FISH ENTRAINED IN 1977 AT COCKENZIE POWER STATION, IN THE FIRTH OF FORTH

Peter S. Maitland, Kenneth East and Kenneth H. Morris
Institute of Terrestrial Ecology

INTRODUCTION

The phenomenon of the entrainment of fish at the intake works to power stations is becoming a well known one, and the factors related to entrainment and to the subsequent fate of entrained fish are now the subject of a considerable amount of research in many parts of the world (Thorpe and Gibbons 1978). The requirement of almost all kinds of electricity generating power stations (coal, oil and nuclear) for very large amounts of water for cooling purposes has meant that all of them are situated beside large bodies of water – the sea, estuaries, large rivers or large lakes. Though it is possible to screen the intake tunnels to such power stations in various ways it is virtually inevitable that zooplankton, other larger invertebrates and small fish are entrained and passed into the stations.

Most stations have a further form of screening through which the water passes, usually after it has been chlorinated, and this removes the bulk of larger particles and animals in the water, which then passes through the cooling system of the station itself. Screened fish and other objects are washed into trash baskets which require to be emptied regularly. There is often a very high mortality among animals which are entrained due to the chlorination, the mechanical effects of screening or passage through the water ducting system, and the thermal effect of raised temperatures after passing through the condensers. In the case of pumped-storage hydro-electric power stations no chlorination nor temperature effects are involved and damage to fish is usually mechanical or hydrostatic.

Originally most of the research on fish at such power stations was of a purely applied nature and related to operational problems (e.g. the actual blockage of intakes or cooling systems by fish, thereby causing shutdowns and financial loss), or to ecological problems, the main concern here being the impact of mortalities caused by the power station on the local fish populations. However, in recent years power station intakes have been recognised as having considerable value to biologists and much of the present research is directed at examining the value of screen catches as a biological method of monitoring water quality or of studying the population dynamics of various species (e.g. Claridge and Gardner 1978).

During initial studies of the distribution of fish in the British Isles (Maitland 1969) it was quickly apparent that very little information existed on the fish communities of certain habitats, particularly large rivers and estuaries. In Scotland, relatively little was known about any of the four major estuaries there — Forth, Tay, Moray or Clyde. In the Firth of Forth for example, several fish known to be common more than 100 years ago (Maitland 1979) now appear (from the few data available) to be scarce or absent. Thus the Smelt *Osmerus eperlanus* (Linnaeus 1758), was formerly very abundant in the Forth (Parnell 1838), but there appeared to be no recent records. It was believed that the examination of fish catches at power stations in the area would be an economical and efficient way of assessing the status of fish populations in the areas as has been clearly shown for the River Thames by Wheeler (1969a).

SITE AND METHODS

In the first year of study (1977) it was decided to carry out a pilot project at just one of the Forth power stations, and Cockenzie was chosen as being the most suitable. Like the power station at Leven on the opposite (north) side of the estuary, Cockenzie power station is situated on the open seaward end of the estuary, where tidal and salinity conditions are more or less fully marine (McLusky 1978). This is in contrast to the two power stations further west (Kincardine and Longannet) which are more influenced by fresh water.

Cockenzie is a 1200 megawatt, coal-fired power station, built on the southern shore of the Firth of Forth about 16km east of Edinburgh. It occupies a site covering in all some 93 hectares (ha). The main buildings are to the north of the coast road on an area of 24 ha, half of which was reclaimed from the sea. South of the road are the coal store, railway sidings, and the 275 kV switch-house. Work on site began in January, 1962 and Cockenzie Power Station was formally opened in May, 1968.

The cooling-water intake is set some 150m outside the sea wall in a minimum depth of 4.6m at low tide. Water is drawn into vertical shafts, of 4.3m diameter, which are joined to twin tunnels driven 24.4m below sea level. Coarse screens at the intake head-works inhibit the passage of extraneous matter, and chlorine points prevent mussel-fouling. Fine screening is carried out at the pumphouse. Some 136000m^3 (30 million gallons) an hour of chlorinated seawater are passed through the steam-condensers for cooling purposes. In addition there is a daily requirement of 2955m^3 (650000 gallons) of domestic

water to provide make-up feedwater for the boilers.

