Fish Guidance Systems Ltd

About the Company

MISSION STATEMENT

"Fish Guidance Systems Ltd aims, through continuous research and development, to lead the field in acoustic fish guidance and protection, and to make systems cost-effective, so as to ensure widespread implementation to the benefit of both users and the natural world. Our market is worldwide."

Formed in 1994 by Fish Biologist Dr Andrew Turnpenny and Underwater Acoustics Engineer Dr Jeremy Nedwell, Fish Guidance Systems Ltd brings together a formidable combination of scientific and engineering expertise.

FGS Ltd is a manufacturing company which specialises in the development, production, planning and installation of acoustic fish guidance systems. With applications ranging from fish protection at large nuclear and hydro-electric power plant, to fish guidance for trapping and census purposes, FGS has innovative solutions which can cater for all aquatic environments.

Acoustic fish guidance brings the benefits of screening or diverting fish from water flows, without the attendant problems of fish damage and debris blockage that occur with conventional mechanical screens.

What is Acoustic Fish Guidance?

Almost all fish can detect sounds travelling through the water in which they live - either as vibrations (caused by particle motion) or as pressure changes (sound pressure). The *'hearing band'* for most fish lies between 10 and 3,000 Hz, and is thus mostly within a range audible to the human ear (50 - 20,000Hz).

Certain kinds of sound are repellant to fish, and the fish simply do not get used to them, just as humans cannot easily adjust to the sound of a police siren. Such sounds have been developed in the laboratory for a wide range of species and are used for fish guidance. Repulsion is thus the chief principle used to guide fish: the skill is in creating a well-defined sound field which will act as a deflecting or guiding surface.

FGS Customers

Our products are aimed at a wide range of markets and applications, including:

- potable water, irrigation and flood-relief pumping stations;
- nuclear, fossil-fuelled and hydro-power plant;
- fish farms and aquaculture units;
- fish ladders and fish census schemes.

We pride ourselves in our flexibility and will do our best to design systems to meet each customer's requirements.

Research Development and Testing

FGS systems have been developed in conjunction with Fawley Aquatic Research Laboratories Ltd and Subacoustech Ltd, of Southampton, both companies with international research credentials. When you purchase an FGS system, you are purchasing the benefits of years of collaborative research into fish behaviour and underwater acoustics. In 1993-94 and 1994-95, Subacoustech and Fawley jointly won DTI SMART Awards (Small firms Merit Award for Research and Technology) for developments in the field of acoustical fish guidance. For many of the systems installed to date, Fawley and Subacoustech have been commissioned by the customers to conduct proving trials to assess performance, an additional service which is available to all our customers. The Institute of Freshwater Ecology has also been commissioned by the National Rivers Authority to undertake independent trials of FGS systems.

FGS Services

FGS provides the following range of services in the field of fish guidance and protection. Full insurance cover is provided for all our services:

- Initial site survey and planning;
- Manufacture/supply of all the necessary hardware and software;
- Installation and commissioning;
- Acoustical measurement and optimisation;
- Customised instrumentation and integration with existing plant control systems;
- Full after-sales servicing;
- Leasing arrangements.

Dr Andrew Turnpenny, DIRECTOR

Andrew Turnpenny took a first degree in Zoology from the University of Nottingham in 1974 and was awarded a PhD in Fish Biology at the University of Wales, UWIST, Cardiff in 1978. In 1977, he joined the Marine Biological Laboratory of the Central Electricity Research Laboratories, later being appointed Head of Aquatic Technology and Analytical Chemistry for the National Power Technology and Environmental Centre. In 1991, Dr Turnpenny formed, with colleagues, the independent company Fawley Aquatic Research Laboratories Ltd, of which he is a Director.

From 1983-89 he served as the Hon. Secretary and on the Council of the Fisheries Society of the British Isles, and in 1988 he was elected a Fellow of the Institute of Biology.

The main theme of his research since 1977 has been the problem of marine and freshwater fish becoming entrained in power station and industrial water flows, and associated aspects of fish behaviour. He has published more than 60 scientific papers, articles and reviews, and is an internationally recognised authority in this field.

