.3	12.6			

It does seem from this that the addition of nitrates and phosphates along with lime gives excellent results but, aside from the high costs of such fertilisers, there are serious dangers associated with their use which has led to the use of limestone in many fisheries. The danger is that the addition of nitrates and phosphates may in some instances (and these are not predictable) lead to serious problems of algal blooms in the summer which if not resulting in summer fish kills may make angling difficult and unpleasant. As a method of chemical improvement therefore the dangers would seem to outweigh the advantages. From some work done recently on the addition of soluble limestone this would seem to be a safer method of improving production in trout waters (R. Owen, 1976). Owen has identified desirable minimum and maximum levels of calcium in waters of 8.0 mg/l and 20 mg/l of calcium respectively, below which productivity is very poor and above which growth rates are not substantially improved. This is supported by, for example, the work of Reynoldson (1961) who has shown that the critical level for the occurrence of <u>Asellus aquaticus</u>, a very important prey item of trout is 7 mg/l calcium and that above a level of 12.5 mg/l calcium Asellus is usually present.

Working on a 33 acre fishery Owen found that 40 mg/l of limestone (equivalent to 8.0 mg/l Ca) was sufficient to raise the calcium level at Loch Walton (Stirlingshire) from 2 mg/l Ca to 9 mg/l Ca. This was estimated to bring about an overall increase of biomass of an indicator species (Lymnaea peregra) of 451%. If Thorpe's (1974) figure of conversion efficiency of 10.3% for brown trout is accepted then the increase in biomass could be expected to effect an increase in trout growth of 46.5%. For a two to three year old trout this could quite easily mean an increase of 1" - 2" in a year. The amount of limestone added to a water clearly depends on the initial state of the water: at Loch Walton the amount added was ten tonnes (0.33 tonnes/acre) and, according to Owen, for a fairly poor water the amount may be anything from 0.33 - 0.5 tonnes per acre.

At Loch Walton treatment would have to be carried out annually due to the large throughput of water at the loch, for other waters with a low throughput treatment may only be necessary bi-annually.

6.2.3 COSTS OF IMPROVEMENT

Animals and Plants

The commercially available shrimps and snails cost £12 and £9/10,000 respectively. Labour and materials would be required to erect enclosures around the animals in order to prevent immediate exploitation. The total cost at the minimum stocking density recommended is £1,050 including £600 for shrimps and £400 for snails. The cost is therefore very high and perhaps explains the suppliers observation that few managers follow the recommended density. If the density is reduced, as long as the population is given some protection until it becomes established, then the stocking will still be successful although it will clearly take longer for the population to become established. Reducing the density to half the minimum density suggested incurs a cost of ca. £500 and, including the cost of enclosures may be ca. £650.

The likely costs for the transplanting of suitable plant species, based on the time involvement quoted by Howman, would be ca. £200, this being entirely a labour and transport charge.

Chemicals

The costs for a 100 acre loch for liming include both fixed and variable costs. Fixed costs refer to the haulage cost of the limestone from the quarry to the loch and, from an average of four suitable limestone sources quoted by Owen, the haulage cost is £17.85/8 tonne load (this varies with distance, this figure relating to a journey of 100 miles round trip). Variable cost refers to the limestone cost, the average cost being £4.73/tonne and also to the labour cost involved in the distribution of the limestone in the loch. It is estimated that this can be carried out at a rate of two tonnes/man-day. If it is assumed that the limestone is added at a rate of 0.5 tonnes/acre then total costs for the liming operation amounts to £562. The breakdown of costs is shown in Table 6.5

TABLE 6.5

Limestone Costs

	Cost/unit £'s	Total Cost £'s
*48 tonnes limestone	4.73	227
Haulage - 6 loads	17.85	107
Labour 24 man-days	9.50	228
	Cost £'s	562

* Limestone taken to nearest multiple of 8.

6.2.4 EFFECTIVENESS

There are several ways of placing a value on this management method.

(A) For the natural fishery the value lies in the method's success in producing fish of an acceptable size to the angler in the shortest possible time: the longer a fish population remains in the water the greater will be the loss of fish through natural mortality. (B) For the mainly artificial fishery there are two factors which may be considered. Firstly where fish are planted at an acceptable size and, in the main are removed within the season, it is often the case that around 20% of the population survive until the end of the season, (Behrendt, 1974). In many fisheries of this type, where the productivity of the water is low, the remaining fish are fed with dry pellets over winter. The establishment of good natural food supply would dispose of this necessity to feed the fish artificially. Secondly, an improved growth rate of trout may mean that the artificial fishery may be able to stock with smaller fish than would otherwise have been possible, in the knowledge that fish will attain a satisfactory size in the loch.

(A) For the natural fishery the objective must be to improve the fishery to the state where the required number of acceptable sized fish are produced in their third year of life (2+). According to several workers (e.g. Le Cren 1961) natural mortality from the 2+ year to the 3+ year is approximately 50%. The actual value of the fish lost through not achieving a satisfactory improvement of the water may be assessed in several ways. For example, the smaller number of fish which will be available to the anglers when takeables are not available until 3+ may very well result in a smaller demand for tickets. Hunt & Jones (1972a) indicated the possible magnitude of this when they reported the effect of a drop in the catches per rod on subsequent sales. In their example catches amounted to 1.6 fish/visit in one season and dropped to 0.5/visit the following year. In the following year, in response to this drop in catch the sales figures dropped to 45% of the two previous years. This assessment is of course too specific to be generally applied since the effect on demand of such a reduction in catch must vary considerably depending on local conditions but it does serve to highlight the importance of management.

It might perhaps be easier to consider the 'value' of the 50% mortality which may result if the fish have to over-winter another year before being takeable. Thus an assessment of the approximate number of fish involved and their current commercial value would determine the cost to the fishery of the over-winter loss. The current commercial price for Brown trout is approximately £450/1,000. Thus the loss to the fishery could, even in a small water, amount to a few hundred pounds per year. However it is again rather difficult to cost this since it will be very variable between fisheries, depending on the population structure, standing crop and average annual yield.

(B) Perhaps the easiest method of valuation would be to consider the artificial fishery valuation methods discussed. Where initial stocking of plants and animals and the regular liming of waters is carried out on waters of fairly low productivity the potential improved growth rate of fish could mean that a fishery will be able to stock with smaller fish than previously. Thus a 100 acre loch may stock at a density of 50 - 100 fish/acre (this is discussed in detail in 6.7.2) of 25 cm (10") fish in September for the following season, in order to ensure catches of 25-30 cm (10-12") fish: with improved feeding it would be possible to stock with 23 cm (9") fish and still maintain a 25-30 cm fish size during the season. The difference in cost/1000 fish between 23 cm and 25 cm fish is £97/1000 (this has been calculated from the quoted prices from a number of fish farms, see Appendix 6). This gives a total saving of £485-£970 depending upon the stocking density for the 100 acre loch.

While the improvements in water quality and food availability may therefore effect an improved growth rate of fish a further advantage of such improvements is that, in the artificial fishery, as already mentioned, the over-wintering takeable sized fish (often up to 20% of those stocked) no longer have to be fed. The cost of feeding these fish with pellet food until the next season can be calculated from data on the energy requirements of fish. According to Allen (1951) trout require 1.23% of body weight in food per day to maintain their condition (i.e. without growing). Morgan (1974) investigating this more fully considered the importance of temperature in determining this value (temperature affects both metabolism and feeding rate). He found that the maintenance requirement decreased from 2.6% at 15°C to 2.1% at 10°C to 0.5% at 5°C. Mid-winter temperatures in Scottish waters are most likely to be at the low end of this scale. For example, at Loch Leven, a eutrophic Scottish loch, Smith (1974) recorded out of season temperatures in the years 1968-1971 of, on average, 4.6°C. Since Morgan's curve of daily requirements does not go below 5°C it has been necessary to assume that the maintenance requirements remain fairly constant below 5°C. For a 30 cm trout weighing about 280g, the maintenance requirement out of season would be about 110g food. The derivation of this figure is shown in Table 6.6. The figures of maintenance requirement are calculated on the basis of wet food where 1g of wet food = 4.184×10^3 joules. The energy content of dry pellet food is very much higher than the natural wet food of the trout being around 21,000 joules/g. Thus an equivalent maintenance ration for a 30 cm trout at 5°C would be only 0.28g dry food per day (biologically the comparison should be between dry pellet and dry natural food and here the energy value is approximately the same since the water content of the natural food is 80-90%). Thus the total maintenance requirement out of season amounts to about 110g pellet food. This of course assumes that the trout are 100% efficient at collecting the food which is not likely to be the case. Behrendt (1974) has estimated that the

TABLE 6.6

Maintenance Requirement of a 30 cm Trout Weighing 280g During the Winter Period

Month and Average Temperature °C	% Body Weight	g Wet Food/Day	Joules 10^3	g Pellet/Day	Total g Pellet/Month
Jan 2	0.5	1.4	5.8576	0.28	8.7
Feb 2	0.5	1.4	5.8576	0.28	8.7
Mar 3·5	0.5	1.4	5.8576	0.28	8.7
Apr 8·5	1.75	4.9	20.5016	0.98	29.4
Oct 10.5	2.15	6.02	25.1877	1.20	37.2
Nov 5	0.5	1.4	5.8576	0.58	8.4
Dec 3	0.5	1.4	5.8576	0.58	8.7
				TOTAL	108.90

loss is well over 50%. Allowing for a high loss of 100% to accommodate the worst situation the corrected amount of food will be ca. 220g pellet food/fish. Considering the 100 acre loch again which, during the season would carry 50-100 fish/acre a carry over of 1000-2000 fish until the following season is quite possible. The maintenance requirement for these fish would be 220kg-440kg of pellet food. At a cost of £320/tonne this would amount to £70-£140 per year. Although this may seem a modest sum the labour costs involved must also be included. It is customary in these cases to feed the fish three times per day at selected sites and this could easily involve an hour per day. Over the winter period this amounts to 200 hours at a cost of £250. A more economical method involves the use of motorised food dispensers with an automatic timing system. Such dispensers spread the food over quite a wide radius (one manufacturer quoted a radius of 15-20') and this method drastically reduces the manpower required since the food is contained in large hoppers which would only require refilling once a week. The cost of these dispensers is £120 each and, for a 100 acre loch five dispensers would probably be necessary to ensure that all fish can be fed. The cost per year assuming a life span of ten years would be £60 and, including manpower and food costs, total annual costs would be £170-£240. This therefore represents the 'saving' of the food improvements over the winter period.

Thus total savings for the artificial fishery may be in the region of £650-£1200 including the additional costs of stocking with larger trout and feeding over-wintering trout.

6.2.5 CONCLUSIONS

Although initial investment in productivity improvement may be high at ca. £1500, annual costs will at most be about one-third of this figure. Considering the valuation of both total benefits (£650-£1200) and total costs it does seem that the benefits exceed the costs. It is however clear from the discussion that costs may vary between fisheries depending upon the original quality of the water, water depth, throughput of water etc., and also that benefits will vary depending upon the stocking regimes selected and the size of the over-wintering population.

6.3 THE REMOVAL OF UNWANTED SPECIES

6.3.1 INTRODUCTION

In Chapter 5 the main competitors and natural predators of trout were identified. Of the species mentioned,there are three fish species which are often controlled including pike, perch and eels. From the discussion in Chapter 5 it is apparent that while there are occasions when these species appear to be in balance with the trout and are not causing the reduction of stocks of trout below an acceptable level, in many fisheries the presence of any one or more of these species is often regarded as detrimental to the trout fishery. However, most common of all is the removal of pike since most, if not all, fishery can be fed. The cost per year assuming a life span of ten years would be £60 and, including manpower and food costs, total annual costs would be £170-£240. This therefore represents the 'saving' of the food improvements over the winter period.

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6.3.2 METHODS OF CONTROL

There are two basic methods of brining about control: firstly, by attempting complete removal on one occasion, or at most, infrequently: secondly, by adopting annual control measures.

Complete Removal

This method is one which is often used in the early stages of development of a new fishery. Various methods have been used to accomplish a complete clearance including trapping, netting, use of explosives, electric shock, and poisoning. Of these methods only poisoning has proved to be a reliable technique, the others usually failing to bring about a complete removal and unfortunately resulting in only a temporary reduction in population size. The poison is non-selective and will kill all fish and it will only be useful where a fishery is being established or where the infestation is so bad that the trout population is considered of negligible value.

The commonly used fish poison is Derris powder, the ground root of the Derris plant. The active substance is rotenene, the effect of which is to terminate gill functioning (Lindahl & Oberg, 1961). Not all waters are suitable for this treatment, only lochs and ponds where the water can be isolated until the poison becomes inactive, it must also be possible to prevent re-infestation from feeder streams. The method of application usually involves spraying the surface of the water with a suitable concentration of the poison although where deep pools exist it is advisable to pump the poison down into the depths. The concentration used is normally from 0.02-0.05 ppm of rotenone (usually 5% of Derris powder) and at this concentration homeotherms are not harmed. It will of course affect not only fish but also the invertebrate fauna. According to Morris and Struthers (1975) the effect of 0.04 ppm was quite variable depending upon the invertebrate species present and their stage in the life cycle when affected. Some species which lived in the mud appeared not to be badly affected and survival of some of these species was quite good. In general while some species were more susceptible than others and the recovery rates of such species differed such that the balance of species after treatment was altered, the original balance was still restored within a year after the treatment. The authors found that while the balance was disturbed for some time some species did recover very quickly such that within three of four months of treatment invertebrate fauna were once again available.

The time taken for the poison to break down varies considerably depending on sunlight and aeration but if done during the summer months then the higher water temperatures accelerate not only the effects of rotenone but also the breakdown of it. Weir (1970) quotes an average breakdown period of five weeks but this can vary from a few days to four or five months in exceptional circumstances.

Rotenone has been used on fairly large water bodies. It was for example successfully used on Loch Fitty (McKenzie, 1975) a 160 acre (65 ha) loch with an average depth of 1.98m and a maximum depth of 5.1m. It is however rarely suitable for rivers since in most instances it is impossible to isolate the section to be treated. Furthermore, it is most unlikely that the authorities would permit the use of the poison for reasons of public health (it is necessary to apply to the Secretary of State for Scotland for permission to use the poison under Section 9 of the Salmon and Fresh Water Fisheries (Protection) (Scotland) Act 1951).

Annual Control

The second method of control involves the use of annual control measures. Such methods as spot poisoning with rotenone, trapping, netting and electro-fishing are often employed.

The Inland Fisheries Trust of Ireland is perhaps one of the most experienced groups in dealing with pike. For the control of pike they list three methods for use in lochs which they have tested over many years and found effective. They use spot doses of rotenone to kill pike fry in the first few months of life: drum nets or wire traps which will remove pike from about 6-15 months of age and finally gill nets which will take pike from about one year and above. All three methods must be applied with extreme care since they could potentially remove trout and/or interfere with anglers if not carefully positioned. Long lines and otter boards have also been used by the Irish but are not regarded as important as the first three methods.

The spot poisoning must be carried out in areas where fry are known to be congregated after it has been ascertained that there are not large numbers of trout fry in the area. The dose must be adapted so that the concentration is not stronger than necessary and care must also be taken to ensure that winds do not carry the poison into other areas. Drum nets are set around the edge of water bodies in shallow, weedy areas, and, to avoid interfering with the anglers are usually set out of season. Gill nets are generally used during the spawning period February to April and often from September to November. In the early stages of management, where large populations of pike exist nets may be used all year round until the population numbers are reduced.

The effects of these methods on the pike populations is best exemplified from Irish experiences. In 1972, 19 loughs were exposed to all five of the methods described with the following results (Table 6.7).

TABLE 6.7

Catch of Pike in 1972 by Five Different Methods
(From IFT 1972-73)

	Traps	Gill Nets	Otter Boards	Long-Lines	Rotenone
No. caught	3521	15,035	794	286	6805
Total weight (lb)	1475	34,550	1672	1956	906
Average Weight (lb)	0.4	2.3	2.1	6.8	0.1
% Nos.	13.3	56.9	3.0	1.1	25.7
% Weight	3.6	85.2	4.1	4.8	2.2

It can be seen from Table 6.7 that the different methods are selective with regard to the size of pike which are susceptible to them. Between the two most effective methods, trapping and gill netting, a successful control programme can be instigated which will reduce both the average size and overall numbers of pike. The reduction in average size is clear from Table 6.8 which shows that the average size was reduced steadily from 4.9 lb to 1.8 lb over the period 1968-1970 as a result of gill netting on the 19 loughs. Similar reductions in average size have been noted by Thompson and Bagenal (1973) from gill netting in Lake Windermere over the period 1944-1947. The removal of the larger pike by gill netting not only reduces the average size of pike and the total number of larger pike but also reduces the recruitment to the population since it is a most effective method of removing spawning fish. The control of the younger age groups is further enhanced by the use of traps. These younger pike which are not susceptible to the gill nets are still of course able to exploit the younger trout thus reducing the potential number of takeable fish for the angler.

TABLE 6.8

Average Weight of Pike Gill Net Captures, 1963-1970
(From IFT 1970-71)

Year	1963	1964	1965	1966	1967	1968	1969	1970
Average weight in lb	4.9	4.2	3.3	3.1	2.9	2.3	2.0	1.8

In the purely artificial fishery gill netting itself may be sufficient since all trout will be of a larger size which are not vulnerable to the small pike. Such small pike may well perform a useful function in the artificial fisheries which have perch present since they will exclusively exploit the young perch populations and may keep the perch population under control. In the fishery which relies to a reasonable extent on natural reproduction of trout however both gill netting and trapping are likely to be necessary.

6.3.3 COST OF MANAGEMENT

(a) Complete removal of fish using rotenone

The cost of the use of rotenone on even a small water is fairly high due to the high cost of the poison and the amount of manpower required for the treatment operation. In order to assess the costs involved reference will be made to two waters where the treatment has been carried out and records maintained of costs involved. The waters are Loch Fitty, reported by McKenzie (1975) and Peckhams Copse Trout Fishery reported by Gates (1972). Loch Fitty, a 160 acre loch was treated with rotenone in 1970 as part of the development plan for the Loch as a trout fishery. Since no depth soundings in recent years were available the first step was to carry out a bathymetric survey of the loch so that calculations of volume required and coverage of deep pools could be carried out. It became necessary as a next step, to dam the outlet burn to prevent water outflow until after the water became non-toxic, the dam being 7.5m high and constructed of stones and earth. This required four man days work and the use of moving machinery. The actual treatment time was one day requiring 40 people divided into seven teams of five individuals, two leaders of the teams and three supervisors. The clearing up process took many days although no actual figures were quoted. At Peckhams Copse an area of 40 acres was treated. Again a survey of the water was carried out to assess the volume of poison necessary. Treatment time was half a day involving six teams of two men. Clearing up took eight days.

The entire treatment cost can therefore be divided up into the survey, actual operation (rotenone and labour) and clearing up.

Survey. Neither author recorded the time involved in this but a similar operation was carried out at Loch Walton, Stirlingshire, a loch of 32 acres and of similar depths to the two lochs in question. This loch took one man day to survey, map and calculate volume. Thus the Peckhams Copse fishery could most probably have been completed in one man day while Loch Fitty would probably have required about five man days.

Actual Operation. The amount of rotenone required depends on the volume of the water body and the concentration required. The recommended concentration as already stated is from 0.02-0.05 ppm rotenone. From the literature the concentration used is usually around 0.05 ppm although the local water authorities through the Secretary of State may request a lower rate: at Loch Fitty a concentration of 0.025 was used at the demand of the water authorities. The total volume for Loch Fitty was estimated as 1,280 million litres while Peckhams Copse was 270 million litres. The volume of solution required was therefore 1,280 litres and 270 litres (Rotenone can only be obtained as a liquid derris extract containing 5% rotenone). The cost of the solution has risen markedly in recent years from £6/gallon in 1972 £20/gallon in 1975. Thus the total cost for Peckhams Copse and Loch Fitty (allowing for reductions for bulk buying) would be £1,080 and £2,520 respectively.

The labour costs for the operation would be £57 for Peckhams Copse and £380 for Loch Fitty. Although the number of individuals may seem very high in both examples it was found at both sites that dividing the water up into areas and appointing a team to cover each area was the most efficient method ensuring complete coverage and avoiding duplication.

Clearing Up. The quoted time involved at Peckhams Copse was eight days at a cost of £76 and the estimated cost for Loch Fitty, assuming a proportionate increase in labour would be 32 man-days at a cost of £304.

The total costs involved in both operations are summarized in Table 6.9.

TABLE 6.9

Comparative Costs of Rotenone Treatment

	Peckhams Copse 40 acres (16 ha)	Loch Fitty 160 acres (65 ha)
Survey	9.50	47.50
Operation: Rotenone	1080.00 (0.05 ppm)	2520.00 (0.025 ppm)
Labour	57.00	380.00
Clearing up	76.00	304.00
TOTAL	1222.50	3252.50
Cost/ha	76.00	89.00
Cost/acre	31.00	20.00

The difference in cost per acre is quite substantial indicating the importance of the chemical costs in the treatment. It is felt that the concentration used at Loch Fitty is the lowest concentration permissible and that considering the amount of capital involved it is better to err on the high side than the low side where there is a risk of re-treatment. However the Peckhams copse concentration may in fact be rather higher than necessary even allowing for some margin of error. Thus the average cost per acre of water, for a eutrophic loch must be approximately £26, and, for the 100 acre loch would amount to ca. £2600.

(b) Gill Netting

Gill nets can be purchased, ready to use for £40 for 100 yard stretches (64 yards when roped for use). Three such nets would be sufficient for a 100 acre loch incurring a capital cost of £120. Netting can be carried out all year round although it is best to avoid mouths of spawning burns in Autumn to minimise the loss of trout. Thompson and Bagenal (1973) suggest that the loch should be divided up into sectors and fished in a methodical manner, netting in one sector until catches decrease and then moving on to the next sector. It is suggested by the authors that nets should be set and then examined two or three days later (although if trout losses appear to be heavy this can be minimised by daily checks). Setting the nets requires two men and, with three nets could be done within one hour. Checking the nets requires two men and again could be done in an hour. If a three day interval between setting and checking is used, and an allowance made for the shifting of nets every two weeks then 300 man hours would seem a reasonable time cost in a year. This involves a labour cost of ca. £356/year.

6.3.4 EFFECTIVENESS

It has been shown that the cost of rotenone treatment can be fairly high and, although capital costs for netting are low, labour costs may be quite substantial. It is therefore important to determine the efficacy of such management procedures.

Clearly the levels of infestation with pike in relation to the trout population will vary considerably from water to water and therefore the effect on the catchable trout population will vary accordingly. However if one considers only one 3+ pike and one 2+ pike weighing approximately 2.3 kg (5 lb) and 0.9 kg (2 lb) respectively then assuming that such fish will eat ten times their body weight in a year the 2+ fish will consume 9 kg and the 3+ fish 23 kg of fish per year. Since at this size they are quite capable of removing trout in the 23 cm - 38 cm (9"-15") range, this would involve the removal of 140, 28 cm fish (11") weighing approximately 32 kg. The total cost of replacing these fish from commercial suppliers amounts to about £63. Even if one considers that a perch population were present and that the pike exploited both populations equally then the replacement cost would be £32.

The size of pike population in a loch may very well bring about this sort of exploitation per acre of water: according to Irish workers (I.F.T. 1972-73) a good, productive water may produce up to 69 kg (150 lb) per acre of fodder fish for pike per year, which would support, for example, the population of pike shown in Table 6.10.

TABLE 6.10

Food Consumption of Pike

Number	Age	Weight kg	Consumption kg	Total Consumption
1	3+	2.3	23	23
2	2+	0.9	9	18
3	1+	0.3	3	9
				50 kg

Such a population of pike would thus consume 50 kg (110 lb) per year. While such production figures are very high and not often obtained in Scottish waters it would seem quite feasible that one 3+ and one 2+ pike could exist within one acre removing 32 kg/acre of fish. The cost to the trout fishery would be £32 per acre. If one considers the cost of treatment of a loch to eliminate pike of about £26 per acre (a non-recurring cost) then the efficacy of the management practice is apparent. Similarly, where netting alone is carried out the cost/acre allowing for renewal of nets every five years amounts to only £4-5/acre and again the benefits of removal outweigh the costs.

6.3.5 CONCLUSIONS

Where rotenone is used, although the capital involved may be high the benefits may well 'pay' for the costs within a year. There are situations however where rotenone cannot be used (e.g. because of legal or physical restrictions or where the re-introduction of pike seems likely to occur) and in such situations annual netting practices would seem an economically worthwhile activity for many waters.

6.4 POPULATION CONTROL

6.4.1 INTRODUCTION

A typical problem of many Highland waters is the presence of excellent spawning streams with pure, cold water and a suitable gravelly substrate but rather unproductive waters resulting in a paucity of trout food organisms. The result in both lochs and rivers is a large population of small, slow-growing fish, unacceptable in size to the majority of anglers.

There are many methods which may be employed to improve this situation and these may be divided into two groups: methods involving improvement of the environment to make it more biologically productive or suitable for trout and those involving control of the trout population such that there are fewer individuals competing for a limited food supply. The former has been dealt with under food improvement and predator/competitor control, the latter is the subject of this section.

6.4.2 METHODS OF CONTROL

There are two basic alternatives open to the manager including the control of the adult population size in the water and the control of recruitment.

(a) Control of adult population. This may be accomplished by netting the water using seine nets, removing size and bag limits or by introducing pike to the water. Netting on the scale necessary would be a time consuming business and it is often found that the most abundant, smallest fish are not sufficiently vulnerable to netting to allow the removal of a large enough number of fish. Removing size and bag limits in order to bring about a drastic reduction in numbers is really only successful where a very heavy fishing pressure can be brought to bear on the water. It does not really attempt to get to the root of the problem and, in many cases, may not bring about a sufficient reduction in numbers to improve the growth rate of the remaining trout. A further possibility is the introduction of pike which would reduce the trout population. This is not recommended as a suitable method since although it may solve the immediate problem, it may introduce other equally serious ones.