While Cockenzie Power Station is built on a site covering 93 ha, ash from the spent fuel is being used elsewhere to reclaim more than 110 ha from the sea. When it is considered that 12 ha of the station's main building area also were recovered from below tide-level it is plain that the net loss of ground to the firth is 122 ha.

Collections of fish were made at Cockenzie on ten different dates during 1977, normally in the morning between 0900-1000h. When possible, six different samples were taken – one from the channels and trash basket associated with each of the six screens. On several occasions, however, individual screens were not operating and fewer than six samples were obtained. Fish were collected by examining material from the channels and baskets in a systematic way until a total of 100 fish had been collected. The time taken to collect this number, or the whole sample if fewer than 100 fish were available, was recorded. The trash collected by the screens include a wide variety of other organisms (mussels, shrimps, crabs, seaweed etc.) as well as miscellaneous rubbish (plastic bottles, paper etc.).

The samples were taken back to the laboratory where the fish were washed, sorted and identified. The fork lengths of a random sample of 20 of each species in each sample were measured. Type specimens of all species were preserved for subsequent checking and the remainder of the collection discarded. No systematic records of weight or sex were kept, but regular notes were taken of unusual species, obvious parasites etc. The nomenclature used here is after Wheeler (1969b).

RESULTS

The main results from the 1977 collections are given in Tables 1 and 2. It can be seen that a total of 28 different species was recorded, but that the total catch was dominated by relatively few species – notably Sprat, Herring, Whiting and Sand Goby. Some species were recorded only occasionally, e.g. Eel, Weever, Painted Goby etc.

No attempt was made to quantify the catch involved at this power station and so there is no information on the total numbers entrained. The numbers included in Table 2 are intended solely to indicate the relative abundance of each species compared to the others and the relative number of occasions each species occurred in the total number of samples collected. In general it is true to say that the most abundant species also occurred on the highest number of occasions, and vice versa.

Seasonal information on the numbers of fish collected and the number of species identified on each sampling date is shown in Figure 2. It is clear that far more individuals and species were entrained during the colder winter months of the year than during the warmer summer months. Numbers were particularly high at the beginning of 1977.

The sizes of some of the fish collected are given in Figure 3. For the most part, the fish involved are rather small, representing the full range of size of the smaller species (e.g. Sand Goby) but probably only the smaller (and presumably younger – perhaps first and second year classes) of the larger species (e.g. Whiting). The length distribution of the four most abundant species in January 1977 is shown in Figure 3.

CLUPEIDAE	
Sprattus sprattus	Sprat
Clupea harengus	Herring
ANGUILLIDAE	
Anguilla anguilla	Eel
SYNGNATHIDAE	
Syngnathus acus	Great Pipefish
Entelurus aequoreus	Snake Pipefish
GADIDAE	
Merlangius merlangus	Whiting
Pollachius virens	Saithe
Gadus morhua	Cod
Raniceps raninus	Tadpole-fish
Ciliata mustela	Five-bearded Rockling
AMMODYTIDAE	
Ammodytes tobianus	Sand Eel
Hyperoplus lanceolatus	Greater Sand Eel
TRACHINIDAE	
Trachinus vipera	Weever

GOBIIDAE	
Pomatoschistus pictus	Painted Goby
Pomatoschistus minutus	Sand Goby
PHOLIDIDAE	
Pholis gunnellus	Butterfish
ZOARCIDAE	
Zoarces viviparus	Eelpout
MUGILIDAE	
Crenimugil labrosus	Thick-lipped Mullet
COTTIDAE	
Myoxocephalus scorpius	Bull Rout
Taurulus bubalis	Sea Scorpion
AGONIDAE	
Agonus cataphractus	Pogge
CYCLOPTERIDAE	
Cyclopterus lumpus	Lumpsucker
LIPARIDAE	
Liparis liparis	Sea Snail
Liparis montagui	Montagu's Sea Snail
GASTEROSTEIDAE	
Spinachia spinachia	Fifteen-spined Stickleback
PLEURONECTIDAE	
Limanda limanda	Dab
Platichthys flesus	Flounder
Pleuronectes platessa	Plaice

