FISH AS BIOMONITORS - AN INTEGRATED PERSPECTIVE.

Thesis presented in partial fulfilment of the requirements for the degree of
Master of Science (Environmental Protection)

by

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Abstract

There is a perception in some quarters that because there has been a reduction in fish kills in Ireland in recent years that the fishery resource is no longer under threat to the same degree as heretofore. This is not necessarily the case as this study demonstrates that fish kills are merely one indicator of many by which fish respond to deteriorating water quality. Effects of pollution on fish can be measured at different levels of biological organisation - at the cellular level, the organ level, the individual level, the population level or the community level. Effects can range from fish kills, changes in fish density or species composition, or increasing incidence of water quality related diseases. This study reviews and examines the potential for an improved role for the use of fish as biological indicators of the aquatic environment. In recent times, the most important advances have been made in computer software development and increasingly modules are becoming available which relate to resource and environmental management. The use of models is explored. A G.I.S based approach for the implementation of an integrated data collection, assessment, reporting and classification system suitable for use under Irish conditions is recommended. The ultimate aim should be to develop an improved fisheries environmental information system. The need is to identify and record existing data sets but also to incorporate newer technological advances into meaningful formats. These could then be correlated with water quality trends over time. The potential range of data sets are so varied that any new system should allow for the input of a large number of varied spatial and non spatial information, which should be linkable to related database information and be such that it can be integrated into a geographic information system. Fortunately, the G.I.S approach allows for this in so far as the basic environmental module can be expanded upon by the user depending on the nature of the databases under examination. It would also facilitate a uniform and integrated approach in which fish by virtue of their absence, presence, relative abundance, health status etc. would reflect prevailing environmental conditions in a manner that was not possible heretofore.

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Chapter 1.0: Introduction.

1.1 Background and Objectives.

The nations fisheries are a valuable and sustainable natural resource which is being increasingly valued by the public. Exploitation of the resource make a significant contribution to G.N.P and it is widely recognized that it is a sector with considerable scope for further development (Dept. of the Marine, 1987, Central Fisheries Board, 1991). The recent announcement of £19 M in structural funding under the "Operational Programme for Tourism 1994 - 1999" is designed to further develop the resource and thereby boost angling tourism. Thus the fishery authorities view seriously anything which adversly affects the resource.

In recent years, public concerns about water pollution and implications for fish stocks is a regular news item. Headlines such as, "Tide of pollution drives anglers from Ireland's lakes" are damaging the image of Irish angling (Sunday Times, April 30th, 1995). There is an onus on the statutory bodies responsible to ensure that corrective measures are taken but the fishery authorities should document the effects of pollution on fish stocks in the first instance.

During the last twenty years, many schemes have been devised using invertebrates, plants and algae as biomonitors. These schemes are an efficient way in which to assess water quality. However, the inferred relationship between these biomonitors and the reactions of fish are sometimes based on assumptions which have not always been fully evaluated in the field. Despite their widespread distribution, their economic value, and their key position in the food chain, fish have not been used widely as indicators of water quality. Indeed Geraghty, (1987) criticised existing indices, stating that "while these indices may be valid within their own terms of reference, they will not, except in extreme cases, pinpoint rivers which are denuded of fish stocks." The "Precautionary Principle" has increasingly been advocated in recent years but it is clear that it should not be used so as to weaken the need for the best scientific advice which is an essential part of the Precautionary Approach. (N.A.S.C.0, 1994)

The aim of this study therefore, is to examine and explore the potential for use of fish as indicators and to suggest possible approaches by which a system could be established under conditions prevailing in Ireland.

All forms of life including fish are intimately interlinked with their environment. Hodson, (1990) stated that,

> "......*aquatic biota integrate spatial and temporal variations in exposure to many simultaneous stressors. Top predators typical of specific ecosystems indicate whether environmental criteria have been met. Generally, the presence of naturally reproducing, self sustaining and reproductive stocks of edible fish demonstrates a high quality environment. If these conditions are not met there is clear sign of environmental degradation.*"

In the international context, the development of new approaches in relation the use of fish as biological indictors of freshwater quality is developing apace (Muller and Lloyd, 1994).

Fish communities in inland waters react to exploitation patterns and environmental stresses in ways which can be assessed scientifically. In the 1960`s and 70`s, thinking was influenced by the by the publications of the European Inland Fisheries Advisory Committee.

This was reflected in the E.U. Dangerous substances Directive which contains a list of 132 chemicals with set standards to protect all uses including fish life. The E.U. Freshwater Fish Directive was also largely based on critical reviews made by E.I.F.A.C but "*after an encouraging start appears to have faded into oblivion in several member states*" (Lloyd, 1992).

The 1980`s was marked by a number of significant publications which described both acute and chronic effects of toxicants on fish (E.I.F.A.C Technical Papers 24 and 43).

For the purposes of the proposed E.U Directive on the Ecological quality of water, (COM (93) 680 - 15/08/1994) "ecological quality of water is an overall expression of the structure and function of the biological community taking into account natural physiographic, geographical and climatic factors as well as physical and chemical conditions, including resulting from human activities."

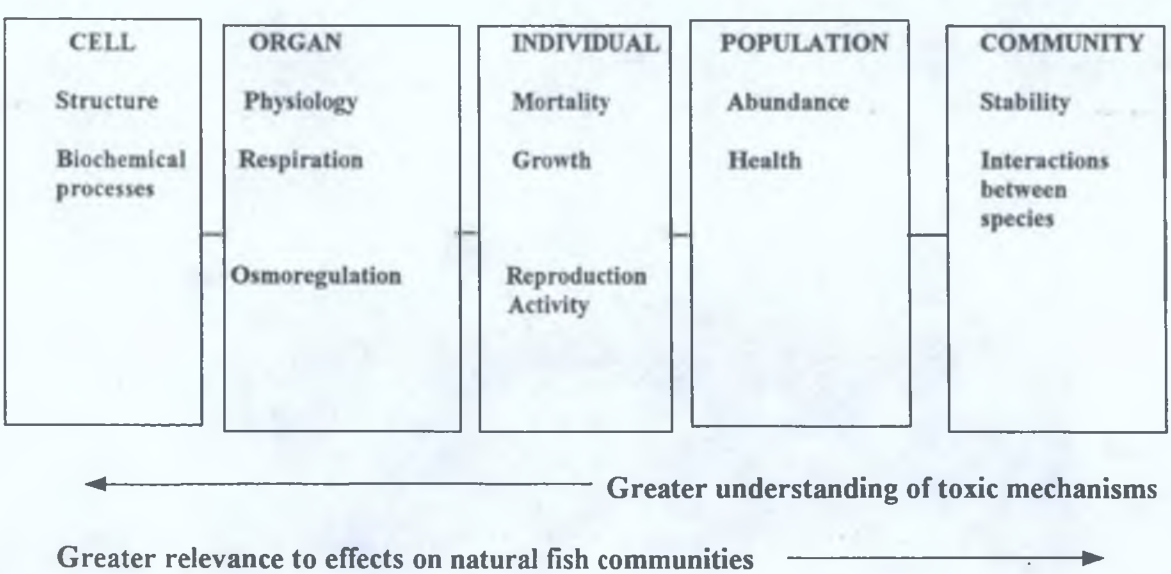
"Good ecological water quality is the quality inherent in a given ecosystem which is demonstrated not to be significantly affected by human activities. " Inherent in the Directive is the concept that natural resources are properly managed. This suggests not only an understanding of the basic ecology of species but also the application of modern management practices.

Muller and Lloyd, (*op.cit*) argued that the effects of pollution on fish can be measured at different levels of biological organization, for example at the,

- *cellular level (changes in cell structure,enzyme induction, immunology),*
- *organ (physiology, respiration, osmoregulation),*
- *individual (mortality, scope for growth, activity, reproduction)*
- *population (growth rate, reproduction) and*
- *community (species interaction).*

Lloyd, (1992) attempted to summarize the interactions as set out in Fig. 1.

Fig. 1: Processes that can be affected by chemicals at different levels of biological organization (*Lloyd, 1992 as modified from Haux and Forlin 1988*).



The challenge therefore is to devise a system which recognizes the significance of the above hierarchical approach but is practicable in both a resource management and environmental context. Any such system would have to be tailored towards the specific conditions prevailing in Ireland, but should be guided by best practices internationally. Such a system if properly devised would constitute a strategically important step by the Irish Authorities.

1.2 Normal fish populations.

Under normal circumstances, most studies demonstrate that water quality is not the sole determining factor with regard to the presence or absence of indigenous fish populations in a particular water body.

However, as different fish species have different water quality requirements, it follows that changes in water quality can impact on fish populations. For example, Tonn and Magnuson ,(1992) suggested that habitat, complexity factors, and particularly vegetation diversity were significantly correlated with summer species richness of fish assemblages in Wisconsin lakes and described certain assemblages to be in ecological equilibrium.

Mann, (1989) reported that numbers of *Salmo trutta* in an English chalk stream were limited initially by availability of gravel spawning areas and then by areas suitable for newly emerged fry. They stated that a reduction in stream discharge in the spring can lower the number of 0+ *salmo trutta* that survive.

Kozel *et al.*, (1989) found that there were significant differences in habitat features and standing stocks of trout >100 mm between two classes of channel gradient (low 0.1 - 1.4% channel slope) and moderate (1.5 - 4.0%) and determined statistical relationships between habitat features and trout standing stocks in each class of channel for unaltered streams.

Philippart, (1989) in a study of the River Meuse, Belgium found that the composition of riverine fish communities and the quantitative characteristics of the specific populations are mostly determined by abiotic ecological factors linked with river morphology (shape, flow, velocity) and climate (water temperature, discharge regime and water chemistry).

Bond *et al.*, (1988) in a study of 25 common species of Oregon freshwater fishes found that statistically significant habitat use patterns appear for 17 of the species for temperature, 17 for substrate, 19 for stream width and 22 for current velocity.

Thus, because of the often diverse factors influencing fish populations, it is not surprising that indices which use fish have been slow to emerge. In section 4 of this thesis, an approach is illustrated which attempts to incorporate the aforementioned fish and habitat factors into an index which may be applicable under Irish conditions.

1.3 Fish as biological indicators.

Moriarty, (1991) pointed out that to monitor for effects of pollution has two aspects; the ability to detect changes, and the ability to ascribe causes to those observed changes. He argued that the effects of pollutants on species of wildlife needs to be considered in ecological terms, of population dynamics and genetics. Baseline electrophoretic patterns of fish within each catchment would be required if this approach was adopted. There are many factors which influence population size not least of which is the impact of pollutants. Populations and communities do change from to time, and it is usually difficult to discover the causes of these changes. It is because of these difficulties that base line data is frequently urged. If an index or measure of a population or community is taken for a long period of time, before the risk of impacts from pollutants it should then be less difficult to interpret changes that occur when pollutants may be having an effect.

This supports the need for a data base of all fish population assessments whether the are undertaken as part of a synoptic survey or as a comparative evaluation.

At best one acquires correlative data where changes in the chosen area of biological performance correspond to changes in the measure of contamination.

During recent decades, there have been several schemes proposed whereby stretches of river could be ranked based on a key parameters reflecting the extent to which water is polluted or contaminated. These parameters can be biological or chemical (National Water Council scheme., UK) or a combination of the two. In the early 1960s a map was produced showing fishless rivers in England and Wales but the exercise was not repeated (Lloyd, 1992).

Monitoring methodologies are well developed and in addition fish are easily recognizable.

Laboratory or field based monitoring for effects has two specific aspects; the ability to detect changes, and the ability to ascribe causes to those observed changes.

Historically, fish have not been extensively used for a number of reasons, some of which are set out in Fig. 2.

Fig. 2: Advantages and disadvantages of using fish as indicators.

Advantages	Disadvantages
Integrate response	Mobility/avoidance
Easily identified	Sampling difficulties.
Sensitive to pollution	Easily damaged or killed.
Long life cycle	Natural fluctuations
Trophic level	Communities not always diverse
Suitable size for chemical analysis	Response more general than localised
Monitored anyway	Costly

Sampling methodologies for fish tend to be more complex and time consuming than for invertebrate which are more commonly used as biological indicators. Different sampling strategies are required in rivers and freshwater lakes and for migratory and non migratory species. Studies of fish stocks can be targeted towards the estimation of absolute abundance, indices of abundance, or multispecies sampling (E.I.FAC/T33,1980).

1.3.1 As indicators of deoxygenation.

The response of fish and fish population to deoxygenation is well documented. (EIFAC Salmonids in particular are extremely sensitive to depleted dissolved oxygen levels and are particularly susceptible to low oxygen levels in organically polluted waters. Fish kills are an extreme manifestation of low dissolved oxygen levels. Thus the monitoring of the spatial and temporal distribution of salmonids is likely to be a fruitful approach. Under unfavorable environmental conditions, encroachment by cyprinid species is a likely scenario which merits systematic surveillance.

1.3.2 As indicators of eutrophication.

Nutrients are rarely a lethal factor in themselves in natural systems - their lethality being executed by depressed dissolved oxygen which sometimes reaches anoxic levels especially under hypereutrophic conditions. Total fish biomass is low in oligotrophic lakes, increases toa maximum in meso - eutrophic lakes, and fluctuates around the maximum value in hypereutrophic lakes Total fish density, likewise is low in oligotrophic lakes and increases to a maximum in mesotrophic - eutrophic lakes; but unlike biomass, fish density declines as lakes becomes hypereutrophic (Kautz, 1980).

Jones and Lee, (1986) demonstrated a link between, normalized phosphorus levels and fish yield. The review which examined lakes of varying trophic status worldwide predicted fish yields of between 0.02 g - 5.0g wet weight/m^2/year for lakes with normalized phosphorus loading varying from 2 - 2,000 mg P/m^3. However, the difficulty arises in apportioning the predicted or actual fish yield between game species and coarse fish species which would be variable for each lake. Nevertheless, the literature suggests that the recording of fish population trends and biomass are sensitive to changes in trophic status. In the Irish context, much data was collected as part of the predator control programme but was never fully correlated with water quality.

1.3.3 As indicators of acidification.

There are numerous studies which illustrate the damaging effect of acidification of acidification on freshwater fisheries . These effects range from, firstly to a reduction in fish densities, Lacroix, (1987), Rossiland, (1990); secondly to senescence with partial or complete recruitment failure coupled with a preponderance of large, old fish and juvenilization associated with increased post spawning mortality (Bravington *et al.*, 1990) Hesthagen *et al.*, (1991) stated that in Norway S*almo salar* have been virtually lost in 25 rivers due to acidification and estimated the total annual number of salmon lost to be between 92,016 and 306,720 individuals weighing some 345 - 1150 tonnes.

Norrgren *et al,* (1993) reported that hatching frequency was low in acidic aluminum rich rivers and whole body concentration of potassium and sodium decreased as early as after 13 days of exposure. Similar reports have been documented in Scotland (Harriman and Morrison, 1982) and in Wales (Stoner and Gee, 1985). Laitinen *et al.*, (1994) also concluded that the main impact of acidification is on reproduction which can be exerted at various stages of the life cycle from reduction ingamete production and quality to mortality of the developing eggs and alevins, the nature of the changes varying with the developmental stages of fish. The study displayed the protective effects of calcium and magnesium. All of these studies once again point to the need for regular monitoring of fish populations with particular emphasis on studies of ova survival, fish density and population structure. The Norwegian work suggests the need for establishing a database of fishless waters or waters where salmonid populations have declined or collapsed. Alistair, (1993) stated that current UK thinking centered on the critical loads concept described as the pollutant combination causing the highest deposition load that the environment can withstand without long term damage occurring. This approach suggests the need for catchment sensitivity maps for those particular fisheries at risk.

1.3.4 As indicators of habitat degradation.

Hynes, (1975) recognized that features of watersheds such as geology, soils and vegetation could have influences on the physico- chemistry and ecology of streams and rivers which drained them. Rinne *et al.,* (1988) in a stepwise regression analysis of fish populations in six headwater streams in Arizona, suggested that livestock grazing was a significant contributor to increased substrate fines and reduced fish populations in several of the streams.

Peat exploitation, open cast mining, land reclamation, quarrying and gravel extraction are all likely to impact on fish populations. Most of these activities release sediments, which in addition to altering breathing mechanisms of fish are liable to cause lesions which constitute a channel of penetration for pathogenic agents (Rivier *et al*., 1990).

Land use maps for river catchments are an essential aid in assessing impacts of this nature. Where key spawning and nursery areas are adversely affected the consequences for the entire fishery can be serious and the effects are best documented by monitoring salmonid ova to parr stages.

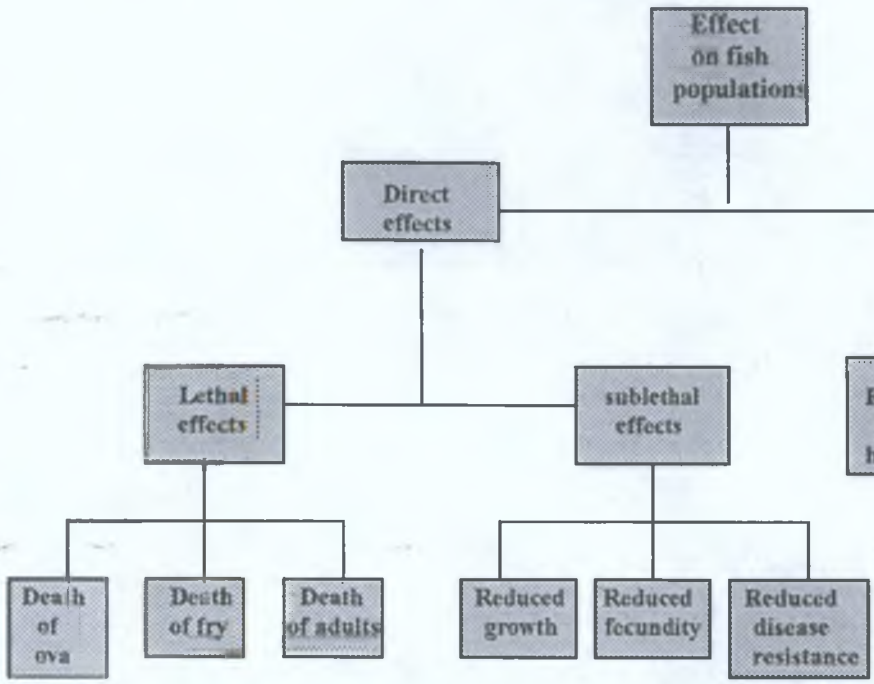
1.3.5 As indicators of toxic contamination.