(b) Control of Recruitment. This may be accomplished by erecting barriers across spawning burns such that trout are not able to ascend the burns to spawn, or by poisoning burns after spawning in order to kill off all fry in selected burns.

Barriers and Traps

The use of barriers is a cheap method of control but there are certain problems associated with its use. Firstly there may be physical problems regarding the installation of the barrier and secondly the barriers are prone to blocking with vegetation etc. which then causes water to flood around the barrier, permitting the passage of trout. Barriers are also of limited value if a large resident trout population exists in the burns since this population will maintain a supply of fry for recruitment to the loch. According to Campbell (1967b) the number of spawning trout required to maintain a loch population is very small in relation to the number of mature trout available and he estimates that where a resident burn population exists the surplus progeny from their reproduction is often enough to maintain the population of the loch without supplemental recruitment from the mature loch population. Thus where large burn populations exist it may be impossible to use barriers and effectively control recruitment to a desired level. However in some circumstances they can be very effective especially when used in conjunction with traps. In such cases all burns are barriered and trapped and fish enter traps when ascending the burns. In this way only a selected number of trout may be allowed to ascend the burns to spawn.

Poisoning

A more controlled method of controlling recruitment of trout is by poisoning selected spawning burns. This method has been successfully carried out by Walker (1975) on a small Highland loch (Loch Bhac, 31 acres). Although it would be most useful to be able to quantify the amount of juvenile recruitment and then determine by how much it ought to be reduced in order to bring about a satisfactory size of adult trout it is very difficult to carry this out and in most cases impracticable.

It is more usual to use a trial and error procedure and this was the method adopted by Walker. Three of the main burns at Loch Bhac were selected leaving 6 smaller inflows unaffected. Based on a crude estimate of water flow, an exposure of 30 minutes was allowed for, with a concentration of 0.05 ppm of rotenone. A total length of 6 km was treated from July to mid-September (in May fry are too small and numerous to be effectively treated and there is a high risk of missing large numbers of them while November may be too late since some migration to the loch may have already taken place), the solution being quickly detoxified on reaching the loch by the dilution with loch water. It was found that the treatments were completely successful and were both easy to carry out and quick.

Of the basic alternatives discussed it is apparent that the control of the adult population is a difficult and unreliable process while the control of recruitment appears to be a more successful solution which attempts to get to the root of the problem.

6.4.3 COST OF CONTROL

(1) Barriers and traps. The cost of making and erecting barriers and traps involvesboth materials and labour costs. To make and instal takes approximately two man-days and would cost ca. £25 in materials including wood and weldmesh for the trap (G. Scott, pers. comm.). The total cost per stream including barrier and trap will be in the region of £45.

Labour is also involved once the traps are installed: during the spawning season it will be necessary to visit the traps when fish are running and visits will have to be made at intervals to ensure traps and barriers are kept clear. The labour costs of this are rather difficult to determine but allowing three visits per week during the spawning season and extra time required to deal withspawning runs when they occur

(3-5 major runs occur usually per season) the total manpower costs may amount to about 12 man days, £114. Total costs including building, installation and manpower (assuming there are six main burns) will therefore be in the region of £384 for the first year and £114 per year thereafter.

(2) Poisoning. The cost of poison is likely to be very small. In the example quoted 6 km were treated at a cost of about £4 for poison and £6 for labour making a total of £10 per year.

6.4.4 EFFECTIVENESS

The results from the use of barriers and poisoning from the examples available are fairly encouraging. In one loch (Fincastle Loch, Campbell 1967b), the prevention of natural spawning with the use of four barriers over a five year period brought about an increase in cropping rate from 8.3 kg/ha (7.5 lb /acre) to 14.9 kg/ha (13.5 lb / acre). The average size of fish actually dropped over this period from about 35 cm to 28 cm (management first began four years previous to the erection of barriers and the first four years increased the average size of fish from 160g to 350g but brought about a reduction cropping rate from 9.0 kg/ha (8 lb/acre) to 8.3 kg/ha (7.5 lb/acre). By the end of the period reported, the fishery had settled down to an average cropping rate of about 14.9 kg/ha as noted above. The value of the increase in catch over the latter four years when barriers were in use amounts to the value of 6.6 kg/ha of 28cm trout on a water of 2.6 ha (6.5 acres) in area. At current costs this amounts to a value of £35. Considering costs of installation and annual running costs the efficacy of the management procedure is not clear in this example and this highlights the need to consider fully the costs involved in management, particularly the labour cost which is often ignored in such assessments. However

Fincastle Loch is very small and while the improvements in the fish were really quite substantial (valued at about £5/acre) the financial benefit on such a small water was very small. If similar benefits could be brought about in a 100 acre loch then the value of the benefits would be £500, while costs, assuming 5-6 barriers were necessary would be ca. £350.

From the work of Walker on Loch Bhac it is not possible to calculate the actual increase in number and size of takeable fish as a result of rotenone treatment since the only figures available indicate that over period of treatment, from 1971 to 1974, the number of trout from samples which were over an acceptable size limit of 23 cm (9") increased from 11% in 1971 to 23%, 49% and 43% in 1972, 1973, and 1974 respectively. The last two figures would suggest that a stable position had been reached and that further increases in size of fish without some other management method (e.g. chemical fertilization of the loch) would be unlikely. Such increases in the number of takeable fish would have marked effects on the number of anglers which could be supported by the fishery.

6.4.5 CONCLUSIONS

It has been rather difficult with the paucity of data and the variability of the effect of this management procedure on different waters to assess the benefits from management but the costs of using poison for all fisheries are likely to be fairly small both in the initial costs and the recurring costs and it would seem a most useful technique for certain waters. The costs of using barriers and traps is a rather more expensive method but may be necessary if the use of poisons is not permitted. However even these costs are likely to be covered by the benefits in fisheries with a serious over-population problem.

6.5 AQUATIC PLANT CONTROL

6.5.1 INTRODUCTION

Although this section is about the control of aquatic plants it should already be clear from Chapter 5 that plants have an important role to play in the trout environment. Their uses are listed by Robson (1973): aeration of water; shelter for animals; consolidation of banks and beds; provision of food for other aquatic organisms; interception of silt and plant detritus. It is clear therefore that elimination of all plant material would have deliterious effects. However control of plant growth by selective eradication is often necessary on fishing waters when the plant growth impinges on water areas used for fishing: uncontrolled growth over a few years can, in some waters, lead to substantial reductions in water area, where excessive in shallow water, bank fishing may become impossible.

In streams the velocity of water and nature of river bed generally determine the weed growth. In fast flowing waters (0.6m/s) and where there is no muddy deposit there is rarely any need for weed control. The slower the flow the greater is the likelihood that weed growth will become a problem.

6.5.2 METHODS OF CONTROL

There are several methods of control used in Britain which vary considerably in their manpower requirements and their effectiveness and they include cutting, biological control and use of herbicides.

Cutting: this is a safe method of control in that it does not have any detrimental side effects. Cutting may be done by hand or by mechanised cutters mounted on boats. Although it is found that many perennials grow very quickly after cutting (e.g. is is said that Bur-reed may grow 10 cm in three days after cutting in mid-May) generally it proves to be a useful technique, particularly where some degree of automation is introduced with the use of mechanised cutters. Hand cutting although effective is so time consuming that in large waters it is impractical. From several sources (e.g. G. Scott, pers. comm.; R. Boyd., pers. comm.) it is known that anything up to one fifth of the surface area of a shallow loch may have to be cleared each year in order to keep weed growth under control. According to G. Scott, hand cutting can be done at the rate of ca. 100 $yards^2$/6 man hours. For one acre 36 man-days would be required. Clearly, for a large loch the time requirement and therefore cost would be prohibitively high. Motorised cutters are available which drastically reduce the man power required. Cutters are available either permanently mounted on a boat or as units which are detachable so that the boat can be used for other purposes.

Biological Control: herbivores such as sheep are used on occasions to control the growth of some waterside plants. Some domestic duck and wildfowl species are encouraged on some waters since they can efficiently crop many plant species (Grizzell & Neely, 1962). Too many can however contaminate the water. Grass carp, an herbivorous fish species have been used as a control technique, (Cumming, Burress & Gilderhus, 1975). Unfortunately none of these techniques are sufficiently quantitative to be of much value for further consideration.

Herbicide Control: selective herbicides are available for aquatic plant control. The chemicals, used correctly, are non-toxic to fish and most invertebrates (as with all of these methods some invertebrates will be indirectly affected through loss of habitat). The chemicals should be used when plant growth is small or the treatment area should be divided into sections for treatment in order to minimize de-oxygenation through plant decomposition. Of the methods described this is perhaps the most dangerous since misuse or errors of judgement with regard to concentration may result in complete devastation of the plant species present, very much to the detriment of the fishery. However it is reputedly the quickest, cheapest and most efficient method. (It is necessary to obtain permission from the local river authority before using chemicals on any loch which discharges into a stream (Rivers (Prevention of Pollution) (Scotland) Acts 1951 and 1965)).

Herbicides come in liquid or powder form. For emergent and floating leaved weeds a foliar spary is usually used while for submerged species granules are often used which slowly dissolve around undesirable plants. A range of chemicals are available but for the fishery manager the choice is helpfully reduced by the Government publication 'The control of aquatic weeds', (Robson, 1973). Two commonly applied herbicides are Dalapon, for use on emergent species and Diquat, for use on submerged and floating leaved species. The former, if sprayed early in the year will require annual use although re-growth is reported to diminish after three or four years. It is a translocated herbicide and, according to Robson it is effective on reeds, reedmaces, sedges, while rushes, bullrushes and broad-leaved plants seem less susceptible. Diquat should be used early to prevent de-oxygenation through loss of plants and decomposition but must be used when the plant is actively growing (May). It affects a wide range of floating and submerged species and treatment must be repeated annually. Diquat also successfully controls an alga, Cladophora (Blanketweed) but chemical control of algae has proved relatively unsuccessful.

6.5.3 <u>COSTS OF CONTROL</u>

<u>Cutters</u>

There are two cutters available for use on lochs including the permanently mounted and detachable models. The cost of the cutters is £2,700 and £870 respectively (no boat is supplied with the latter), the former cutting at a rate of 6500m^2/hour and the latter cutting at half that rate at 3250m^2/hour. Running costs for both models include an allowance for maintenance and it has been established from various sources that 20% of the depreciation allowance for the cutter is a realistic maintenance estimate. For the small cutter this amounts to ca. £12/year (assuming a 15 year life for the cutter) and for the large cutter, £36/year. Labour costs for the cutters at the quoted cutting rates amounts to £2.80/acre for the small cutter and 0.70p/acre for the large cutter (the small cutter requires two men to operate it while the large cutter can be operated by one man). Total operating costs therefore amount to £14.80/acre and £36.70/acre for the small and large cutters respectively. If a depreciation allowance is included then an additional £58 and £180 must be included with the operating costs. Using the small cutter on the 100 acre loch, where 20 acres/year is cleared, would incur a total annual cost, including labour, maintenance and depreciation of £126.

There is a suggestion (Adams, pers. comm.) that the small cutter may be underpowered for the very large waters where many acres have to be cut in a year. However the manufacturers have confirmed that for a 100 acre loch the small cutter would be adequate.

<u>Chemicals</u>

The cost for the two recommended chemicals, Dalapon and Diquat, used at the recommended concentration of 1 ppm would be ca. £10 per acre each, making a total cost of £20. Labour costs would be fairly low amounting to no more than £5/acre. All costs here are of course annual running costs there being no capital cost for this treatment. Total costs for the treatment of 20 acres would amount to £500.

From this assessment of costs the earlier statement on the economy of chemicals does not appear to be substantiated. However a closer comparison of the relative costs of treatment reveals that the mechanised cutters have a high fixed cost, in the form of the capital costs of the cutter and very low variable costs (the annual running costs which are variable depending upon the amount of labour required). The chemical treatment, on the other hand has high variable cost but no fixed cost. This suggests that where smaller areas are involved the chemical treatment may become financially more attractive. This could be assessed simply by comparing the annual costs for the cutters (including the depreciation allowance, labour and maintenance) with the annual cost of the chemical treatment (chemicals and labour) for a range of acreages. However this comparison does not consider the timings of the cash out-flows. As already described above these are very different for the two methods. In order to compare the two projects it is necessary to bring the two sets of costs to a directly comparable level to allow for the fact that money spent now costs more than an equivalent sum at a later date. This fact is accounted for in the discounted cash flow methods of economics which, by discounting the cash flow over the life of the project effectively pays for the opportunity cost of the capital. One such method is the net present value method (NPV). The formula for the calculation of the NPV is:

$$NPV = \sum \frac{R}{(1 + r)} i$$

where R = Revenue - costs (net cash flow)

r = rate of interest

i = number of years project is expected to last.

In this example actual annual costs are used instead of cash flows and these costs are discounted over 15 years for both the chemical and cutter methods for a range of acreages. The interest rate used is 14%, this being a reasonable post-tax return on long-term investments in

July 1975. The initial comparison is made between using the small cutter and chemicals for waters up to 100 acres and the calculated NPV's are shown in Table 6.11 (actual costs are shown in Appendix 7). From the table it is clear that up to and including six acres of weed clearance (i.e. up to a 30 acre loch) it is more economical to use chemicals while from seven acres and above it becomes more economical to buy the small cutter.

TABLE 6.11

Comparison of Cutter and Chemicals using NPV's

Loch Size a.	Acres Cleared	£870 Cutter NPV £'s	Chemicals NPV £'s
25	5	909	767
30	6	941	920
35	7	959	1073

An examination of the large cutter: chemicals comparison indicates that for all waters over 100 acres the large cutter is the best economic proposition (see Appendix 7). Clearly for these waters the small cutter would be the most economical method of all but since it has been impossible to establish the limitations of the small cutter (the only definitive statement on this is that for a 360 loch the small cutter is underpowered (Adams, pers. comm.)), it is only possible to say that assuming that the small cutter is limited to 100 acre lochs the large cutter becomes the most economic clearance method for waters above 100 acres or with more than 20 acres of weed to clear in a year.

From this analysis it is clear that the manager must give careful thought to the selection of a control method for weed.

6.5.4 EFFECTIVENESS

The actual area of water recovered for the boat angler by weed clearance may be as much as 20% in the shallow productive water. Furthermore, a 100 acre loch could easily support up to 30 bank anglers at any one time and without weed clearance, angling for bank fishermen could become at best difficult and, at worst, impossible.

While it is difficult to actually cost this improvement it is clear that more boat and bank anglers could be supported by annual weed control. At a well managed fishery costs for boat angling may be anything from £4-£6/boat while bank anglers may pay from 50p-£1 for a day permit. The cost of clearance using the mechanized cutter was ca. £200 per year, the equivalent of ca. £1/day during the angling season and from a comparison of this cost with the probable saving from increased sales it does seem likely that the benefits will outweigh the costs for at least some fisheries.

6.5.5 CONCLUSIONS

Up to a 30 acre water, which may be clearing six acres of weed each year, it has been found that the use of chemicals (if permission can be obtained from the local river authorities) is the most economically efficient way of controlling weed. Over 30 acres and up to 100 acres the use of a small motorised cutter becomes more economical. Over this size of water it may become necessary to consider the large cutter and, in this case for all clearances over 20 acres the large cutter proves more economical than the use of chemicals.

In all cases it does seem likely that the amount of area saved for the angler is going to make this management method a viable proposition in many waters.

6.6 MONITORING AND CONTROL OF FISHERIES

6.6.1 INTRODUCTION

Irrespective of whether a natural or an artificial fishery is run, some attempt must be made to monitor and control the state of the fishery. Monitoring may be carried out on a very sophisticated basis or it may be done very simply: much depends on the skills available and the needs of the water. Much can be concluded from fairly simple monitoring techniques. For example, Hartley (1947) produced a table of water classifications which provides a useful guideline for anyone involved in management, the amount of analysis required to determine the condition of fish being quite within the capabilities of any fishery manager. Table 6.12 is reproduced from Hartley and indicates the possible conditions of populations along with a suggested course of action.

TABLE 6.12

Classification of Waters

Condition of Fish	Action
Fish are large and young	A moderate amount of stocking
Fish are large and old	No change
Fish are of average growth	Fertilization of the water and removal of competitors as far as is practicable
Fish are young and small	Fertilization of water and removal of competitors
Fish are old and small	Drastic reduction of stock and introduction of predators if necessary. Temporary reduction of size limits. Fertilization of water after reduction of stock

The techniques of monitoring and control of fisheries are varied, some of the fairly simple methods are considered below and most of these can be used by managers with no formal scientific training.

6.6 MONITORING AND CONTROL OF [illegible]ING FISHERIES

6.6.1 INTRODUCTION

[illegible] some attempt must be made [illegible] fishery. Monitoring may be [illegible] or it may be done very [illegible] and the needs of the [illegible] monitoring techniques. [illegible] of water classifications [illegible] involved in management. [illegible] the condition of fish [illegible] (1968) manager. Table 6.12 [illegible] possible conditions of [illegible] action.

TABLE 6.12

Classification of Waters

Condition of Fish	Action
Fish are large and young	[illegible] of stocked fish may [illegible]
Fish are large and old	No change
Fish are of average growth	Fertilization of the water and [illegible] is practicable
Fish are young and small	Fertilization of water and [illegible] of competitors
Fish are old and small	Drastic reduction of stock and [illegible] necessary. Temporary reduction [illegible] water after reduction of stock.

The techniques of monitoring and control of fisheries [illegible] some of the fairly simple methods [illegible] these can be used by managers with [illegible]

6.6.2 METHODS OF MONITORING AND CONTROLLING FISHERIES

A. Fish Records

This involves the recording of numbers and sizes of fish removed and also, in the artificial fishery, the number of fish stocked. While the latter is often recorded the former is rarely carried out except in the large fisheries where full-time supervisors are present. The recording of numbers and sizes of fish caught is not a lengthy process for the individual angler and yet most anglers seem unwilling to carry out this task. With some fisheries the most efficient method appears to be the recording of catches by a supervisor but others have found that taking a 'hard-line' with the anglers works well. Oliver (1968) for example, reports that all anglers at a particular fishery are required to complete a return card at the end of the day, those failing to do so are first warned and then asked not to come again. This method appears to have worked well.

The information on fish stocked and size and number of fish removed is of great value to the fishery manager, giving a record of exploitation rate for the artificial fishery. A low return of stocked fish may suggest poor survival of fish, insufficient pressure on water from anglers etc. A record of numbers and sizes of catches in the natural fishery will allow the detection of a fall in catch and size of fish which requires management to restore it to its original level. The analysis of returns is greatly enhanced if some attempt to assess the age of fish caught is made. This may be done from scale analysis.

B. Scale Analysis

The analysis of fish scales may be carried out to determine both the age and growth rate of fish. The former information is most useful in conjunction with size and number of catch in assessing the state of the population being exploited by the anglers. Obviously the ageing of all fish caught would be time consuming but sufficient information can be collected from scales taken from a random sample of fish throughout the season. The sort of assessment described by Hartley may be carried out in this way. Although the reading of scales does require some training on the part of the manager it is well within the capabilities of the average person. (Frost & Brown (1967) provide detailed information on the method of scale analysis.) Growth rates may also be assessed from scales but this requires more skill again and although the information received can be most useful since it may detect over-population of the water or suggest improvement of the water it is more demanding on technical skills and is more time consuming.

C. Fish Marking

In the early stages of development of a natural fishery and at times throughout its life as a fishery it is often desirable for the fishery manager to have an estimate of the population size of trout so that some estimate of exploitation and population density can be made. The methods usually involve catching a number of individuals, marking them and then releasing them either to be caught by anglers or netted. The proportion of marked to unmarked fish in subsequent catches in relation to the total number marked then allows the calculation of population size. This again is a rather more sophisticated technique and, if anglers catches are being used, then a co-operative body of anglers is very necessary to ensure accuracy. The possible methods of marking fish include tagging, fin-clipping, dye marking and cold branding. The basic requirements of a mark are ease of application, ease of identification by the average angler, low cost, minimal effect on the fish.

Fin-clipping. This method of fish marking has been used for many years in fisheries and it is fair to say that every fin with the exception of the caudal fin has been removed and in almost every possible combination.

However it is equally fair to say that all fins with the possible exception of the adipose fin serve some function and it is probably safest to remove this fin rather than any of the others. Regeneration can take place, the extent depending on the efficiency of clipping, and depending on the time scale this may prove troublesome, particularly when the anglers are required to identify the marked fish when caught.

Dye-marking. This suffers from much the same problem as fin-clipping in that the mark is often no more than a dark streak and although identifiable by a trained eye this may not be so with the angler. Dyes may be either injected intracutaneously (Kelly, 1967) or applied by a high pressure jet inoculator after the method of Hart and Pitcher (1969). Both methods require the fish to be anaesthetized and the latter, although more expensive than the former has the advantage of speedy application.

Cold Branding. As with both fin-clipping and dye marking this is largely a batch marking technique. The technique uses liquid nitrogen as the cold source, the brand being silver letters or numerals. The fish must be anaesthetized with this method which does make it slower than fin-clipping. Work by Piggins (1972) indicates that the brand mark is still visible after one year in the field while the work by Turner, Proctor and Parker (1974) asserts that with 4"-6" rainbow trout the mark is still visible after two years in the field. The damage to the fish is though to be very little causing no mortality (Laird et al 1975) and it is thought to be superior to tagging and fin-clipping as a result of this (Champion & Hill, 1975). Again however the problem lies in the identification of the mark by the untrained eye. However where catches are checked in by a fishery attendant this is not a problem.

Tagging. This method has the very definite advantage over the others of ease of identification even to the most inexperienced eye and is therefore valuable to the fishery using anglers returns as the only means of assessing the capture of marked fish. One tag, the Floy tag, has been successfully used at a loch during the course of this study (reported in Chapter 7) and is preferred by many workers to wire tags (e.g. Rawstron, 1973) largely for reasons of economy. It was selected because of its relative ease of application which means that the method can be used by inexperienced hands and also that the length of time out of water and amount of handling is minimised. Although causing some retardation of growth (this is a common occurrence with tags) the Floy tag does not affect survival (Carline & Brynildson, 1972).

Of the four methods discussed cold branding is preferable to either dye marking or fin clipping in situations where an experienced eye can check the catches and tagging preferable to all the others where anglers are required to report marked fish.

D. Regulations

Regulations are often imposed on fisheries in an attempt to control the number, size and condition of fish removed by anglers. By law a closed season is imposed on trout fisheries (7th October - 14th March) which protects the fish during the spawning season. Size and bag limits may be imposed by individual fisheries although these are not controlled by law and they may help to protect the population.

Size Limit. Perhaps the most lucid discussion of the determination of size limit is that given by Allen (1953). There are several objectives which must be recognized in the setting of limits. These include biological, economic and angler satisfaction objectives. The biological objectives recognized by Allen include to remove annually the largest proportion of the weight of trout which the water body produces and to have a majority of trout reproduce at least once before capture. The angler satisfaction objective defines the need to have a satisfactory

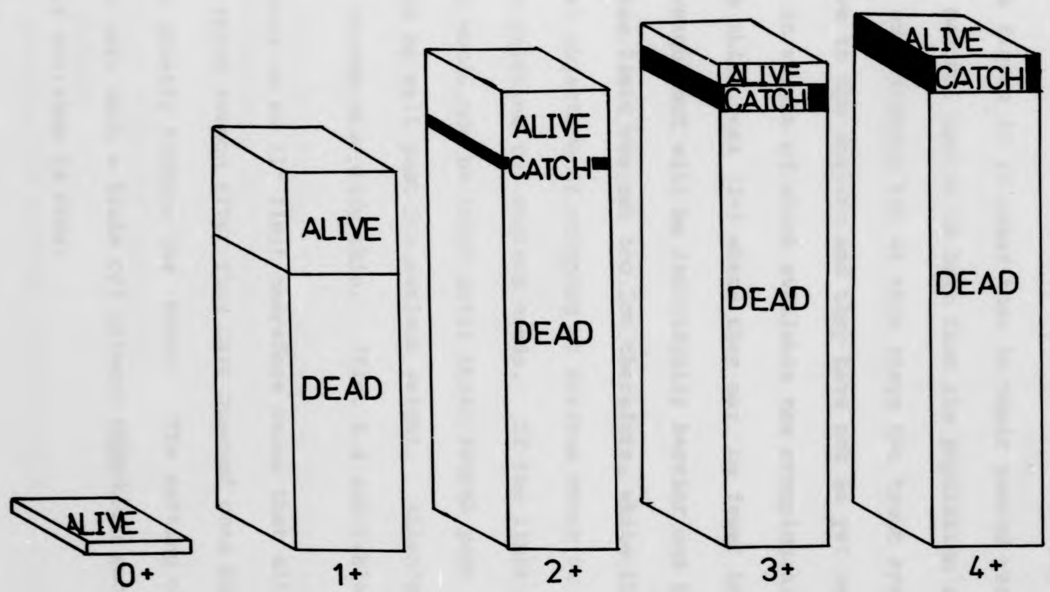

FIG. 6.4 Stock Production, Yield to Anglers and Death Through Natural Causes in Trout of Different Ages (From Allen, 1951)

size and number of fish available to anglers and finally, the economic objective requires the removal of that amount of fish which maximises the value of the catch. However since the 'value' of the catch is really value as perceived by the angler these last two objectives are identical: more satisfied anglers is concomitant with increased sales. From his work on the Horokiwi stream the stock production and crop is as shown in Fig.6.4. From this figure it is clear that in their second year (1+) the weight of stock is maximal and it is here that the population should be cropped to maximise exploitation but at this stage the trout are too small to be attractive to the anglers and they have not as yet reproduced. Despite the loss in weight of stock available the cropping times must be delayed until the third year (2+) where they may be fewer in number and less in overall weight but will be individually heavier and will also have spawned. If the size limit was set too low therefore, while it may satisfy the biological objective of cropping at maximum stock it would not satisfy the objective relating to anglers needs. If the limit were set too high then fish would not be taken until their fourth year (3+) when the population would be well past its maximum weight. Allen's figures for the Horokiwi stream exemplify this. (Fig. 6.4 and Tables 6.13 and 6.14).