TABLE 1 Check list of fish caught on Cockenzie Power Station Screens in 1977 (Nomenclature after Maitland (1972))

Species	% of Catch	% of Occurrences
Sprat	18.1	71.1
Herring	18.1	71.1
Eel	0.2	11.1
Great Pipefish	0.6	17.8
Snake Pipefish	0.1	4.4
Whiting	8.4	60.0
Saithe	0.7	22.2
Cod	0.3	15.5
Tadpole-fish	0.03	2.2
Five-bearded Rockling	1.1	26.7
Sand Eel	4.2	62.2
Greater Sand Eel	0.3	13.3
Weever	0.03	2.2
Painted Goby	0.03	2.2
Sand Goby	35.0	84.4
Butterfish	0.5	15.5
Eelpout	5.9	51.1
Thick-lipped Mullet	0.03	2.2
Bull Rout	0.1	6.6
Sea Scorpion	0.3	15.5
Pogge	2.8	48.9
Lumpsucker	0.03	2.2
Sea Snail	0.1	6.7
Montagu's Sea Snail	0.1	4.4
Fifteen-spined Stickleback	0.2	11.1
Dab	1.4	26.7
Flounder	0.9	24.4
Plaice	0.6	20.0
Totals	2956	46

TABLE 2 Composition of fish catch at Cockenzie in 1977 expressed as a % of the total number collected and a % of the total number of occurrences in screen collections.

DISCUSSION

One of the problems of interpreting fish catch data from power stations is to know just what they mean in terms of the natural fish population of the estuary itself. Short-term and long-term changes in

the amounts of water pumped through the screens, in winds, tides and temperatures, and in both inter- and intra-specific behaviour (which may change seasonally) of the fish themselves, can lead to difficulties of interpretation. The quantification of data in particular, is often very difficult. In this premlininary study therefore, interpretation is restricted to simple aspects of the data, which are hopefully more or less free of the problems noted above.

The total number of species recorded in 1977 from the Firth of Forth at Cockenzie was 28. This is very many fewer than the 125 recorded in total for the estuary as a whole (Parnell 1838) but compares favourably with the 24 species recorded recently from regular Agassiz trawling at various places between Longannet and Aberlady (Dr M. Poxton personal communication). This confirms recent work reported by the Central Electricity Generating Board that power station intakes are relatively unselective. They are certainly far less demanding in terms of fisheries man-power.

With the exception of Eel, Thick-lipped Mullet and Flounder all the fish collected were purely marine species. All Eels and many Flounders though hatched in the sea do spend some time in freshwater – up to 25 years in the case of the former species, but naturally pass through estuaries travelling to and from the sea. Many Flounders and most Mullets spend the greater part of their lives in or near estuaries and are typical members of the fauna there. It is of interest to note that although only one Mullet was collected at Cockenzie during 1977, these fish are commonly caught by anglers fishing near the heated effluent discharged from the power station.

Few of the marine species call for special comment. Sprat are known to be abundant in the Firth of Forth and form the basis of a fishery there. Herring on the other hand, though once caught in large numbers in the area (Thomas and Saville 1972) are now relatively unimportant. All the species concerned are indicated by Wheeler (1978) as occurring in inshore areas along this part of the British coast, with the exception of the Snake Pipefish, which is mainly an off-shore oceanic species and the Painted Goby which is supposed not to enter estuaries. However, both species were really rather rare at Cockenzie.

The work reported here was continued and extended in 1979 to cover three power stations in the Firth of Forth – at Cockenzie, Longannet and Kincardine. The data from these more recent comparative collections are at present being analysed and will be reported in a future paper. In addition, in that paper it is hoped to describe some much earlier unpublished work carried out in the early 1960's at Kincardine power station by the Department of Agriculture and Fisheries for Scotland.

In general, the composition of the fish catch at the three power stations (Cockenzie, Longannet and Kincardine) is similar – but there are certain consistent differences. For instance species with strong freshwater affinities are very rarely found at Cockenzie, but are taken regularly at Longannet and Kincardine. Lampreys, Trout and Eels, which all spend part of their lives in fresh waters and part in salt water, come into this category.