Woltering, (1984) reviewed a total of 173 tests including exposure to metals, pesticides and other xenobiotics. The data which was summarized for 24 species of fish, (12 warm - water, nine coldwater and three marine species) according to the most sensitive response. In these tests, fry survival gave the most sensitive response, a reduction in survival being significant in 57% of the tests. Fry growth was reduced in 36% and hatching success in 19%.

Physiochemical analytical methods can never detect and identify all the polluting loads that occur in the environment so that bioassays, growth rates, reproduction, induction of enzymatic systems or physiological alterations and changes in behavior are required for monitoring of dangerous substances in effluent and waterways.

An example of how elevated ammonium levels can impact on fish populations is illustrated.

Fig. 3: Classification of possible effects of ammonium on fish.



Source: Wishart et al (1990).

As many pollutants affect fish either directly or indirectly as illustrated above, it is likely that a broadly based approach is likely to be most informative.

A number of studies illustrate the use of fish for monitoring radioactivity levels. Hakanson *et al.*, (1992) reported on radioactive cesium in trout and pike in Swedish lakes citing radioactive fallout and lake water retention as the factors influencing variability.

Elliot *et al.*, (1992) also studied cesium in brown trout and perch from Devoke water and Loweswater England and reported that ecological half lives for Cs-137 varied, the variation being explained by different metabolic rates for different species and differences between the lakes due to variations in their limnology and the nature of their catchments.

Continuous automated fish biomonitoring systems are being used for industrial effluent control and monitoring water quality. These systems utilize the fact that fish opercular rhythms increase under toxic conditions. Any increase which is above normal is monitored electronically by processing the signal which arises as a result of a change in potential between stainless steel electrodes. The change in potential is caused by ventilatory movements and locomotory activity and is usually monitored by means of ultrasonic echoes. (Morgan, 1994). The system described which was capable of responding to toxic concentrations from 5 - 10% of the 48 hr lethal limit forthe fish species tested. These studies suggest that there is greater scope for the use of fish in innumerable circumstances where the priority might range from the need to protect public health to monitoring purified wastewater's before release into the aquatic environment or simply as a monitoring technique for assessment of natural waters.

Different fish species respond differently in their ability to accumulate and metabolize various toxic substances. The problems of toxicants such as PCBs in fish is important both for their survival and for hygienic requirements for edible flesh. Svobodova *et al.*, (1994) reported that fish with a high lipid content were found to be the most important indictors of environmental contamination by PCBs.

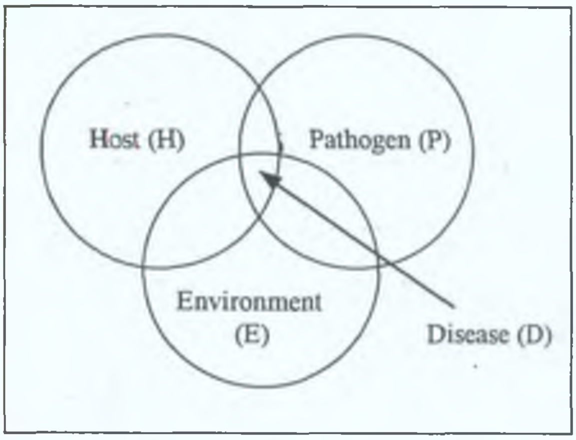
However before embarking on a contaminant biomonitoring programme utilizing fish, caution is advised. In this regard the National Contaminant Biomonitoring Program undertaken in the U.S by the Fish and Wildlife Service demonstrated that there was no significant upward or downward trend between collection periods for lead, mercury, cadmium, arsenic, selenium, copper and zinc (Lowe *et al.*, 1994).

Top predators such as pike are clearly good bioindicators because of their position in the food chain.

1.3.6 Fish populations and disease.

Poleksic *et al.*, (1992) demonstrated that in a degraded aquatic environment where pollutants occur at chronic and sublethal concentrations, changes in structure and function of aquatic organisms occur more frequently than their mass mortality. Water quality, if allowed to deteriorate can cause sub- lethal stress which can be manifested by outbreaks of disease or increased parasitic burdens. The interrelationship between fish, their pathogens and environmental factors is summarized in Fig 4. Environmental factors in this context are all embracing and includes biotic and abiotic factors and perturbations which exert a sub lethal or other deleterious effect on the well being of fish communities.

Fig. 4: Interactions between host, pathogen and environment.



Equation: H + P + E = D

(The importance of E increases markedly with reduced water quality)

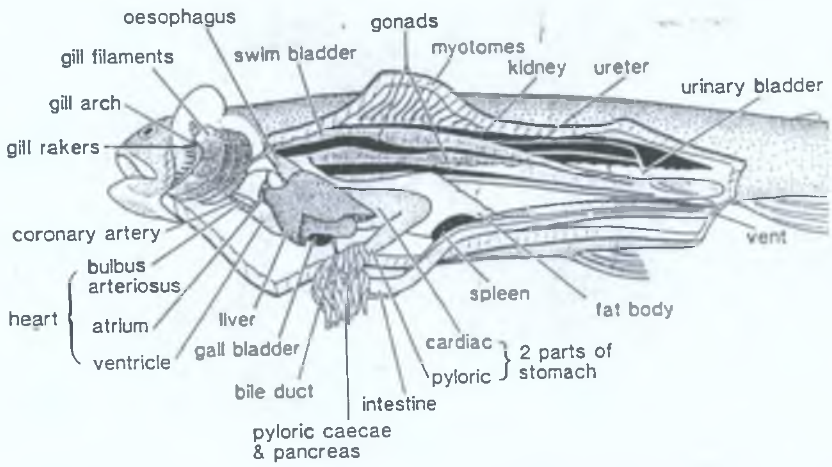
Source: Water Quality and fish health, 1993
E.I.F.A.C Technical Paper 54.

In an unpolluted environment there is a natural balance between H, P and E. A reduction in the quality of E will lead to a marked increase in the frequency and severity of D mainly by reducing resistance to disease.

This model suggest that certain diseases should also be monitored if fish are to be fully utilized as water quality indicators. The question arises as to whither there is an overlap between reported outbreaks of disease and deteriorating water quality.

From an anatomical examination of fish, it is clear that the target organ can vary depending on the type of pollutant and mode of action (Fig.5). Pollutants can effect the skins protective mucous layer, or they may affect internal organs such as the kidney, the liver or other organ.

Fig. 5: Anatomy of a typical salmonid fish.



Source: Roberts, R.J Shepherd, C.J (1990) Handbook of Trout and Salmon Diseases.

For example, in a degraded environment, gills are a well known target organs in fish. Poleksic *et al* ., (1994) identified first, second and third stage changes in gill tissue stating where only first stage changes are recorded, that normal morphological structure can be restored after an improvement in environmental conditions. The gill tissue plays a key role in the osmoregulatory processes which facilitate parr to smolt transition. In the Irish context, in relation to sea trout, it has been demonstrated that the ability to osmoregulate varies according to size, small smolts being more susceptible to mortality in sea water challenge tests. The results also confirmed that the ability to osmoregulate did not vary according to the place of origin (Fishery leaflet 158 , 1994).

Generally, when fish moralities occur, gill lamellae should be examined under objectives from 10 to 100x for lesions, cysts, swellings, clubbing, excess mucous, protozoa, monogenea, and other organisms.

Boelens, (1991) described a range of hematological measurements including haemocrit values, leucocyte counts, cortisol and serum glucose levels which are important for evaluating physiological stress in fish. Blood parameters, he stated, tend to exhibit rather wide variation even under clean water conditions but changes in replicate groups of fish from the same population, in response to toxicant exposure can usually be determined with reasonable accuracy provided the sample size is sufficiently large.

Boelens, (*op.cit*) recommended the use of the liver somatic index as described by Heidinger and Crawford, (1977). The index expresses the liver weight of fish as a percentage of total body weight . However, in the Irish context, there are no known studies of correlation between water quality, fish kills and outbreaks of disease. Information on diseases is recorded by the fish pathology section of the Department of the Marine and attempts are now being made to establish a disease database. For example, from 183 cases attended to in 1993, only 18% concerned wild fish Scullion, 1994). Thus in the context of fish as biomonitors, the existing database in relation to disease in wild fish populations is clearly inadequate.

Chapter 2: The situation in Ireland.

2.1 Irelands freshwater fish fauna.

Fish populations tend to fluctuate but are often described as being in a dynamic ecological equilibrium (Cotton. D, pers. comm.). For example, after a fish kill, a reduction in population occurs a new equilibrium is reached. As our understanding of the ecological requirements of fish increases, it should be possible, based on an understanding of ecological factors to predict what fish population would be expected to be present in any given set of circumstances.

Courtney, (1982) stated that Ireland appears to have had eight species of native fish at the end of the last glacial age but now hosts at least twenty species of freshwater fish. More recently, Irelands fish fauna has been described as somewhat impoverished with just 26 freshwater fish species compared with 55 for Britain and 215 for Europe (Whilde, 1993).

Documented introductions are those of *Oncorhynchus mykiss, Cyprinus carpio, Leuciscus leuciscus, Rutilis rutilis* and *Tinca tinca.* Of the documented and undocumented introductions, *Oncorhynchus mykiss, Esox lucius, Cyprinus carpio, Leuciscus leuciscus, Rutilus rutilus* and *Tinca tinca* have established with *Oncorhynchus mykiss* and *Cyprinus carpio* having restricted reproducing populations. Courtney concluded that these introductions were generally viewed as positive but that *Esox lucius* have adversely impacted *Salmo trutta*, *Leuciscus leuciscus* and *Rutilis rutilis* have caused a decline in salmonid production in one location and have also been implicated in the displacement of *Salmo trutta*. For example, *Esox lucius* became established in Ireland in the 13th - 14 th century whereas *Rutilis rutilis* were introduced from Britain in 1889 and have only become widespread since the 1960s (F.A.O., Technical report T213, 1981).

However, this does not present a problem although variations in fish assemblages between different regions and different countries does present problems of comparability. The total list is given in appendix 6.1.

2.2 Irish Fishery classification schemes.

There is no formalized scientifically derived fishery classification scheme in use in Ireland. Existing classification schemes categorize different waters into different categories based on a scientific consensus approach. In this way the various classification schemes which all use the predominant fish species approach. By reference to the known sensitivity of various fish species, a specific water quality status is inferred. Waters are in accordance with,

- The Fisheries Acts.
- The E.U. Freshwater Fish Directive.
- The Bord Failte Brand Marketing scheme.
- Central Fisheries Board list of Waters and regulations.
- N.A.S.C.0 scheme.

2.2.1 The Fisheries Acts.

The Fisheries Consolidation Act, 1959 does not provide for a classification of rivers but there are legal definitions within the Act by which a river can be categorized. For example the expression "salmon river" means "*any river frequented by salmon.*" Coarse fish are defined by The Fisheries Act 1980 as "*any freshwater fish or the spawn or fry thereof other than salmon, trout, rainbow trout, charr or eels or their spawn or fry.*" It is notable that both S*alvelinus alpinus* (charr) and *(Salmo trutta L.)* sea trout were not defined in the main Act but the legal definition of salmon was usually interpreted as including sea trout. The situation was clarified by the introduction of the sea trout conservation bye laws (reference no. 175 of 1992, 684 of 1993, 196 of 1993, and 683 of 1993) which define sea trout as "the migratory form of the species *Salmo trutta trutta*".

Thus it is a reasonable assumption that rivers containing significant stocks of sea trout can be classified as sea trout rivers and any evidence of any departure from this classification would require an explanation.

2.2.2 The E.U. Freshwater Directive.

The E.U. Freshwater Fish Directive 78/659/EEC of 18 July 1978 as transposed into Irish law by S.I. 293, the European Communities (Quality of Salmonid Waters) Regulations, 1988 provides for the designation of specified waters - 15 in total as either salmonid or cyprinid waters by reference to a range of water quality standards.

Fig. 6: List of waters designated as salmonid waters.

1. Aherlow	18. Moy plus following tributaries
2. Arigdeen	Owengarve
3. Blackwater	Mullaghanoe
4. Boyne	Spaddagh
5. Bride	Trimogue
6. Flesk	Glore
7. Corrib include L.Corrib	Yellow
8. Dargle	Gweestion
9. Feale	Manulla
10. Fergus	Castlebar
11. Finn	Deel
12. Glashagh	Corroy
13. Lee	
14. Leannan	19. Nore
15. Lurgy	20. Slaney
16. Maggisburn	21. Swilly
17. Maine	22. Vartry

The main benefit of the regulations are that the listed waters are routinely monitored. The designations were made due to the presence of self sustaining salmonid populations coupled with acceptable water quality. It is proposed by the E.U that the Directive will be revoked by the proposed Directive on the Ecological Quality of Water.

2.2.3 Bord Failte Brand Marketing scheme.

Bord Failte in association with the Fisheries Boards operate a fishery branding scheme which is used primarily for marketing and promotional purposes (Geraghty, 1992).

Fish stocks are required to meet a certain standard as regards quality and quantity. Also the fishery has to be managed in a proper manner and to a certain level. A fishery could lose its branding if environmental or water quality was unsatisfactory, although no specific criteria is stipulated. The list of branded salmon and coarse angling fisheries is set out in appendix 6.6.

2.2.4 Angling guides.

These are simply angling guide and booklets issued by the Fishery Boards and Bord Failte describing the waters, the quality of angling and the fish species present. Particularly useful publications which include generalised distribution maps of different fish species include as follows,

- Angling in Ireland, Only the Best - Bream, Rudd, Tench, Roach, Hybrids, Pike, Perch and Dace.
- Angling in Ireland, Only the Best - Salmon, Sea Trout, Brown Trout.
- Ireland for Angling - A Central Fisheries Board Guide.

Using these guides, it is possible to discern the predominant fish populations in the various river and lake catchments throughout the country. However, in the context of this dissertation, the maps lack the detail required for spatial and temporal comparisons to be made.

2.2.5 N.A.S.C.0., scheme.

Ireland are also cooperating with N.A.S.C.O., the North Atlantic Salmon Conservation Organization. However, Irish rivers are only now in the process of being categorized in the context of this scheme (Maoileidaigh, pers. comm.). N.A.S.C.0., (1994) operate an international database for classification of salmon rivers as follows.

Category 1 - Lost: Rivers in which there is no natural or maintained stock of salmon but which are known to have contained salmon in the past.

Category 2 - Maintained: Rivers in which there is no natural stock of salmon, which are known to have contained salmon in the past, but in which a salmon stock is now only maintained through human intervention.

Category 3 - Restored: Rivers in which the natural stock of salmon is known to have been lost in the past but in which there is now a self sustaining stock of salmon as a result of restoration efforts or natural recolonization.

Category 4 - Threatened with loss: Rivers in which there is a threat to the natural stock of salmon which would lead to the loss of the stock unless the factor(s) causing the threat(s) is (are) removed.

Category 5 - Not threatened with loss: Rivers in which the natural salmon stocks are not considered to be threatened with loss (as defined in category 4)

The proportion of Irish rivers in each category once it is compiled will of interest in the context of the approach being suggested in this study. The relatively favorable geographical of Ireland compared with Norwegian countries should be reflected in such classification schemes.

Irish fisheries legislation provides a framework for the various authorities and agencies to gather statistics, many of which are of relevance in an environmental context. For example, drift net application forms set out details of income generated from salmon fishing for the preceding year and may if analyzed provide a barometer of stock levels.

2.3 Relevant studies of fish populations in Ireland.

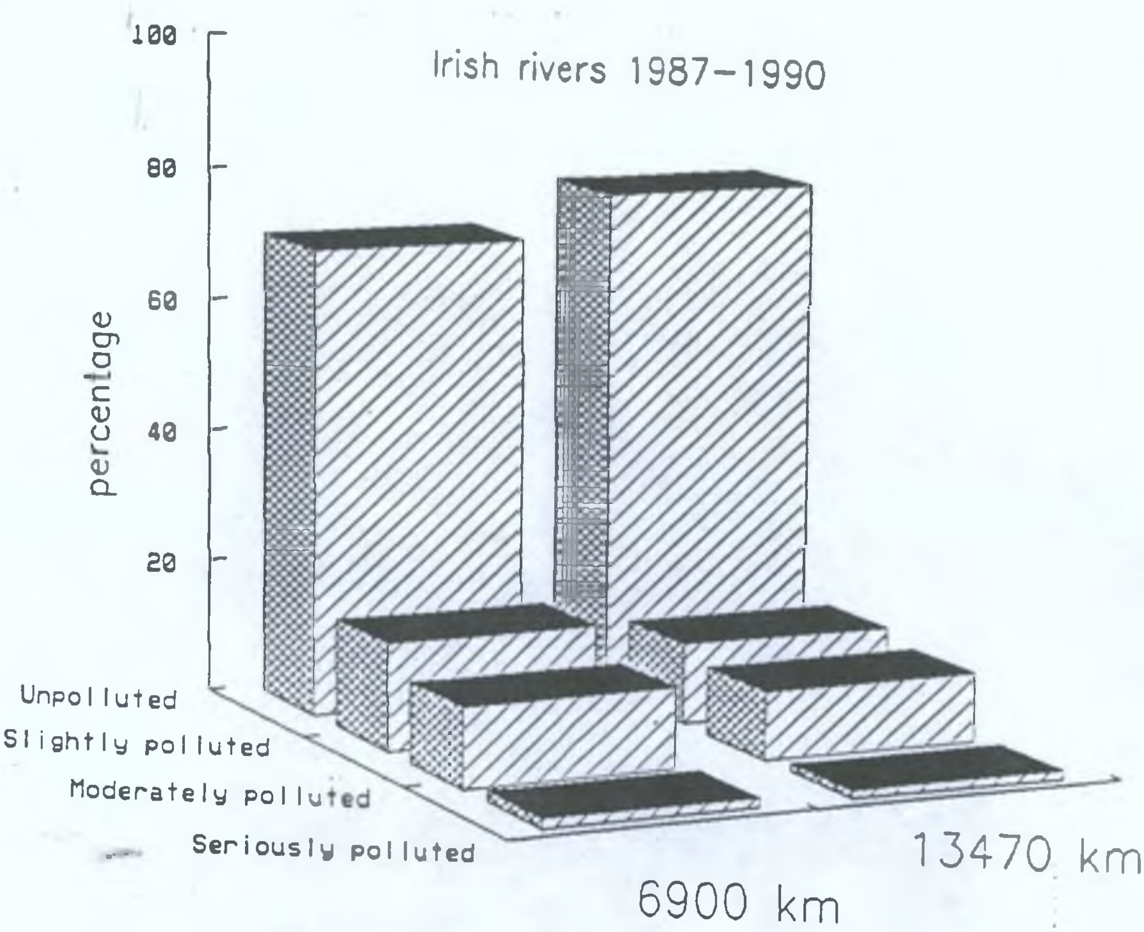
The basic ecology of most Irish freshwater fish species is now well known. Much scientific information has been collected on all aspects of the life cycles of the different species of freshwater fish in Irish waters in particular in respect of the economically important species. Factors such as non availability of spawning grounds or excessive predation may account for the absence of salmonid species (C.F.B position paper No.74). This suggests the need for habitat maps.