Working to an 11" limit therefore means that all fish are takeable in their third season after they have spawned once but before natural mortality greatly reduces the stock. The setting of a size limit is therefore very much a trade off between objectives such that the optimum management decision is made.

TABLE 6.13

Trout Takeable at 2+

Age	Nos.	Wastage (Natural Death)	Angler's Catch
2+	100 trout 80 die	53	27 Average weight 12 oz
3+	20 trout 16 die	11	5 Average weight 1 lb.
4+	4 trout 3 die	2	1 Average weight 1½ lb.
Total Trout Yield		33	26^3/4 lb.

TABLE 6.14

Trout Takeable at 3+

Age	Nos.	Wastage (Natural Death)	Anglers Catch
2+	100 trout 65 die	65	
3+	35 trout 28 die	19	9 Average weight 1 lb.
4+	7 trout 6 die	4	2 Average weight 1½ lb.
Trout/Total Yield		11	12 lb.

Bag Limit. This again is lucidly discussed by Allen (1953). A bag limit is set in order to reduce the number of fish caught by the most expert anglers in an attempt to spread the fish more evenly over a larger number of anglers. Clearly if demand is not high enough then the fish saved by an angler reaching the limit and stopping will not be caught by another angler. These saved fish may be lost to the anglers through natural mortality if not taken and thus such a bag limit is in fact detrimental to the fishery. Bag limits are however invaluable in the heavily fished waters both natural and artificial and when correctly adjusted usefully controls the distribution of fish amongst anglers as well as accommodating more anglers.

6.6.3 COSTS OF MONITORING AND CONTROL

(A) Fish Records

Some fisheries run half day permits and some also try to synchronize the arrival and departure of anglers. In order to maintain records at these fisheries catches can be recorded by a fishery attendant at the end of each fishing period. For a 100 acre loch which may have 10-12 boats out in each fishing period this would involve perhaps one hour per day, making a total of ca. 200 hours/season. The total cost including analysis of catch statistics would amount to ca. 208 hours, at a cost of £220.

(B) Scale Analysis

This is again largely a labour cost and it is estimated that the ageing of scales may be done at a rate of 10 fish per hour. For the 100 acre water an allowance of 30 hours would seem adequate: assuming a catch of ca. 6,000 fish in an artificial loch of 100 acres, 30 hours would permit the analysis of 5% of the catch. The cost involved here would be £35.

(C) Fish Marking

As stated earlier it is envisaged that this would be carried out infrequently, every three of four years at the most would seem a likely frequency. Where fish have to be caught initially (as opposed to marking hatchery fish before release) then material costs would include the cost of a seine net for the capture of fish for marking. This amounts to ca. £100.

Tagging Costs. The cost of the tags and tagging gun amount to £70 including £20 for the gun and £50 for the tags. Labour including netting and tagging would amount to 40 man-hours (20 man-hours for seining and 20 man-hours for tagging at a rate of 100 fish/6 man-hours) involving a cost of £49. Total cost for the tagging operation, including all materials and labour therefore amounts to ca. £220, of which £100 would be a recurring cost for materials and labour for future tagging operations.

Cold branding costs. The brands for the marking would cost £20. Liquid nitrogen cost on each marking occasion would be small at a maximum of £5. Labour, including 20 man-hours for capture and 8 hours for marking at a rate of 1,000 fish/man-day, totals 28 hours at a cost of £32. Total costs therefore amount to £157, of which £120 is the initial capital cost and £37 the recurring running cost.

It has already been stated that tagging is the most easily identified marking method, but it is also more expensive: cold branding, a more satisfactory method both economically and biologically should be used where an experienced eye can check all catches.

Total costs for monitoring and control therefore amount to £100-£200 in capital costs and £200-£300 in annual running costs, the latter being largely a labour cost.

6.6.4 EFFECTIVENESS OF MONITORING AND CONTROL

Of the management methods so far assessed this is perhaps the most important one in general terms for all fisheries, the effectivness of it is also the hardest to translate into economic terms. This is largely because the methods described are, in a sense, preventative measures: they are largely methods which assist the manager to assess the efficacy of other management practices and permit the early detection of failures of management which might be rectified before directly affecting anglers' catches.

6.6.5 CONCLUSIONS

It has been difficult to show empirically the value of this kind of management but it is still thought to be one of the most important for all fisheries.

6.7 FISH STOCKING

6.7.1 INTRODUCTION

The final management technique to be considered here is the use of artificially raised fish in the running of a fishery. It is considered in great detail here because it is probably becoming the most widespread technique in fisheries management particularly in areas where fishing pressure is heavy and, where it is in use, it is likely to be a major part of the annual running costs.

There are five main reasons why artificially propagated stocks may be used in the running of a fishery. Firstly it may be necessary where natural reproduction is inadequate due to the paucity of suitable spawning areas. For example, the Lake of Menteith has approximately 300 yards of stream available to trout to supply a loch which is 650 acres in area. The available stream area is both inadequate in quality and capacity and although the trout in the loch may attain good growth rates due to the small population exploiting the food supply, the number of trout produced is very much smaller than that required to support the fishery. In such cases it is possible to either buy in trout annually from a commercial supplier to supplement the stock or to trap the spawning streams available and strip the fish as they try to ascend the stream. The spawn can then be artificially reared and stocked in the water. If some reasonable spawning area is available then it is possible to remove and strip some of the trout while allowing a suitable proportion to ascend the stream and spawn naturally. In such instances the artificially propagated fish are acting as a supplement to the naturally propagated stocks.

A special case of supplemental plantings of fish is described by the work of Bulkley and Benson (1962) on cut-throat trout (Salmo clarkii). They deduced from their work that large fluctuations in year - class strength occurred as a result of wide variations in recruitment. They attempted to correlate this with several factors including stream water levels, timing of spawning runs, summer air temperatures etc. Finding that water levels were by far the most significant factor they then went on to derive a formula to predict year-class strength. On the basis of this prediction they suggest that in years when poor recruitment is predicted it would be possible to stock with fry or fingerlings to supplement the natural stock. However even if the sport fishery had such information available to it caution is still advisable. Allen (1951) asserts that in years of bad flooding, when spawning is not likely to be very successful, it is often the case that fry are added to supplement stocks such that no appreciable drop in catchable population is detected in two or three years time when this age class becomes takeable. However Allen found that while the liberated fish did speed up the recovery from the flood their addition brought about an increase in competition for a food supply which had been seriously reduced by the flood. Such competition led to a reduction in growth rate and therefore smaller fish, and particularly a smaller size of females at breeding age. This in turn leads to a reduction in the number of ova produced by this age class. Thus while there are some benefits in this example there are also adverse effects which will have to be rectified. Millard and McCrimmon (1972) also issue warnings about the actual contribution of supplemental plantings of trout in many situations emphasizing the ability of the natural population to recover after reductions in recruitment through improved survival of the year class and also the contributions of other year classes to the catches. It is clear therefore that while in some situations supplemental plantings may be useful there are instances where such an investment would not benefit the fishery to any extent and in the long run may constitute a cost to the fishery.

Secondly, artificially propagated fish are clearly essential where spawning areas are non-existent. This situation often prevails with reservoirs and gravel pits etc.

Thirdly, in certain cases where waters have supported a mixed population of fish species it has become desirable to remove all coarse fish in the development of the water as a trout fishery. If a complete kill method as described in Section 6.3 is employed then once the treatment is over and the toxicity subsided it becomes necessary to re-introduce trout to the water. If adequate trout spawning and nursery areas are present then this may well be a single piece of management.

Fourthly, completely artificial fisheries may be adopted where fishing pressure is so high that over-exploitation of a natural population is inevitable. This embodies the idea of carrying capacity, defined by Bennet (1971) as "the maximum poundage of a given fish species that a limited and specific habitat may support during a stated interval of time". Le Cren (1961) working on a trout stream found in trials with stocking five similar areas of a stream with fry densities from 3-234 per square yard that by the end of six months each stretch had about seven fry per square yard surviving. There would therefore appear to be a maximum density for a stream and to try to go beyond this carrying capacity by heavier stocking would seem wasteful since death through starvation and/or mutual disturbance is likely to ensue. With older trout increasing numbers may not result in widespread mortalities but in many cases it is likely to lead to a depression in growth rate such that average size of the population decreases. Although this carrying capacity may be increased by the management practices such as food improvement, predator control etc. there is an upper limit beyond which it is impossible to improve the habitat for trout. If the demand for angling at a water is such that anglers are removing more fish than the water is capable of replacing then it is clear that if the demand is to be satisfied for any length of time then an artificial fishery rather than a natural fishery must be developed.

An extreme example of the completely artificial fishery is the 'put and take' fishery. Here the management procedure represents an attempt to largely eliminate natural mortality through not exposing the exploitable population to the natural environment for a long period. With this system the population of takeable size fish is planted in the water body with the intention of removing the majority of them in a very short time (this varies anything from a few days to a season at most). Since it is only necessary for the fish to maintain themselves and not necessary for them to grow or reproduce, the water quality with regard to its ability to support fish is not critical although the basic requirements discussed in Chapter 5 cannot be ignored. With the water body functioning largely as a keep-tank it is possible to maintain a much higher density of catchable fish than that which could be sustained under natural conditions. For example at one artificial fishery in Scotland the fish are stocked at a density of about 100/acre (40/ha). This represents a standing crop of ca. 50 lb/acre (56 kg/ha) of takeable fish, yielding about 30 lb/acre (34 kg/ha) to the anglers. This standing crop is in fact the equivalent of the very best natural fisheries: Frost & Brown (1967) quote standing crops of 50-60 lb/acre (56-67 kg/ha) and yields of 10-20 lb/acre (11-20 kg/ha). It is apparent from this that the fishery in question which is certainly not of very good quality with regard to its trout rearing potential, is giving a yield of approximately double that of the naturally productive waters. The standing crops are about the same but of course it must be remembered that while the standing crop of the artificial fishery is entirely made up of takeable fish that of the natural fishery is made of all loch age groups.

The 'put and take' fishery represents an extreme case of an artificially run fishery and there are many variations on this type of management. These variations revolve around the relative amount of dependence the stocked fish have on the environment between planting and exploitation. Thus a fishery which stocks annually with fry relies still to a very great extent on the quality of the water to support these fish until they are of takeable size and must also anticipate fairly high losses through natural mortality throughout this period. A fishery which stocks with yearlings still relies on the environment to support these fish for at least a year before they become of takeable size (size limits vary considerably from water to water but are generally within the range 20 cm - 30 cm) although this may not be true of faster growing species of fish which are stocked as game fish such as rainbow or brook trout. However such a method of stocking clearly eliminates both the natural mortalities which would be associated with raising fish to the stocking size and also the food requirements over this period. For example, in Loch Leven fish enter the loch from spawning burns between September and March as 8 cm (Autumn migration) or 13 cm (Spring migration) fish i.e. as either 1+ or 2- fish. With a size limit of 23 cm it is at least one loch year and for the majority of fish two loch years before these fish become of takeable size. If it was felt that this method of running the fishery was not satisfying the angler demand then it might be possible for the fishery to stock with takeable fish and thus eliminate the two loch years which fish must spend before becoming takeable. With the elimination of these stages of growth and the associated food uptake it would seem reasonable to assume that a larger population of these fish would be maintained in the loch for the current season.

Finally artificial stocking may be utilised in sport fisheries simply for ease of management. The manager of an artificial fishery has to contend to a much lesser extent with the vagaries of nature which may produce fluctuations in the size of exploitable population from year to year: the control of the fishery is very much more in the hands of the artificial fishery manager than the natural fishery manager.

Thus, in the management of fisheries, artificially propagated stocks have been used both as a supplement to naturally propagated fish and as an alternative. Artificial fisheries may be adopted where a purely natural fishery is not feasible due to some physical, chemical or biological factor which may prevent the water from producing at its full potential capacity or where the fishing pressure is so great that even at full potential the fish population is not enough to satisfy demand. It may also be adopted simply for ease of management, giving the manager more control over the fishing than is possible with a natural fishery.

It may seem that the artificial fishery is the best proposition for a sport fishery given that it is more under the control of the fishery manager but some thought must first be given to the disadvantages of the artificial over the natural fishery.

The first major consideration is the cost of the stocking programme. More detailed analysis of this appears later in this section and it is sufficient to say here that irrespective of whether the fish are bought from commercial suppliers or reared at the fishery and irrespective of the sizes of fish involved, stocking is a major expenditure for the artificial fishery.

A second problem relates to the relative sporting merits of the hatchery fish: it is rarely disputed that hatchery fish are less wily than their wild counterparts, the extent of this depending upon their length of time in the hatchery, domestication of parent stock, and the length of time between stocking and exploitation. As a result hatchery fish tend to be much easier to catch than wild fish. To some anglers this may represent a reduction in the sporting quality of the water and may discourage them from using the fishery. On the other hand this characteristic may have quite the opposite effect on other anglers since it gives the average angler a much better chance of catching a fish than he would have in a natural fishery. This particular problem may therefore exist for a certain sector of the angling population and may also be a problem for the fishery manager since a population of fish which is too catchable may be as troublesome as one which is the opposite. Finally, hatchery fish are not only less wily than wild fish they are also reported to have a higher mortality rate in the natural environment than wild fish of the same age. Clearly fish living under optimum conditions in a hatchery are likely to be placed under considerable stress when suddenly deposited in a natural environment. This is particularly true when fish are taken for example, from an alkaline environment to a very acid one or have to endure sudden temperature changes.

Despite these problems it is the case that many sport fisheries are supported entirely by artificially propagated fish. This is certainly true in England where the demand for game angling facilities is very high and it is becoming more widespread as a management alternative in Scottish waters.

The 'methods' section wich follows attempts to bring together the vast amount of literature on stocking methods with regard to species, size and number selection. The information relates to experiences both in this country and also in North America.

6.7.2 STOCKING METHODS

In this section the vast amount of literature on stocking methods is brought together in a discussion of the three major decisions which confront any manager contemplating stocking. The first part discusses the selection of an appropriate species for stocking, the second considers the size of fish which should be stocked and, finally, the third part considers the factors affecting catch of fish, relating catch to stocking numbers, fishing pressure and other factors.

(a) Species selection

In Britain there are three species of fish which are either stocked or exist naturally which come under the general heading of game fish (excluding both salmon and sea trout which, as already stated are not the concern of this thesis). These include the brown trout, the rainbow trout, and the American brook trout. Brown trout is the only indigenous species and as already discussed is both widespread and abundant in Scotland while rainbow distribution tends to be mainly in central and lowland areas of Scotland with very few recordings in the North of the country. The brook trout, like the rainbow, is an introduced species (the rainbow is originally from the West of North America while the brook is an introduction from the East of North America). Brook trout distribution is at present both local and rare with only a few self-supporting colonies known in the Torridon area and a few other localities in Scotland. It is more numerous in England although still local in distribution. Both rainbows and brook trout have been known to breed naturally in this country but the occurrences of this are rather rare.

The foregoing has given some background on the three species but what criteria should the fishery manager use in comparing them as potential stock fish? Below is given a list of the criteria which are thought to be the most relevant for the sport fishery:

1. Hatchery performance
2. Sporting qualities in the wild
3. Environmental requirements for survival in the wild
4. Growth rate in the wild
5. Disease susceptibility
6. Over-wintering survival

These are presented in Table 6.15 for ease of comparison of the three species. Thus the brown trout is the most expensive to rear artici-cially due to their much slower growth rate and clearly from the economic point of view this is a relevant consideration. However compensating for this to some extent is the brown trout quality as a sport fish. It is also the only indigenous species and therefore historically and thus traditionally it is the accepted species. The rainbow and brook trout are similar in many characteristics and are both ideal as hatchery fish because of their fast growth rate. They do however fill slightly different niches in the natural environment since the brook trout is reputed to thrive in cool waters and survives well in acid conditions (A. Walker, pers. comm.). In rainbow trout survival is thought to be rather poor under such conditions. In such ways therefore the brook trout is more akin to the brown trout and may

TABLE 6.15

Comparative Characteristics of Trout Species

	Brown	Rainbow	Brook
Hatchery performance	Slow	Fast	Fast
Sporting qualities	Good	Poor	Poor
Environmental needs	Cold acid/alk	Warm alk	Cold acid/alk
Growth in the wild	Slow	Fast	Fast
Disease susceptibility	U.D.N.	I.P.N.	I.P.N.
Over-winter survival	Good	Poor	Good

be better suited to the natural loch conditions found in the Highlands of Scotland. It is also reputed to over-winter better than the rainbow: A. Walker (pers. comm.) has had excellent over-wintering results with brook trout. The reasons for poor over-wintering returns from rainbows are many: Hunt and O'Hara (1973) suggest that it is the adoption of a bottom feeding habit in winter which is then perpetuated; Oliver (1968) suggests that predation by large fish already in the water is the explanation; Brown (1970) argues that it is the natural decline in fish food items in Autumn which causes heavy mortality; Cragg-Hine (1975) and Miller (1958) both put forward the theory that it is the presence of a resident population which causes severe competition for space and also a place in the social order and that this stress causes heavy mortality of introduced trout. Miller does in fact maintain that this happens to brook and brown trout as well, although the evidence does suggest that rainbow trout have a much poorer record than the other two. There is therefore some controversy over the cause of heavy mortality of stocked rainbows but this does not alter the central observation: when rainbow trout are Autumn stocked very poor returns to anglers must be expected. Thus rainbows only become a reasonable proposition where they are planted as takeables at the start of the season or in situations where the water quality is enough to ensure that sufficient growth takes place in the early part of the season for the fish to reach catchable size during the season.

On the basis of these comparisons the trend in many artificial fisheries is to stock either browns and rainbows or browns and brook trout, the browns for their unique qualities as the traditional fighting fish and the brook and rainbows for the lower cost of rearing and because their presence is likely to give most anglers a chance of catching a fish: for example, according to Walker (1975) and Howman (1973) rainbows provide sport during the daytime in some of the summer months when the browns are difficult to catch.

(b) Age Selection

Fish have been stocked in waters at all growth stages from green eggs to takeables and at different densities. Initially stocking was carried out with eggs, fry or fingerlings almost exclusively (Cooper 1959) and although in some cases reasonable returns were recorded,in most cases, the returns from such plantings were negligible. Gradually the age at planting has increased until the ultimate of planting takeable size fish has become the popular management procedure. This section of the chapter outlines the criteria which must be considered when discussing age selection of stocked fish. The factors which are thought to be most important are listed below (not in order of importance).

1. Environmental suitability
2. Relative wildness
3. Relative cost

Environmental suitability. Considering the first factor the success of stocking with very small trout such as fry or fingerlings depends very much on the water available, its quality and size. The natural mortalities associated with different growth stages are high: comparative figures from three workers are shown in Table 6.16 and they indicate quite clearly that if fry or fingerling stages are stocked then heavy natural mortalities must be expected. This therefore requires the stocking of a much larger number of fish than would be necessary with larger fish in order to get the same size of catch. When fry or fingerling are stocked it is necessary too for the water to support the population from the size at stocking to takeable size. Furthermore the water must be capable of supporting a large enough population to ensure the satisfaction of the anticipated fishing pressure.

TABLE 6.16

Comparative Survival Figures for Trout

	Frost & Smyly 1952	Le Cren 1961	Allan 1951
0+	67	375	1,250
1+	41	10	25
2+	8	5	5
3+	4	2.5	1
4+	1	1	

If it is thought that the water size and the quality with regard to its potential trout food supply are adequate then the stocking of this size of fish can be successfully carried out. Where however fishing pressure is heavy and the water body is not of a sufficiently high quality then the planting of larger fish must be carried out.

Relative wildness. It is well documented that fish raised under hatchery conditions where food is always delivered from the water surface, are more easily caught than natural fish due to their tendency to rise to any small object alighting on the water surface. This behavioural characteristic becomes stronger with increasing time spent in the hatchery although the length of time between planting fish and the onset of exploitation may overcome the effect to some extent e.g. Autumn planted fish are reputed to be harder to catch than Spring planted fish. This may reflect differential mortality rates between the two groups rather than behavioural differences but from results of an experiment carried out on a small sport fishery which is discussed later, this seems unlikely .

Relative cost. The costs of the different sizes of fish are shown in Table 6.17 and represent an average cost from a sample of Scottish fish farms. However while the immediate conclusion from this might be that it is more economical to stock with small trout if the water is capable of supporting the population, account must be taken of the

TABLE 6.17

Costs of Different Sizes of Brown Trout

Age	Size (cm)	Mean* Cost/1000
0+	8	59
1-	15	121
1+	20	221
2-	25	425
2+	28-30	560

* Mean calculated from several Scottish fish farms

survival of trout of different sizes to takeable size. There are many studies recorded in the literature whose prime aim has been to indicate the returns which can be expected from the stocking of certain age groups of fish at different stocking densities. Unfortunately these experiments have not taken place under standard conditions and the results are rather difficult to compare quantitatively. Differences in environmental quality and population density occur both of which will affect fish growth, differences in fishing pressure and technique occur which will affect the catch through the efficiency of the angling effort, differences in size and bag limit and seasonal restrictions occur which will also affect the catch. This by no means exhausts the list but is sufficient to assert that it is rather difficult to generalise on thes results with any degree of certainty. However an attempt has been made to collate results on the returns of various sizes of fish indicating the situation as it exists for the three species discussed earlier.

The Table 6.18 shows the variation in results which have been obtained by various authors. The figures given by Mills are summary figures drawn together from a variety of sources including some from work carried out in American waters. Unfortunately little information is available on either rainbow or brook trout studies.

TABLE 6.18

Returns from Stocking Different Age Groups of Trout as Reported by Various Authors

Age	Returns (as % of Fish Studied)								
	Brown Trout						Rainbow Trout		Brook Trout
	Oliver (1963)	Brown (1969)	Oliver (1968)	Hunt & Jones (1972a)	Bulleid (1971)	Mills (1969)	K S Brown (1969)	Oliver (1968)	A. Walker (pers. comm.)
0+	0.13	1-2		1		7-37 (0+ and 1- (AUT))			
1- (AUT)	5								
1+ (SPR)	10	20-30		13.6		Aut: 17-83 (1+ (SPR) to 2+ (SPR))	30-40		
2- (AUT)	40					Spr: 29-80 (1+ (SPR) to 2+ (SPR))			
2+ (SPR)	60	60-75	75		70		40-50	60	
3- (AUT)									66

Table 6.19 shows the average return of different sizes and their associated costs of stocking assuming that a catch of 6,500 fish per annum is required from a 100 acre loch. The final conclusion therefore is that for brown trout it is in fact more economical to stock with larger fish. With rainbow trout which are takeable at 1+ stocking with small fish is never carried out because, as mentioned earlier, survival is poor over-winter. Unfortunately there is not enough information available on the survival of brook trout but it is unlikely that the conclusion would be any different than that for brown trout.

TABLE 6.19

Comparative Cost of 6,500 Takeable Fish

Age	% Survival to Creel	Number Required	Cost £
0+	1	650,000	38,350
1-	5	130,000	15,730
1+	15	43,000	9,503
2-	40	16,250	6,906
2+	65	10,000	5,600

It should be remembered that the cost of stocking with fish which are required to grow before becoming takeable should also include the cost of feeding these fish. Where a water has enough natural food present then the opportunity cost is zero but where feeding has to be improved then the opportunity cost becomes a positive figure and ought to be included. This would have the effect of creating a greater disparity between the takeable and smaller sizes.

These gross returns which are to be expected from the stocking of different sizes of fish is only a rough guide to the stocking density. However of importance to the fishery manager is the catch per unit of effort which can be expected from different stocking regimes. Clearly this is the important factor from the point of view of the angler who is more concerned with his own catch or expected catch and the catches of other anglers which he sees or hears of. It is these factors which will determine to some extent whether a particular site is patronised or not.

(c) Catch per Unit of Effort

The catch per unit effort is determined by a combination of several factors. Perhaps the most obvious is the density of fish available in relation to the density of fishermen. However, other factors must also be given some consideration and these include angler skill and techniques of fishing, the variability in feeding of fish and the effect of weather on the catchability of fish.

Feeding of Fish: Fisherman skill and technique

Work by Lux and Smith (1960) noted that seasonal changes in angler catch of an American fish species occurred which were significantly correlated with food availability. Thus during the season when food was most abundant angler catch was lowest while during periods when the food availability was lowest angler catch was high. Unfortunately no comparable data is available for the species under consideration here. However analyses of stomach contents of these fish indicates that the main factor which determines what trout eat is most likely to be the availability of food organisms. Selectivity of food has been noted with salmon parr (Allen 1941) and this may very well apply to trout also. Allen found that when feeding vigorously fish tend to be selective while when feeding slowly or at the start of feeding they tend to feed at random. This selectivity is corroborated by anglers' experiences which have shown that trout at certain times rise consistently and persistently to one species of fly which is abundant at that time often in preference to an equally available other fly species. (It is suggested by Frost and Brown (1967) that by consistently selecting one abundant food type the fish saves energy by repeating the same feeding movement rather than altering the feeding movement to take different food organisms.) Thus when no food organism is particularly abundant trout are likely to feed at random while if certain species are particularly abundant at some point in time then selective feeding will take place. Clearly then at such times angler success will depend on his ability to assess what the fish are feeding on and adjust his tackle accordingly. Since in most Scottish water only fly-fishing is permitted an angler has the choice only of wet or dry fly fishing. Whatever the fly type the selection of the right fly at the right time may greatly enhance the chances of success. Thus both angler skill and feeding variations may be important factors in determining success.

As a brief aside at this stage it seems reasonable to consider why fishing is so restricted in method in Scotland: neither worming nor spinning is permitted on many waters. Some work carried out by Shetter and Allison (1955) provided some rather interesting results which may justify the restrictions on angling methods. Their work involved comparing the mortalities resulting from worm hooked and fly hooked brown, rainbow and brook trout. The comparison of resulting mortalities is summarised in Table 6.20.