ACKNOWLEDGEMENTS

We are grateful to the South of Scotland Electricity Board for permission to visit the power station at Cockenzie during 1977. In particular, we would like to thank Mr M. Ilett and Mr Burdett for their help in arranging facilities there. Mr A. A. Lyle gave valuable help with the collecting of fish.

REFERENCES

CLARIDGE, P.N. and GARDNER, D.C. 1978. Growth and movements of the Twaite shad *Alosa fallax* (Lacepede) in the Severn Estuary. *Journal of Fish Biology* 12, 203-211.

McLUSKY, D.S. 1978. Ecology of the Forth estuary. *Forth Naturalist and Historian* 3, 10-23.

MAITLAND, P.S. 1969. A preliminary account of the mapping of the distribution of freshwater fish in the British Isles. *Journal of Fish Biology* 1, 45-58.

MAITLAND, P.S. 1972. A key to the freshwater fishes of the British Isles, with notes on their distribution and ecology. *Scientific Publications of the Freshwater Biological Association* 27, 1-139.

MAITLAND, P.S. 1979. The freshwater fish fauna of the Forth area. *Forth Naturalist and Historian* 4, 33-47.

PARNELL, R. 1838. Fishes of the district of the Firth of Forth. *Wernerian Natural History Society* 7, 161-520.

THOMAS, H.J. and SAVILLE, A. 1972. The fisheries of the Forth-Tay estuaries. *Proceedings of the Royal Society of Edinburgh* Section B 71, 171-188.

THORPE, J.H. and GIBBONS, J.W. 1978. Energy and Environmental Stress in Aquatic Systems. U.S. Department of Energy, Springfield, Virginia.

WHEELER, A.C. 1969a. Fish life and pollution in the lower Thames: a review and preliminary report. *Biological Conservation* 2, 25-30.

WHEELER, A.C. 1969b. The Fishes of the British Isles and North-west Europe. Macmillan, London.

WHEELER, A.C. 1978. Key to the Fishes of Northern Europe. Warne, London.

Figure 1 Map of part of the Firth of Forth showing the position of Cockenzie power station.