O Grady, (1981) suggested that morphometric features may account for the large trout carrying capacity of L. Sheelin (30.6 - 18.5 kg/ha). Bracken and O Grady, (1991) in a comprehensive review of freshwater fisheries research in Ireland from 1950 to the present day, pointed out the need for stock assessment, habitat management, the creation of index rivers, and the control of environmental and pollution problems. Maitland, (1972) published a series of maps depicting the distribution of 30 freshwater species of fish in Britain and Ireland. Since then, few distribution maps have been prepared with the exception of that of Quigley *et al*, (1984) who have updated Irish records in relation to *Salvelinus alpinus*. Fish distribution maps require regular updating using more detailed maps than used heretofore.

Mc Cumiskey *et al.*, (1992) stated that the main quality trend in Irish rivers over the last two decades has been the increasing incidence of eutrophication pointing out that "further intensification of the effect is likely to create unsuitable conditions for salmonid fish."

The trend towards increasing levels of moderate pollution is illustrated diagramatically. (See Fig. 7).

Fig. 7: Water Quality trends in Irish rivers



Source: EPA 1992

Therefore, the onus now rests with the fisheries agencies to document these impacts in terms of the actual effects on the fishery resource but as this study indicates, this can only be achieved by the adoption of modern mapping and information systems. The widely acclaimed video "While Fishes Watch The Water" had as its central theme the concept that fish by their presence were the unpaid guardians of water quality (C.F.B.,1980). Thus, a scientifically derived system making effective use of fish as biomonitors is what is now required. If this is to be achieved, greater attention to data collection and collation is required.

2.3.1 Key fish species.

As it is not feasible to monitor all 26 species of freshwater fish in Ireland, key species should be targeted. The position is that sensitive fish species such as salmonids are widespread and are particularly sensitive to dissolved oxygen depletion. It is largely for this reason that they frequently feature in fish kill statistics (Moriarty 1992).

2.3.1.1 *Salmo trutta.*

Salmo trutta as a salmonid species is particularly responsive as a water quality indicator as is evident from fish kill data. Its main advantage as an indicator is that it is largely non migratory although it displays avoidance reactions to pollutants. Important indicators of brown trout populations include,

⇒ distribution patterns.
⇒ population densities, structure.
⇒ morphometric characteristics.
⇒ angling catches and in particular catch per unit of effort.

In the Irish context, *salmo trutta* is probably the most suitable indicator as they are both sensitive to pollution and are widely distributed. Stream fish densities are normally assessed using a portable cybertronic electrofisher with a 12 volt battery source.

For example, a report on fish stocks in the Owenmore catchment, Connemara categorized *Salmo trutta* populations into 5 categories with the following results as shown in Fig . 8.

Fig. 8: Densities of *Salmo trutta* and *Salmo salar* in the Owenmore catchment.

Fish densities (No/m^2)					
	0.00	>0.01 - 0.04	>0.04 - 0.07	>0.07 - 0.1	>0.1
	Sites	Sites	Sites	Sites	Sites
Trout(>0$^+$)	16	17	4	5	3
Trout fry	4	27	7	5	2
Salmon fry	12	13	11	1	8
Salmon parr	11	7	4	10	6
Sub total Sites	43	64	26	21	19

Source C.F.B., 1995

The data clearly demonstrates the need for further investigations of those sites which were fishless or which contained very low stock densities. In routine surveys of this nature, water quality would require more detailed consideration especially if both *Salmo Trutta* and *Salmo salar* were similarly absent. Thus, electrofishing a small number of sites in a catchment is of limited value.

Mixed salmonid fisheries are commonly encountered. Kennedy, (1985) following an intensive sampling programme on the River Bush found that the mean summer holding capacity to be 116 salmon fry (age 0+) 65.4 salmon parr age 1+ and older, 63.4 trout fry (0+), 27.5 yearling trout (age 1+) and 8.0 older trout per 100m^2 of good unpolluted nursery habitat in Northern Ireland`s streams.

O, Grady, (1986) stated that the fastest growing fish in many Irish lakes tend to be those fish that migrate from their spawning streams into the lakes at a young age whereas the slower growing fish remain in the streams for an additional, 2 or 3 years before migrating lakewards.

The Lough Conn study suggested that the average size of trout in the lake increased from 0.45 kg in the 1970s to 0.675 kg in recent years (*op. cit.*).

Brown trout (*Salmo trutta*) angling statistics for selected Irish lakes are set out in Fig. 9.

Fig. 9: Brown trout statistics for selected Irish lake system 1968

Irish lakes	Mean weight per fish(g)	Fish caught/angler visit
Arrow	453	1.1
Conn	453	1.8
Sheelin	1,041	1.8
Mask	498	1.9
Corrib	598	2.2
Carra	589	2.4

Source: Strategies for Management and Development - C.F.B., 1987.

It is notable that the mean weight for trout was heaviest in the most eutrophic lake, L. Sheelin but the abundance of fish of this weight declined subsequently. It is also notable that since the above table was published that the number of fish caught per angler visit per day has dropped to < 1.0 on the Western lakes.

Duggan and Champ, (1991) reported on the decline in trout in Lough Sheelin which they attributed to effects of cultural eutrophication.

Allot *et al*, (1993) based on a study of forested and non afforested sites in upland areas in Galway and Wicklow found that fish density was increased proportionally with minimum pH values and concluded that the relationship was probably a reflection of a higher density and diversity of invertebrate food and the generally more favorable living conditions for fish at sites with lower acidity levels.

The report of the Irish specimen fish committee details the results of specimen and record fish caught by fair angling methods. The fact that the heaviest specimens of *Esox lucius* and *Salmo trutta* usually come from either Lough Mask or Lough Corrib suggests that lake area rather than water quality is the determining factor. Thus comparative evaluations of lake size, water quality and frequency of records of specimen fish may be worth investigating.

Fahy (1984) demonstrated the differing condition factors applicable to sea trout from the Irish east cast and west coast.

Bolger and Connolly, (1988) reviewed the selection of condition factors and concluded that the choice of condition index should be based on an understanding of the underlying assumptions and after a detailed examination of the properties of the data set. This data can be supplemented by fish weight frequency distribution.

Changes in the relationship between fish fork length and number of eggs can be suggestive of a population under stress. Deviations from normal fecundity levels would merit further study. Shoesmith, (1990) compared four methods for the estimation of fish fecundity and recommended differing approaches for large and small samples in order to reduce bias.

Farrell *et al.*, (1983) described a non destructive technique for the removal of fish stomach contents for examination..Water quality influences dietary composition, fish foraging ability and behavior. Maoileidigh and Bracken, (1989) attributed the relatively high growth rates of tench in Ross bay, L. Leane to the prevailing eutrophic conditions.

Tully, (1991) used morphometric, hematological and plasma biochemistry techniques in order to identify the impact of sea lice infestations on salmon smolts. Thus, the continued development and adoption of protocols for the monitoring of fish stocks is required.

2.3.1.2 *Salmo salar.*

Reddin *et al.*, (1993) pointed out that for North American rivers, the minimum egg deposition rate is 2 - 4 eggs per m2 river salmon rearing habitat and suggested that the further the spawning escapement is below the target egg deposition and the longer this situation occurs the greater the possibility exists of incurring the following risks.

- accentuation of annual fluctuations in run size.
- increased susceptibility to extinction from genetic or environmental catastrophes.
- permanent change in demographic characteristics of the spawning population.
- possible replacement in the ecosystem by other competing fish species.

The Western Fisheries Region for example, accounted for only 3 - 8% of salmon taken by weight between 1961 and 1986 (Salmon Review Group Report, 1987)

Salmon can be either counted, trapped or routinely sampled at various stages throughout their life cycle. Browne *et al.*, (1985) in an attempt to model salmon stocks in the Corrib catchment reported poor correlation between juvenile salmon populations in streams and subsequent smolt migration.

While the presence of good stocks of salmon fry are indicative of good water quality, salmon are unreliable as indicators because of the complexity of the salmon life cycle and the differing patterns of exploitation. Estimated salmon densities for the Currane, Suir and Errif catchments are as follows.

Fig. 10: Estimated mean densities for juvenile salmon from selected Irish Rivers.

Location	No. of sites	Fry	Parr	Total
Inny	n = 16	0.295	0.084	0.378
Currane	n = 8	0.241	0.072	0.313
Glenna/Ray	n = 4	0.292	0.061	0.353
Errif	n = 10	0.309	0.171	0.480
Inagh	n = 3	0.245	0.128	0.373
Feale*	n = 33	0.153	0.065	0.218
*(*excluding main channel*)				

Source C.F.B., 1995

These densities represent typical values which can be use as a yardstick for comparison purposes. However, all such statistics should be held on a relational database, with each site accurately grid referenced for visualization using G.I.S.

For example, for the Burrishole fishery, the average rate of survival from the ova to the smolt stage averaged 0.61% for the period 1970 - 1984. Ova to smolt survival is the more relevant statistic in terms of water quality as it is influenced by variables in freshwater.

The use of an electronic nose tag at the based on the relationship between numbers of microtagged hatchery smolts migrating and subsequent return as grilse to Irish coastal waters Maoileidigh *et al*, (1994).

The electronic nose tag is also being used to evaluate returns from wild salmon stocks but to date no specific water quality related applications have been undertaken. Nevertheless, for the investigation of water quality impacts, it remains a very useful tool for monitoring survival rates of fish. (Browne,undated)

2.3.1.3 *Salvelinus alpinus.*

Whilde, (1993) classifies *Salvelinus alpinus* as "vulnerable and prone to the effects of pollution, eutrophication, climate change and possibly competition with and predation by native and introduced species." The arctic charr is non migratory fish that lives in deep, cool, infertile lakes. The distribution of *Salvelinus alpinus* in Irish lakes is shown in appendix 6.3.

A commentary prepared by the National Science Council in 1977 and quoted in a letter from DGX1 of the European Commission (complaint 4156/94) observed that, "the arctic Charr and brown trout are characteristic fish of the larger oligotrophic European lakes (Toivonen, 1992). Charr have similar oxygen requirements to trout but however are more sensitive to high temperatures. In exceptionally warm summers during extended periods of stratification Charr are particularly vulnerable in productive lakes due to reduced oxygen levels in the hypolimnion. *Salvelinus alpinus* were present in Lough Ennel and Lough Owel during the last century and disappeared during the 1920`s and 1930`s. They disappeared from Lough Neagh system in the early 1800`s." The presence of *Salvelinus alpinus* has been confirmed in Lough Mask as recently as Feburary 1995 (W.R.F.B survey). The virtual disappearance of *Salvelinus alpinus* (Arctic Charr) from Lough Conn has been recently reported (Mayo Co. Council L. Conn report, 1994). Partly for this reason the E.P.A have announced a £0.25M research programme focusing on the littoral zone in the western lakes (Mc Garrigle, pers comm.).

2.3.1.4 Coarse fish.

In response to water quality and changes in ecological conditions, coarse fish tend to outbreed and overrun game fish. Coarse fish have much lower oxygen requirements and have a competitive advantage where dissolved oxygen levels deteriorate. Changes in ecological conditions such as increased vegetation which provides additional habitat for coarse fish is also a factor. Kennedy and Fitzmaurice, (1971) described some aspects of *Gobio gobio* (L.). A number of Irish studies of *Esox lucius* (L.) have been undertaken (Bracken and Champ, 1971, Fitzmaurice, 1981). See appendix 6.2 for distribution map of *Esox lucius*. For example, Mc Carthy, (1983) documented the effects of arterial drainage on the Trimblestown river Co. Meath which altered from predominantly salmonids to small riverine coarse fish communities. Thus trends in the distribution and size of coarse fish populations can be used as a barometer of water quality and changing ecological conditions. Bracken and Kennedy, (1985) published the first key to the identification of the egg and young stages of coarse fish in Irish waters.

Studies of the *Phoxinus phoxinus* and *Gasterosteus aculeatus* L. were undertaken by Dauod *et al*, (1985). O` Maoileadaigh *et al.*, (1988) associated the abundance of *Tinca tinca* (L.) to the relatively eutrophic conditions of Ross bay, L. Leane. O, Sullivan et al, (1995) in reported on post Chernobyl radio cesium. Lakes in the North west of the country and Lough Owel in the Midlands were most affected by the fallout, the higher concentrations being found in pike and perch which are higher up the piscivorous food chain. Maximum levels recorded in Ireland did not exceed 400 bq/kg. Fish biomass concentrations are best illustrated graphically in order to discern trends both spatially and temporally.

The explosion and subsequent decline in the population of *Rutilus rutilus* in Lough Corrib has not been directly linked to water quality fluctuations although it occurred at a time when maximum chlorophyll levels in lower Lough Corrib were much higher than the are currently.

Maximum chlorophyll levels appears to have stabilized in the lower lake in recent years and it will be of interest to see if population of *Rutilus rutilus* which has contracted, will again expand in a cyclical manner. Indeed in the Irish context there is evidence to demonstrates that coarse fish populations can increase independently of water quality.

Rutilus rutilus and *Leuciscus leuciscus* were accidently introduced to the Blackwater, Cork in 1899. In 1963, *Rutilus rutilus* was first noted by anglers in the middle regions of the river Erne and by 1973 they had colonized the whole of the Erne system including the head waters. Since then *Rutilus rutilus* have colonized the river Shannon and its three major lakes, L. Derraveragh, L. Sheelin and L. Ennel (C.F.B position paper No. 74).

They have also spread to the R. Liffey the R. Dodder, the R. Boyne, the R. Lee, L. Corrib and the Royal and Grand canals.

Scardanius erythrophthamalus is a fish of virtually still water, and occurs mainly in lakes ponds canals and sluggish waters of large rivers such as the Shannon, Erne, Barrow, Lee and upper Boyne catchments. More recently, it has been recorded in Aughrusbeg lake, Claddaghduff, Clifden, Co. Galway (Gargan, 1994). Thus, while the distribution of coarse fish is being recorded, the rate of encroachment and extent of penetration within catchments is unclear as is the association with altered water quality status. This suggest the need for regular updating of databases in the context of G.I.S as information becomes available.

2.4 Fish kills

Fish kills, often an extreme manifestation of poor water quality are recorded monthly by the Regional Fisheries Boards and the data is forwarded to the Dept. of the Marine for collation. For example from an examination of a review of fish kills in Ireland it is clear that most kills occur in summer.

Fig. 11: Fish Kills in Ireland 1983 - 1994

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Total
Jan		1			1			1			1		4
Feb		2	1		2	1					2	1	9
Mar		4	1	1		3	1	2		1	1	1	15
Apr	1	4	2	1	1	6	3	3	1		1	1	24
May	2	10	3	1	16	9	15	10	13	5	2	3	89
Jun	23	34	23	36	51	19	34	12	13	18	3	8	277
July	38	31	6	17	31	1	48	10	10	22	18	7	239
Aug	15	12	1	3	18	6	9	7	16	1	1	5	94
Sept	3	8	1	1	1	2	3		6	5	3		34
Oct	3	1	6			1	1				1	2	15
Nov	2	1	1			1	1		1				7
Dec	1		1					1	1	2			6
Total	**85**	**110**	**41**	**66**	**122**	**50**	**112**	**52**	**60**	**51**	**33**	**31**	**813**

Source: Fishery leaflets 159, 1994

With the decline in fish kills in recent years, as is evident from the above table, there is a good case for utilizing a wider range of indices for assessing the impact of water quality on fish stocks on an ongoing basis.

Fahy, (1987) gave a breakdown of species killed in pollution incidents in Ireland.

Fig. 12: Species affected by fish kills in Ireland.

Species	Number
Salmo salar	*20*
Salmo trutta	*48*
Esox lucius	*14*
Phoxinus phoxinus	*9*
Rutilus rutilus	*8*
Abramis brama	*6*
Noemacheilus barbatulus	*5*
Gobio gobio	*2*
Scardanius erythropthamalus	*1*
Anguilla anguilla	*11*
Gasterosteus aculeatus	*6*
Perca fluviatilis	*1*
Lampetra fluviatilis	*1*
Platichthys flesus	*4*
Dicentrarchus labrax	*1*
Crenimugil labrosus	*1*

The table suggests, that as expected, salmonids are the most sensitive species. Fahy, (1988) demonstrated that channel lengths of good water quality as surveyed by An Foras Forbatha correlated highly significantly with numbers of fish kills but that the strongest correlation existed between the number of kills and moderately polluted channel length.

Such waters, he concluded, " were more likely to be fish bearing and stressed, a deterioration in water quality, typically in summer precipitating a fish kill. " Questions arise as to whether surviving fish are more prone to disease. Undoubtadly, fish are amongst the most sensitive of all aquatic organisms to impaired water quality as was documented on the River Barrow (Lucey, 1987).

Following a spillage of PCBs into the river Breagach, a tributary of the river Nore in 1980, a large scale experimental removal of fish was undertaken in 1988 in order to alleviate the contamination of the fish population (Fishery leaflet 153 of 1993).