TABLE 6.20

Comparative Mortality Rates with Worm and Fly Hooked Fish

Species	% Mortality Worm Hooked	% Mortality Fly Hooked
Brown	20.3	0
Brook	42.4	3.3
Rainbow	35.4	11.3

These figures refer to all fish caught and include a very substantial proportion of under-sized fish (fish of catchable but not takeable size). The experiment therefore indicated the high mortality of under-sized fish which may occur when worm fishing is permitted.

A further factor is that spinning by boat may interfere with the natural drift of the fly-fishers' boat and so makes the mixing of both types of fishing undesirable.

Finally, from some recent work it seems that allowing only fly-fishing provides a better seasonal distribution of catches in stocking waters, than permitting fly, spinning and worm fishing, (Cragg-Hine, 1976).

Weather Effect

Weather in general can have an effect on the success rate of anglers. Calm, sunny weather has an adverse effect on fishing since (a) fish can see movement of anglers on the water surface and are therefore disturbed and (b) calmness makes it almost impossible to cast on the water without the line being seen by the fish. It is both unfortunate and frustrating for the angler that calm, sunny weather is often associated with hatches of flies which fish will rise to take on the surface. Perhaps the ideal conditions exist when there is a light wind causing a ripple on the water, since in such conditions the fly cast landing on the water is adequately concealed by the water movement.

Wind can be a very great problem if it becomes much more than a light breeze. Very strong winds may terminate angling altogether while a fairly strong breeze can make casting difficult whether boat or bank fishing.

Temperature may also be important since at either extreme fish are reputed to stop feeding.

Density of fish and fishermen

These two factors are considered together simply because they are difficult to consider in isolation. The relationship between catch per unit effort is rather difficult to quantify because of the number of factors which affect catches of fish and as a result few studies have dealt satisfactorily with this subject and from those that have it is rather difficult to extrapolate to the general situation.

Perhaps the best method of summarizing the relationship between catch per unit effort and the density of both fish and fishermen is to consider hypothetical situations (after Le Cren 1961). Let us assume that there exists a fishery with a population of 10,000 fish available for exploitation and consider the effects which different fishing pressures have on the total exploitation and the exploitation per unit of fishing effort. Certain assumptions must first be made about the basic fishing system.

1. During the season the effort expended on the population by the anglers is equal in intensity over the whole water. That is to say that a fish in any one part of the water is just as likely to be caught as a fish in any other.

2. Fish are randomly distributed over the water.

3. The amount of fishing effort is the same throughout the season and is equally effective throughout the season. Thus each unit of angler effort catches a fixed proportion per unit time of the population available at that time.

Accepting these assumptions, it is possible to go on to consider different fishing efforts and associated fish mortalities and the resultant catch per unit effort. The example shows the effects of 50, 100, 200, 300 and 400 units of effort per week on the population of 10,000 fish assuming that each angler per week effects a mortality of 0.05% of the fish population available. Thus 50 anglers per week will inflict a 2.5% mortality per week and 100, 200, 300 and 400 anglers per week will bring about a mortality of 5, 10, 15 and 20% respectively. The results of this mortality over a 20 week period are shown in Fig. 6.5. From the graph it is apparent that the greater the effort the greater the total exploitation of the population over the 20 weeks until over fishing takes place and the water is fished out before the 20 week period is over. However one must consider the catch per unit effort in assessing the success of the strategy since the angler is more concerned with what he himself catches than with the overall exploitation of the fish population. The catch per unit effort over the season is depicted in Fig. 6.6. This allows two further conclusions to be drawn. Firstly irrespective of the fishing pressure the catch per unit effort decreases over time and secondly the decrease is greater with increasing fishing pressure. Thus, a fishery, in trying to maintain an acceptable average catch per unit effort must make some sort of compromise between fish density and fisherman density.

This theoretical example has tried to identify the effects of fisherman and fish density on the catch per unit effort. It has however over-simplified on several counts. Firstly it assumes that fish are evenly distributed over the water body: given the earlier discussion on fish habitats this, in most waters, is an unrealistic assumption. Secondly, it assumes that fish are equally catchable throughout the season. Again earlier discussion on the effects of food and weather variability casts some doubt on the accuracy of this assumption. Thirdly and finally it assumes that all units of angler effort are equally effective. This is most unlikely to be the case although it is fair to say here that angler skill is likely to vary randomly over the season and thus the overall effect of angler skill may be unimportant. While it may have over-simplified the real situation it has none-the-less served as an illustrative example of the interactions involved and gives useful management points to the fishery manager.

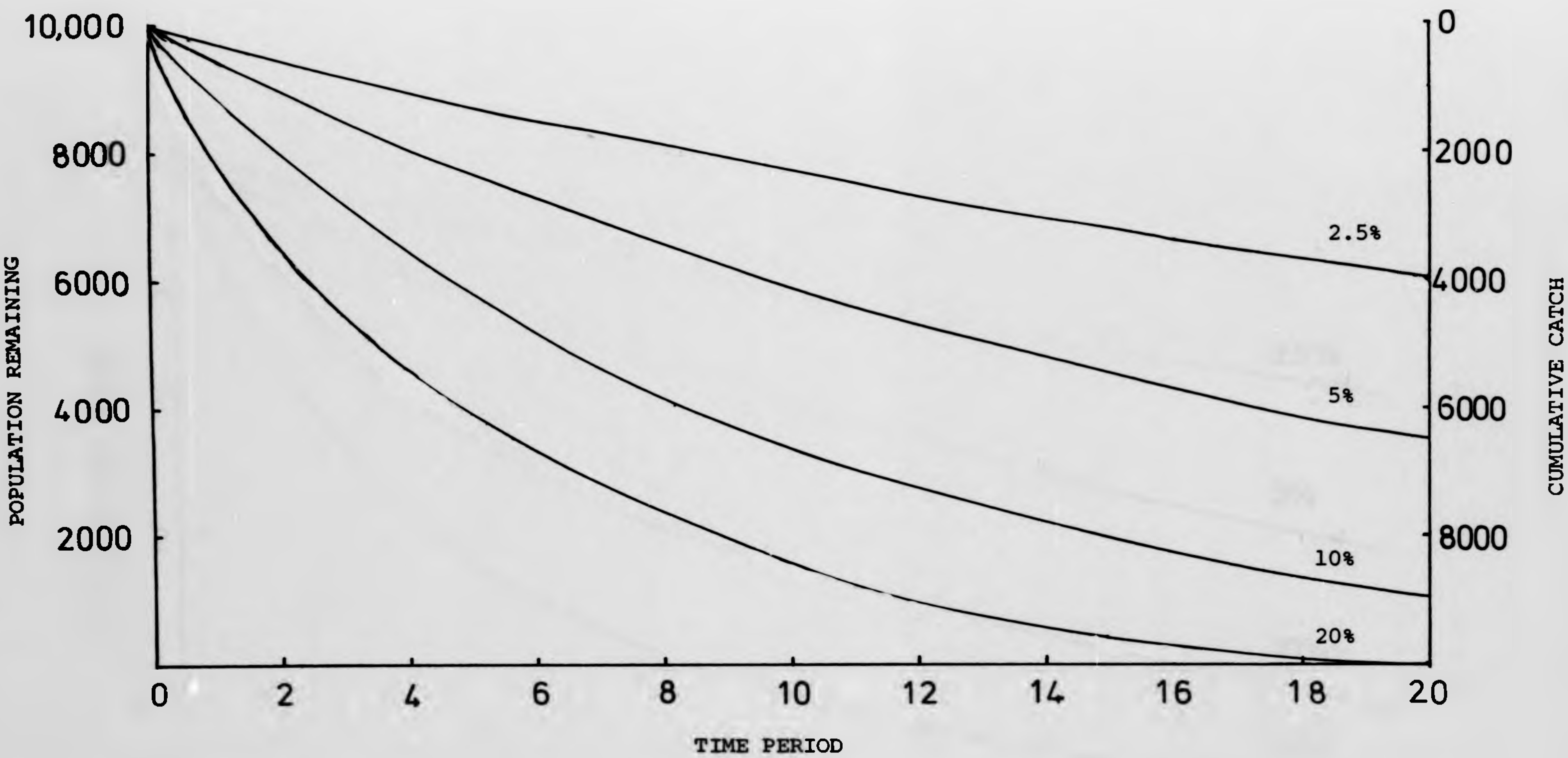

FIG. 6.5 The Relationship Between Fishing Effort and Catch

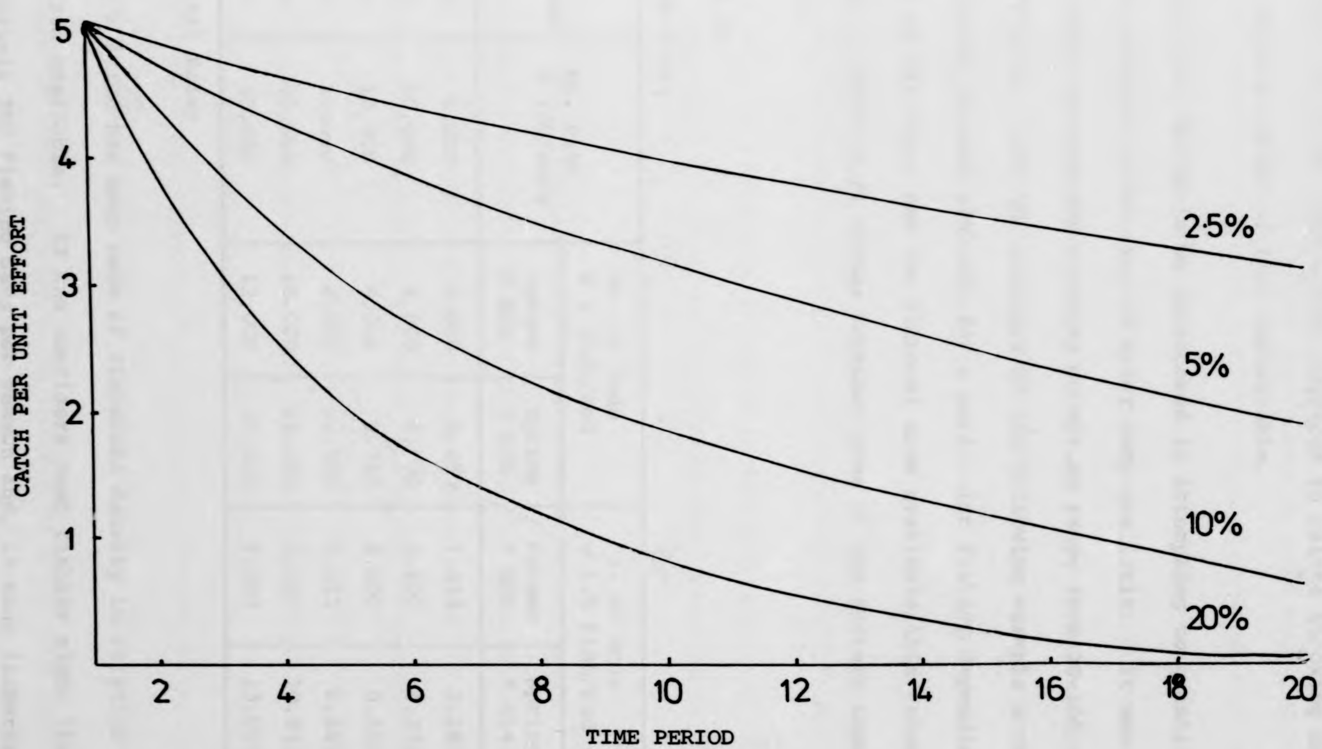

FIG. 6.6 The Relationship Between Catch Per Unit Effort and Mortality Rate Over Time

<u>Summary of recommended stocking densities in relation to survival fishing pressure, catch per unit effort and size of water body.</u>

This brief section brings together the data on stocking returns in relation to time of stocking with some attempt to include differences in average catch per unit effort required to relate stocking density to the maximum number of rods sustainable.

The final factor to be considered in attempting to quantify stocking regimes is the size of water body available. It was stated earlier that recommended stocking densities range from 20-100 takeable fish per acre. For the purposes of the following example a value of 100 per acre is used although for a particular fishery, depending on the quality of the water and the littoral area available, this value may be lowered. Table 6.21 brings together some of the factors important in stocking.

TABLE 6.21

Stocking Rates

Acreage	No. Fish @ 100/acre	No. of Rods @ 1 fish/rod		No. of Rods @ 1.5 fish/rod	
		Autumn * 40%	Spring * 65%	Autumn * 40%	Spring * 65%
50	5,000	2,000	3,250	1,333	2,167
100	10,000	4,000	6,500	2,400	4,333
150	15,000	6,000	9,750	4,000	6,500
200	20,000	8,000	13,000	5,333	8,667
250	25,000	10,000	16,250	6,667	10,833
300	30,000	12,000	19,500	8,000	13,000

* Survival Rates

No mention has been made of fisherman density in relation to water area available. If one considers boat fishing alone there are approximately 200 fishing days per season and, in many fisheries, two fishing periods per day: at this rate of usage there are unlikely to be any overcrowding problems.

The details in stocking density in relation to size of water body, density of fishermen and catch rate are no more than average figures from which a new fishery may make an initial start: adjustments will have to be made in the light of actual working experiences of the fishery. Thus the new fishery must adopt to some extent trial and error procedures to determine the stocking system which will best suit the needs of their particular fishery. (An attempt has been made to develop a stocking formula based on assessments of carrying capacity of waters, spawning areas available and survival of trout from fry to takeables (S. B. Smith et. al., 1969) but the measurement problems are formidable and very time consuming.)

6.7.3 STOCKING COSTS

For the fisheries utilising artificially propagated stocks there are basically two choices with regard to the acquisition of their annual requirements: fish must be either bought from commercial suppliers or raised at the fishery.

There are many fish farms in Britain and although a large number are exclusively producing rainbow trout for the table market there are a number which produce brown and rainbow trout for re-stocking purposes. The condition and appearance of trout reared for re-stocking purposes must be superior to that required for the table market and this is generally brought about by reducing the stocking density of fish in the tanks, thus making the process rather more expensive. There are at least 25 fish farms producing for the re-stocking market in Scotland and several also in the North of England supplying some Scottish waters.

Some fisheries requiring large numbers of trout each year have established their own fish farms and rear their own fish, some also selling excess fish. Howman (1974) argues that this is not always satisfactory and in her opinion it is best to use reliable commercial farms which have the necessary experience and skili and thus avoid the risks associated with rearing trout. Certainly it is true that there are risks associated with raising trout since fish, especially when very young, are extremely susceptible to high water temperatures, oxygen levels, diseases etc. and even a small error of judgement can result in high fish losses. To overcome some of the risks some fisheries buy in trout from commercial suppliers once they are past the most critical stages of development (around 6-8 cm) and then raise these trout to the required size. Even at this stage however there is risk of heavy losses. Despite these problems there are some fisheries in Britain where rearing is carried out completely at the fishery. This would suggest that there are some advantages in home growing which overcome the risk involved in fish rearing: firstly there may be an economic advantage and secondly it assures a fishery a supply of trout at a time when demand for trout for stocking would seem to be increasing faster than supply. The former is investigated in some detail in the following section.

<u>Trout Rearing</u>

The major consideration before setting up a fish farm is the suitability of the site available. The demands on the environment of a fish farm are high: firstly there must be an all year round supply of unpolluted water; secondly the water temperature at all times of year must be within safe limits for trout (see Chapter 5). These factors are important in determining whether a fish farm is feasible on a particular site but within these broad limits there can be considerable variation which will affect the efficiency of the unit.

<u>Water temperature</u>: within the lethal limits high temperatures for long periods are undesirable since they increase the metabolic rate and thus the food consumption of trout. A low temperature for long periods

results, on the other hand, in low food consumption and slow growth. High temperatures also reduce the solubility of oxygen in water and may therefore lead to oxygen depletion of the water.

Oxygen levels: this is of great importance since to a large extent it determines the density of fish permissible. Oxygen levels are affected not only by temperature but also by altitude and flow rate of water.

Flow rate: if this is too fast energy is wasted in swimming against the current. If too slow toxic metabolic wastes may build up in the water and the slow water exchange will support a smaller density of fish through oxygen limitations.

The characteristics of the site and water supply are therefore very important in determining not only site suitability but also potential farming efficiency. Because of this potential variation it is only possible to consider costs under optimum conditions. (The most comprehensive source of information on trout farming is found in the work of Shepherd (1973) and it is from this source that much of the information which follows has been derived.)

Capital Costs of Rearing Systems

The rearing system can conveniently be divided into three functional systems including hatchery; early-rearing; and on-growing.

Hatchery: this involves rearing from eggs to unfed fry and is usually carried out with the use of perforated metal trays on which the eggs are placed. The trays are placed in wooden rectangular boxes and fed by a flow of water. As the eggs hatch the alevins fall through the tray into the box leaving the egg shells.

Early-rearing: This involves rearing from fry to fingerlings (about 6 cm in length). This is usually done in some kind of fabricated system such as concrete or fibreglass tanks either square or circular in shape or in raceways (long narrow ponds with high water exchange rates).

On-growing: this includes all stages from 6 cm up to the required size. Fabricated systems similar to those described above are used here and also in some farms excavated earth ponds are used.

Shepherd (1973) found only slight differences between the use of ponds, raceways or tanks and the major advantage of tanks for the game fishery is their self-cleaning design: these tanks have a narrow inflow from the perimeter and a central outflow pipe such that a vortex flow is created which greatly facilitates cleaning. This reduces both the labour input and also the disease risks. Partly for this reason and partly because the comparative costs of the different systems will vary considerably according to locality and costs of contractors only circular fibreglass tank systems will be costed, assessing the cost of raising 1, 2 and 3 tons of fish of average size of 28 cm (11") and weighing about 230g (0.5 lb). This would be sufficient to support fisheries of approximately 50, 100 and 150 acres respectively (assuming a density of 100 fish/acre). Tank costs are summarized in Table 6.22.

Other costs associated with rearing include piping, feeders and buildings (for food store). The cost of piping will of course vary depending upon individual site characteristics but Shepherd (1973), from an analysis of several British fish farms, quotes an average figure of one-third of the capital cost of tanks. There are two types of feeder necessary, including automatic fry food dispensers and demand

TABLE 6.22

Fish Tanks, their capacity and cost

Stage	Size	Usable Capacity	Fish Capacity	Cost/Unit £	Cost/1 ton £	Cost/2 tons £	Cost 3/tons £
Hatching	5'4"×8½"×9"	3 egg baskets @ 500 ova/basket	15,000 ova	37	37	37	37
Early-Rearing	6'×6'×2'	54 ft^3	13,000 *	85	85	85	85
On-Growing	16'×16'×3'	640 ft^3	1,280 *	637	2548	5096	7000
				TOTAL COST	2670	5218	7122

* Shepherd (1973) quotes densities of 4.9 lbs/ft^3 and 2 lbs/ft^3 for early growing and on-rearing respectively. These figures are lower than those recommended by the manufacturers but are thought to be more conducive to good growth of the fish. These figures are however for 'table' fish and the condition of such fish is not desparately important: this is not the case with trout for stocking purposes and densities here must be lower still. Recommended densities of 3 lbs/ft^3 and 1 lb/ft^3 for early-growing and on-rearing respectively are given by Trouvit, a fish food company (Trouvit Trout Food, internal publication) and these are the densities used in this analysis.

feeders for the older fish. The former is a water driven device which works off the water inflow to the tank and the latter is a device which has a pendulum projecting into the water which delivers food into the water when knocked by the fish. A building is required for the store of food and Piggins & Lawrie (1974) give some indication of the amount of space required for storage purposes. Estimates have been made for wooden, sectional buildings for the different production units. The total capital costs including tanks and these associated costs are shown in Table 6.23

TABLE 6.23

Capital Costs

Item	Cost/1 ton £	Cost/2 tons £	Cost/3 tons £
Tanks	2670	5208	7122
Piping (1/3 tanks)	890	1739	2374
Feeders	133	266	320
Buildings @ £60/m^2	1080	1260	1500
TOTAL	4773	8483	11316

Annual Operating Costs

Ova. Both brown and rainbow trout ova are readily available in this country. Brown trout ova may in fact be collected from spawning adults in the fishery: this saves little in costs since ova are very cheap, but there is an advantage in selecting the females which supply the eggs. It has been found that, in general, within a water the larger females produce more and larger eggs (Southern, 1932), the advantage in this being that mortality of large eggs is less and also that large eggs give rise to larger, hardier alevins. The size differential is not maintained even in early growth but the improved survival of eggs and hardier alevins is advantageous.

Insurance. Insurance cover is necessary in fish farming because of the losses which may occur. Shepherd identifies two kinds of losses: normal losses which with good management may be minimal and at any rate are too variable to be quantifiable and abnormal losses which are more serious losses such as disease. Lloyds cover against most diseases and major mishaps which are likely to occur and the value which is insured is usually taken as the replacement cost at any one time in the production line. For full cover including certain diseases and fish kills the premium is 10% of the replacement cost.

Labour. This is the only cost item for the sport fishery which will vary according to whether brown or rainbow trout are reared: brown trout, a much slower growing species both in the wild and in the farming situation, take approximately twice as long as rainbows to reach a comparable length. The amount of food consumed is almost exactly the same with both species: the difference is only in rate of growth (S. Shorthouse, pers. comm.). The cost of labour for rainbow trout is estimated by Shepherd as 15 tons/man year while that of brown trout is exactly half that (S. Shorthouse, pers. comm.).

Maintenance. From Shepherd's analyses of British fish farms the annual maintenance costs are, on average, 20% of the annual depreciation provision. The life of the tanks may be 15-20 years and the former figure has been used in the calculation of annual depreciation of the capital cost items (Table 6.23). From this depreciation allowance maintenance costs have been assessed.

Food. The amount of food required by trout depends on both the water temperature and the size of fish and tables are available which relate the amount of food required to these two factors. These factors determine the conversion efficiency of the fish and using either Trow or Cooper's diets in Britain the usual range of conversion rates is

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1.4 - 1.8. A conversion rate of 1.5:1 has been used in this study: Shepherd uses a figure of 1.6:1 and Trouw suggests that 1.45:1 may be a realistic working average.

Administration and Miscellaneous. This includes postage, telephone, rates etc. and Shepherd found that for all farms investigated the cost was less than 10% of the annual operating costs and averaged about 7%. Piggins and Lawrie (1974) assessing the costs of salmon smolt farming quoted a sum amounting to 5% of the annual operating costs.

A summary of the annual operating costs is shown in Table 6.24.

TABLE 6.24

Annual Operating Costs

Item	Cost/1 ton £	Cost/2 tons £	Cost/3 tons £
Food	480	960	1440
Ova	14	28	42
Insurance: Rainbow	158	315	473
Brown	384	668	1002
Labour: Rainbow	167	334	501
Brown	334	668	1002
Admin (7%): Rainbow	27	54	81
Brown	34	67	100
Maintenance	64	113	151
Total: Rainbow	910	1804	2688
Brown	1129	2241	3343

Having calculated the capital costs and annual operating costs for home rearing of trout it remains now to compare these costs with the commercial costs for brown and rainbow trout. In Section 6.5.3 the NPV method of discounting was described and it is this method which is used to bring both the commercial and the home growing costs to a directly comparable level. The NPV's, using a 14% interest rate, are shown in Table 6.25 (see also Appendix 8) and indicate quite clearly

TABLE 6.25

The NPV's of Home Grown and Commercially Supplied Trout

	1 ton		2 tons		3 tons	
	Home-Grown	Commercial Suppliers	Home-Grown	Commercial Suppliers	Home-Grown	Commercial Suppliers
Brown Trout	11,111	12,420	21,186	24,840	30,430	37,260
Rainbow Trout	8,768	9,660	18,506	19,320	26,413	28,980

that on this assessment the home rearing of trout is seen to be the most economic proposition. Thus, even although the home rearing of trout involves a considerable investment at the outset, the overall savings over a 15-year life show this to be more economical than utilising commercial sources of both brown and rainbow trout.

It must be remembered that the costs used for home reared trout do assume that the manager has some technical knowledge of fish farming and for the complete novice, costly errors may be made in the early years. However the home-rearing of trout apears even more economical if it is observed that these calculations have included the labour costs involved in home grown fish and, it may be, that in some fisheries the opportunity cost of labour is zero. For example, a fishery may require the services of a full-time person simply to ensure adequate protection of the fishery. In such a case the opportunity cost of any management work the individual does may be considered as zero. This situation may well arise in fisheries which are very near to population centres since interference from local individuals is often quite a problem in fisheries. In such cases the difference between the home-grown and commercially reared fish will be even greater.

6.7.4 EFFECTIVENESS

It is rather difficult to generalize upon the efficacy of stocking. In some waters it may mean the difference between running a game fishery and not running one. With other waters, where a natural fishery already exists stocking may permit the fishery to support a much greater intensity of angling then would otherwise be possible. The manager of such a fishery must therefore consider the additional costs associated with stocking and the additional income generated by it. This is of course quite difficult to assess since there are several factors which must be considered including the number of anglers which the natural fishery supports and the price they are willing to pay for the privilege of fishing. Also the number of anglers which could be supported by the development of an artificial fishery must be considered, this depending upon the stocking policy, the demand for angling in the area, the price these anglers would be willing to pay to fish an artificial water, and, of course, the costs associated with the provision of fish and any other costs associated with the increase in anglers (e.g. more boats may be necessary). It is therefore an assessment which is very specific to a particular water but the economically rational decision should always be based on an assessment of the potential financial return on the investment in the fishery when run as an artificial or semi-artificial water compared with the return on the investment in the fishery when run as a natural fishery.

6.7.5 CONCLUSIONS

It has been shown that there are many factors to be considered in the development of an artificial fishery and that trial and error methods will have to be used to some extent in determining the technologically - economic optimum strategy. It is apparent from the costs section that in most situations it is advisable to utilise home-reared trout for stocking where this is possible. Whatever the source of trout it is apparent that stocking costs will be a substantial annual cost to the fishery and it must be ensured by the manager that the development of an artificial fishery is likely to be a financially acceptable proposition.