Dr Jeremy Nedwell, DIRECTOR

Jeremy Nedwell graduated with honours in Engineering Acoustics, at the Institute of Sound and Vibration Research, Southampton University, in 1981. He was awarded a PhD in Underwater Acoustics in 1986, and was appointed Admiralty Lecturer in Underwater Acoustics at the ISVR in 1985. An appointment as Director of the newly-formed Underwater Acoustics Research Centre was made in 1992. He was responsible for founding the University's A B Wood Laboratory, and served on several national and international advisory panels, including as an expert in Underwater Acoustics to the Commission of the European Community.

In 1993, he formed Subacoustech Ltd, an independent company specialising in Underwater Acoustics. He has been involved in a wide range of research including modelling of underwater sound fields in complex geometries, investigations of sources of underwater sound, numerical modelling in acoustics, and assessing the environmental impact of sound, including blast. He is retained as an expert advisor to several government bodies.

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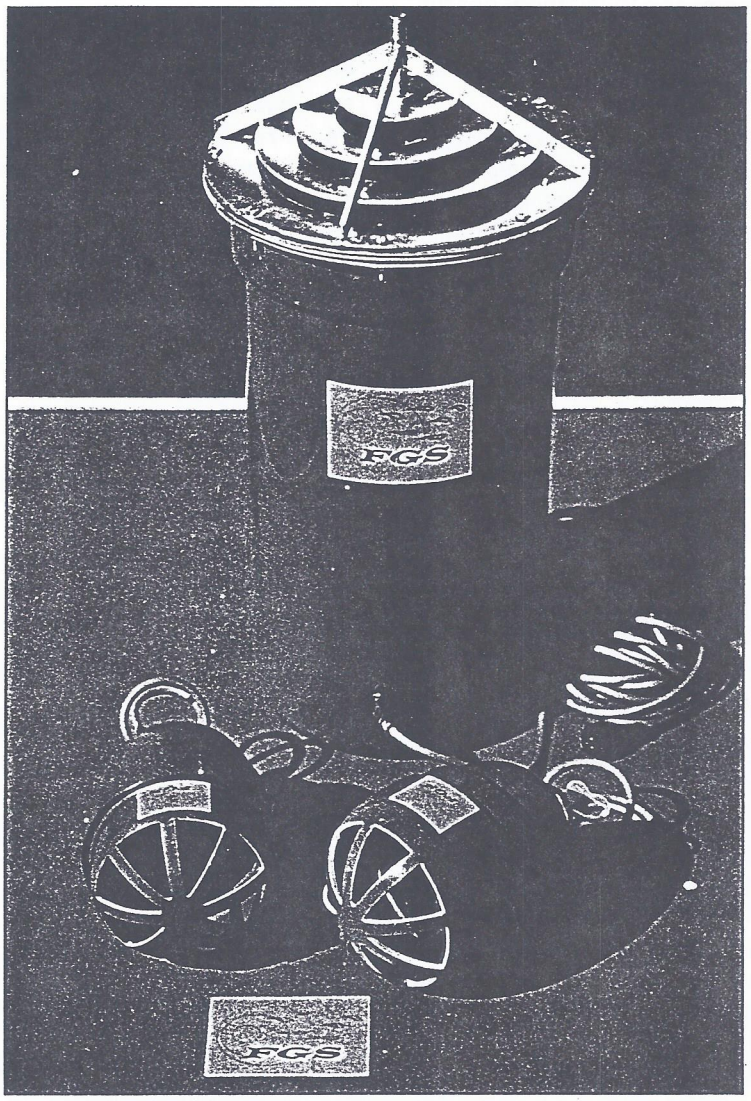
Fish Guidance Systems Ltd

The FGS 15 and 30 Series Sound Projectors



Introducing the FGS 15 and 30 Series Underwater Sound Projectors - the first British-made transducers designed specifically to meet the needs of acoustic fish guidance and deflection, built to quality and performance standards matched to their task.