Chapter 3:0 The way forward.

3.1 G.I.S and natural resource inventory.

There is now an emerging recognition that scientific organizations with responsibilities for resource management have many common data requirements such as base maps, topographic details, geology, rainfall etc. This information is likely to be commercially available in digitized map format in future. The Ordinance survey are now producing digitized maps which are available for leasing (Finch, pers. comm.). In recent years, the most significant technological advances have been made in areas of information technology, G.I.S and I.S.D.N systems. In addition hand held global positioning systems are now available which allow sites to referenced to the national grid and distances between "waypoints" to be calculated. Jones *et al*, (1994) described a UK land information system for environmental risk assessment. This application involved collaboration between the UK Soil survey and the Land Research Centre.

Cruickshank *et al.*, (1992) described the use of G.I.S in Northern Ireland to map and cross reference salmon rivers affected by overgrazing and peat extraction.

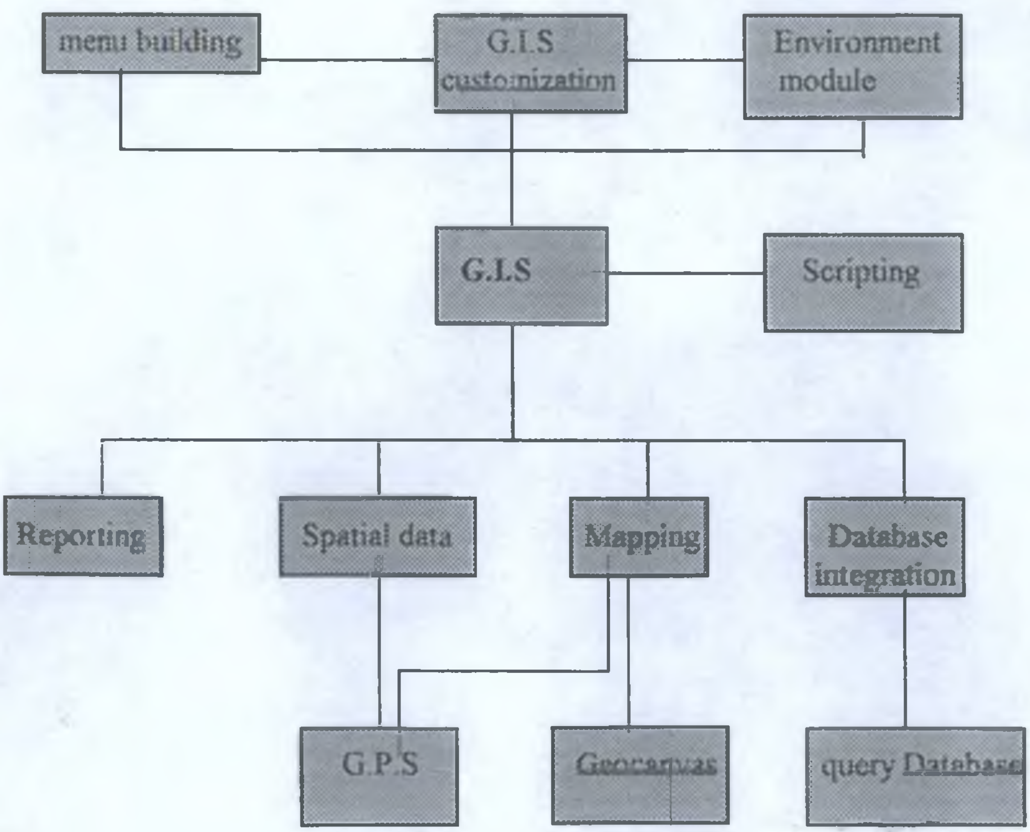
The study by Allot *et al* (1993) utilized a G.I.S system and categorized the geological strata as high ANC - (acid neutralizing capacity), medium ANC and low ANC. One module on the system was used to compute the average slope for different river systems in the connemara region. If fish are to be effectively used as indicators of water quality, then there is a need to define essential data sets and then to implement an integrated data collection, recording and analysis system which uses the available information.

The numerous datasets can be subjected to a series of geoprocessing techniques to produce composite thematic datasets which could include, stream gradient, flow, water quality, fish stock statistics etc. The fact that the status of fisheries is influenced by a myriad of factors, both natural and man made suggest that simplistic approaches are unlikely to prove fruitful.

Of prime importance is the need to identify key data sets which best reflect the use of fish as indicators of water quality.

Existing organizational database information can easily be integrated. Once this is determined, the G.I.S is usually customized as appropriate. This information can then be displayed, manipulated and interrogated in an interactive fashion to answer more complex user defined queries relating to various potential locational scenarios (Bulfin *et al.*, 1993). *The system provides the tools for users to access, visualize and query both geographic and tabular data for better analysis and decision making. The system enables users to integrate vector (x, y locations) map data, raster images such as photographs, scanned documents or satellite images, CAD drawings, sound and video data, as well as a wealth of tabular DBMS data into a single integrated environment.* (Arc - Info leaflet, 1994).

Fig. 13: Basic elements of Geographic information system.



The use of G.I.S typically involve interaction between different agencies with responsibility for different geographic layers.

Typical layers might include,

⇒ Digitized base maps of all watercourses and lakes to an appropriate scale.
⇒ Classification of waters as (a)salmonid (b) cyprinid or (c) fishless.
⇒ Classification of waters by fish species present.
⇒ Freshwater Fish Directive classification.
⇒ Bord Failte Brand Marketing status of all fisheries.- branded - unbranded.
⇒ N.A.S.C.O designated rivers.
⇒ Fisheries Acts implied designations.
⇒ Fisheries index.
⇒ Zonation of river biotopes as fish production zones by reference to riffle, glide and pool zones - totalled by category for each river system.
⇒ Obstructions or barriers to fish movement.
⇒ Fishery statistics.
⇒ C.P.U.E, angling returns,specimen fish, smolt output, stream surveys,density/biomass/condition, population structure,traps and counters.
⇒ (Note: Fishery statistics to be organized in relational databases.)
⇒ License sales/returns/statistics.
⇒ Salmon and sea trout smolt output for selected fisheries.
⇒ Fish distribution maps for salmonid and cyprinid species.
⇒ Fish densities - spatial and temporal.
⇒ Fish kills - species affected -length of channel/ area of water affected.
⇒ Outbreaks of fish diseases - water quality related.
⇒ Endemic fish diseases in Irish rivers
⇒ Redd counts.
⇒ Minimum water levels

3.1.1 Existing user groups.

In the Irish context, organizations utilizing G.I.S include Teagasc, FRC, Coillte Teoranta, Bord na Mona, the ESB etc - all organizations with responsibilities in relation to the natural resource development . From the fishery viewpoint, digitized maps of the nations streams rivers and lakes are required at different scales ranging from 1:50,000.

For example the Irish forestry Board, Coillte Teoranta utilize an Arc info GIS system since 1986 containing inventories, soils, roads forest compartments (Ryan, pers comm).

The Irish Naval Service use “Seaguard” a G.I.S based approach developed by Paradigm International Ltd.

The primary objective of this system was to was the creation of a graphics based system that would give dynamic and easy access to the Oracle database (Pollitt M, 1994).

During 1993, the Dept. of the Marine acquired under stride funding a comprehensive data management system consisting of Skybase, a relational database management system (RDBMS) and Arc/info a geographical information system.

The GIS which was commissioned in May 1993 includes an A0 digitizing table, an A4/A0 pen plotter and an A3/A4 ink jet colour plotter. However, problems have arise due to restrictions imposed by the availability of data in digital form from the Ordinance Survey and the high cost of the Ordinance survey copyright policy. In order to circumvent some of these problems, the Fisheries Research Centre in association with the National Marine Data Centre, the Naval Service and the Biomar project (OPW/TCD) have jointly drafted a digitizing specification document for selection of a contractor through open tender (Fishery leaflet 158, 1994). Goldin, (1995) reported on computerization and the acquisition of G.I.S by the Central Fisheries Board with the primary focus in the initial stages being directed towards maintaining a log of ownership of Irelands rivers and lakes.

3.2 Laying the foundations.

Boyle, (1995) called for, integrated Environmental Information Systems for Management of River Catchments and in the context of the Environmental Reporting Directive 91/692/EEC suggested Supervisory Control and Data Acquisition (SCADA) and G.I.S systems. Key features of any system, he stated, include as follows,

- flexible system capable of updating.
- Ease of use and access.
- capable of presenting relationships in map format.
- Open system - available to other users.
- Protected database core.
- Established protocols for updating.
- Compatible with mainstream computer software.

In the context of E.U initiatives, datasets in relation to key environmental statistics are likely to be agreed and prioritized in the near future. Organizations involved in fisheries data collection and processing in Ireland include,

- The Dept. of the Marine.
- The Fisheries Research Centre.
- The Central and Regional Fisheries Boards.
- The Salmon Research Agency.
- The Universities and third level sector.
- The E.S.B.
- The Marine Institute.
- Private fishery owners.
- Office of Public Works.
- Angling cooperatives and clubs.

All play a role in the acquisition of fishery statistics. Indeed the lead role in relation to the collation of salmon statistics has only recently been given to the Marine Institute. (Marine Institute Act, 1992). Recent reports (E.I.F.A.C., 1994) have stated that there is evidence of a deterioration in the quality of European inland fishery statistics due to a wide range of problems with data collection at the National level in most countries.

Fisheries statistics relate to,

⇒ stock levels (surveys, traps, counters)
⇒ angling catches.
⇒ disease outbreaks.
⇒ commercial catches.
⇒ predator monitoring and cropping.
⇒ habitat.
⇒ economic data.

The environmental value of existing data is often significantly reduced due to the use of different methodologies, information gaps, defective fish counters and the time lag between data collection, collation and publication. In addition, established databases, where they exist do so independently and are often not part of a relational database or G.I.S which would facilitate greater analysis. Also, various organizations use different referencing systems for streams and rivers.

A joint initiative by all bodies aimed at the establishment of a digitised map of Irelands rivers would be a useful exercise together with an agreements on a rivers referencing system. The O.P.W referencing system which is the most well known only applies to rivers which are included in their drainage programme.

Also, there is a need for all fishery authorities to develop and adopt proven fish sampling techniques and to accredit or licence other organizations for use of similar techniques before information is entered onto a national database.

In the context of fisheries management and conservation, there is a need for the establishment of a fisheries database system suitable for the storage, analysis and retrieval of conservation data. The database(s) which would form the backbone of the system would have to regularly updated. The existing fragmented approach towards data collection sometimes serves to obscure than enlighten. There is now the additional requirement in law to provide data to the general public in a format which complies with the E.U., Directive on the freedom of access to information on the environment.

The benefit of accumulated scientific knowledge which have led to an increased understanding of the ecology of fish populations and their interaction with biotic and abiotic factors can best be interpreted and understood by the application of geographic information systems. Key datasets require systematic collection and protocols for continuous updating. Relevant fishery statistics such as species present, population structure, density, growth, fecundity, condition factor, are normally assessed at the time of sampling. If healthy, self sustaining fish populations are present, - deductions can be made with regard to the quality of the aquatic habitat.

The preparation and regular publication of fish distribution maps for all of the twenty six species of freshwater fish indigenous to Ireland for all of the main catchments would be a an impossible task but it should be attempted as an ongoing continuous process with all key species being selected.

3.3 Data acquisition.

Statistical information on fish stocks levels is presently being collected in the context of The Operationl Programme for Tourism, in which surveys and commissioned studies are being undertaken before funding of fishery development programmes is approved. Major stock assessment surveys have been recently undertaken on the River Moy, River Clare and Owenmore rivers.

The Environmental Protection Agency sample 480 sites as part of their biological monitoring programme (Enfo, factsheet No.4, 1990). Thus, in order to accurately assess each fishery the number of sites chosen needs to be quite large. In the Owenmore study, Connemara, a total of 45 sites were selected. Thus if this were replicated nationally, the number of sites would be quite large and would present logistical problems. However, as such studies are not required annually, the fishery authorities should select a range of sites for ongoing evaluation.

For example in the Anglian region, U.K., regular assessment of fish biomass are undertaken (N.R.A, 1994). Logistically, in the Irish context, it may be possible to sample only about 10 - 20 % of the rivers being surveyed annually. Six categories of waters could be categorized and selected,

⇒ salmonid - salmo salar/salmo trutta waters.
⇒ salmonid - salmo trutta waters.
⇒ salmonid - salmo salar waters
⇒ salmonid - salmo trutta (migratory form)
⇒ coarse fish/ salmonid waters.
⇒ coarse fish waters

By assessment of 20% of the nations rivers annually, all rivers could be surveyed every very five years.

Over time trends should be discernible such as,

- the extent, distribution and penetration of salmon (salmo salar) in any given catchment.
- changes in the population structure and densities of salmonids in index streams and rivers.
- the replacement of salmonids by cyprinids in specific catchments.
- extent and distribution of coarse fish species.
- fish kill zones.
- occurrence and extent of environmental related fish diseases.
- fish morphometric characteristics - length, weight and condition.
- trends in redd counts/spawnig activity.

Surveys should facilitate the following comparisons,

⇒ temporal comparison of sites.
⇒ spatial comparison of sites within river catchments.
⇒ temporal and spatial comparison of different catchments.

The data accumulated for should be stored in a relational database linked to G.I.S which allows spatial querying and provides the possibility of examining relationships between geographical and environmental data sets. Different fisheries could be compared in relation to key statistics and sites anthropoginically affected would be screened. A database which records distribution and stock level for all 26 freshwater species should be established which should be updated regularly. Much more detailed fish distribution maps would be come available than those set out in appendices 6.2, 6.3, 6.4, 6.6.

Van Deventer *et al.*, (1989) described a software system for generating population statistics from electrofishing data in which the system output includes maximum likelihood population estimates, total catches, capture probabilities, removal patterns, lengths, weights, condition factors and biomass. Sample size programs display the number of electrofishing passes to achieve a desired precision level in the population estimate. The development or modification of such a program for use under Irish conditions should be pursued.

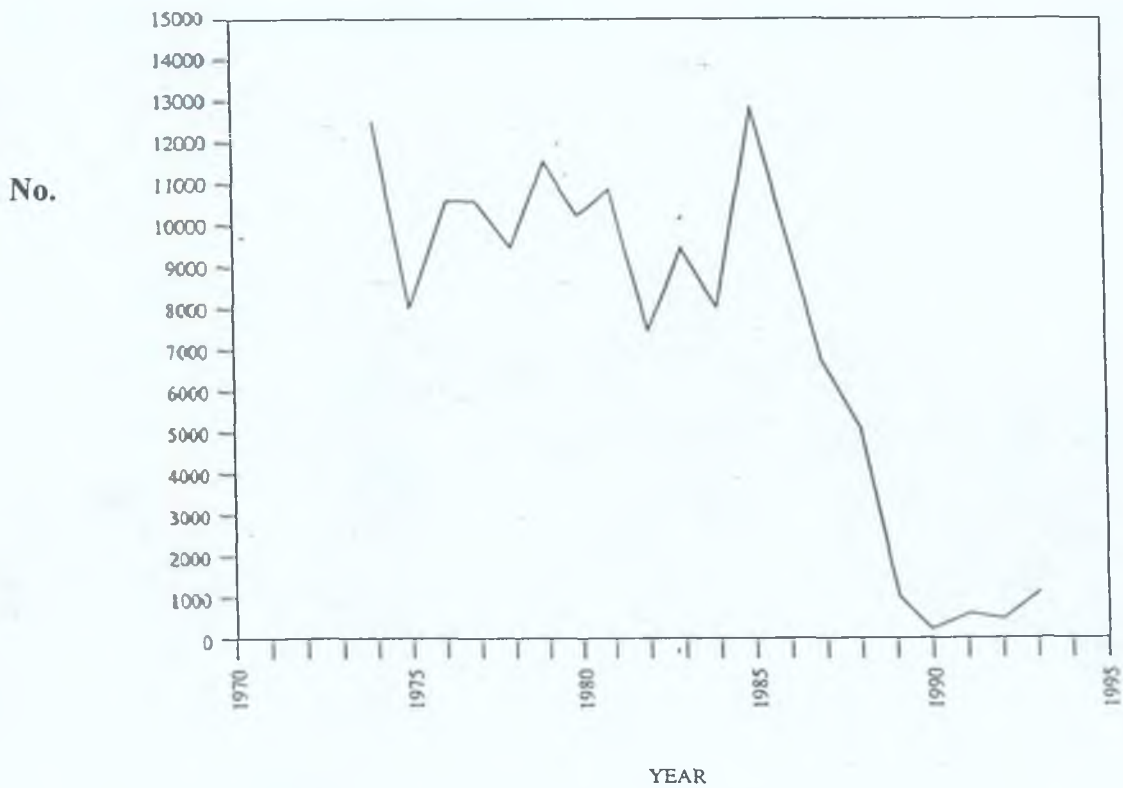
3.3.1 Salmonid populations.

Salmonid population assessment profiles by electrofishing using the Schnabel modification of the mark recapture method or the depletion method are most popular. (Cross, 1972) In lakes gill netting surveys are the most effective method of population assessment and catch per unit effort is normally calculated on the total number of fish > 19.8 cm in length captured divided the number of gill net sets fished (Gargan, 1994).

3.3.1.1 *Salmo trutta trutta*.

Statistics in relation to the migratory form of *Salmo trutta* are sourced primarily from private fishery owners, reports of fishery inspectors and scientific agencies such as the Salmon Research Agency. The collapse in stocks of migratory *salmo trutta* in the west of Ireland was documented in the first instance by a decline in angling catches as demonstrated in Fig 14.