6.8 GENERAL CONCLUSIONS

This chapter has considered management of Scottish lochs from both the technological side (the biology of management) and the economic side (the cost of management). It has integrated these two sides to consider the effectiveness of management by using a common economic base for comparison of the costs and effectiveness of the management practices. Despite the existence of a good theoretical economic basis for decision making in management the analysis used has been very basic embodying little of the economic theory. However it must be remembered that technological economics is concerned with the "ways in which individuals and groups make decisions on allocation of resources and how they use the available technological and economic data to make choices" (Bradbury and Loasby, 1970). This chapter has discussed how the manager may make decisions on management using the technological and economic information which is likely to be available to him.

The discussions on the management techniques have considered each management method in isolation while Fig. 6.1 clearly indicated that the management methods are inter-related, the effects of one affecting others. This has been a necessary simplication. For most of the methods the efficacy of mangement for the poorer water is clear but it must be remembered that for the individual fishery some attempt must be made to assess the likely benefits of the management method since this will vary so much depending upon the individual characteristics of the water. Such an assessment is particularly necessary where relatively high costs are involved (e.g. use of rotenone, food improvement).

The complete breakdown of management costs, including capital and labour costs discussed in the text for the different management methods are summarized in Appendix 9 showing both the initial and running costs for a 100 acre loch. However in assessing costs most firms consider the total annual operating costs, rather than the initial and annual running costs. All equipment costs must therefore be depreciated over the expected life of the item to give an additional annual cost to the fishery for the equipment. Total anual operating costs are shown in Table 6.26.

TABLE 6.26

Annual Operating Costs of Management at a 100 acre Loch

	Capital Costs		Labour Costs		
	£'s	% of total	£'s	% of total	Total
With stocking	2526	59	1790	41	4316
Without stocking	500	33	1009	67	1509

The general conclusions which may be drawn from this Table include:

(i) Stocking costs play a dominant role in total costs amounting to 65% of total costs.

(ii) Where stocking is not carried out labour costs are dominant, amounting to 67% of total costs.

(iii) Capital costs of management, where there is no stocking, are likely to be low (in the £100's) while capital costs where there is stocking will be higher (in the £1,000's).

CHAPTER 7

THE COST OF RUNNING A FISHERY

7.1 INTRODUCTION

Chapter 6 has given some indication of the costs which may arise through various management practices. However, in establishing and running a fishery, not all of these management methods will be utilised and there are, of course, many other non-management costs which must be considered. This chapter assesses the likely costs of running a fishery including possible management costs and other developmental and annual costs.

7.2 ITEMS OF EXPENDITURE IN RUNNING A FISHERY

It is obviously difficult to generalize on the cost items involved since so much will depend on the individual site characteristics and management objectives. However a comprehensive list of items is shown below including initial development costs and annual running costs.

Initial items

1. Site preparation
   - i Car park
   - ii Pier
   - iii Anglers' hut
   - iv Store/workshop/office
   - v Landscaping and planting

Annual items

1. Office costs
   - i Printing, stationery, postage
   - ii Advertising
   - iii Bank charges, accountancy
   - iv Insurance
   - v Rates
   - vi Heating and Light
   - vii Wages
   - viii Rent*

* This may represent a real rental cost or may be an imputed cost if in fact the land is owned by the developer. The imputed rent represents the cost to the owner of running the fishery rather than renting it out to someone else.

2.	Management	2.	Management
i	Rotenone/netting	i	Liming
ii	Liming	ii	Trap control
iii	Animal/plant stocking	iii	Predator/competitor control
iv	Barriers/traps	iv	Aquatic plant control
v	Farming equipment	v	Monitoring and control
3.	Other	3.	Other
i	Boats	i	Maintenance

It would be difficult to assess the actual costs for any fishery without dealing with specific examples or without recourse to pure speculation. However a case study is reported in the next section which exemplifies the costs involved in both management and other costs, as well as considering in detail the management procedures within one fishery. Two further case studies are discussed, although in very much less detail in order to exemplify the variation which may occur and to make a realistic assessment of costs for an 'average' fishery.

7.3 LOCH WALTON - A CASE STUDY

7.3.1 INTRODUCTION

Loch Walton is a 33 acre loch at an elevation of 800' in a largely acid basalt area. As a result of this base rock the water quality is poor making the water rather unproductive. The loch has been run as a private brown trout fishery since 1907 and up until 1971 survived as a largely natural fishery although some supplemental planting of fish had been carried out from time to time within the period. From the records of fish caught over this period it is clear that in the early years although as many as 1000 fish were taken annually the average size of the catch was very small (ca. 5 oz.). A gradual decline in catch took place until by 1930 the catch had fallen to 200-300. After this various methods of improving the catch were instituted including addition of limestone, addition of snails and additions of varying numbers of 1+

and 2+ trout. As a result of the efforts the average weight and number of catch did improve but not to a sufficient level to satisfy the anglers. In an attempt to establish a management plan which ensured satisfaction of the anglers' a new keeper was appointed in 1971 and at the same time a decision taken to convert Loch Walton into a completely artificial fishery.

7.3.2 MANAGEMENT OBJECTIVES AND METHODS

The basic management objectives for Loch Walton may be summarized as follows:

(i) to sustain a yield of 800-900 fish per year and a catch per unit of effort of 1-1.5 fish per visit,

(ii) to produce takeable fish of a satisfactory size, this being within the range of 25-30 cm weighing at least 280g (0.5 lb),

(iii) to produce satisfactory sport. The anglers have a stated preference for brown trout and where hatchery fish are utilised there is a preference for fish which have been in the water long enough to adopt 'wild' trout behaviour,

(iv) to run a completely artificial fishery which produces its own fish at the site.

To attain these objectives certain management methods were employed both in the initial development of the water and as annual management practices. Particular methods employed since 1971 are described below.

1. Construction of traps

With the decision to run the fishery artificially it became necessary to eliminate natural spawning. To this end the five burns were blocked by fish traps in 1971 and natural spawning has effectively been stopped since then. During each spawning season it is necessary forthe keeper to strip the fish entering the traps and release them into the loch. At Loch Walton there are, on average, five runs in a season and anything up to 600 fish may be stripped in a good year.

2. Food Improvement

It was mentioned earlier that Loch Walton is a poor water and is relatively unproductive. In 1974 a programme of improvement was developed including the regular liming of the water and an initial stocking of shrimps and snails. In Chapter 6 the effects of liming Loch Walton have already been discussed and it is only necessary to say here that unlike many waters Loch Walton requires to be limed every year because of the fast throughput of water. It has been found that liming at a rate of about eight tons per year gives satisfactory improvements in water quality.

3. Farming equipment

It has been stated that one of the objectives was to become self-sufficient for fish and to this end tanks and accessories have been acquired since 1971. By 1974, the period in which the work was carried out on Loch Walton, the fishery owned a hatching box and four fibreglass tanks (6'×6'×20"). All accessories including piping and feeders were also purchased. This equipment was sufficient for the production of 1000 1+ fish. In 1976, for reasons which will become apparent later the fishery also invested in a floating cage (12'×12'×5') capable of holding 400-500 2+ fish.

4. Plant control

It is common in most fisheries to carry out aquatic plant control often on an annual basis. At Loch Walton the keeper hand cuts weeds annually, clearing up to one acre.

5. Monitoring and Control

i Controls The fishery works to a 25 cm size limit and has no bag limit.

ii Monitoring

(a) Population assessment. By 1974 when natural stocks of trout were very much reduced (last natural spawning occurred in 1970/71) it became necessary to try to assess the stocking policy of the loch: up until that time stocking had been carried out on very much an ad hoc basis. It was decided to assess the population size of the loch and attempt to find the exploitation rate of the population in the angling season of 1974. The assessment was carried out by tagging a number of fish in Autumn 1973 and recording captures the following season. The full details of the method and calculations are reported in Appendix 10. The population estimate using 95% confidence limits was between 1089-1594 fish with a mean of 1350 fish. Of these fish 500 were clearly hatchery fish from the commercial suppliers (assuming that immediate mortalities were low) while the remainder were made up of 3+ and 4+ fish some of which would be hatchery fish from previous years stocking while some may have been naturally spawned in the loch. A number of the Loch Walton 1+ fish stocked in Autumn would also be included in this but it is apparent from later calculations that at most ca. 100 of these would be catchable in 1974. This population density would appear to be satisfactory since the total catch for the season and the catch per unit of effort was acceptable to the anglers.

(b) Exploitation Rate

It is possible to determine the age of trout from their scales and an analysis of a sample of the scales from fish recorded as part of the population analysis programme was carried out to determine the age distribution of the catch. From this analysis it was estimated that the total catch for the season included the proportions of the different age groups shown in Table 7.1

TABLE 7.1

Proportions of Different Age Groups in the Total Catch

	2+	3+	4+
Number	354	412	58
%	43	50	7

From the tag analysis it was apparent that of the 500 hatchery fish stocked in November 1973 approximately 265 (53%) were caught during the 1974 season. This return on Autumn stocked fish is within the range identified in Chapter 6 and represents a good return on stocking at this time of year. Some natural spawning still occurs within the loch, but the contribution of this is thought to be negligible and thus the majority of the remaining 2+ fish (ca. 90) as determined from Table 7.1 will be Loch Walton raised 1+ fish stocked in Autumn 1973. It seems unlikely therefore that more than 100-150 of these fish were takeable in 1974. These Loch Walton fish will therefore, in the main, have to over-winter twice in the loch before attaining a satisfactory size and the majority could not appear in the catch until 3+, by which time of course natural mortality will have reduced the population considerably.

The results of the analysis indicate the high dependence on hatchery fish and, since naturally spawned fish in future years will not be available to any great extent, this dependence can only increase. Furthermore, from the returns in 1975 season it appears that only a very small number of tagged fish were caught (ca. 5) which would suggest that either they become less catchable through time or the natural mortality of two winters results in low survival of remaining fish. The latter seems the most likely explanation. These two factors would suggest that stocking at the current rate is unlikely to maintain catches at the 1974 level and that future stocking will have to be increased and this is the policy to be followed in future years.

(c) Catch per Unit Effort

Initially it was intended to use the record cards completed for the population assessment to assess angling effort. To this end anglers were requested to indicate the number of hours fished when recording their catches. However from an analysis of the results it was found that the "angler day" could be utilised as measure of angler effort rather than the "angler hours" recorded on the cards (see Appendix 11). Since there were many incomplete cards this allowed the inclusion of considerably more data than would otherwise have been possible.

Catch per unit of effort varied considerably over the season, ranging from 0.69 to 2.35 fish over the 14 day time periods (time periods start from 15th March). The variation over the season is depicted in Fig. 7.1 (see also Appendix 12). Thus the catch per unit effort while starting off fairly low rises to a peak in late May and early June. As with many waters fishing at Loch Walton begins in mid-March before a substantial increase in water temperature over the winter temperatures has taken place. The bottom temperature of Loch Walton at the start of the season was 42°F this temperature rising slowly to 64°F by early May and remaining high until late August. The early low catch per unit effort is most likely to be the result of the low water temperature since growth of food organisms will only just be beginning to rise in response to water temperature changes. At this time the fish are not likely to be feeding voraciously and, since no hatches of flies are likely, they will probably be feeding mainly on bottom organisms and are therefore

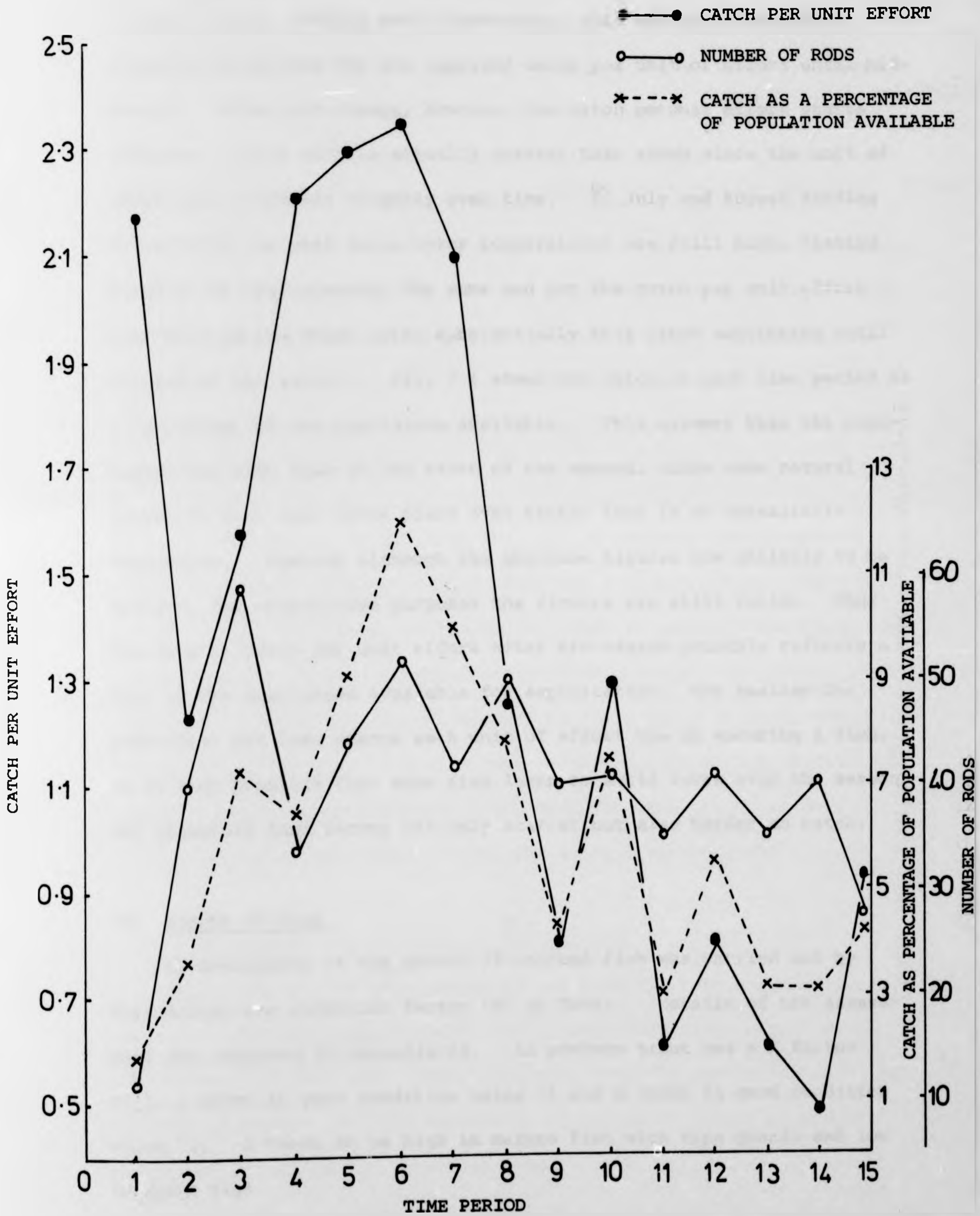

FIG. 7.1 Catch Per Unit Effort, Catch as a Percentage of Population Available and Total Effort Over Time at Loch Walton.

not likely to rise very readily to a fly at this time of year. However as the temperature continues to increase and feeding improves fish are likely to start feeding more voraciously, this change in behaviour probably accounting for the improved catch per unit of effort until mid-season. After mid-season, however, the catch per unit effort starts dropping. This drop is actually greater than shown since the unit of effort does increase slightly over time. In July and August feeding should still be good since water temperatures are still high, fishing pressure is approximately the same and yet the catch per unit effort over this period drops quite substantially this trend continuing until the end of the season. Fig. 7.1 shows the catch in each time period as a percentage of the population available. This assumes that the population was 1350 fish at the start of the season, since some natural mortality must have taken place over winter this is an unrealistic assumption. However although the absolute figures are unlikely to be correct, for comparative purposes the figures are still valid. Thus the drop in catch per unit effort after mid-season probably reflects a drop in the population available for exploitation: the smaller the population the less chance each unit of effort has in securing a fish. It is also possible that some fish learn to avoid lures over the season and therefore fish become not only scarcer but also harder to catch.

(d) Growth of Fish

An assessment of the growth of stocked fish was carried out by determining the condition factor 'K' of Trout. Details of the assessment are recorded in Appendix 13. An average trout has a K factor of 1, a trout in poor condition being <1 and a trout in good condition being >1. K tends to be high in mature fish with ripe gonads and low in spent fish.

The assessment of condition was carried out on the tagged fish before stocking and after capture during the 1974 season. A sample of 50 of the recaptured tagged fish was taken and the K factors calculated for each fish. The results indicated that while 3 out of 50 (6%) fish had K's of less than 1 at stocking, 11 out of 50 (22%) were less than 1 at capture. This suggests that the fish deteriorated to some extent: this might be expected with hatchery fish where they have been taken from a safe, controlled environment to a natural environment. However the fish still appeared to survive as well as their wild counterparts since figures from 1973 and 1974 showed that 3+ fish (any 2+ fish may have been recently stocked) had 28% and 44% respectively with K's below 1. Thus the tagged hatchery fish would seem to have adapted to their new environment without any abnormally deleterious effects on their health.

The increase in length from the time of stocking until capture was also assessed from the record cards and indicated that a majority of fish (> 90%) increased in length (and also in weight) over the period. The increase in length (a much less variable quantity than weight) varied from 2-25%, increasing from an average of 2% in April to 7% in May, 7% in June, 8% in July and 10% in August. Although it is not possible to compare these figures with wild trout over the same period it does signify that the trout were feeding and growing in the loch.

7.3.3 MANAGEMENT EFFECTIVENESS AT LOCH WALTON

At the end of the 1974 season it was apparent that a satisfactory number of trout had been taken by the anglers (824 fish) with a catch rate of ca. 1.5 fish/rod. This indicates that the population level of ca. 1400 catchable fish (42 fish/acre) in Autumn is likely to produce satisfactory angling the following season.

The return from the stocked fish from commercial supplies of 53%

represents a good return from Autumn stocked fish and suggests that the water is being quite efficiently exploited by the angling intensity. Analysis of captured tagged trout from this source asserts that the fish were feeding and growing in the loch after stocking.

Further information from the tagging experiment strongly suggests that the Autumn stocked Loch Walton raised 1+ fish were rather too small at stocking to contribute much to the 1974 catches. During this season it was estimated that less than 100 of these fish were taken and it seems unlikely from this that more than 100-150 were of takeable size during the season. Thus the majority of these fish will have to over-winter twice before becoming takeable: natural mortality must drastically reduce the potential contribution of these fish to the fishery. An attempt to overcome this problem was made in 1974 for the 1975 season: fish were retained through the winter of 1974/75 and stocked as 2+ fish in Spring 1975. 400 fish were involved and, at stocking, all fish were over 25 cm in length. Although these fish were not marked in any way they were reckoned to have contributed considerably to the anglers' catches and are thought to have given a higher return than the Autumn stocked fish. However one problem with such a system became obvious during the 1975 season when the Spring stocked fish were heavily exploited by the anglers. With such a stocking practice fish have very little time in which to become relatively wild before exploitation.

It would seem therefore that by 1975 the self-sufficiency objective had not quite been satisfied and that there were several strategies open to the club in following years, based upon their past stocking experiences. These include (a) running a two year system stocking Loch Walton 1+ fish in Autumn, these becoming takeable at 3+ and over-wintering twice. The disadvantage of this, of course, is the heavy mortalities which result requiring the stocking of large numbers of 1+ fish (at least 1500); (b) running a mixture of a one year and two year system where 1000 1+ fish and 500 2+ fish are stocked annually, the latter being stocked in Spring or during the season. The disadvantage of Spring stocking has already been discussed; (c) running a one year system planting 2+ fish in a manner similar to (b). This would most likely result in a more catchable population of fish and might necessitate in season plants to distribute the catch over the season. Clearly problems of tame, easily caught fish make this system undesirable for the club; (d) running a one year system using commercially raised fish, stocked in Autumn and takeable at planting. The main disadvantages of this system are the cost of such fish and the possibility of a supply problem with more and more demands being made on existing fish farms by fishing waters; (e) running a one year system planting Loch Walton raised 2+ fish in Autumn giving 3+ fish at capture. This satisfies two objectives including an assurance of both good sport from Autumn stocked fish and acceptable sized fish at capture (30-35 cm). The disadvantage of this system is the added food and labour cost for the extra year in the farm but it has been calculated by the club that the net cost (net of income from sales) will be less than the cost of buying similar sized fish from commercial suppliers. It has not been established that the cost will be less than the cost of commercial 1+ fish but there is, of course, the added advantage of larger fish at capture. This last strategy is in fact the one which has been selected by the club as satisfying the most objectives and, to this end, they have purchased a floating cage for the loch to enable the production of 1000 2+ fish.

The system of management of Loch Walton, in particular, the establishment of a stocking strategy has therefore taken several years to develop (1971-1975) and it is not yet clear that the current system is the optimum one for the club. This development of the most suitable strategy for the club highlights the value of monitoring methods in the management of fisheries.

7.3.4 COSTS OF MANAGEMENT

The costs of management of Loch Walton which follow include both the initial development costs and also the annual costs (all at 1975 prices), where relevant labour costs as well as capital costs are shown.

(i) Traps

There are five burns flowing into or out of Loch Walton. An estimated cost for the construction of a trap in each burn amounts to 1½ days labour and £20 materials for each trap. The total cost is therefore £35 per trap and £175 in total. This is the initial development cost and there are also annual costs involved in the clearing of traps and stripping of trapped fish. The cost here is purely labour and it is estimated by the keeper that the approximate time involved in each season is, on average, 50 hours (this does vary depending on the number of spawning runs in a season, the average number of runs is 5). The annual cost of labour amounts to ca. £60.

(ii) Food improvement

Both liming and animal stocking were carried out at the Loch in the initial development of the water. This required the addition of eight tons of lime and 10,000 each of snails and shrimps at a cost for lime of £40 for materials and £40 for labour and for animal stocking £25. The annual treatment involves only liming and, at eight tons/year the cost amounts to £40 for materials and £40 for labour.

(iii) Farming Equipment

The farming equipment at Loch Walton has already been listed, the capital cost of all equipment is shown in Table 7.2

TABLE 7.2

Capital Cost of Farming Equipment

Item	Cost £
Hatching box	28
4 tanks 6'×6'×20"	360
Feeders	100
Piping @ one-third capital cost	163
Cage 12'×12'×5'	40
TOTAL	697

The annual running costs include food and labour. The labour input comprises feeding, cleaning and grading and it requires 90 hours, 260 hours and 10 hours respectively per year. The total annual running costs for the farm are shown in Table 7.3.

TABLE 7.3

Annual Running Costs

Item		Labour (hrs)	Cost £
Food			185
Labour:	Cleaning	90	108
	Grading	10	12
	Feeding	260	309
TOTAL			614

Considering the costs shown in Table 7.3 it is clear that the labour and feed costs here are higher than the estimated costs reported in Chapter 6. Two explanations are offered for this. Firstly the situation at Loch Walton with regard to the layout of the tanks is far from ideal. Because of the limitations of water supply it was found necessary to situate two of the tanks near one burn and two near another burn at the opposite side of the loch, neither of the burns are near the keeper's house. Both of these factors contribute to the increased man hours recorded at Loch Walton over the anticipated costs from Chapter 6. A second factor, associated with the quality of the water at Loch Walton, is the difficulty of raising fish to a suitable size before Autumn stocking (this is thought to be due to the low temperatures of the Loch Walton water) which has led to the retention of some 1+ fish until the Spring of their 2+ year. This has contributed to food costs. Both these factors may therefore help to account for the high rearing costs of Loch Walton fish.

Associated with the increased food costs is the keeper's practice of retaining more of the younger fish than is necessary to produce the requirements for the loch. Very little cost is involved in this and the income from the sales of excess fry and fingerlings helps to offset the rearing cost. In 1974 £300 were raised by this means with the sale of several thousand young fish to a local fish farm. The keeper has a guaranteed market for these fish every year and this income is therefore assured. This means that the net cost of rearing approximately 800 1+ fish for Autumn stocking and 500 2+ fish for Spring stocking amounts to £360. The comparative commercial costs of a similar number and size of fish (calculated as 800 at 9" and 500 at 10"-11") amounts to ca. £420. The appropriate method of comparing these two sets of costs is again the Net Present Value discounting technique described in Chapter 6. The calculations are shown in Appendix 14 and indicate that, when labour costs are included, the NPV of the home reared fish (£2532) is lower than the NPV of the commercially supplied fish (£2576). Thus the home-grown trout present a slightly better economic proposition than the commercially reared trout. However there is very little difference economically between home-reared trout and commercially supplied trout. When it is remembered that the costs at Loch Walton were substantially reduced by the income from the sale of excess fish it does appear that the cost at Loch Walton was much higher than calculated cost for home-grown trout assessed in

Chapter 6. This finding has already been discussed and partly explained but may still be an indication of the variation in costs which may occur.

However the club still regard the home-rearing of trout as a substantially better proposition and, indeed their calculations do substantiate this. The explanation is that they have not considered labour costs in their calculations regarding the opportunity cost of labour as zero, including only capital expenditure. As a result of this their economic argument is quite clear since home grown fish represent in this instance, a much better economic proposition. However it is necessary to consider whether their economic analysis is valid. The club has found it desirable to employ a keeper on a full-time basis largely because they regard it as essential to have an individual on site and on call 24 hours a day for the protection of the loch and the farm from poachers: a person living on site is often a deterrent to potential poachers. The problem of poachers is often more acute in the artificial fishery where the population density is high presenting a potentially lucrative site for the poacher. Loch Walton is fortunate in having been declared a 'stank' which means that all fish in Loch Walton legally belong to the club and any person caught removing fish without permission can be prosecuted. It is therefore quite sensible for Loch Walton to employ a full-time keeper even although there is not enough management work to justify this: in summer there is work available full-time especially since the keeper is used as a ghillie by the members during the season but in winter, even with the maintenance work and farm work, there is not full-time employment for one man.