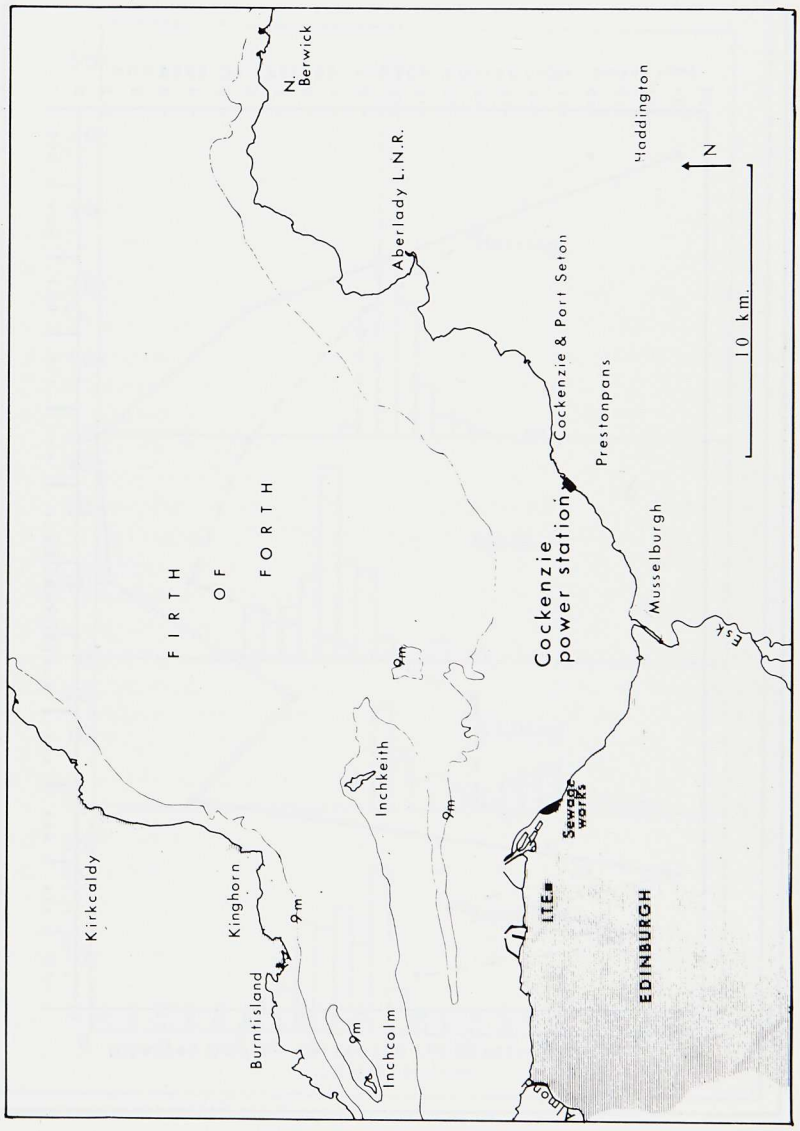

Figure 2 Numbers of fish per screen and numbers of species in each collection during 1977.

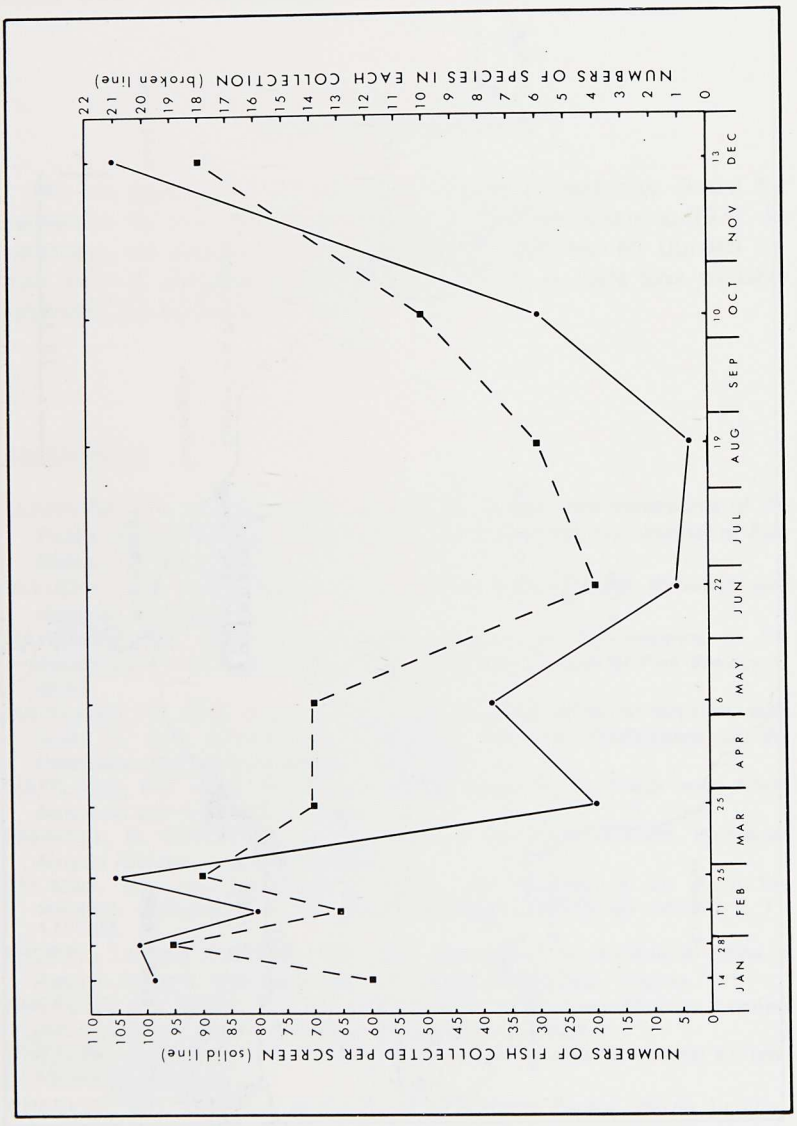

Figure 3 Length/frequency distributions of the four most abundant species in the collection taken on 28th January 1977.