Fig. 14: Annual Sea Trout Rod Catch in Connemara for period 1974 - 1993

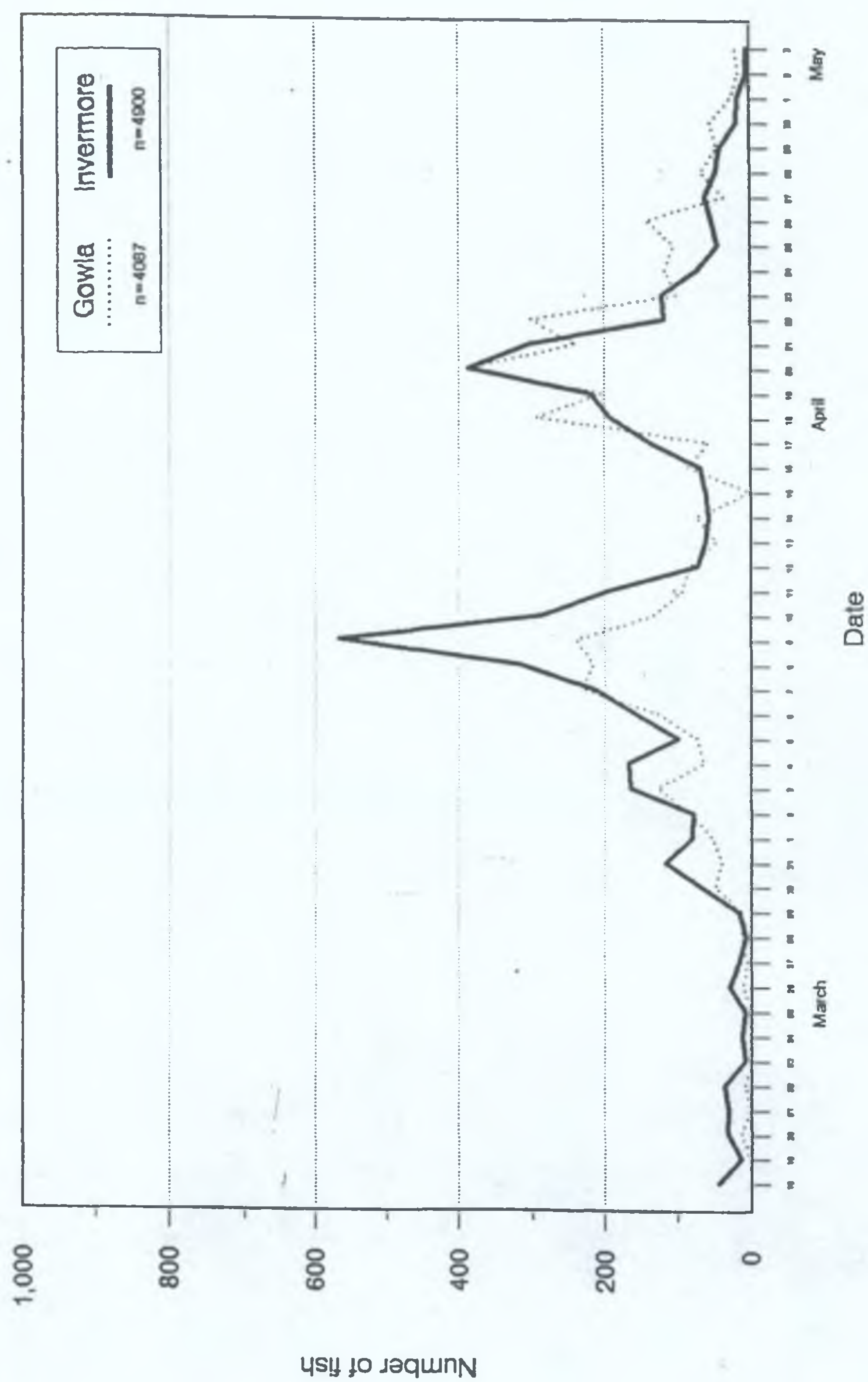


Source: Report of the Sea Trout Task Force 1994.

The chart illustrates the importance of angling returns as an indicator which in this instance highlighted that all was not well.

In addition, ongoing studies of sea trout smolt output from two adjacent fisheries in Connemara is in progress. The Invermore has a 25% afforestation cover (pers. comm J. Kelly) whereas the Owengowla is free of forestry and therefore a decline in sea trout smolt output would be expected if forestry is adversely affecting fish populations. See Fig. 17. The acidifying impact of forestry is not expected to intensify until the trees reach the closed canopy stage. Comparison of smolt output in adjacent fisheries both with different land use characteristics is a technique worth replicating elsewhere in order to elucidate the response of fish populations to catchment characteristics. Indeed comparision of the vital statistics for fisheries with similar characteristics often provides clues as to performance. See appendix 6.4 for map of Irish Sea Trout fisheries.

Fig. 15: Daily sea trout smolt counts from the Gowla and Invermore Rivers.



Source: Western Regional Fisheries Board report, 1994

Attempts are now being made in the western region to introduce a free-post creel census card in the western region. (See appendix 6.8).

Apart from entries in angling registers at some fisheries and end of year returns submitted by salmon and sea trout anglers, no audit trail exists in relation to angling statistics. Trout angling statistics are particularly defective and the logistics of attempting to document angling catches in major lakes is a difficult task. For this reason, effort should be focused on key angling competitions and selected angling centres.

Angling success is related to the stock of catchable fish and angling catches are used as a guide to stock levels.

Indeed, the present system whereby fishery statistics are acquired, collated, and published has evolved in an *ad hoc* manner with the result that data is not readily available and is rarely correlated with water quality data.

Redd counts are a subjective attempt at assessment of egg deposition but for most river systems are extremely difficult to assess due to water turbidity, colour etc.

For example, detailed *Salmo trutta* trout redd counts are available for the most of the streams in the Corrib catchment some of which are given in Fig.

Fig. 16: *Salmo trutta trutta* redd counts from the top 5 spawning waters for Lough Mask.

Redd counts

	Year	**Year**
L. Mask	**1973/74**	**1993/94**
Finney stream	1014	1430
Owenbrin R.	1100	810
Srah R.	960	264
Aille R.	429	556
Cahergall stream	268	54

Source: W.R.F.B

The data indicates that there was a drop in trout (*salmo trutta L.*) spawning activity over the period but that it alone would not account for the deterioration in angling catches. Closer analysis would compare the redd counts on the western end of the lake with that of the eastern end where predatory fish are more common.

Allen, (1951) pointed out that for New Zealand streams egg losses in different redds varied from 0 - 82% but mean loss was only 11% and in 84% of the redds examined losses were less than 20% (I.B.P Handbook No.3). The use of vibert box experiments to monitor ova survival is a useful tool for the assessment of environmental conditions.

A possible statistic (Geeritz- Hasen and Rasmussen, 1994) which reflect anthropogenic impact is given by,

Percentage egg hatch,

$$= \frac{\text{Number of incubated eggs} - \text{Number of dead eggs}}{\text{Number of incubated eggs}} \times 100$$

Examination of dead egg embryos can pinpoint the approximate timing of pollution incidents although salmonid ova are rarely disturbed until the have reached the green egg stage. See Microscopic examination of dead ova by reference to the developmental stage reached can help pinpoint the timing of a pollution event. Using vibert boxes larval survival can also be calculated in a similar manner.

The different stages of development of fish eggs is illustrated overleaf.

Fig. 17: Stages of development of fish eggs.

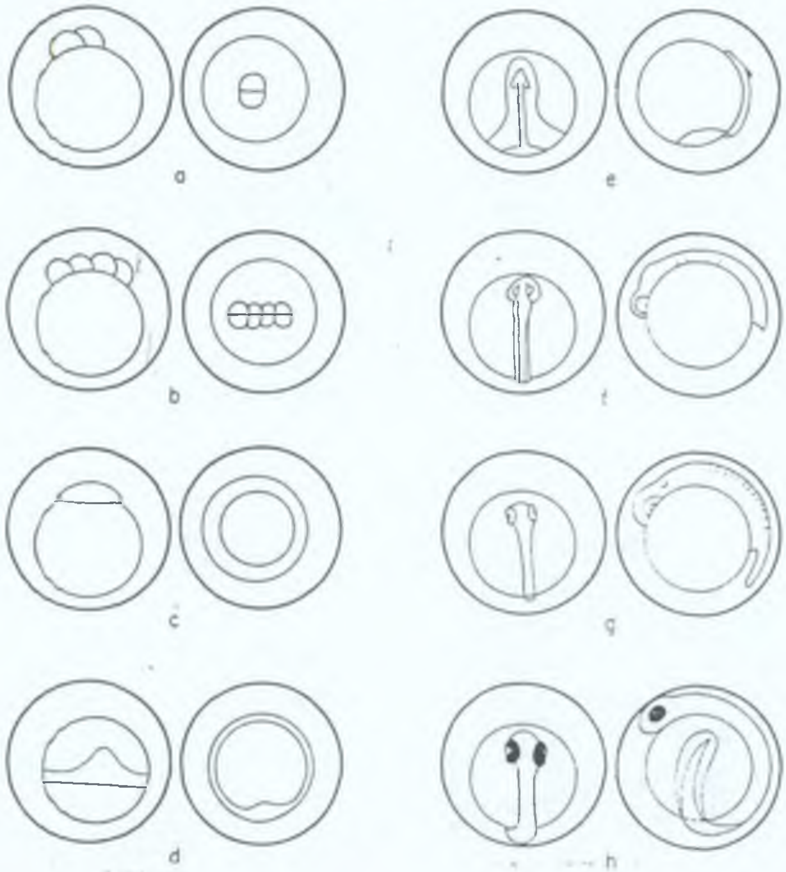


Figure 7.8. Stages of development of fish eggs. For each stage is shown the chorion (outer circle), the perivitelline space, and the embryo on the yolk.

a. 2-cell stage
b. 8-cell stage
c. embryonic disc
d. early gastrula, with embryonic shield formed
e. embryonic shield enlarged, blastopore still open
f. blastopore closed; the embryo half surrounds the yolk; myomeres appear in the middle of the trunk
g. tip of tail free of the yolk sac; eyes well developed; myomeres numerous
h. larva before hatching.

Source:IBP Handbook No.3.

3.3.1.2 *Salmo salar.*

The egg to smolt stages or the non migratory stages of *Salmo salar* are best used of indicators. Datasets should be established in relation to,

- Fry and parr populations in streams and rivers.
- Smolt counts.
- Fish counters

The Fisheries Research Centres salmon microtagging programme has been ongoing since 1989 and involves the use of a microscopic "coded wire tag" injected into the nose and is used primarily for monitoring salmon survival at sea (Browne *op. cit.*). Fishery statistics are published in the annual reports of the Dept. of the Marine.

3.3.1.3 Salvelinus alpinus.

Trends in char populations are normally estimated by deep gill netting of lakes. However, at present, there is no systematic monitoring programme in place for ongoing assessment of Charr populations in Irish lakes. They are protected under the Berne Convention. In the Irish context, administrative arrangements for the protection of *S. alpinus* could be improved if this a formal agreement with regard to protection and monitoring was agreed between O.P.W and the Fisheries Boards.

3.3.2 Coarse fish.

Distribution patterns, population trends and shifts in populations or year class structure in species such as pike, perch, roach etc. are indicators of ecological change which may have a water quality dimension. Indeed by the year 1968, a total of 32.4 tonnes of perch and 26.4 tonnes of pike (i.e. 38,463 pike) were removed from trout lakes nationally (I.F.T., Annual report. 1969).

Shifts in distribution patterns of other fish such as stone loach, stickleback etc. also reflect underlying ecological conditions which may be influenced by quality conditions.

Thus regular assessment of distribution patterns of these species may be suggestive of underlying habitat alterations. Eutrophication can stimulate primary productivity but much of the production occurs at the level of phytoplankton rather than at the macrophyte level. Coupled with reduced water transparency macrophytic vegetation often associated with cyprinid ecology can decline with implications for cyprinid populations.

Coarse fish statistics are readily available but only on those lakes on which predator control operations in operation. Specialized surveys would be required as the method of choice.

Populations of the ova of *Esox lucius* can be assessed by focusing on examination of spawning habitats such as flooded lake margins, vegetated areas etc.

In general, fish species can be identified by ova characteristics. (Bracken and Kennedy, 1967).

The use of global positioning hand held meters facilitates mapping of these areas in a manner that was not possible heretofore. (Garmain, 1994)

3.4 Fish diseases.

Fish disease are monitored by the Fisheries Research Centre, the main emphasis being on salmonid diseases. Other laboratories are required to report outbreaks to the centre. The Northern Regional Fisheries Board in 1993 reported that up to three million coarse fish fry were lost due to pollution and pointed out that in that region the industry was worth £6.9M and employs over 300 people in 110 hotels and guesthouses which cater for 16000 anglers annually. The Central Fisheries Board reported that throughout 1992/93 there was an "alarming increase in reports of ulcerated and distressed bream, perch and roach mainly from Athlone, Portumna and Shannonbridge areas with up to 10% of anglers catches being affected". Sub-lethal stress brought about by adverse water quality is suspected as a causative factor at least in some cases.(Champ. pers comm). It would appear that while there is a reasonable understanding of salmonid diseases, that the pathology of coarse fish is lagging behind.

Whatever the cause, the fishery authorities are increasingly concerned at the incidence of disease in coarse fish.

Again, as part of a national programme, comparative evaluations between different coarse fish waters with different water quality may provide clues. This again suggests the need for a relational database interlinked to G.I.S so that relationships can be explored.

3.5 Economic statistics.

The level and scale of fisheries related economic activity at different waters reflects the quality of a particular water as an angling amenity. For this reason, key economic indicators indirectly reflect environmental quality. Indeed, such an approach would be likely to result in corrective environmental measures being applied, particularly where the evidence of declining economic activity was significantly correlated with deteriorating water quality.

3.5.1 Licences, permits and share certificates.

Obviously polluted waters are unlikely to be fished and accordingly a fall off in licence revenue would be expected.

An interesting approach by O. Grady, (1991) contrasted salmon angling license returns for two rivers, the Slaney and the Boyne, the latter which had been the subject to arterial drainage over a prolonged period. However, a relational database linked to G.I.S would would greatly improve this approach with the result that trends would become readily apparent once the data was inputted.

3.5.2 Angling bed nights.

Angling bed nights are likely to decline in response to deteriorating water quality. Thus, information held by tourism agencies can reflect the quality of angling available. For example, the collapse of sea trout stocks in the Connemara region has resulted in a significant decline in anglng related bed nights in the region.

3.5.3 Angling equipment.

Sale and use of boats, engines, fishing tackle are indicators of angling activity. For example, aerial surveys of lakes in the Corrib catchment were undertaken in order to assess boat/angler activity during the current mayfly season.

4. Chapter 4.0: Models and indices.

4. 1 Models of fish populations.

Gray *et al.*, (1994), pointed out that " *many commercial organizations involved in water and environmental issues have recognized the reality that the development and support of a true software product is unrealistic unless it is initiated by a long term strategic decision and allocation of resources are guaranteed.* "

The development of models of fish populations and their response to a range of environmental influences provides a tool whereby different fish bearing waters can be evaluated. For example, Wright *et al.*, (1993) developed a very useful technique for evaluating the biological quality of rivers in the U.K using RIVPACS, (river invertebrates prediction and classification scheme) - a microcomputer based application. Using TWINSPAN analysis, macroinvertebrate communities and site physical factors at a large database of sites located throughout Britain were analysed. It became possible to predict with a high degree of probability, the precise macroinvertebrate community at any given site. There is scope for a similar approach using fish. The usefulness of establishing a database of sites throughout Ireland could ultimately serve as a basis for the development of a scheme whereby fish populaions could be predicted with a high degree of accuracy. The actual population could then be compared with the predicted population and a score allocated. Increasing emphasis is now being placed on managing salmon fisheries in order to maximize the return to the salmon angler. This has led to the development of models which are being used as a predictive tool in the context of management objectives. This is illustrated in a report on the potential grilse catch in the Owenmore catchment (*op. cit.*).

Potential grilse catch in the Owenmore catchment based on 1994 salmon parr production derived from electrofishing /habitat survey

			YEAR
21319	Estimated salmon parr production from streams/rivers	21319	1994
27% McGinnity(pers.comm.)	(survival to smolt)	44% (Browne,1990)	
5756	Estimated number of survivors to smolt stage(70% of total smolt output)	9380	1995
+ 2467	(30% of total smolt output - produced in lakes)	+4020	
8223	Total output of smolts from catchment MEAN NO. OF SMOLTS PRODUCED = 10812	13400	1995
8.60%	(8.6% survival to river - Crozier & Kennedy 1991)	8.60%	
707	Estimated return of grilse to river	1152	1996
16%	(16% rod exploitation rate - O'Farrell et al.,1989)	16%	
113	Estimated number of grilse to rod & line MEAN NO. OF GRILSE TO ROD = 149	184	1996

Source: C.F.B., 1995

Fig. 18: Potential grilse catch in the Owenmore catchment based on 1994 salmon parr production derived from electrofishing/habitat survey.

Such a model requires testing and fine tuning and variations are likely from catchment to another. However, as the quality of information with respect to different catchments improves and in light of the possible measures to curtail drift netting at sea, (Vigfusson,1995) any significant decline would immediately require an explanation.

The attempt by Browne and Gallagher, (1989) using Leslie matrices to model the salmon smolt output from the Corrib catchment based on stream densities of juvenile salmonids is relevant. The model overlooked the contribution from littoral zone of L. Corrib.

For example, models have been developed which are used to predict Chinook salmon spawning habitat (Shirvell , 1989).

4.2 Indices.

The scientific literature in relation to fisheries assessment stresses the importance of the following features,

⇒ water quality.

⇒ habitat/slope.

⇒ water depth.

For example, if spawning habitat is absent or limited, self sustaining fish population are unlikely to be present. Also if water depth falls to zero, the stream as a fishery rates poorly. Indeed, extensive growths of filamentous algae is liable to develop in very shallow water.

water. Thus any index which ignores these variables is liable to be defective. House, (1994) outlined four stages in the development of a water quality index,

- Determinand selection.
- Determinand transformation.
- Determinand weighting.
- Determinand aggregation.

However, the models developed are not readily applicable to fish, thus as part of this study a new approach was tested whereby the basic principles of an index could be maintained but adapted for use in a fisheries context.

Grey Seal Pup

Halichoerus grypus

Lao róin ghlais

The Grey Seal is the most commonly found seal around the coast of Ireland. The young seal pup is covered in a white fur to keep it warm for the first few weeks of life. As the weeks pass the fur turns grey and the seal builds up a thick layer of blubber with the help of its mother's milk.