It is apparent therefore that the club justifiably regards the production of trout for stocking purposes as an economic venture and it is likely that this will also be true of their current rearing plans

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It is apparent therefore that the club justifiably regards the production of trout for stocking purposes as an economic venture and it is likely that this will also be true of their current rearing plans although figures are not available to substantiate this.

(iv) Plant Control

It has been stated that plant control is carried out annually at Loch Walton and that approximately an acre is cleared each year. This involves no capital cost since the cutting is carried out by hand, the estimated labour cost being £230 for approximately 24 days work.

(v) Monitoring

This involved both the tagging experiment and analysis and interpretation of scale samples. The former is not an annual cost although may be repeated at some other time. The cost of the tagging work was made up of capital cost (including tagging gun, tags, dye gun, dye) which amount to £50 and labour cost (six man-hours) which amounted to £7. The analysis of scales (150 fish) required an estimated 15 hours and the analysis of catch statistics (e.g. catch per unit effort, growth etc) an estimated ten hours involving a total labour cost of ca. £35.

The total management costs for Loch Walton including both initial development and annual running costs are summarized in Table 7.4.

TABLE 7.4

Total Management Costs at Loch Walton

Item	Development Cost £ Capital	Development Cost £ Labour	Annual Cost £ Capital	Annual Cost £ Labour
Traps	100	75		60
Animal stocking	25			
Lime			40	40
Farm	691		185	429
Plant Control				230
Monitoring	50	42		35
Sub-Total	866	117	225	794
TOTAL	983		1019	

7.3.5 OTHER COSTS

Table 7.4 records the management costs at Loch Walton but there are of course, other costs in running the fishery which must be included. Additional expenditure at Loch Walton has occurred for both initial development and annual running items.

In the initial development of the fishery items include:

(i) Buildings: Anglers' clubhouse, 20'×10', wooden;
Store/workshop, 20'×10', wooden;
Keeper's cottage, 30'×20', brick;

(ii) Pier, wooden;

(iii) Boats: clinker built, 5 × 14', 1 × 10'

(iv) Outboards: 2 × 4.5 h.p.

Annual expenditure items include:

(i) Wages, one full-time keeper;

(ii) Rates, including water rates, building rates and tank rates. The water rates are estimated on the annual catch of fish which is then valued at the current retail price for trout. The rateable value is then 5p-6p in the £ and water rates are paid on the basis of this (this will vary regionally, these being the figures for the Central region). Buildings are rated at 15p/ft^2 for dwelling places and 5p/ft^2 for fairly basic timber buildings. Tanks are rated according to their capital value which is then de-capitalized at 6% (i.e. it is assumed that the rental value is 6% of capital cost) this giving the rateable value.

(iii) Maintenance, including all minor repairs to buildings, traps, farm equipment, boats etc. Most of the time is spent on boat maintenance each year, the boats requiring regular stripping and repainting. This activity alone is reckoned by the keeper to amount to 25 days per year. Cost for all maintenance materials is estimated at ca. £50 per year.

(iv) Miscellaneous, including postage, telephone, printing, heating and lighting in anglers' clubhouse etc, amounting to £200 per year.

(v) Rent. The land is owned by the Club so the figure used is an imputed rent. This has been calculated on the capital value of the land and the return on this capital value which might be expected. The value of fairly poor rearing land is ca. £300-400 acre and the average return on land is 1-3% of its capital value. Thus a rental cost for such land would be ca. £7/acre or £245 for Loch Walton.

Table 7.5 summarizes these costs.

TABLE 7.5

Initial and Annual Expenditure at Loch Walton

Initial Items	Cost £'s	Annual Items	Cost £'s
Buildings	8440	Rates	110
Pier	75	Wages	2500
Boats	1430	Rent	245
Outboards	220	Management	225
Management	866	Maintenance	100
		Miscellaneous	200
TOTALS	11031		3380

If all initial items are depreciated over 15 years then annual operating costs amount to £4115.

7.4 FURTHER CASE STUDIES

7.4.1 INTRODUCTION

The detailed case study on Loch Walton has given some idea of both the management and costs involved in running a small fishery. The next two case studies, although discussed in very much less detail indicate to some extent the variation in costs which may occur.

7.4.2 LOCH FITTY

Loch Fitty, a 160 acre, natural lowland loch is situated in a fairly populous area of Fife. It is run as an artificial fishery, stocking both brown and rainbow trout, although with considerable emphasis on the latter species. Fly fishing only is permitted in the two half-day fishing periods throughout the season.

When purchased the loch was already equipped with three piers and two buildings including one large brick built building (60'×20') with heating, lighting, cooking facilities and one small timber building (20'×10'). The former was converted into a tackle shop/snack bar/ anglers' lounge and the latter utilised as a workshop.

The management problems at Loch Fitty are fairly typical of the shallow eutrophic lowland lochs: coarse fish control has proved essential; annual water weed control must be carried out on a fairly large scale; no problems of natural spawning control have been encountered due to the paucity of spawning ground, natural spawning being unable to support the fishery; no problem of water productivity is likely due to the richness of the water. The management at Loch Fitty since its development has included an initial treatment with rotenone (reported in detail in Chapter 6) to rid the loch of both pike and perch. Pike however reappeared three years after treatment (almost certainly re-introduced into the loch rather than an incomplete rotenone kill) and pike gill netting must now be carried out annually. Annual weed control is necessary in this shallow loch requiring the clearing of 20-30 acres per year. To assist with this the fishery bought a second-hand weed cutter mounted on a boat. Management also involves the running of a fish farm raising early 1+ fish to 28 cm,2+ fish (browns and rainbows).

Aside from the income from permit sales there is an annual income from three additional activities at the loch. Firstly a tackle shop is run at the fishery covering a wide range of rods, reels, flies, lines and other accessories. This is regarded largely as a service to the anglers but it is none-the-less profit making on a fairly small scale. Secondly additional income is obtained from the sale of brown and rainbow trout to other fisheries every year. Finally the fishery runs a management advisory service for other sport fisheries which do not have the necessary management skills.

Table 7.6 summarizes both the initial and annual costs of running the fishery. In some cases an estimate has had to be made where actual figures were not obtainable (marked *).

TABLE 7.6

Initial and Annual Costs at Loch Fitty

Initial Items	Cost in £'s	Annual Items	Cost in £'s
Building Repairs	500*	Rates	1000
Caravan *1	2000	Imputed rent	1120
Car Park	200*	Labour	5000
Fish Farm	2500	Fish	5500
Weed Cutter *2	200	Miscellaneous *3	2000
Boats 17 × 14'	4760		
Engines 17 × 4.5hp	1870		
Rotenone	2500		
TOTALS	14530		14620

*1 Caravan on site for manager, largely for security purposes.

*2 Second-hand price.

*3 Includes all other costs from repairs to fish treatments, electricity, advertising, postage, etc. etc.

If all initial items are depreciated over 15 years then annual operating costs for Loch Fitty amount to £15,600.

7.4.3 LOCH ORE

The final case study is another lowland loch in Fife, Loch Ore in Lochore Meadows, a proposed country park being developed by Fife Region. The total area of the park is 900 acres of which Loch Ore comprises 360 acres. The loch, although used for sailing and canoeing is reserved primarily as a fishing water largely for historical reasons (it has been used as a fishing water by a small local club for many years). The water is open seven days a week and from 9 a.m. to dusk during the fishing season. Over 70% of the time is given over exclusively to anglers the remaining time being shared by the sailing and canoeing enthusiasts.

The loch is 20'-25' at its deepest point and averages 8'-9' over most of its 360 acres. It is a very productive water, a recent chemical analysis of the water indicating a total hardness of 226 ppm of $CaCO_3$, and supports natural populations of brown trout (up to 5 lb), pike (up to 12 lb) and perch (3-4 oz).

The loch was originally leased to a local angling club but in 1974, the local authorities, with the help of the angling club, developed the water for more intensive fishing and the water was opened to the public as a boat and bank, fly only loch. In the developmental stages it was decided to bring in experts to carry out an initial survey of the water and advise upon a suitable management plan for the fishery. Once the suitability of the water was established it became necessary to prepare the site for more intensive angling. This involved the construction of a pier for boats, the erection of bridges over inlets and outlets for the bank anglers, the construction of fish gates to retain rainbow trout which were to be introduced, the improvement of the access and car parking and the improvement of the anglers' clubhouse facilities. Because of the potential interference from vandals it was found necessary to fence off a compound which would house the pier, boats and buildings.

Initially 13 boats were made available although it is felt by the manager that the maximum number is about 20. This will eventually be attained. No outboards are available at present but it is felt by the manager from conversations with the anglers that these are regarded as very necessary (on such a large open loch wind can be a great problem without outboards). As a result it is intended to buy six outboards for hire and permit anglers to bring their own outboards for use on the loch. Bank fishing on such a large water is unlikely to reach the maximum possible: the largest number at any one time has been 200 during a competition and even this number, on a water with a perimeter of over three miles, was not considered to be near the maximum. Fishing is by permit only and there are two fishing periods per day.

With regard to the management of the water it was decided in the initial stages to develop the water as a semi-artificial water, stocking 30 cm rainbows and browns annually. This policy has however been changed in the light of experience and it is intended by 1978 to have greatly reduced the amount of stocking apart from a fairly small stocking of brown trout which will be added more for its psychological effect on the anglers than for the anticipated contribution to anglers' catches. The stocking regime since opening and the future plan are shown in Table 7.7.

TABLE 7.7

Stocking Regime at Loch Ore

Species	1975	1976	1977	1978
Brown		8,000 A	8,000 A	-
Rainbow	19,500*	3,000 S	-	-

* 12,500 RT in August 1974
7,000 RT in Spring 1975

N.B. A = Autumn stock
S = Spring stock

Although there are large populations of both pike and perch in the loch the populations would seem to be in a balanced state with the trout. The situation would seem to be very similar to that at Loch Leven with the perch providing a ready food supply for the trout and pike. The pike, although they are controlled by netting and trapping, are not regarded as a serious problem since all pike which have been examined have been feeding exclusively on perch. The removal of pike is carried out more as a precautionary measure rather than as vital predator control measure. Perch are also trapped in the loch but for purely recreational reasons since they are then placed in a small netted off area of the loch where young children are permitted to fish for them free of charge.

Weed control at Loch Ore, as may be expected of a shallow eutrophic water, is a serious problem. It is estimated that 1/5th of the area of the loch is covered by weed growth in a year. Although it was originally intended to remove the growth manually it soon became apparent that this was completely impractical: it was estimated that this would require two men for four months each year, involving 160 man days per year. At the time of year when this must be done additional labour would have to be employed to carry out the work and the cost would be ca. £1500 per year. Thus in agreement with the findings in Chapter 6 weed cutting on a large water body cannot be carried out by hand. At Loch Ore a weed cutter was purchased costing £2,800 the price including a boat with mounted cutter which would cut a 2m width and 1m depth. Cheaper cutters are available which can be mounted on any boat (cost about £800) but when tried out at Loch Ore it was found to be rather underpowered for the job and furthermore required two men to operate: the more expensive model requires only one man. The manager at Loch Ore intends to hire out the boat and cutter to small waters which are unlikely to buy one of their own although the anticipated revenue from this is unknown.

There are two individuals employed by the region to run the fishery, one full-time manager and a part-time assistant. In addition to this labour is supplied by the fishing club, who helped in the development of the water and bailiff the water every evening apart from one when there is no fishing permitted. This involves four members of the club six evenings per week from 6 p.m. until dusk (two working at any one time) and is regarded as a vital function since it is so near to population centres and therefore open to potentially serious poaching, particularly since bank fishing is permitted. The bailiffing therefore requires approximately 54 hours per week and is clearly the equivalent of one other assistant. Although the club members are not paid in cash for their services the club is given the free use of three boats through the season for their bailiffing service and this is the equivalent of £33 per week throughout the season. While this amounts to only one half of a man year the club also assist with some of the management work carried out at the loch and their total input is regarded as the equivalent of one full-time assistant. However for the purposes of costing their effect £33 per week for the 30 weeks of the season (i.e. the loss in boat revenue) has been assessed.

The initial development costs and annual running costs at Loch Ore are shown in Table 7.8 along with some explanatory notes where necessary. If all initial costs are depreciated over 15 years then annual operating costs at Loch Ore amount to £10,250.

7.5 THE COST OF RUNNING THE 'AVERAGE' FISHERY

The three cases studies have been reported in varying detail with only one covering the management procedures in any depth. However all three have adequately assessed the initial development and annual running costs of the fisheries and from this it is clear that costs will vary considerably from one water to another. This variation results from several interacting factors: obviously the size of the fishery and the maximum number of anglers it wishes to or is capable of accommodating

TABLE 7.8

Initial and annual costs at Loch Ore

Initial Item	Cost	Notes	Annual Item	Cost	Notes
Compound	5000*	Includes pier, two buildings, fencing and car park. Cost is materials only, labour supplied free by Club	Fish	500	Represents cost after 1977. Annual cost until then ca.£4000
Bridges & Fish gates	350		Labour	5150	Manager at £3000 + labourer (half-time) at £2500 + 30 weeks at £30 per week.
Survey	500		Rates	300	Includes fish rates based on annual catch of 10,000 fish + rates on buildings.
Boats	3640	Represents cost of 13 × 14' boats.	Imputed Rent	2540	
Outboards	660	Represents cost of six outboards	Printing & Advertising	500	
Weed cutter	2800		Miscellaneous	400	Includes all other costs such as electricity, minor repairs etc.
TOTALS	12950			9390	

* Labour cost has been estimated at £7000

will be an important factor; site characteristics at the time of development will determine both the necessity for and the cost of access improvement, building construction etc,; the 'type' of water concerned will also be of some relevance since this will dictate to some extent the management practices required to run the fishery at a satisfactory standard. Thus while Loch Walton is concerned with chemical improvement of the water Lochs Ore and Fitty are primarily concerned with predator control and weed control on a large scale. Typically the highland oligotrophic loch is not concerned with stocking since good spawning sites are normally available while the lowland eutrophic loch is often hampered by poor spawning facilities and very heavy fishing pressure.

It is clear from the case studies that variation in cost is to be expected not only between 'types' of waters but also within 'types'. From the examples certain items of expenditure clearly emerge as relatively important while others are relatively unimportant. Table 7.9 reflects the important items and describes in general terms the ways in which these factors will typically vary from one water to another.

TABLE 7.9

Variation in Set Up and Running Costs

Item	Variation Category
i Initial Items	
a Buildings	Variable for all waters, i.e. depends on facilities available. Will vary to some extent also on number of anglers catered for.
b Boats and Outboards	Varies largely with capacity of site.
c Weed cutter	Variable between 'types' i.e. shallow eutrophic: deep oligotrophic. Will also vary to some extent with size of body, e.g. Loch Walton: Loch Ore
ii Running Items	
a Labour	Varies largely with size of water body
b Fish	Varies largely between types

However from the analysis of the case studies it is apparent that while these factors are variable a large proportion of the annual operating costs is relatively constant between waters: labour plus stocking costs constitute 65%, 67% and 55% of annual operating costs for Lochs Walton, Fitty and Ore respectively. This finding is in common with the Inland Fisheries Trust of Ireland mentioned in Chapter 2 where salaries were found to constitute a very high proportion of annual costs.

Therefore while detailed calculations of potential costs are difficult to make without reference to a specific water it is none-the-less possible to assess the approximate initial development cost and potential running cost of an imaginary water which is likely to be of the correct order of costs. For the purposes of this assessment the 'type' selected is a typical shallow, eutrophic, lowland loch. It is assumed that the water is 100 acres in area and that there are no facilities at all available at the site. It is intended to run the fishery as a boat only water and although there is a good natural population of trout the required annual catch is 6,500 trout each year. This will necessitate artificial stocking of the water annually since even a good quality water is unlikely to give this yield from natural production of trout. However natural fish should make some contribution to the catches in a productive water with good spawning facilities and it is possible therefore that annual stockings of ca. 5000 trout may be sufficient. The potential costs for this water are shown in Table 7.10 which also includes details of the derivation of the figures where this is thought necessary. From the figures total development costs will be in the region of £19,000 while annual running costs will be ca. £7000. Annual operating costs for this 100 acre loch amount to £8500 (initial items are depreciated over 15 years).

TABLE 7.10

Potential initial and annual costs of 100 acre loch

Initial Item	Cost	Notes
i Site		
Piers	100	
Buildings	7760	Clubhouse/office, 30'×30' @ £60/m^2 Store/workshop, 20'×20' @ £40/m^2
Car Park	300	
ii Management		
Barriers	250	5 barriers at outlets and inlets
Weed cutter	870	
Gill nets	120	
Fish farm	4800	
iii Other		
Boats	3360	12 × 14' clinker boats at £20/foot
Outboards	1320	12 × 4.5hp @ £110 each
TOTAL	18880	
Annual Item		
i Office		
Postage		
Telephone		
Stationery	300	
Advertising	300	
ii Management		
Fish	1130	
Labour	4250	1 manager £3000 + half-time labourer £1250
iii Other		
Imputed Rent	700	
Rates	300	Rates on 10,000 fish per year + buildings
Maintenance	200	
TOTAL	7180	

The costs for different waters will vary very considerably depending upon whether the water is intended for intensive angling or not. The three case studies are all examples of fairly intensive fisheries. As such, costs include stocking, boats, outboards, and angler facilities. This is therefore likely to be a maximum cost range. For fisheries which are not intended as intensive fisheries costs will be very much reduced. In such fisheries, fishing intensity will not be high and stocking is not likely to be necessary. Without stocking poaching is less likely and it is very likely that labour input will be less as a result of this. It has been shown that the labour cost of management at a 100 acre loch will be ca. 40% of a man-year. Apart from this vital management requirement costs could be very much reduced in this type of fishery. Since labour and stocking have been shown to be the prominent costs in the intensive fisheries a reduction in both of these is likely to substantially reduce annual operating costs.

SECTION 5 SUMMARY AND CONCLUSIONS

CHAPTER 8 THE DEVELOPMENT OF TROUT ANGLING IN SCOTLAND

CHAPTER 8

THE DEVELOPMENT OF TROUT ANGLING IN SCOTLAND

8.1 INTRODUCTION

Before embarking upon a discussion of the development of trout angling in Scotland it would be useful at this stage to briefly summarise the last chapters in order to bring together the main findings which are of relevance to this final discussion. In the interests of brevity these are presented in note form.

CHAPTER 1

1. Participation in angling has increased very substantially over the last 100 years.
2. At the time of writing trout angling is not well organised in Scotland.
3. Recent government discussions on trout angling have stated that there is a need to make more waters available to local and visitor anglers.
4. In order that re-organisation of the sport be carried out efficiently and effectively there is a very great need for more information on the state of the angling industry at present and the potential for development.

CHAPTER 2

1. The suggested developments in the organisation of angling are reminiscent of the Inland Fisheries Trust of Ireland. Re-development along the lines suggested by the White Paper on angling is likely to be financially demanding.
2. From the information available the financial viability of the Scottish Anglers' Trust, the body which is to develop trout angling, is unknown. It is suggested that an investigation into the requirements, both physical and financial of the SAT is required.

CHAPTER 3

1. The game angling industry is very mixed with private individuals, public organisations, clubs and associations involved in the running of fisheries.

2. In general terms the industry is very variable in many ways: sales; prices; evidence of management.

3. Many waters are under-utilised and many have a very low income. Only a few waters could possibly give a living to one person.

4. There is an excess demand over supply for some types of fishery.

5. Some of the findings of this chapter prompt the question 'what determines the demand for angling'?

CHAPTER 4

1. Economic theory helps to identify the variables which may be important in determining sales including, price, quality, competition and population but it does not suggest a functional form for the variables.

2. The gravity model has been used in other studies and seems appropriate for this particular problem. From the result of the analysis and the general discussion in the chapter, it is believed that quality, price (thought to reflect the quality of the site here) and population are all positively related to sales while competition from other sites will be negatively related to sales.

The indications are therefore that the location of a fishery is of some importance in determining sales and there does seem to be a demand for the more 'managed' fishery.

3. It does seem therefore that the potential for expansion (Chapter 2) may be realised if due attention is paid to the quality and location of new fisheries.

This being the case, the question now arises 'what are the costs involved in developing and running fisheries'?

CHAPTER 5

1. The factors controlling both the number and sizes of trout which will be present in a particular water are many and varied and the inter-relationships are very complex.

2. As a result of this complexity the exploitation of trout must be carried out in a controlled manner.

CHAPTER 6

1. Stocking costs, often likely to be necessary in intensively fished waters, are likely to be the dominant costs. Where heavy stocking is not carried out labour costs are likely to be dominant.

2. Expenditure on management items is often going to be worthwhile but there is a need to assess the benefits especially where high cost management items are being considered.

CHAPTER 7

1. For the intensively managed fishery, initial costs for an average 100 acre loch are likely to be ca. £19,000 while annual running costs are likely to be ca. £7,000.

2. Costs for less intensively managed fisheries are likely to be very considerably less than this.

It is now possible to consider the development of trout angling from two standpoints: that of the private entrepreneur and that of the SAT or similar organisation.

8.2 THE PRIVATE ENTREPRENEUR

8.2.1 INTRODUCTION

Given that there exists some excess demand over supply in the angling industry for the good quality waters it would be possible for a private entrepreneur to consider an investment in a trout fishery in Scotland.

8.2.2 THE INVESTMENT DECISION

Before discussing investments in trout fisheries it is useful to consider the factors which govern any investment decision. Basically any potential investor must have made a decision on what he wants from his money: there is no general rule for the investment of money and each individual must come to some decision on his expectations from his money. At one extreme there is the investor who does not want to work for himself but wants his money to work for him. Such an individual could invest in almost anything from savings bonds; government securities; shares; property or even a trout fishery. The decision finally taken will depend on which investment maximises the return on the original investment. At the other extreme there is the individual who is interested in trout fisheries and who wants to work for himself in a fishery. Such an individual would invest in a trout fishery if the investment gave him a living and some return on the investment. This return would not necessarily be a maximum return but simply sufficient of a return to allow, perhaps, some re-investment in the fishery. Decisions made by these two extreme types of investor would therefore be very different and there are of course many other categories of investor in between these extremes, again making different investment decisions.

8.2.3 METHODS OF INVESTMENT ASSESSMENT

Irrespective of the objectives of the investor he still requires some appropriate investment analysis in order to assess whether his objectives are likely to be fulfilled with any given project. The basic form of the most appropriate method, the discounting cash flow method has already been discussed in Chapter 6. However the NPV method which incorporates this basic idea and which was used in Chapter 6 presents some problems for this particular kind of analysis: it is necessary to select an appropriate interest rate and with so many possibilities this can be a difficult choice. However the yield discounting method overcomes this problem in that it determines the interest rate which discounts future cash flow generated by an investment down to a present value which exactly equals the cost of the investment. Obviously the final decision on whether the rate of return is sufficient to make the project worthwhile still has to be made but the method involves only one calculation and one answer.

There are still difficulties with the yield method: it is a rare business where net cash flows can be assessed with a firm degree of assurance, the majority must accept that risk and uncertainty are an integral part of running a business and this clearly makes the application of the yield method more difficult. If, however risk and uncertainty can be quantified at least to some extent then this can be incorporated into the analysis. Sensitivity analysis is a fairly simple method of incorporating risk and uncertainty into the yield method, requiring the identification of the critical variables in the project and a subjective assessment of the best, average and worst values of these variables.

From Chapter 7 it is apparent that a manager should be able to predict with some accuracy most of his annual costs. There is one possible exception to this, the assessment of stocking costs, and since this is a dominant management cost, any errors in judgement could be quite important. From Chapter 6 it is apparent that the trial and error methods employed in developing stocking regimes may well lead to inaccuracies in the estimation of stocking costs. A second difficult variable is the assessment of sales. Clearly the new manager will know the upper limit of sales since he must know his maximum capacity but beyond that there must be some uncertainty. These two variables are therefore likely to be the most critical in the assessment of a trout fishery project.

8.2.4 THE ASSESSMENT OF AN INVESTMENT IN A 100 ACRE TROUT FISHERY

In order to exemplify the kind of analysis suggested, the assessment of a 100 acre trout loch, based on the cost assessment in Chapter 7 is now carried out using the yield method in conjunction with a sensitivity analysis of the critical variables. Three possible levels of sales are identified, a best (6,500 tickets), average (6,000 tickets) and worst (5,500 tickets) value and two possible levels of stocking cost are identified including the level set in Chapter 7 (the cost of raising 5,000 takeable fish) and a higher level assuming that requirements have been underestimated (the cost of buying in an additional 2,500 trout, assuming a 50% error in the judgement of requirements). The yields from the six different outcomes are shown in Table 8.1 (details are recorded in Appendix 15) and these results do highlight the need for some kind of realistic sensitivity analysis of the critical variables in such a project. As stated earlier the manager still has to decide whether the projected returns are satisfactory and his decision will depend upon his basic objectives. For many investors the returns from most of the outcomes may well be acceptable but it is unlikely that the very worst outcome (minimum sales and maximum stocking costs) would be an acceptable proposition to any private entrepreneur and the investor would therefore have to assess, even if subjectively, the chances of this outcome occurring before making any investment decision.

TABLE 8.1

Yield from Several Possible Outcomes from the Investment*

Outcome	Yield %
Maximum sales** + minimum stocking	12
Average sales + minimum stocking	9
Minimum sales + minimum stocking	5
Maximum sales + maximum stocking	7
Average sales + maximum stocking	4
Minimum sales + maximum stocking	<1

* Investment is considered over a 15-year life

** Price has been set at £2/ticket

8.2.5 CONCLUSIONS

For the private entrepreneur there are many decisions to be made before making an investment decision. He must decide in the first instance what he wants from his money and, using the accounting methods discussed, whether any particular project is likely to fulfil his financial objectives. From the example given here it is likely that several types of investor would consider a 100 acre trout fishery a viable economic proposition although it would obviously be necessary to consider a particular fishery rather than this 'average' fishery.

8.3 THE SCOTTISH ANGLERS' TRUST OR SIMILAR ORGANISATION

8.3.1 OBJECTIVES

While the objectives of the private entrepreneur are likely to be profit maximisation or something approaching this, the objectives of the SAT will be quite different. In Chapter 2 the objectives of the IFT were discussed and it was stated that the angling organised by the IFT should really be considered as a public utility since prices for the facilities are maintained well below actual costs. The total income to the IFT includes (a) the income from anglers (membership fees, charges to non-members and additional charges to members for certain waters); (b) the intangible benefit of angling as a national amenity; (c) the tangible benefits from the economic activity generated by angling visitors. It would appear from the White Paper on Scottish angling however, that it is intended that the SAT become financially self-sufficient after a period of three years. Thus the income to the SAT will consist entirely of the income from licences, rates, membership fees and direct charges to both members and non-members. The SAT must therefore aim to break-even and this will clearly be reflected in costs to the anglers.

8.3.2 DEVELOPMENT OF TROUT ANGLING AND THE ROLE OF THE SAT

It is suggested that, from the findings in earlier chapters, the new system to be developed by the SAT should include the following provisions.

Firstly there is some need for the 'intensively' managed high quality fishery and it is envisaged that only a few such fisheries should be developed. It is apparent from Chapter 6 that intensively managed fisheries are relatively costly and it is necessary therefore to ensure that exploitation is also intensive. From Chapter 4 it is thought that locational factors are important in determining sales and it will therefore be necessary to ensure that the fisheries are carefully located such that sales will be high.

Secondly, it is clear that there is a need for development of many less intensive fisheries (it must of course be remembered that 'development' here does not necessarily mean the opening of new waters: hopefully many existing fisheries will be turned over to the SAT). Such fisheries will be intended for relatively low exploitation and although clearly some thought will have to be given to the location of these fisheries this will not be so critical as with the intensive fisheries.

These fisheries will therefore be located all over the country, catering for anglers even in low population density areas. Since these fisheries are intended for low exploitation it is certain that stocking costs would be very low and probably eliminated altogether. From Chapters 6 and 7 it is clear that the elimination of stocking costs would considerably reduce total costs. Labour costs would therefore become dominant for these fisheries. From Chapter 6 it is apparent that it is important for fisheries to ensure that management is carried out efficiently and to this end it has been shown that efforts must be made to carry out the necessary management work annually and to ensure, by monitoring of the water, that management work is successful and efficient. If this is to be carried out satisfactorily it is clear that not only will labour costs be dominant but they may also be very high relative to potential revenue from anglers. It is suggested that labour costs and equipment costs for management could be reduced while still maintaining management efficiency by developing a new system of management. This would involve area superintendents who would be responsible for the day-to-day running of the fisheries within their geographical area. These persons would be assisted by seasonal labour employed to help with the disbursement of permits and control of anglers. Working in conjunction with the superintendents would be mobile teams of management experts who would carry out most of the management work at these low intensity fisheries including assessment of management success. This new system would bring about an efficient utilisation of both labour and equipment and thus minimise costs whilst maximising management efficiency. As a result the cost to the anglers of these fisheries will be very much lower. These fisheries will be natural rather than artificial, catches will probably be lower as a result and of course there will be no extra facilities (e.g. large clubhouse, refreshments etc.). These will therefore be the lower quality fisheries.

8.3.3 COSTS OF THE NEW SYSTEM

In order to assess costs accurately detailed knowledge of the precise waters involved, number of staff and amount of equipment required would be necessary. Given the remaining gaps in knowledge this is not possible at this stage and it is only practical to talk in rather more generalised terms. However the similarities between the proposed Scottish system and the Inland Fisheries Trust suggest that it would be realistic to use the Irish experiences as a yardstick. To this end some basic facts about the Inland Fisheries Trust are listed below followed by a discussion of the implications of this for the SAT.

1. Total expenditure in 1975 amounted to £503,866.
2. Of this sum 86%, £433,325, was spent solely on trout fisheries.
3. The total income in 1975 amounted to £465,725 of which only £20,905 came from anglers' contributions (from permits, donations from clubs and members, sales of fish).
4. Staffing in 1975 included 160 full-time and 20-30 seasonal workers. Of these 90% of the full-time staff (125) and all the seasonal workers were involved in field work. The number of administrators included 15 full-time employees.
5. The Inland Fisheries Trust actively manages approximately 37 lochs, totalling 150,000 acres and six rivers. Two of the lochs total 60,000 acres between them while at least 21 of the remaing waters are each 100 acres or less, (Inland Fish. Trust, 1975).

Implications of these facts for the SAT

The costs to the IFT of the trout fishing in Ireland amounts to almost £0.5 million. Southern Ireland covers almost the same area as Scotland but has only half the population of Scotland. It seems likely therefore that the costs to the SAT are unlikely to be less than the Irish costs. It is obvious from the Irish literature that there are two additional functions of the Inland Fisheries Trust which have not been discussed in detail with regard to the SAT. These include (a) research on management of fisheries and (b) control of pollution. The latter in Scotland is not likely tc be included in the remit of the SAT since it is, at present, in the hands of the river authorities and while the SAT, in the course of its duties may be of some assistance in this matter, it is not likely to become more deeply involved. However, from the information available, it does not seem that the IFT plays too important a role in their remit. It seems unlikely therefore that the omission of this function from the SAT remit will produce very substantial savings in cost. The former, on the other hand, must be a part of the work of the SAT: earlier in the chapter it was suggested that the mobile management teams ought to assess the effectiveness of their management work and it has been shown in Chapter 6 that this kind of work is essential for the effective development of trout waters. It is also likely that the SAT would find it useful to carry out management experiments on waters in order to improve their management success (as long as this is carried out carefully it is unlikely to duplicate the efforts of the Freshwater Fisheries Laboratory in Pitlochry which carries out some applied research on trout waters in Scotland). Thus a research team or a management/research team would be an essential component of the SAT.

It does not appear, therefore, that the costs of the SAT will be less than those for the IFT and, given the greater population in Scotland, costs may well be higher. While it would be most useful to give a precise cost assessment, including details on the numbers of waters which ought to be developed and the likely costs this is not possible given the limited knowledge available. Indeed, it is perhaps unrealistic to expect such perfect information to be available and in such circumstances informed guesses are more likely to be employed rather than precise details. At best therefore it can be suggested that from 50-100 waters ought to be developed, from 5-10 of these being intensively managed and carefully located trout fisheries. Given the Irish figures a sum of £0.5-1 million may be required annually by the SAT to develop and run these waters.

In Chapter 2 an estimate was made of the likely total annual income for both the area boards and the SAT. The estimate made in Chapter 2 of ca. £350,000 did not include any income figures from permit sales to non-members or additional charges to members and clearly these charges to anglers will have to make up the difference between costs and revenue from licences, membership fees and rates. However while it has been stated that the SAT will have to become self-sufficient it may be possible to justify some financial support on the basis of its importance for tourism, from the government direct or from the Scottish Tourist Board or some similar organisation. It would of course be necessary to determine the importance of angling visitors to the national economy. Mills (1971) quotes some interesting figures from Ireland indicating that in 1967 it was estimated that angling in Ireland attracted a total of 111,100 visitors bringing an estimated revenue of £3,919,000 and an average expenditure figure of £35 per visitor. There are unfortunately no comparable figures for Scotland with regard to numbers of visiting anglers but from the work of Jamieson (1970) the income generated by the average angling visitor may be of a comparable nature to the Irish figure: Jamieson's work on the holiday angler has indicated that the visitor to the permit fisheries in Scotland fishes mainly for brown trout, spends ca. £27 per week on food, accommodation, permits and local travel and stays on average for one week. If the impact of the holiday angler could be investigated further by the SAT then some financial support may be justified.

In conclusion, it must be stated that for the SAT to develop in the manner suggested and fulfil the objectives laid down by the government there are several points which have been discussed in this study and which, it is felt, are vital for the success of the SAT.

Firstly, while the White Paper and the Hunter Report highlighted the need to make more waters available to the Scottish tourist anglers, this thesis has shown that although there is some excess demand over supply this exists only for the more managed fisheries. Furthermore, from Chapter 4 the importance of locational factors as well as quality of the fishery has been identified. Thus, while it is suggested that a few high quality fisheries ought to be developed, it has been made clear that these fisheries will have to be carefully located. An initial task for the SAT must be then to further investigate the demand for angling, examining the locational factors in greater depth so that sites for development may be carefully selected.

Secondly, it was briefly mentioned in this chapter that the Inland Fisheries Trust have a research force which monitors management and carries out applied research which is very much geared to solving their management problems. In Chapter 6 the need for management assessment was highlighted and it is particularly necessary here where large sums of money are involved. For example, from the Irish figures it is apparent that of the £433,000 spent on trout angling in 1975, £140,000 in wages and £7000 in equipment were spent on predator control. Although this is the main management work carried out this expenditure figure does not represent the total management cost. Financially therefore management is a dominant cost and, as such, it is important that staff are employed to carry out this function.

Thirdly, a vital factor mentioned in Chapter 2 is the ability of the SAT to procure waters given their limited powers and financial restrictions. It is unfortunate that some of the waters in public ownership are not to be turned over to the SAT. Although it does seem probable that some public bodies will voluntarily lease their waters to the SAT in order to relieve themselves of this responsibility thus giving the SAT a valuable source of waters, the SAT may well find it difficult to procure the required number of waters. An initial task of the SAT should be therefore an investigation into the waters which will be available, followed by, if necessary, suggestions to the government about legislation to make more public owned waters available to the SAT.

Finally, in Chapter 2 the introduction of a licensing system was suggested by both the Hunter Report and the government. The two main advantages of this would be that it provided a source of income and that it permitted a means of identifying anglers. This latter advantage would make the control of anglers easier and would also permit an accurate assessment of visiting angler importance. The licensing system was not even alluded to in the 1976 Act and it is to be hoped that it will be included in further legislation.

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Biology: Professor F G T Holliday
Hans Meidner

APPENDIX 1 First Letter

UNIVERSITY OF STIRLING STIRLING FK9 4LA SCOTLAND | TELEPHONE: STIRLING (0786) 3171

SJH/MBS

19th November 1973

Dear

I am engaged in research at the University of Stirling, investigating the management of freshwater fisheries in Central Scotland. This research involves both biological and economic considerations of fisheries management and it is intended from the analysis to formulate an over-all management strategy.

To do this study certain information is required on fisheries. Such information is only obtainable from the individual clubs and I would be very grateful, therefore, if you could fill in the enclosed questionnaire and return it to me in the post-paid envelope provided.

I have sent this letter at a time when I am sure most clubs are completing their end of season figures and hope that these questions can be answered with the minimum of effort on your part.

Any information received is, of course, strictly confidential, and is treated only statistically in order to complete the analysis.

It is hoped that the analysis, when completed, will be available and of use to all interested parties.

I look forward to hearing from you in the near future.

Yours sincerely

<u>Sandra J Hails</u>

Enc

Biology: Professor F G T Holliday
Hans Meidner

APPENDIX 1 Second Letter

UNIVERSITY OF STIRLING STIRLING FK9 4LA SCOTLAND | TELEPHONE: STIRLING (0786) 3171

SJH/MK

18th January, 1974.

FRESHWATER FISHERIES SURVEY

Dear

Approximately six weeks ago I sent you a letter explaining my involvement in research on the management of freshwater fisheries in Scotland. I also enclosed a questionnaire designed to collect certain items of information vital to my work. I stress that the information is only available from permit issuing bodies such as yourself. To date, I have not heard from you and have therefore sent this reminder along with further questionnaires, should you have misplaced the former ones.

I should like to emphasize again that any information received is, of course, strictly confidential and is treated only statistically in order to complete the analysis.

It is hoped that the analysis, when completed, will be available and of use to all interested parties.

I look forward to hearing from you in the near future.

Yours sincerely,

Sandra J. Hails

Encl.

Biology: Professor F G T Holliday
Hans Meidner

APPENDIX 1 Third Letter

UNIVERSITY OF STIRLING STIRLING FK9 4LA SCOTLAND | TELEPHONE: STIRLING (0786) 3171
EXT. 2483

SJH/MK

21st February, 1974.

Freshwater Fisheries Survey

Dear

In November 1973 I sent you a letter explaining my involvement in research on the management of freshwater fisheries in Scotland. Along with this letter I enclosed a questionnaire designed to collect certain items of information available only from the permit issuing bodies themselves and vital to my work.

In January 1974 I sent off a reminder to those who had not replied and, to date, have had many returns from this. However, for the purposes of statistical analyses the greater the number of replies the more confident one can be about the conclusions drawn from the analyses. I have therefore enclosed further questionnaires and hope that you will be able to complete them. A post-paid envelope is provided for the return of the completed questionnaires. If you have any problems with the questions please do not hesitate to get in touch either by phone or by letter.

I must again stress that any information received is, of course, strictly confidential and is treated only statistically in order to complete the analysis.

It is hoped that the analysis, when completed, will be available and of use to all interested parties.

I look forward to hearing from you in the near future.

Yours sincerely,

Sandra J. Hails

Enc.

APPENDIX 2

Questionnaire Returns: Raw Data

For reasons of confidentiality individual waters cannot be identified.

KEY TO RAW DATA (A computer printout of the raw data is appended at the end of the thesis). Coded data for each individual fishery appears on 2 lines.

First Line

Columns 1 - 4	:	Water Code Number
5	:	1 = loch; 2 = reservoir; 3 = river
6	:	Return group: 1 = 1st return 2 = 1st reminder 3 = 2nd reminder
7	:	Question 2 (1 = Yes; 2 = No)
8 - 11	:	Question 3
12 - 13	:	Question 4 - Permit Type coded 01 - 10
14 - 17	:	Question 4 - Number of permits of particular type sold
18 - 21	:	Question 4 - Permit price (in pence)

(12 - 21 Repeated six times up to Column 71)

Second Line

Columns 1 - 4	:	Water Code Number
5	:	Question 5 (1 = Yes; 2 = No)
6 - 7	:	Question 6a
8	:	Question 6b
9	:	Question 7a (1 = Yes; 2 = No)
10	:	Question 7b: 1 = Brown trout 2 = Rainbow trout 3 = Salmon 4 = Sea trout 5 = Coarse fish
11 - 14	:	Question 7(b) - Number of particular species caught

(10 - 14 Repeated four times up to Column 29)

30	:	Question 8(a) (1 = Yes; 2 = No)
31	:	Question 8(b) - Species code as above
32 - 35	:	Question 8(b) - Weight of particular species caught

(30 - 35 Repeated four times up to Column 50)

51	:	Question 9 - Species code as above
52 - 53	:	Question 9 - Size limit of particular species (inches)
54	:	Question 9 - Bag limit of particular species

(51 - 54 Repeated four times up to Column 66)

67 - 68	:	Question 10
69	:	Question 11(a)(i) - Number of full-time supervisors

APPENDIX 2

Questionnaire Returns: Raw Data

For reasons of confidentiality individual waters cannot be identified.

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12 - 13 : Question 4 - Permit Type coded 01 - 10
14 - 17 : Question 4 - Number of permits of particular type sold
18 - 21 : Question 4 - Permit price (in pence)
(12 - 21 Repeated six times up to Column 71)

Second Line

Columns 1 - 4 : Water Code Number
5 : Question 5 (1 = Yes; 2 = No)
6 - 7 : Question 6a
8 : Question 6b
9 : Question 7a (1 = Yes; 2 = No)
10 : Question 7b: 1 = Brown trout
2 = Rainbow trout
3 = Salmon
4 = Sea trout
5 = Coarse fish
11 - 14 : Question 7(b) - Number of particular species caught
(10 - 14 Repeated four times up to Column 29)
30 : Question 8(a) (1 = Yes; 2 = No)
31 : Question 8(b) - Species code as above
32 - 35 : Question 8(b) - Weight of particular species caught
(30 - 35 Repeated four times up to Column 50)
51 : Question 9 - Species code as above
52 - 53 : Question 9 - Size limit of particular species (inches)
54 : Question 9 - Bag limit of particular species
(51 - 54 Repeated four times up to Column 66)
67 - 68 : Question 10
69 : Question 11(a)(i) - Number of full-time supervisors

APPENDIX 2 (cont.)

Second Line (cont.)

Columns 70 - 72	:	Question 11(a)(ii) - Number of Hours
73	:	Question 11(b)(i) - Number of part-time supervisors
74 - 76	:	Question 11(b)(ii) - Number of hours
77 - 78	:	Question 12(a)
79	:	Question 12(b) - 1 = Mainly Saturdays/Sundays 2 = Mainly Public Holidays 3 = Mainly week days 4 = Mixtures of above

APPENDIX 3

χ^2 Table Comparing Turnovers From 1st, 2nd and 3rd Returns

Annual Turnover £'s	1st Return		2nd Return		3rd Return		Total Observed
	Observed	Expected	Observed	Expected	Observed	Expected	
0 - 1000	50	46.9	39	41.1	13	13.9	102
1001 - 2000	4	5.5	5	4.8	3	1.7	12
2000 +	3	4.6	6	4.0	1	1.4	10
	57		50		17		124

df = 2

χ^2 = 3.54 N.S. (P <0.20 >0.10)

APPENDIX 4

Standardisation of Ticket Sales

There were several cases where waters sold season tickets without selling day tickets. A mean daily equivalent was calculated for all season and day prices available:

$$N = 48$$

$$\bar{X} \; \frac{\text{Season Price}}{\text{Day Price}} = 4.38$$

$$S.E. = 0.39$$

Thus, for those fisheries selling season tickets without selling day tickets the following calculation was carried out:

$$\text{Day ticket equivalents} = \text{season tickets} \times 4.38$$

This conversion was not necessary for other non-day tickets, since day tickets were always sold at these fisheries and thus conversions on the basis of price were always possible.

APPENDIX 5

Figs. 1 - 5 Depicting Observed Sales Against Residual Linear Independent Variables