Photograph: Robbie Murphy

Produced by
SHERKIN ISLAND MARINE STATION

ESB + environment

The index developed as part of this study takes into account, the resident fish population, the habitat and the minimum water depth. Applying these concepts, a fisheries index is outlined incorporating key features as follows,

Fig. 19: Parameters for Fisheries biological index.

Parameters	Input variables
Fish"	5,4,3,2,1
Habitat features.	% riffle, % glide, % pool.
Minimum water depth.	0.0 metre minimum - 0.5 metre maximum.*

The index is designed to operate on an IBM compatible P.C. - Microsoft Excel spreadsheet and the key variables in relation to fish life are inserted as follows,

- **Fisheries status.**

The appropriate value for "fish" (F value) is inserted into the spreadsheet. Values ranging from 5 to 1 are allocated as follows,

5: Normal salmonid fisheries.	4: impaired salmonid fisheries.	3: mixed salmonid/cyprinid fisheries.
2: Cyprinid fish dominant	1: Cyprinid species impaired.	

The model can allocate a maximum of 3,750 points but this would only occur if the river contained normal salmonid populations throughout. The number of points awarded is determined by the nature of the resident fish population. A five option nested IF statement allows the model to deduct points automatically, depending on the status of the resident fish population.

The "IF"statement for "fish" or F value is given as follows,

IF(F373>4.1,I373*E373,IF(F373>3.1,-(100)IF(F373>2.1,-(1000),IFF373>1.5,-(1200),IF(F373>0.1,-(1500),I373*(E373))))))

Thus depending on the F value inputted, the "IF statement" perfoms the appropriate calculation, which in this model involves subtracting either zero, 100, 1000,1200 or 1500 depending on the resident fish population present. Such "IF statements" can easily be modified in order to fine tune this element of the model.

- **Habitat features.**

Under habitat, % riffle, % glide, % pool are inserted. Rivers with 100% riffle score maximum points as such rivers tend to be very good producers of fish and are therefore highly valued.

- **Depth**:

The depth of the model river can vary from 0.0 m to 0.5 metre's and as minimum depth approaches zero, less points are awarded. Conditions obviously become impossible for fish once water levels fall below critical values. This scenario is provided for in the model in that many more points are deducted once the depth falls below 0.025 m. This is achieved by the use of the following "IF" statement.

IF(F380<0.025, -(3000),I380*E380)

This type of index is flexible and allows the biologist to reset the ideal maximum depth for different stream orders ranging from depths of 0.5 m to 0.1 metre. A biologist may wish to set a particular maximum and minimum value for a spawning stream whereas a different or higher values would be more appropriate for a stream containing a good stock of adult fish. For example, a 15 cm long fish needs to lie in channel sections which are at least 20 cm. to 30 cm in depth (C.F.B.,1995). Different idealised values could be established for different stream orders and actual site values inputted into the model for comparision.

One might wish to design a different but specific model for salmonid populations. An appropriate parameter in this regard in relation to the F factor might be percentage of sites electrofished containing 0.0, <0.25, <0.5,<1.0 fish/m^2, scored 1 - 5 respectively. Indeed such an approach may be more appropriate under Irish conditions where mildly polluted waters are increasing.

The model as it appears on the excel spreadsheet is shown in Fig. 20.

Fig. 20: Input variables for Fisheries Biological Index.

	Min	Max	Weighting (points)	Actual value	Range	Actual as %	Actual weighted	Points (total 9250)
F. value								
5,4,3,2,1	1	5	30	5	4	125	3750	3750
Habitat								
Riffle	0	100%	25	100	100	100	2500	2500
Glide	0	100%	10	0	100	0		
Pool	0	20%	5	0	20	0		
Depth (m)	0	0.5	30	0.5	0.5	100	3000	3000
						total	9250	100

FBI

To use the model, simply input the data for any river under "actual value" in the shaded column. Different sections of river would probably have different FBI values and main river channels would have lower values than tributaries as the may have less riffle zone. In this situation an overall index for a river or catchment could be given by the mean value. These kind of models obviously require validation and fine tuning. Their attraction is that this is easily achieved by altering the weighting or the "IF statements" and as with any index, a single number results.

Different scenarious in relation to F. value, habitat and minimum depth are presented in appendix 6.9.1

Based on real field data, fine tuning would allow the model to be designed to allocate scores ranging from 0 - 100 as follows.

Fig. 21: FBI score, fishery status and inferred water quality.

F.B.I Score	Fishery status	Water quality
75 - 100	Good	Very good
50 - 75	Doubtful	Fairly good
25 - 50	Fair	Doubtful
0 - 25	Poor	Poor

Models and indices are capable of graphical representation and as such are complementary to the G.I.S approach recommended. With G.I.S, much of the data would be available in databases and could be easily integrated into an index or model as described.

Chapter 5: Recommendations and Conclusions.

In conclusion, much information is already being-collected in the context of fisheries development and protection, scientific surveys, angling statistics etc. An effective scheme for the use of fish as biological indicators will only be developed as fisheries management information systems evolve. P.C based G.I.S systems are now becoming available (Intergraph, Arc Info, Paradign systems) comprising relational database, digitizing software and G.I.S which are more affordable and are therefore more likely to be adopted at regional level.

The Fisheries Boards already have large volumes of information pertaining to fisheries but not enough solid data methodically collected and collated, mainly due to the limited use of information technology (Cooper and Lybrand Report, 1994). Such a step would also allow for greater standardisation of approach between regions which would be a neccessary pre-requisite for data comparability. It would also facilitate a more integrated approach in which statistics generated could be used as a for a variety of purposes including biomonitoring. While fish are unlikely to replace macroinvertebrate community as primary indicators of water quality, it is likely that the application of G.I.S will facilitate their use to much greater extent than at present. The adoption and development by the fishery authorities of enabling technologies such as G.I.S allied with other emerging technologies will inevitably lead to a greater understanding of fish populations and their responses to environmental stresses.

References.

Allott, N Reynolds, J Cooke, D Gillmor, J Mills, P Farrell, E.P Boyle, G.M Cummins, T Kelly Quinn, M Bracken, J.J Tierney, D Coyle, S (1993) *Evaluation of the Effects of Forestry on Surface Water Chemistry and Fishery Potential in Ireland, Eolas contract ER/90/76.* Final Report Vol 2, Stream Chemistry and Biota, Galway - Mayo Region, pp 1 - 142.

Annual Report (1992/93) *Annual Report of the Central and Regional Fisheries Boards.* Central Fisheries Board, Glasnevin, Dublin.

Bagenel, T (1978) *Methods of assessment of fish production in fresh waters.* I.B.P Handbook No. 3, 3rd Edn, Blackwell Scientific Publications, Oxford, England. ISBN 0-632-00125-9.

Boelens, R.G (1991) The use of fish in water pollution studies. In: Steer, M.V. (ed) *Irish Rivers: Biology and Management*, Royal Irish Academy. pp. 89 - 109.

Bolger, T Connolly, P.L (1988) The selection of suitable indices for the measurement and analysis of fish condition. *Proc. 3rd Brit. Freshwater conf. 1983.*

Bond, C.E Rexted, E (1988) Habitat use of 25 common species of Oregon freshwater fishes, in: *Northwest Science*: **62** (5) pp 223 - 232.

Boyle, O.C (1995) Integrated catchment management information systems. I.W.E.M lecture, Bush Hotel, Carrick-on -Shannon.

Bracken, J.J Kennedy, M. (1967) A key to the identification of the eggs and young stages of coarse fish in Irish waters, *Sci. Proc.* R.D.S, 2B, 12:99-108.

Bracken, J Champ, W.S.T (1971) Age and growth in five Irish limestone lakes, *Sci.* Proc. RDS., B3, pp 1030.

Bracken, J O Grady, M (1991) A review of Fisheries Research in Ireland. in: *Environment and Development in Ireland,* J.Feehan (ed), Proc of Conf. at University College Dublin, 9 - 13 December 1991.ISBN 1-870089-76-6, pp. 499-510.

Bravington, M.V Rosenberg, A.A Andersen, R Muniz, I.P Beddington, J.R (1990) Modelling and quantitative analysis of the impact of water quality on the dynamics of fish populations. In: *The Surface water acidification programme*. (Cambridge University Press), 1990. pp 467 - 476.

Browne, J (undated) First resuts from a new method of tagging salmon - The Coded Wire Tag. Fishery Leaflet No.114, Department of Fisheries and Forestry, Dublin 2.

Browne, J and Gallagher, P (1985) The relationship betwen annual atlantic juvenile salmon population estimates and direct estimates of subsequent smolt runs in the Corrib system, Ireland. I.C.E.S, A.N.A.C.A.T., Fish Committee.

Bulfin, M Cullinan E.F, Tynan S (1993) The Develpment of an Indicative Forest Strategy with specific reference to Co. Clare. in:*Irish Forestry,* Journal of the Soceity of Irish Foresters, Vol 50 No.1,1993.

Central Fisheries Board (1984) A development programme for coarse fisheries. Central Fisheries Board, Dublin.

Central Fisheries Board (1986) *Strategies for management and development*. Central Fisheries Board, Glasnevin, Dublin. pp 1-199.

Central Fisheries Board (1987) List of waters and regulations. Central Fisheries Board, Glasnevin, Dublin.

Central Fisheries Board (1992) Job Creation, Central Fisheries Board, Balnagowan, Dublin. pp1-21.

Central Fisheries Board (1992) Ireland for Angling, Central Fisheries Board, Dublin.

Central Fisheries Board (1994) Report of the Irish Specimen Fish Committee. Central Fisheries Board, Glasnevin, Dublin.

Central Fisheries Board (1994) A Survey of fish stocks in the Ballinahinch/Owenmore Catchment, Co. Galway with recommendations for fishery development and enhancement. Central Fisheries Board, Glasnevin, Dublin. pp 1- 41.

Central Fisheries Board (1994) Tourism Operational Programme 1994 - 1999- Angling Measure, Central Fisheries Board Balnagowan, Dublin.

Central Fisheries Board (1995) Habitatat improvement for juvenile salmon and trout in small stream, Information leaflet.Central Fisheries Board, Glasnevin, Dublin.

Chart, T.E Bergersen, E.P (1988) Methods for long term identification of salmonids: A review in: *Biological report, the US Fish and Wildlife Research Unit*.

Cooper and Lybrand (1994) Review of structures and operations of the Central Fisheries Board. Central Fisheries Board, Dublin.

Courtenay W.R (1982) Country review and Lake Kinnernet case In: EIFAC Technical Paper No.42. *Report on the symposium on stock enhancement in the management of freshwater fisheries. pp 24 - 25.*

Cruickshank, M.M Bond, D Devine, P Tomlinson, R.W (1992) GIS and upland land use in Northern Ireland, *Mapping Awareness & GIS in Europe* Vol. 6 No.4.

Dangermond, J (1994) Arc View, Status and Direction, *ARC News*,6, 2: Environmental Systems Research Institute, Inc. 380 New York Street, Redlands, California 92373-8100.Vol 16, 2. pp 1 - 51.

Daud, H.A Bolger, T Bracken, J.J (1985) Studies of the Minnow (*Phoxinus phoxinus* L.) from an upland Irish reservoir system, *Ir. Fish Invest. Ser.* A. No. 26:21pp.

Daud, H.A Bolger, T Bracken, J.J (1985) Studies on the three spined stickleback *Gasterosteus aculeatus L.* from an Upland Irish Reservoir system. *Ir. Fish Invest. Ser.* A No. 27: 16pp.

Dept. of Agriculture and Fisheries (1975) Report of the Inland Fisheries Commision. pp 1-191.

Dept. of the Marine (1987) Report of the Salmon Review group. Department of the Marine, Leeson Lane, Dublin 2. pp.1-103.

Department of the Marine (1992) Fish Kills in Ireland, Fishery Leaflet 157

Dept. of the Marine (1993) *Report of the sea trout working group*. pp.1-127.

Dept. of the Marine (1994) Fish kills in Ireland in 1993, Fishery leaflet 159.

Dept. of the Marine (1994) Fisheries Research Centre Report for 1993, Fishery Leaflet 158.

Duggan, P and Champ,T (1991) Lough Sheelin reviewed, in: Proc. *Environment and development in Ireland,* UCD 9 - 13 Dec 1991, J.Feehan(ed), pp. 487-495.

duQuesne Ltd (1990) Acidification of surface waters in connemara and South Mayo, current status and causes. Du Quesne Ltd., Economic and Environmental Consultants, 4 Merrion Sq., Dublin 2.

EIFAC: Technical Reports on Water Quality for European Freshwater Fish, FAO, Rome, Italy. Technical Papers: TP1 Suspended solids (1964); TP4 Extreme pH values (1968); TP6 Temperature (1968); TP11 Ammonia (1970); TP15 Monohydric phenols (1972); TP19 Dissolved oxygen (1973); TP20 Chlorine (1973); TP21 Zinc (1973); TP27 Copper (1976); TP30 Cadmium (1977); TP43 Chromium (1983); TP45 Nickel (1984); TP46 Nitrate (1984); TP37 Rev. 1 Mixtures of toxicants (1987)

EIFAC Technical Paper No. 213 (1981) *Register of International transfers of Inland Fish species*. F.A.O, Via delle Terme, di Caracalla, 00100 Rome, Italy.

EIFAC Technical Paper 54 (1993) *Water Quality and Fish Health.* F.A.O, Via delle Terme, di Caracalla, 00100 Rome, Italy.

EIFAC Technical Paper No. 17 (1972) *Report on the major communicible fish diseases in Europe and their control.* F.A.O, Via delle Terme, di Caracalla, 00100 Rome, Italy.

EIFAC Technical Report No.23 (1974) *Methodology for the survey, monitoring and appraisal of fishery resources in lakes and rivers.* F.A.O, Via delle Terme, di Caracalla, 00100 Rome, Italy.

Elliot, J.M Hilton, J Rigg, E Tillitt, P.A Swift, D.J Leonard, D.R.P (1992) Sources of variation in post Chernobyl radiocaesium in fish from two Cumbrian lakes. Jour. Of *Applied Ecol*. 29(1), pp 108 - 119.

Enfo, fact sheet No. 4 (1990) *River Quality.*

European Commision (1994) Complaint by Carra - Mask Angling Federation.

European Communities (Quality of Samonid Waters Regulations), S.I. No 293 of 1988.

European Communities (1994) Proposal for a Council Directive on the ecological quality of water. COM(93) 680 final, Brussels 94/0152(SYN)

European Communities (1991) Council Directive of 23 Dec 1991 standardising and rationalising reports on the implementation of certain Directives relating to the Environment. O.J.C No. 377 P.48.

Fahy, E Rudd, R (1984) The use of weight - length relationships in sea trout stocks. In: *Salmon and Trout Magazine*, No. 228 of 1984.

Fahy, E. (1987) Tip of the iceberg - Fish kills in Ireland. *Irish Journal of Environmental Science*. **3**, No. 2

Farrell, M.M Mc Carthy, K (1983) An evaluation of stomach flushing as a fishery technique, Proc. 3rd Brit. Freshw. Conf. 1983.

Fewings, A (1994) See how they run, *Atlantic Salmon Research Trust booklet.*

Fitzmaurice, P (1981) Some aspects of the Biology and management of Pike (Esox lucius) L.) stocks in Irish fisheries. Central Fisheries Board, Glasnevin, Dublin.

Gargan, P (1994) A survey of four brown trout lakes in the Clifden area. (unpublished report), Central Fisheries Board, Glasnevin, Dublin.

Geraghty, B (1992) A Brand marketing strategy for Irish fisheries. Bord Failte Eireann, Baggot St., Dublin. pp.1-122.

Golden, T (1995) Angling for a better net, *ComputerScope*, March 1995. pp.1 - 72.

Gray, B Hooper, A Mitchell, G (1995) Computer modelling and the water cycle. *IWEM Year Book* 1995 pp.21 - 27.

Hankanson T and Hansen L.P (1991) Estimates of the annual loss of Atlantic salmon, Salmo salar L., in Norway due to acidification. *Aquaculture and Fisheries Management* 1991, **22**, 85-91

Hankanson, L Andersen, T Nilsson, A (1992) Radioactive caesium in fish in Swedish lakes 1986 - 1988 - general pattern related to fallout and lake characteristics. *Jour of experimental Radioactivity* 1992, **15** (3), pp, 207 - 229

Hickey, P (1985) *Electric Fishing,* Institute of Fisheries Management, 22 Rushworth Ave, West Bridgeford, Nottingham, NG2 7LF, pp 1 - 16.

House, M.A (1989) A water quality index for river management. *Jour of Water and Env Management* vol 3 1989 pp 336 - 344.

Hynes, H.B.N (1975) The stream and its valley.in: *Verhandlung der International. Vercingung fur limnologie* **19:** 1-15.

Henriksen, A Lien, L Rossiland, Traaen, T.S Sevaldrud, I.S (1989) Lake acidification in Norway present and predicted status. *Ambio.* 1989 18 (6) pp 314 - 321.

Hodson, P V (1990) Indicators of ecosystem health at the species level and the example of selenium effects on fish. *Environmental Monitoring and Assessment* 15 (3) pp 241 254.

Jones, R.A Lee, G.F (1987) Eutrophication modelling for water quality management: An update of the Vollenweider - OECD model.

Karr, J.R (1991) Biological integrity: a long neglected aspect of water resource management. *Ecological applications.* 1991 1(1), pp 68 - 84.

Kautz , R S (1980) Effects of eutrophication on fish communities of Florida lakes. *Proc., annual Conference Southwestern Association,* Fish and Wildlife Agencies Office of Environ. Serv. Fla. Game Freshwater Fish Comm. Tallahassee 32301, USA (34), pp 67 - 80.

Kristensen P (1994) Sensitivity of embryos and larvae in relation to other stages in the life cycle of fish: a literature review. *Sublethal and chronic effects of pollutants in freshwater fish* (eds Muller,R and Lloyd, R), Fishing News Books, Oxford, pp. 135 - 166.

Kennedy, M Fitzmaurice P (1971) Some aspects of the biology of the gudgeon Gobio gobio (L.) in Irish waters. *J. Fish Biol.* (1972) **4,** 425 - 440.