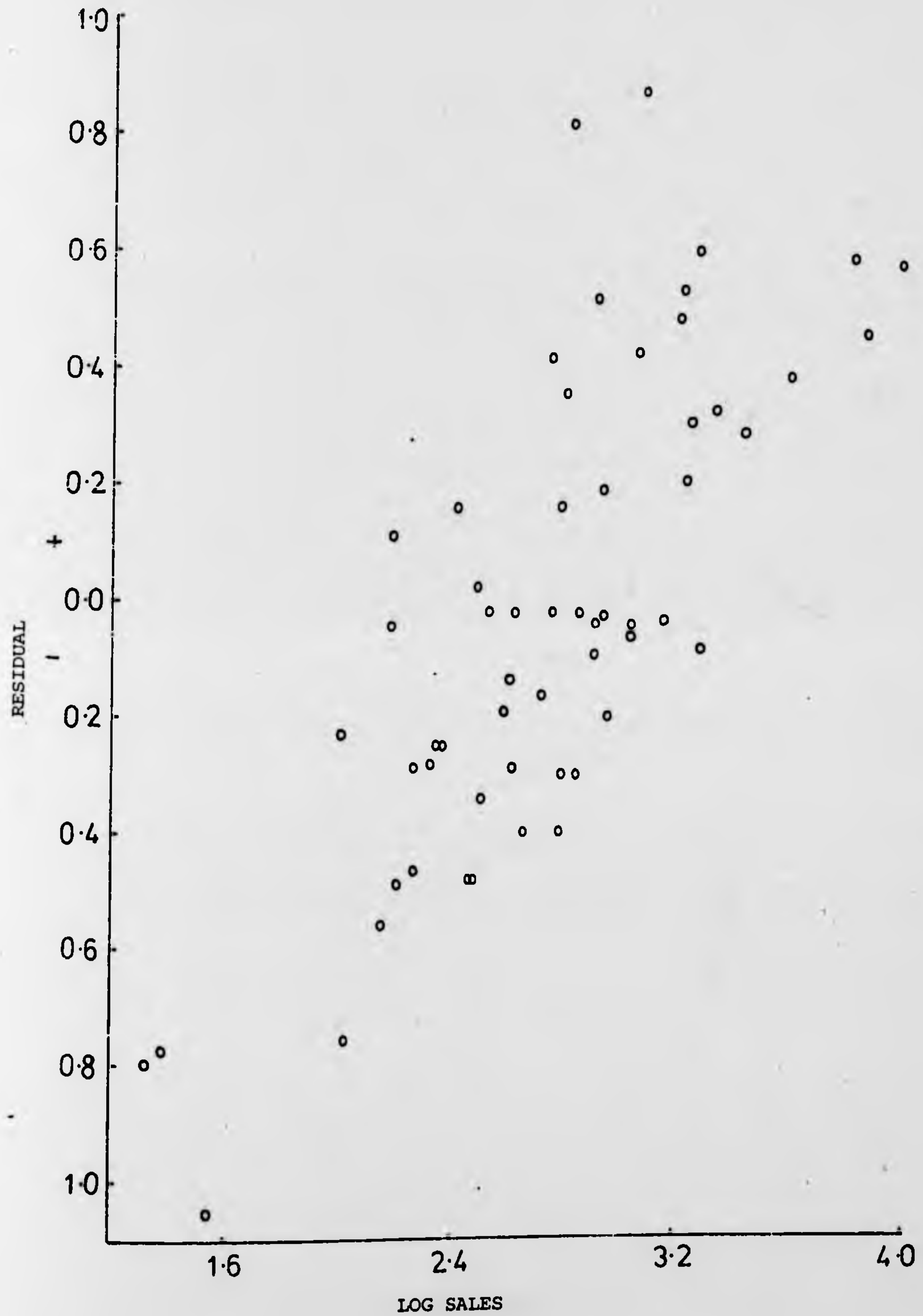

FIG.1 Observed Sales Against Residual with Linear Price Variable

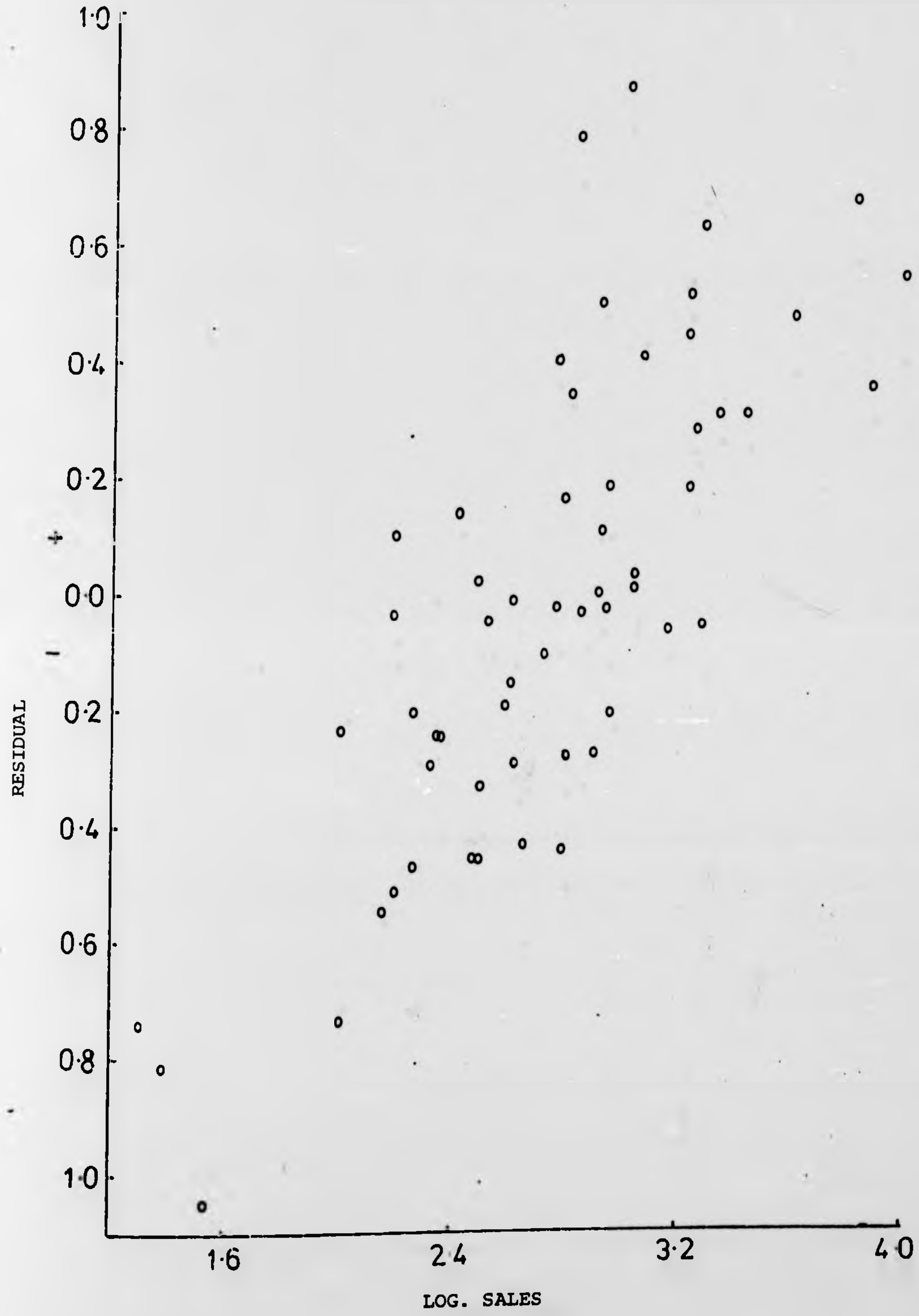

FIG. 2 Observed Sales Against Residual with Linear Competition Variable

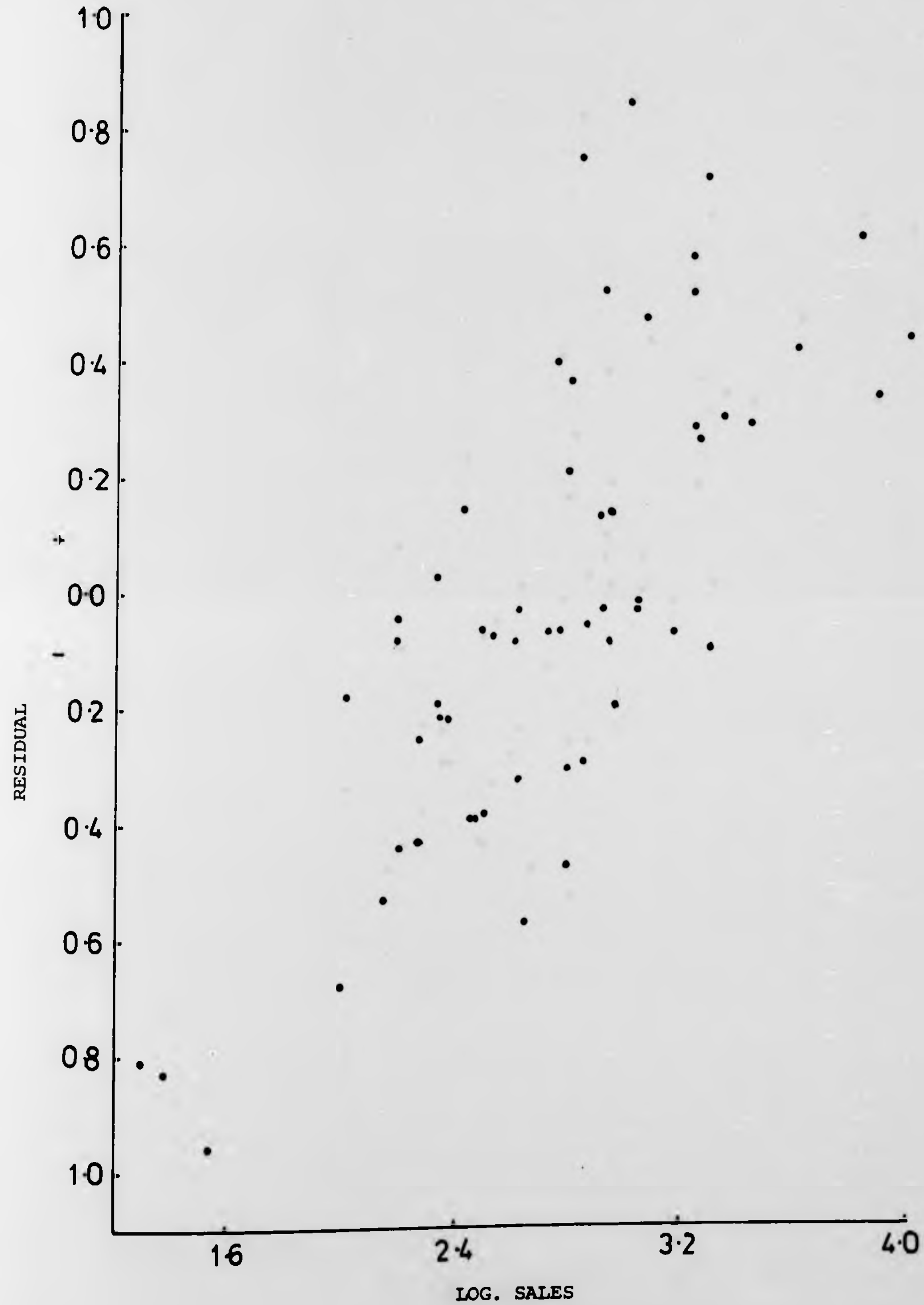

FIG. 3 Observed Sales Against Residual with Linear Quality Variable

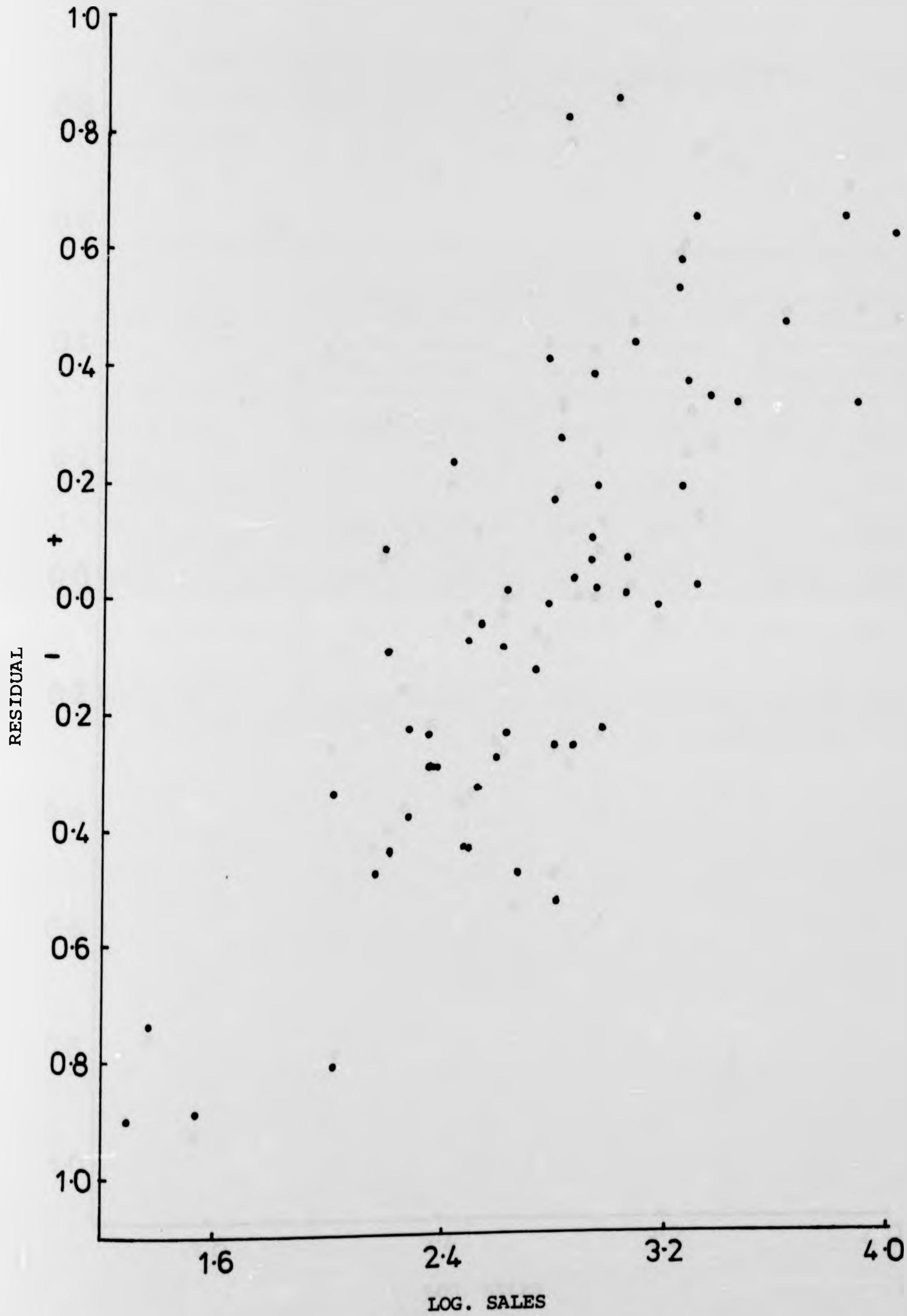

FIG. 4 Observed Sales Against Residual with Linear Population Variable

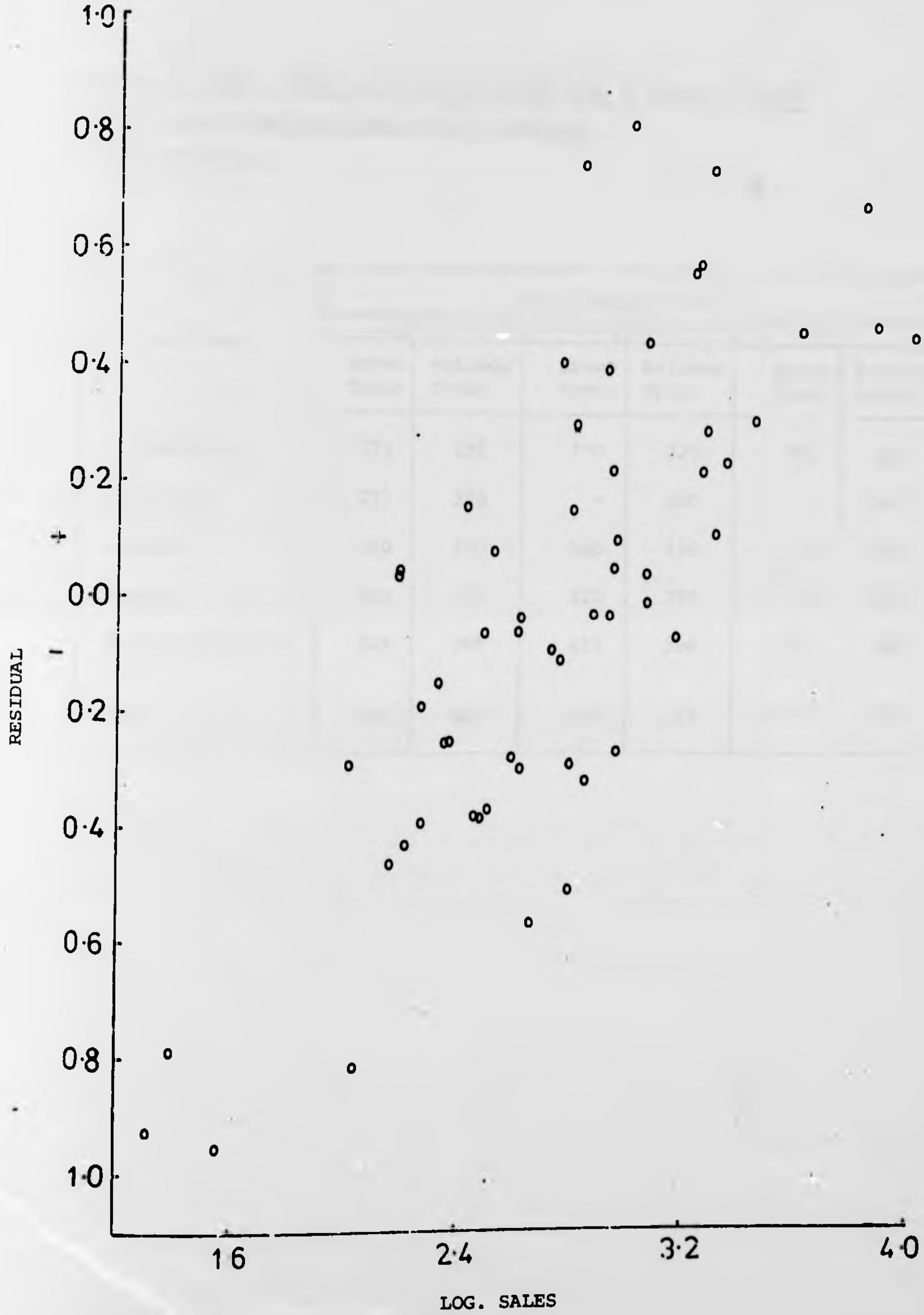

FIG. 5 Observed Sales Against Residual with All Linear Independent Variables

APPENDIX 6

Prices of Brown Trout and Rainbow Trout from a Range of Trout Farms in Scotland and the North of England
(£'s/1,000 fish)

Fish Farm	Fish Length (in)					
	9"		10"		11"	
	Brown Trout	Rainbow Trout	Brown Trout	Rainbow Trout	Brown Trout	Rainbow Trout
Welham Park	273	235	370	325	461	380
Howietoun	277	220	-	300	-	357
Kenmure	260	190	340	230	410	250
Solway	330	275	420	350	510	420
West of Scotland	315	286	425	386	529	481
MEAN	291	241	388	318	477	378

APPENDIX 6

Prices of Brown Trout and Rainbow Trout from a Range of Trout Farms in Scotland and the North of England
(£'s/1,000 fish)

Fish Farm	Fish Length (in)					
	9"		10"		11"	
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Solway	330	275	420	350	510	420
West of Scotland	315	286	425	386	529	481
MEAN	291	241	388	318	477	378

APPENDIX 7

(A) Comparative Costs of Small Cutter (i) and Chemicals (ii) including Labour, Capital and Maintenance Costs

(i) Cutter Costs (£870)

No. of acres cleared	Labour @ £2.80/acre	Capital	Maintenance @ 20% Depreciation	Total £'s
5	14	870	12	896
6	17	870	12	899
7	20	870	12	902

(ii) Chemical Costs

No. of acres cleared	Labour @ £5/acre	Chemicals @ £20/acre	Total £'s
5	25	100	125
6	30	120	150
7	35	140	175

(B) Comparative Costs of Large Cutter (i) and Chemicals (ii) including Labour, Capital and Maintenance Costs

(i) Cutter Costs (£2700)

No. of acres cleared	Labour @ 70p/acre	Capital	Maintenance @ 20% Depreciation	Total £'s
21	15	2700	36	2751
25	18	2700	36	2754

(ii) Chemical Costs

No. of acres cleared	Labour @ £5/acre	Chemicals @ £20/acre	Total £'s
21	105	420	525
25	125	500	625

(C) NPV's of Large Cutter v Chemicals

Acres	NPV	
	Cutter	Chemicals
21	2681	3218
25	2700	3831

APPENDIX 8

Comparative Costs of Commercial and Home-Grown

(i) Brown Trout (ii) Rainbow Trout

(i) Brown Trout Costs (£'s) for 1, 2 and 3 tons

	1 ton		2 tons		3 tons	
	Home-Grown	Commercial	Home-Grown	Commercial	Home-Grown	Commercial
Year 1	5902	2025	10724	4050	14659	6075
Years 2-n	1129	2025	2241	4050	3343	6075

(ii) Rainbow Trout costs (£'s) for 1, 2 and 3 tons

	1 ton		2 tons		3 tons	
	Home-Grown	Commercial	Home-Grown	Commercial	Home-Grown	Commercial
Year 1	5683	1575	10287	3150	14004	4725
Years 2-n	910	1575	1804	3150	2688	4725

APPENDIX 9

Management Costs at a 100 acre Loch

Year 1 (Initial Costs)

Item	Capital	Labour	Total Costs £'s
Food	834	578	1412
Netting	120	356	576
Population Control	150	234	384
Plant Cutter	882	56	938
Monitoring (Records + Scales)		255	255
Stocking	9943	781	10724

Years 2 - n (Annual Costs)

Item	Capital	Labour	Total Costs £'s
Food	334	228	562
Netting		356	356
Population Control		114	114
Plant Cutter	12	56	68
Monitoring		255	255
Stocking	1460	781	2241

Depreciation of Equipment Costs in Year 1 to give Annual Operating Costs

Item	Depreciation Allowance	Running Costs		Total Annual Operating Costs
		Capital	Labour	
Food	57 (15 years)	334	228	619
Netting	12 (10 years)		356	368
Population Control	27 (10 years)		114	141
Plant Cutter	58 (15 years)	12	56	126
Recording	0		255	255
Stocking	566 (15 years)	1460	781	2807
TOTAL	720	1806	1790	4316

APPENDIX 10

POPULATION ASSESSMENT AT LOCH WALTON

INTRODUCTION

The literature in the field of fisheries on the methods of estimating animal population size in the wild is extensive, having developed largely from the work of Peterson (1896). A large number of modifications of this method have been documented but all have basically the same assumptions: individuals whether tagged or untagged have the same probability of capture; the population is sampled in a random manner; the mortality rate of tagged and untagged fish is the same; no tags are lost during the experiment; no tags are recovered and not recorded; no recruitment to the population occurs during the experiment. The mathematical model for computing population size from the tagging results developed by Peterson and modified by Bailey (1951) is

$$N = \frac{m\ (c + 1)}{(r + 1}$$

where N = number in population

m = number of tagged fish released

c = number fish examined for tags

r = number tagged fish recaptured.

METHODS AND MATERIALS

For the 1974 season 800 Loch Walton raised fish (1+) were stocked between August and October of 1973. This was rather early since the fish on average were 18 cm - 20 cm and with a 25 cm size limit these fish were unlikely to reach takeable size in the 1974 season. Even by retaining these fish until late November it did not seem possible to improve the average size enough to ensure that the majority will be catchable in the following season and there seemed little point in tagging these fish. In addition to these 800 fish 500 1+ commercially raised fish were bought and all were 25 cm or greater in size (this is due to the regular grading and superior water conditions). It was decided to tag some of these fish while still in tanks at the commercial hatchery.

The tag selected was the 'Floy' anchor tag since this seemed the easiest of the tags available to insert in the field with largely inexperienced hands. Experiences with this tag by the Inland Fisheries Trust in Ireland suggested that this tag, although rather more expensive than others, was the best available.

The fish to be tagged were removed from the tank at the fish farm and anaesthetized in batches of 12 using tricaine methanesulphonate (MS 222). Each fish was tagged using 'Floy' tags, weighed, measured and dye marked to check for tag loss, using the dye durazol blue and a Panjet gun (after the method of Hart and Pitcher, 1969). The dye mark was placed on the anal fin of each fish. A four man team completed the work in two hours tagging 197 fish within this period. The fish were transported to Loch Walton later the same day and by that time all fish were fully recovered with no post-tagging mortalities or tag loss being noted.

The season at Loch Walton in 1974 began on the 15th March and from the start of the season until late August record cards for the recording of individual fish length and weight. A few scales were removed from each fish caught and placed in a cellophane bag attached to the cards. If a tagged fish was caught the tag was removed and attached to the card. By this method complete records of the catch were obtained including the age of fish caught which was calculated from the scales.

RESULTS

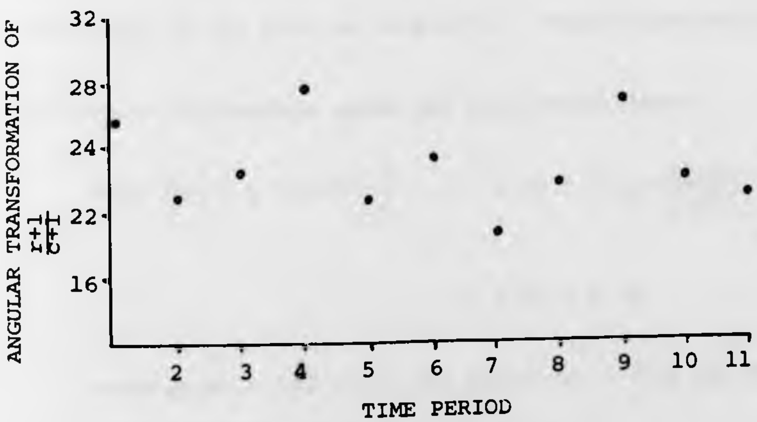
Since the Club is privately run with a very limited membership a fairly complete return of fish caught was recorded on the cards. During the period for which cards were collected 486 fish were recorded on cards and 70 of these were tagged. (This represents ca. 70% of actual catches in the period).

In calculating population size from this data it must be asserted that the conditions required to satisfy the requirements of the model are met with. The assumptions that the population is sampled at random and that no recruitment to the population takes place during the experiment are satisfied in this instance. A further requirement is that the mortality of tagged and untagged trout should be the same. The mortality rate of trout in the wild is rather difficult to ascertain directly. Mortality may have occurred directly as a result of anaesthetizing or handling during the tagging process. However no mortality was recorded five hours after tagging and it is assumed therefore that no mortality occurred at this stage. Mortality may also occur some time after tagging through wound infection, attack by other fish etc. This can be checked by comparing the recovery rate of tags over the time of the experiment since if differential mortality did occur then the recovery rate would decrease with time. This effect if it existed may also indicate a possible difference in catchability between tagged and untagged trout. With many mark and recapture experiments since the marked individuals are taken from the wild population this would be an unlikely occurrence but with this particular case since the tagged population is made up of hatchery fish while at least part of the untagged population is not then it may be a relevant consideration since, as already discussed, hatchery fish are reputed to be more catchable than wild fish. The variation in recovery rate over time is calculated in the table and depicted in the graph below and since no trend in the figures is detectable one can conclude that neither differential mortality nor catchability seems to have occurred over the season. As a final note it may be added that no tagged fish which appeared in the spawning runs in December showed any sings of wound infection and no fish were caught during the season showing any detrimental effects of the tag.

Variation in Recovery Rate over Time

Time Period	Total Catch	Number Tagged	$\frac{c + 1^*}{r + 1}$	$\frac{r + 1^*}{c + 1}$	Angular Transformation of r + 1/c + 1
1	25	4	4.82	0.2077	27.1
2	33	3	7.91	0.1265	20.9
3	73	10	6.17	0.1622	23.7
4	54	11	4.20	0.2382	29.20
5	86	10	7.25	0.1379	21.8
6	110	17	5.64	0.1775	25.0
7	51	4	9.63	0.1038	18.8
8	35	4	6.67	0.1500	22.8
9	19	3	4.65	0.2150	27.6
10	24	3	9.77	0.1720	24.5
11	16	1	8.10	0.1235	20.6

* r is corrected for tag loss.



VARIATION IN RECOVERY RATE OVER TIME

A further problem associated with the tags which, if not accounted for in the calculations, would make the population estimate higher than it really is, is tag loss during the experiment. In order to check this a double marking system can be carried out and to this end each tagged fish was dye marked in the manner already described. Unfortunately the dye mark although reputed to last at least one year was not detectable either by the anglers or the keeper by the 1974 season. As a result of this no direct assessment of tag loss can be made. However, work by Rawstron (1973) using three types of tag on brown trout assessed the tag loss using the Floy tags utilised in this experiment as 9.7%. Losses took place within the first month of tagging and were negligible thereafter. This loss agrees almost exactly with losses experienced by Irish workers using the same tag on brown trout. It would seem reasonable therefore to accept 10% as a fairly accurate estimate of tag losses.

This information, considered along with the data on recapture of tagged:untagged fish allows the calculation of the population of takeable size fish in the loch in late 1973. These calculations are shown below.

Population Estimation using 95% Confidence Limits

$$\text{Mean } \frac{c+1}{r+1} \pm 2.228^{*} \frac{s}{\sqrt{n}} = 6.80 \pm 2.229 \frac{\times 1.92}{3.317}$$

$$= 6.80 \pm 1.29$$

$\therefore$ Population = 197 (m in the equation) × 5.51 to 197 × 8.09 = 1085 - 1593

Mean population = 6.80 × 197 = 1340

* 2.228 = the 5% value of z from t-tables with n-1 df .

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APPENDIX 11

THE MEASUREMENT OF ANGLER EFFORT

From the record cards it was possible to calculate angler effort in hours. The variation in length of visit/angler over the season was assessed by considering the mean number of hours fished/angler over the part of the season for which data were available. The results, shown below, indicate that the average time fished does increase over time. However, the increase is not too great and it was decided therefore to consider the angler visit (i.e. one visit by one angler to the loch) as the unit of effort. This allowed considerably more data to be included in the analysis.

Variation in Length of Visit over the Season

Time Periods (see Appendix 13)	$\bar{X}$	N	SE
1 + 2	1.88	12	0.27
3 + 4	2.00	17	0.20
5 + 6	2.74	25	0.29
7 + 8	2.62	30	0.24
9 + 10	2.82	25	0.28
TOTAL	2.49	109	0.13

APPENDIX 12

Loch Walton Catch Statistics, 1975

Time Period	Population of Fish Remaining	Catch	Catch as a % of Population Available	Cumulative catch	Catch per Unit Effort	No. of Rods
15-28 March	1350	26	1.9	26	2.17	12
29-11 April	1324	49	3.7	75	1.23	40
12-25 April	1275	93	7.3	168	1.58	59
26- 9 May	1182	75	6.4	243	2.21	34
10-23 May	1107	101	9.1	344	2.30	44
24- 6 June	1006	122	12.1	466	2.35	52
7-20 June	884	88	10.0	554	2.10	42
21- 4 July	800	63	7.9	617	1.26	50
5-18 July	737	32	4.3	649	0.8	40
19- 1 August	705	53	7.5	702	1.29	41
2-15 August	684	21	3.1	723	0.60	35
16-29 August	663	37	5.6	760	0.90	41
30-11 September	626	20	3.2	780	0.60	35
12-25 September	606	19	3.1	799	0.48	40
26- 5 October	587	25	4.3	824	0.93	27

APPENDIX 13

GROWTH OF FISH

It is possible to determine the growth of the fish during each year of its life. It has been shown that the growth of scales is related to the increase in body length in both salmon and trout and thus, from the measurement of the width of the summer and winter zone for each year it is possible to assess the length of a trout at the end of each year of its life. The standard method for comparing the growth rate of trout from different waters and within a water involves the use of these back calculations of length. The method rather than comparing the increase in length of a fish in a year as a percentage of its length at the start of that year, considers the incremental growth rate. It is therefore as Frost and Brown describe it a compound interest rather than a simple interest technique. While this is a most useful technique for comparing and assessing growth rates it is also technically quite difficult and it is not a technique generally used by fisheries.

An easier calculation, which is of considerable use to the fishery, is the assessment of the condition factor. This method relies upon the theory that there is a constant length-weight relationship for fish, this relationship being described by the formula

$$\frac{\text{wt. in g}}{(\text{l.in cm})^3} = 0.01$$

The condition factor K is derived from this where

$$K = \frac{\text{wt. in g}}{(\text{l.in cm})^3} \times 100 = 1$$

APPENDIX 14

Comparative Costs of Home-Grown and Commercially Reared Trout at Loch Walton

	Home-Grown £'s	Commercial £'s
Year 1	1005	420
Years 2 - n	314	420

APPENDIX 15

Calculation of Yields from Various Outcomes from an Investment in a 100 acre Fishery

Cash Flows from the Six Possible Outcomes

Outcome	Year	Cash Out £'s	Cash In £'s	Cash Flow £'s
1	1	19,000	-	-19,000
	2-n	7,000	13,000	+ 6,000
2	1	19,000	-	-19,000
	2-n	7,000	12,000	+ 5,000
3	1	19,000		-19,000
	2-n		11,000	+ 4,000
4	1	19,000	-	-19,000
	2-n	8,400	13,000	+ 4,600
5	1	19,000	-	-19,000
	2-n	8,400	12,000	+ 3,600
6	1	19,000	-	-19,000
	2-n	8,400	11,000	+ 2,600