Kennedy G.J.A (1985) River Pollution - How much does it cost fisheries? D.A.N.I Advisers conf., 30 - 31 Oct Loughry College of Agriculture and Food, N. Ireland.

Kozel, S.J Hubert, W.A Parsons, M.G (1989) Habitat features and trout abundance relative to gradient in some Wyoming streams. *Northwest Science* 1989, **63** (4) pp 175 - 182.

Lacroix, G.L (1987) Ecological and physiological responses of Atlantic salmon in acidic organic rivers of Nova Scotia Canada. *Water Air and Soil Pollution* 1989 46 (1 - 4), 375 - 386.

Laitineen, M and Kartunen (1994) Effects of calcium and magnesium in acid water on the ion balance of eggs and alevins of rainbow trout (Oncorhynchus mykiss). *Sublethal and chronic effects of pollutants on freshwater fish,* Muller R and Lloyd R(eds) FAO/ Fishing News Books. pp 262 - 272.

Lowe, T.P May,T.W Brumbaugh, W.G Kane, D.A (1994) National contaminant Biomonitoring program: Concentration of seven elements in freshwater fish, 1978 - 1981. In: *Aquatic Sci & Fisheries Abs.*

Lloyd, R (1992) *Pollution and Freshwater fish,* F.A.O./Fishing News Books, ISBN 0-85238-187-5. pp.1-175.

Lucey, J (1991) Invertebrates as pollution indicators in Irish Rivers, in:Steer M.W. (ed) *Irish Rivers Biology and Management*, Royal Irish Academy. pp.135-150.

Mann R.H.K (1989) Fish population dynamics in the river Frome Dorset. *Regulated rivers, research and Management* 1989. 4(2), pp 165 - 177.

Maitland, P.S (1972) *A key to British Freshwater Fishes*, F.B.A., Ferry House, Ambleside, Westmoreland. pp. 1-135.

Mayo Co. Council (1993) The Lough Conn report. Mayo Co. Council, The Mall, Castlebar, Co. Mayo.

Mc Cumiskey,L.M Toner,P.F (1992) Water resources and management in the Republic of Ireland, in: *Jour. of Instit. of Water and Env. Mgmnt.*, 15 John St., London WC1N 2EB, Supplementary European issue.

Mc Garrigle, M.L Clabby, K.L (1991) Biological assessment of river water quality in Ireland. *Proc. of International conference on river water quality - ecological assessment and control.* Palais de Congres Brussels 16 - 18 December 1991.

N.R.A (1993) *NRA Fisheries Strategy*, NRA Rivers House, Waterside Drive, Aztec West, Almondsbury, Bristol BS12 4UD ISBN 1 873160 50x, pp 1-20.

N.A.S.C.O (1994) *Report of the eleventh annual meeting of the Council,* Oslo, Norway. CNL (94)55, 6 - 10 June 1994. N.A.S.C.O., 11 Rutland Square Edinburgh, EH1 2AS Scotland.

Morgan, W.S.G (1994) Biomonitoring with fish: an aid to industrial effluent and surface water quality control. *Aquatic Sci & Fisheries Abs.*

Moriarty, F. (1991). *Ecotoxicology, The study of Pollutants in Ecosystems,* 2nd edn, Academic Press 24/28 Oval Rd, London. pp.1 - 241

Muller and Lloyd (1994) *Sublethal and chronic effects of pollutants on freshwater fish,* published by arrangement with F.A.O., by Fishing News Books, Osney Mead, Oxford OX2, OEL pp. 1 - 371.

O. Maoileidigh, N Bracken, J.J (1989) Biology of the tench, Tinca tinca (L.), in an Irish lake, *Aquaculture and Fisheries Management*, **20**, pp 199 - 209.

O. Maoileidigh, N Browne, J Cullen, A Mc Dermott ,T Keatinge, M (1994) *Exploitation of survival of reared salmon released into the Burrishole river system.* Fishery Leaflet No.16, Department of the Marine, Dublin.

O. Grady, M (1991) Rehabilitation of a salmonid habitat in a drained Irish river system *in:* Steer, M.W. (ed.) 1991 *Irish Rivers: Biology and Management*, pp 187 - 204. Royal Irish Academy, Dublin.

Poleksic, V Mitrovic-Tutundzic, V (1994) Fish gills as a monitor of sublethal and chronic effects of pollution. *Sublethal and Chronic effects of pollution on freshwater fish*, Mueller,R Lloyd, R, (eds), FAO/ Fishing News Books, pp.339 - 352.

Phillipart, J.C (1989) Relationship between ecology of fish populations and the abiotic characteristics of running waters in the Belgium River Meuse basin. in:*Bulletin Societe Geographique de Liege,* 25 pp 175 - 198.

Pollitt, M (1994) Seaguard, a graphical, chart based system for agencies and organisations concerned with fishery protection, smuggling, terrorism and piracy, emergency planning, pollution monitoring, search and rescue, fleet management, command and control and coastal zone managment. *GIS Europe,* July edn.

Ranta, E Lindstrom, T (1990) Water quality versus other determinants of species specific yield of fish in Northern Finnish lakes. *Fisheries Research,* **8**(4) pp 367 - 379.

Reddin, D.G Friedland, P.J Rago, D.A Dunkley,L Karlsson, L Meerberg, D.M (1993) Forecasting the abundance of North American two sea winter salmon stocks and the provision of catch advice for the West Grenland salnon fishery. in:*Atlantic Salmon Trust Progress Report*

Rinne, J.N Medina, A.C (1988) Factors affecting salmonid populations in six headwater streams central Arizona, USA. in:*Polskie Archivium Hydrobiologii* 1988 **35**(3-4) pp 515 - 532.

Roberts R.J and Shepherd C.J (1990) *Handbook of trout and salmon diseases,* Fishing News Books, Osney Mead, Oxford. ISBN 0-85238-138-7. pp 1 - 222.

Rosseland, B.O Henriksen, A (1986) Acidification in Norway - loss of fish populations - 1000 lake survey. *Science of the Total Environment* 1990, **96** (1-2), pp 45 - 56.

Scullion, F (1994) Veterinary Diagnostic Services. Fisheries Research Centre - *Report for 1993,* Fishery Leaflet 158, pp 1 - 29.

Shirvell C.S (1989) Ability of PHABSIM to predict chinook salmon spawning habitat. *in: Regulated rivers, Research and Management*. 1989 **3** (1-4), pp 223 - 289.

Shoesmith, E (1990) A comparision of methods for estimating mean fecundity. *Jour. of fish biology* 1990, **36**(1) pp. 73 - 84.

Stephen A, S (1993) Acid rain and its impact: the critical loads debate. *Atlantic Salmon Trust Progress report*, pp. 1 - 45.

Svobodna, Z Vykusova, J Machova, M Hrbkova, M Groch, L (1994) The long term effect of PCBs on fish, *Sublethal and Chronic effects of pollution on freshwater fish*, eds Mueller, R Lloyd, R, Fishing News Books pp.339 - 352.

Tonn, W.M Magnuson, J.J (1982) Patterns in the species composition and richness of fish assemblages in Northern Wisconsin lakes. *Ecology* **63**(4) pp 1149 - 1166.

Tully, O (1991) Assessment of the impact of sea lice (Lepeophtheirus Salmonis) infestation on sea trout smolts on the west coast of Ireland during 1991. Report to the Salmon Research Agency, pp 1 - 37.Inc.

Van - Deventer, J.S Platts, W.S (1989) Microcomputer software for generating population statistics from electrofishing data - users guide for Micro Fish 3.0. *General Technical Report*, U.S. Dept. of Agriculture, Forest Service 1989. INT-254, 29

Vigfusson Orri (1995) Talk to Slaney Rodfishers Association Luncheon in Enniscorthy April 8, 1995.

Whilde, T (1993) *Threatened mammals, birds, amphibians and fish in Ireland.* Irish Red Data Book 2: Vertebrates HMSO, 16 Arthur St., Belfast BT1 4GD. pp 158 -161.

Wishart, S.T Lumbers, J.P Griffiths, I.M (1990) Expert systems for the interpretation of water quality data, *Jour. of I.W.E.M,* 15 John St. London WC1N 2EB, 4 (2) pp. 194 - 202.

Woltering, D.M. (1984) The growth response in fish chronic and early life stage toxicity tests: a critical review. *Jour. Aquat. Toxicol.*, **5**: 1 - 21.

Wright, J.F Furse, M.T Armitage, P.D (1993) RIVPACS - a technique for evaluating the biological quality of rivers in the U.K. Inst. of Freshwater Ecol. East Stoke, Wareham, Dorset BH20 6BB, (3) 4 pp 15 -25

6.0 APPENDICES

6.1 List of freshwater fish in Ireland.

No.	Common Name	Scientific name	Specimen weight Kg*
1	Sea lamprey	Petromyzon	
2.	River Lamprey	Lampetra fluviatilis	
3.	Brook lamprey	Lampetra planeri	
4.	Allis Shad	Alosa alosa	
5.	Twaite Shad	Alosa fallax fallax	
6.	Killarney Shad	Alosa fallax killarnesis	
7.	Atlantic salmon	Salmo salar	9.072
8. (I)	Brown trout	Salmo trutta	4.536
8. (ii)	Brown trout (Sea trout)	Salmo trutta	2.721
9.	Rainbow trout	Ocorhynchus mykiss	-
10.	Artic Charr	Salvelinus alpinus	-
11.	Pollan	Coregonus autumnalis poll	-
12.	Smelt	Osmerus eperlanus	-
13.	Common Carp	Cyprinius carpio	4.536
14.	Pike	Esox lucius	13.608
15.	Gudgeon	Gobio gobio	
16.	Tench	Tinca tinca	2.721
17.	Bream	Abramis brama	3.402
18.	Minnow	Phoxinus phoxinus	
19.	Rudd	Scardinius erythrophthamalus	1.021
20.	Roach	Rutilus rutilus	1.021
21.	Dace	Leuciscus leuciscus	0.454
22.	Stone loach	Noemacheilus leuciscus	
23.	European eel	Anguilla anguilla	1.361
24.	Three spined stickleback	Gastereosteus aculeatus	
25.	Nine spined stickleback	Pungitus pungitus	
26.	Perch	Perca fluviatilis	1.361
27.	Flounder	Platichthys flesus	

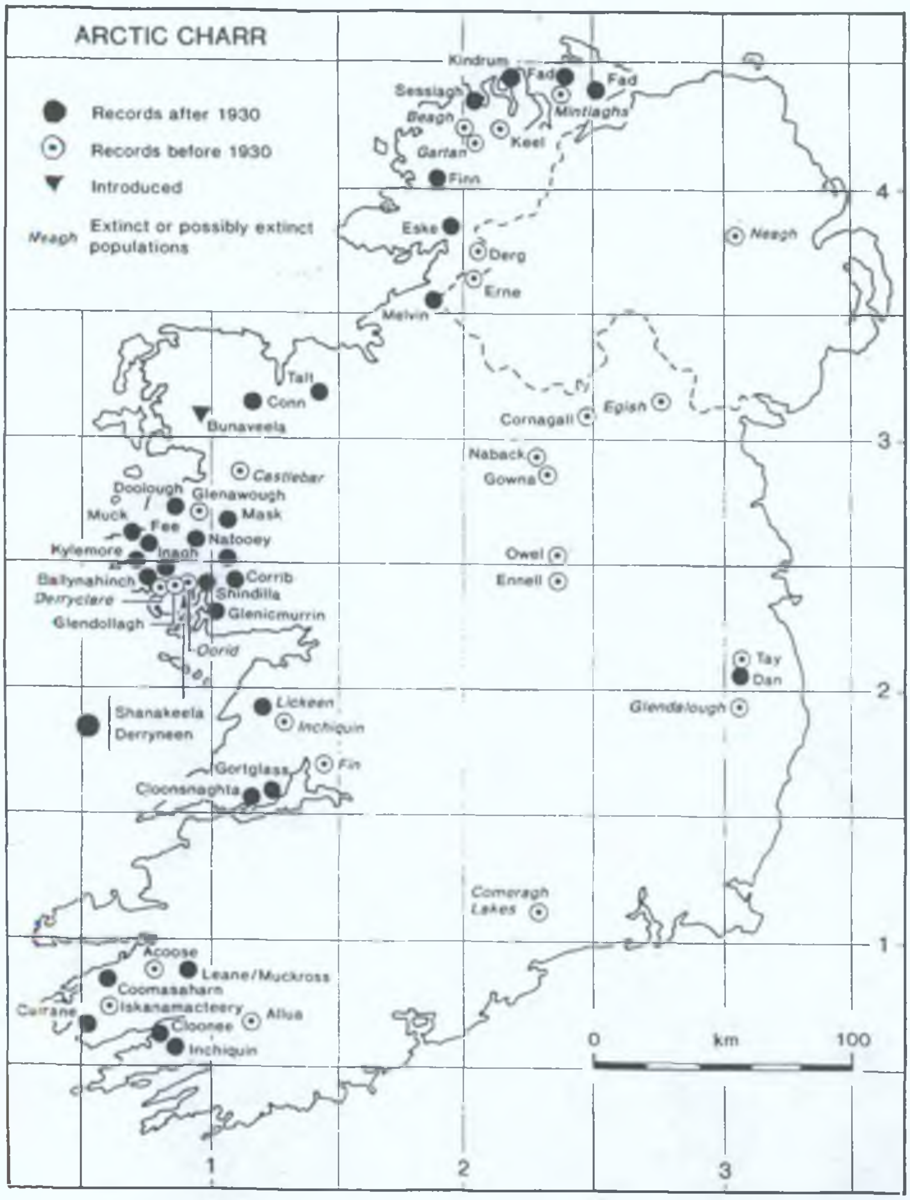
Sources:* *Irish Red Data Book, 1993, Irish Specimen fish Committee Report, 1992

6.2 Distribution of *Esox lucius* in Ireland.

General pike distribution in Ireland excluding the Counties Derry, Antrim, Down, Armagh, Tyrone and Fermanagh. Pike are absent in the shaded areas ; present in the unshaded catchments.

Bracken and Champ, 1971

6.3 Map displaying the distribution of *Salvelinus alpinus* in Ireland.



Irish Red Data Book

6.4 Sea trout fisheries in Ireland.

□ Branded brown trout lakes.

Fisheries	Centre
L. Leane	Killarney
West Cork/Kenmare	West Cork
(put and take)	Kenmare.
L. Inchiquin	Corofin
L. Dromore.	Ennis
L. Rea	Loughrea
L. Corrib	Oughterard, Cong, Headford Clonbur, Cornamona
L. Mask	Ballinrobe, Clonbur, Cong
	Tourmakeady.
L. Carra	Ballinrobe, Claremorris,
	Castlebar.
L. Conn.	Pontoon, Crossmolina
	Ballina, Foxford.
L. Arrow	Riverstown/Ballindoon
	Castlebaldwin, Boyle
L. Key.(Mayfly only)	Carrick on Shannon.
L. Melvin	Bundoran, Kinlough.
	Boyle, Carrick on Shannon.
L. Ennel, L.Owel	Mullingar, Tyrrellspass.
and smaller lakes in	Multyfarnham
the Mullingar area.	
L. O Flynn and R. Suck.	Castlerea, Ballinlough.

6.5 Bord Failte Branded fisheries (Bord Failte, 1990).

□ Branded salmon lakes.

Fisheries	Centres
L. Leane (trolling)	Killarney
Waterville lakes	Waterville.
(L. Currane)	
L. Corrib	Oughterard, Knockferry
	Annaghadown, Headford,
	Cong, Clonbur, Cornamona.
L. Beltra, L. Feeagh	Newport House, Newport,
L. Furnace	
(Burrishole)	
	Wesport and Mulrany.
L. Conn, L. Cullin	Pontoon, Ballina.
L. Melvin	Bundoran/environs.

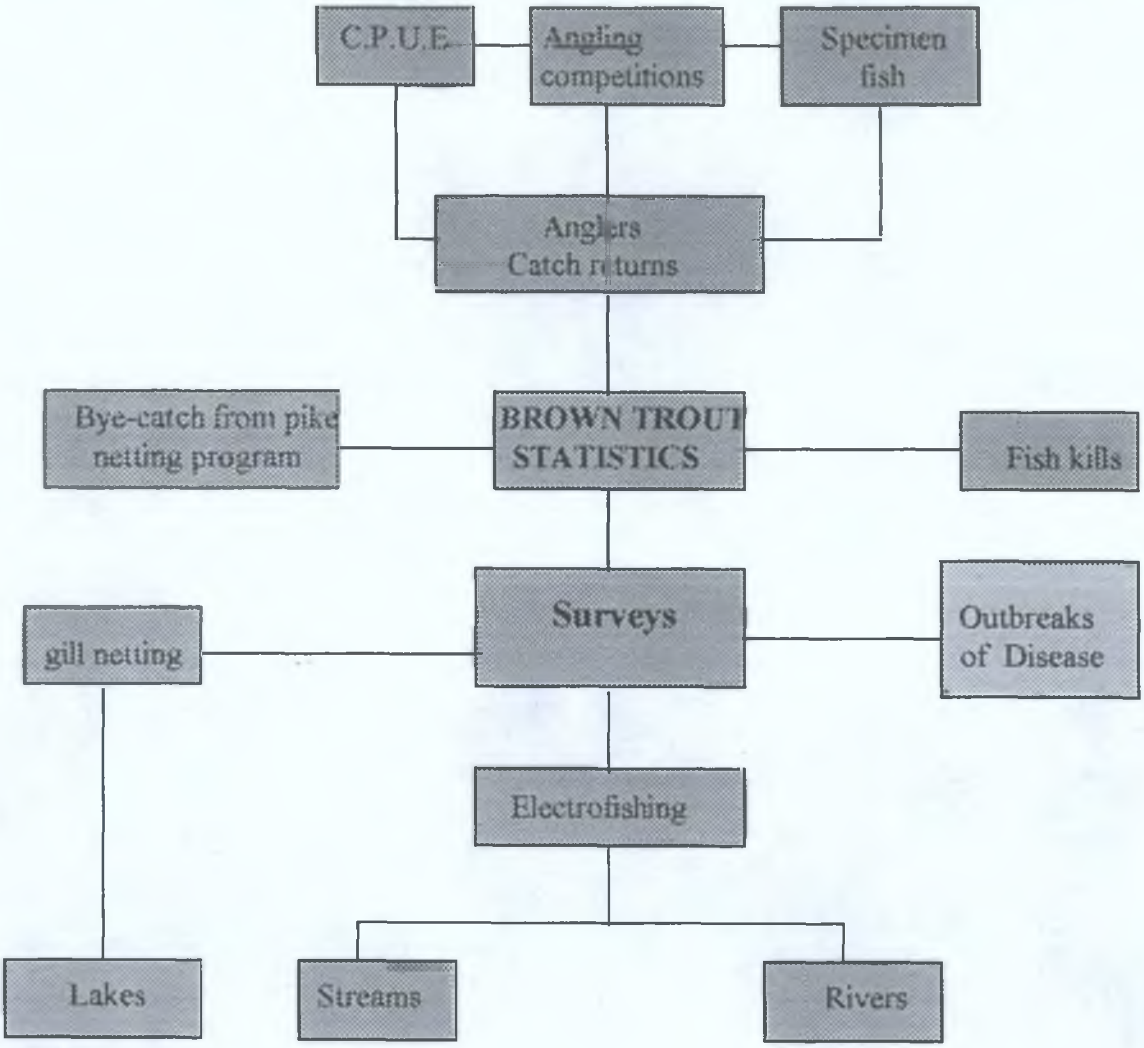
□ Branded sea trout fisheries.

L. Leane	Kylemore/Inagh/Muck and Fee.[f]
Waterville lakes.	Ballinahinch (Tullyboy)[g]
L. Corrib/Mask/Carra.	L. Beltra, Newport R.
L. Conn/Cullin.	Burrishole Fisheries; L. Feagh , L.Furnace.[h]
L. Melvin.	The Rosses Fishery, Glenveagh lake.
R. Slaney.	R. Fane/Deel/Glyde.
R. Nore.	Mid + lower Suir and tributaries.
Blackwater (Munster)	Little Brosna, Clody and Silver Rivers
plus tributaries; Funcheon, Awbeg.	R. Suck, Bunowen, Shiven, L. O' Flynn
Upper R. Caragh.	R. Moy + tributaries.
R. Boyne.	L. Arrow + L. Key.
R. Corrib.	L. Ennel + L. Owel.
R. Erriff, Delphi and lakes.[a]	L. Rea, L. Inchiquin, L. Dromore.
R. Owenmore.	West Cork/Kenmare stocked lakes.
(Ballynahinch Castle Fishery)[b]	L. Sheelin.
R. Bundrowes.	
Costello, Cashel, [c]	
Screebe rivers and lakes[d].	
Gowla/ Inver Fisheries.[e]	

Note: Fisheries a - h removed from current list due to sea trout collapse.

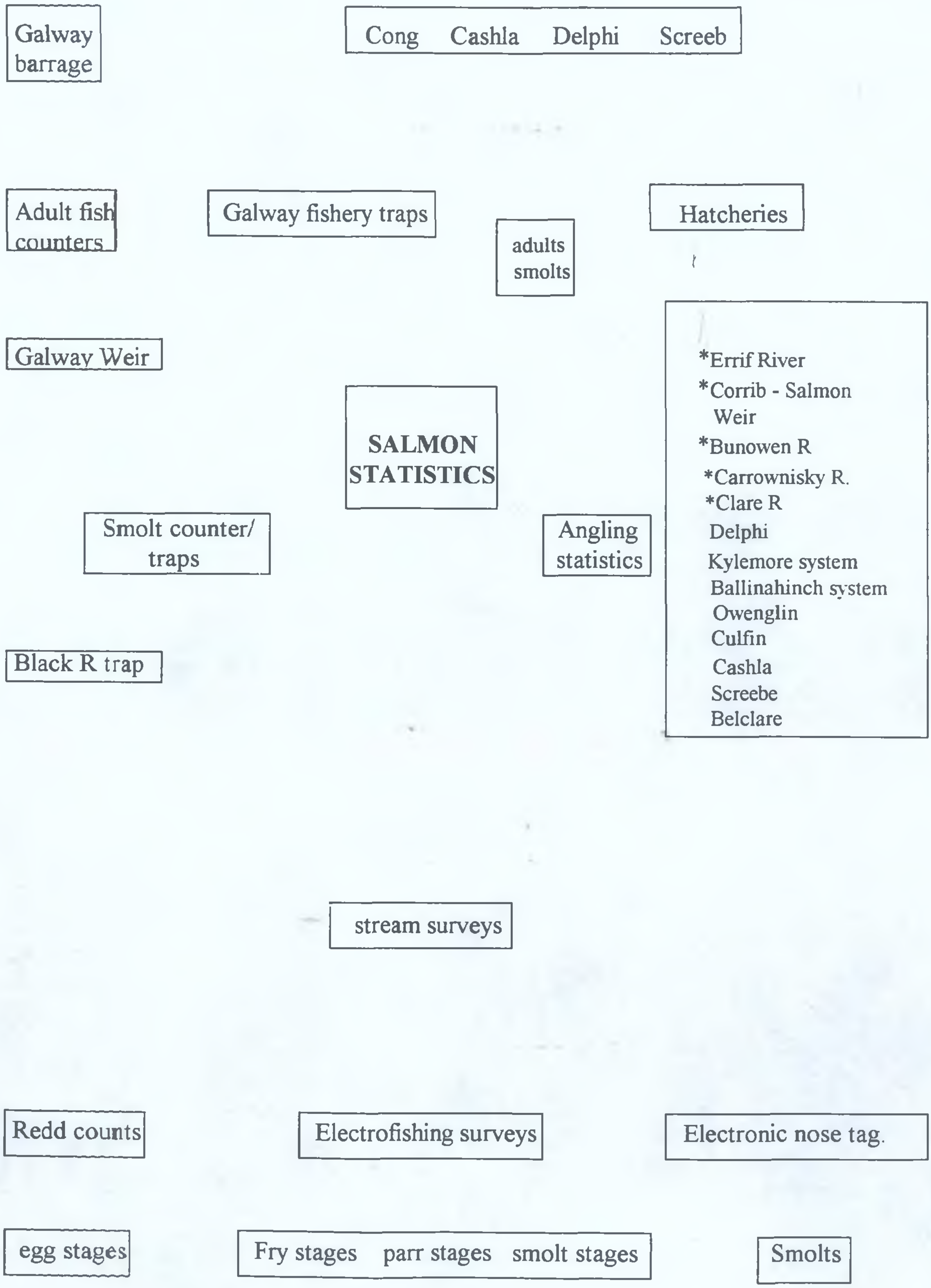
6.6 Distribution map of *Salmo Trutta Trutta*.

5.6.1 *Salmo trutta trutta* statistics in the Western Fisheries region.



6.7 Map showing Salmon Fisheries in Ireland.

6.7.1 Salmo salar statistics - Western Fisheries Region.



6.8 Selected questionaires in use by Fisheries Boards.

Licence No.: GA106

No stamp required if posted in the Republic of Ireland

The Western Regional Fisheries Board,
Freepost,
Weir Lodge,
Earl's Island,
GALWAY.

The Western Regional Fisheries Board
Weir Lodge, Earl's Island, Galway. Tel. (091) 63118. Fax (091) 66335
CREEL CENSUS CARD

Note: It is vital that a card is filled for every day's fishing, whether fish are caught or not!

Name: ____________________ Date: ____________________

Address: ____

Lake or River Fished: ____________________ Area/Location: ____________________

Catch of Game Fish:

Salmon		**Sea Trout**		**Brown Trout**	
No.	Weights:	No.	Weights:	No.	Weights
____	__________	____	__________	____	__________
____	__________	____	__________	____	__________
____	__________	____	__________	____	__________

Best Methods: ____________________ Weather: ____________________

The above information is essential for the careful management of a fishery, the statistics is solely for that purpose. No individual catches will be released without prior consent of the angler involved.

Please return to: **Fish Scale Sample** Nº 5049

The Western Regional Fisheries Board
Weir Lodge, Earl's Island, Galway. Tel: (091) 63118

Angler: .... Date caught: ....

Address: ....

....

Species of Fish: ....

Length: .... Girth: .... Sex: ....

Weight: .... Condition: ....

Where caught: ....

....

How caught: ....

ENTIAL

return to [redacted] Fisheries & Forestry
Lane
2

THE WESTERN REGIONAL FISHERIES BOARD

BALLINAKILL FISHERY DISTRICT

SALMON AND SEA TROUT CAPTURE

eriod .... To ....

, Bay, ry or Sea Area	Salmon		Sea Trout		No. of Boats
	Number	Weight	Number	Weight	
Drift Nets					
Draft Nets					
iff Rods					
lphi Rods					
ndorragha Rods					
lfin Rods					
wros Rods					
ndowen Rods					
arrownisky Rods					
venglin Rods					

......./

CONTROL OF FISHING FOR SALMON ORDER 1960

APPLICATION FOR A SALMON FISHING LICENCE (OTHER THAN ROD AND LINE)

IN THE WESTERN FISHERY DISTRICT

PART 1

NAME OF APPLICANT ______________________________

HOME ADDRESS ______________________________

If you held a salmon net licence for the last salmon fishing season insert in the table below details of your income for the past twelve months.

If you did not hold a salmon net licence for the last salmon fishing season but either:-

(1) Held salmon net licence since 1968.
or
(11) Had regular membership of a salmon fishing crew since 1969
or
(111) Derived your livelihood mainly from fishing.

Complete the table below giving appropriate details (crew members must attach certificates from the licence holders with whom they fished showing the periods served each year).

Year	Details of licence or crew membership since 1968 or years in which livelihood was derived mainly from fishing.	MY INCOME FROM Salmon Fishing £	Other Fishing £	Other Sources £

* Applicants from Galway, Connemara or Ballinakill Fishery Districts should give details in respect of any three of the years since 1968.

6.9.1 Example of FBI index for different model rivers.

Instructions Input values for your river in blue coloured column.

F.Value	MIN	MAX	Un	Weig	**Actual**		Range	Act as percent	Act * Wght		9250
5,4,3,2,1	1	5		30	5	hi	4	125	3750	3,750	
Habitat											
RIFFLE	0	100	%	25	20	hi	100	20	500		
GLIDE	0	100	%	10	75	hi	100	75	750		
POOL	0	20	%	5	5	hi	20	25	125	1,375	
MINIMUM DEPTH (metres)	0	0.5	m	30	0.5	hi	0.5	100	3000	3000	
											88
										8,125	
				100							

(FBI) INDEX

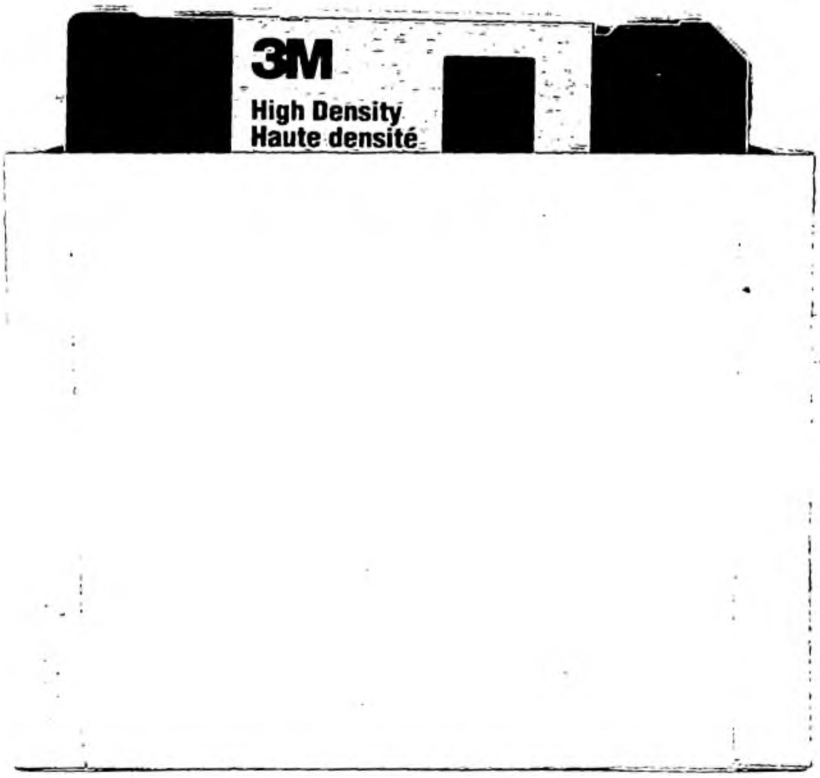
Instructions Input values for your river in blue coloured column.

F.Value	MIN	MAX	Un	Weig	**Actual**		Range	Act as percent	Act * Wght		9250
5,4,3,2,1	1	5		30	2	hi	4	50	-1400	-1,400	
Habitat											
RIFFLE	0	100	%	25	100	hi	100	100	2500		
GLIDE	0	100	%	10	0	hi	100	0	0		
POOL	0	20	%	5	0	hi	20	0	0	2,500	
MINIMUM DEPTH (metres)	0	0.5	m	30	0.5	hi	0.5	100	3000	3000	
											44
										4,100	
				100							

(FBI) INDEX

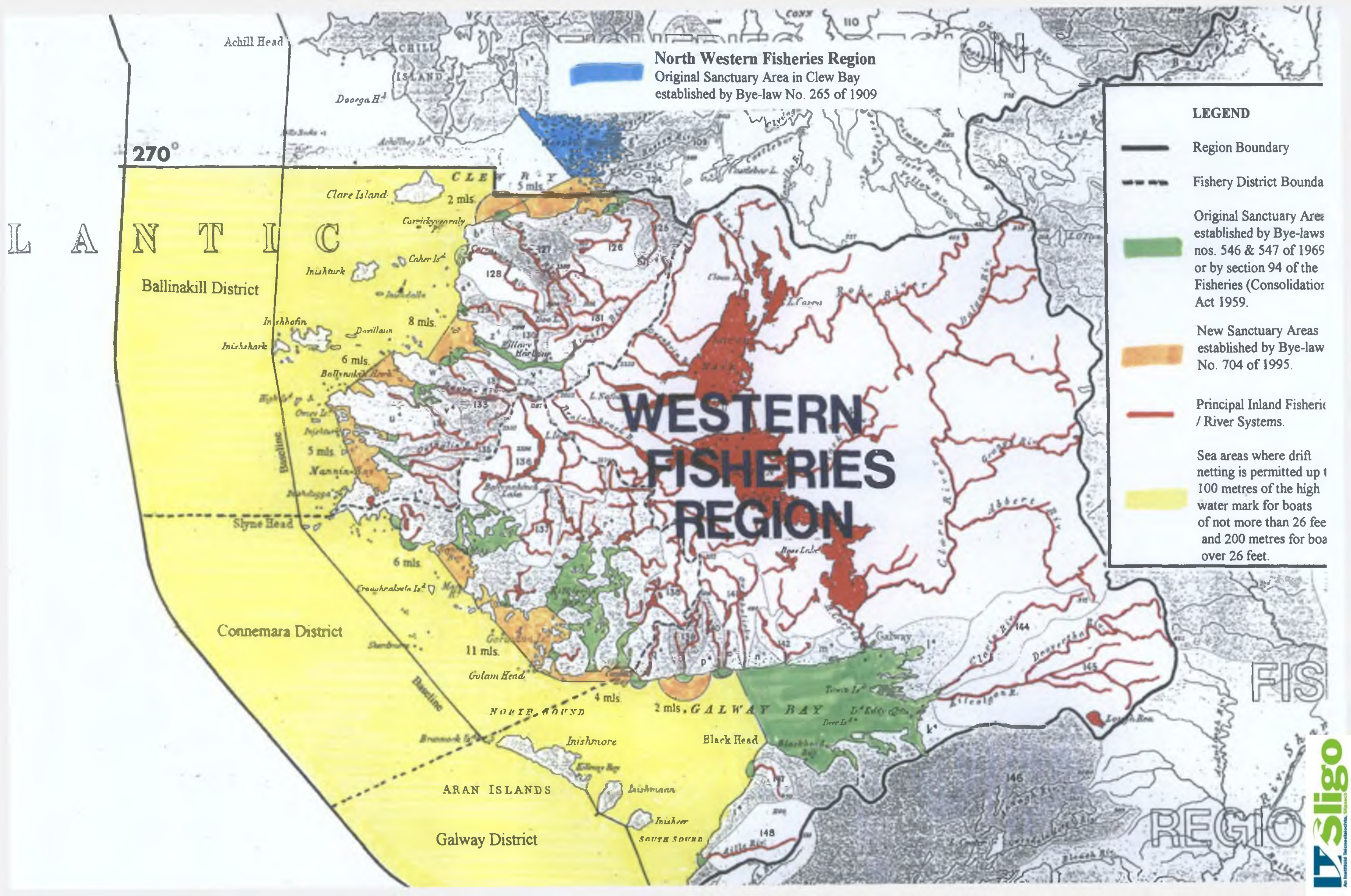
6.9 Fisheries Biological Index (FBI) Floppy disc.

(For use with IBM compatible PC and Microsoft Excel, v.5)



6.10 Map of Fishery Regions of Ireland.

Map of Ireland showing river systems, boundar
Fisheries regions and locations of regional Headqu
(Regional jurisdiction extends to the 12 mile



North Western Fisheries Region
Original Sanctuary Area in Clew Bay established by Bye-law No. 265 of 1909
LEGEND
Region Boundary
Fishery District Bounda
Original Sanctuary Are established by Bye-laws nos. 546 & 547 of 196 or by section 94 of the Fisheries (Consolidatio Act 1959.
New Sanctuary Areas established by Bye-law No. 704 of 1995.
Principal Inland Fisheri / River Systems.
Sea areas where drift netting is permitted up 100 metres of the high water mark for boats of not more than 26 fee and 200 metres for boa over 26 feet.
WESTERN FISHERIES REGION
Achill Head
270°
Clare Island
Ballinakill District
Slyne Head
Connemara District
Galway District
ARAN ISLANDS
Inishmore
Black Head
GALWAY BAY
Galway
5 mls
2 mls.
8 mls.
6 mls.
5 mls.
6 mls
11 mls.
4 mls.
2 mls.
Baseline
Baseline