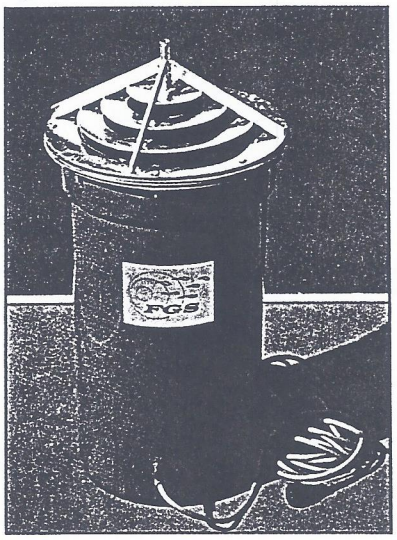
The Model 30-Series Sound Projectors

Suited to larger scale applications, the 30-Series units are made in 300W and 600W versions, according to power requirements. The units feature electromagnet transducers which have a proven track record for reliability and performance in fish guidance applications. A double-skinned, glass-reinforced plastic housing provides a rugged containment which is suited to marine and freshwater installations. The sound-generating surface is a flexible neoprene membrane, and this is protected from external mechanical damage by a conical grill of concentric rings manufactured from marine-grade stainless steel.

Automatic depth-compensation is an additional feature of the Model 30-Series. An internal compliant air reservoir provides dynamic pressure compensation over a 20:1 range, easily coping with tidal ranges in most marine locations and absorbing higher frequency changes caused by turbulence and wave action.

With a frequency range of 10-600Hz (+or- 3dB), the Model 30-Series acts as an omni-directional radiator and can be used in arrays or other configurations to create extensive sound fields.

Where multiple units are used, the FGS Prism Acoustic Model may be used to attain optimum performance.

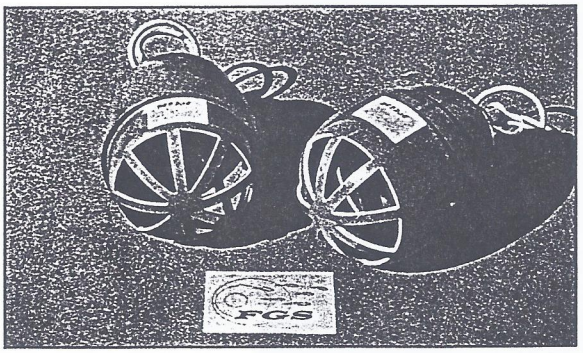


Model 30-Series - Brief Specification:

Maximum dimensions: *770 (H) x 385 (OD) mm*
Power rating: *300 or 600W RMS*
Source level: *168dB 1µPa @ 1m (300W)*
Source level: *174dB 1µPa @ 1m (600W)*
Frequency range: *10-600 Hz (+or- 3dB)*
Pressure compensation: *ratio of 20:1*
Max. operating depth: *30 m*

The Model 15-Series Sound Projectors

Small but very rugged, the Model 15-Series is designed for smaller applications, or where a more finely-controlled sound field is required.



In spite of its size, the Model 15-Series packs a fair punch, delivering a sound pressure level adequate for protecting an area of up to 3m radius or more (depending on species and water conditions) over a 100-600 Hz frequency band.

The Model 15-Series is primarily intended for freshwater applications, having a lower pressure compensation range which is intended to cope with the depth fluctuations normally found in small lakes and rivers.

Nevertheless, the Model 15 is fully marine resistant and can be used in tidal waters when suspended from a buoy or float to maintain a constant immersion depth.

The Model 15 is housed in a resilient GRP capsule which is pre-pressurised to the required operating depth. An integral mounting plate with four stainless steel threaded bushes allows for convenient fixing.

Model 15-Series - Brief Specification:

Maximum dimensions: *320 (L) x 190 (OD) mm*
Power rating: *100W RMS*
Source level: *164 dB re 1µPa @ 1m*
Frequency range: *100-600 Hz (+or- 2dB)*
Pressure compensation: *pre-pressurised to operating depth*

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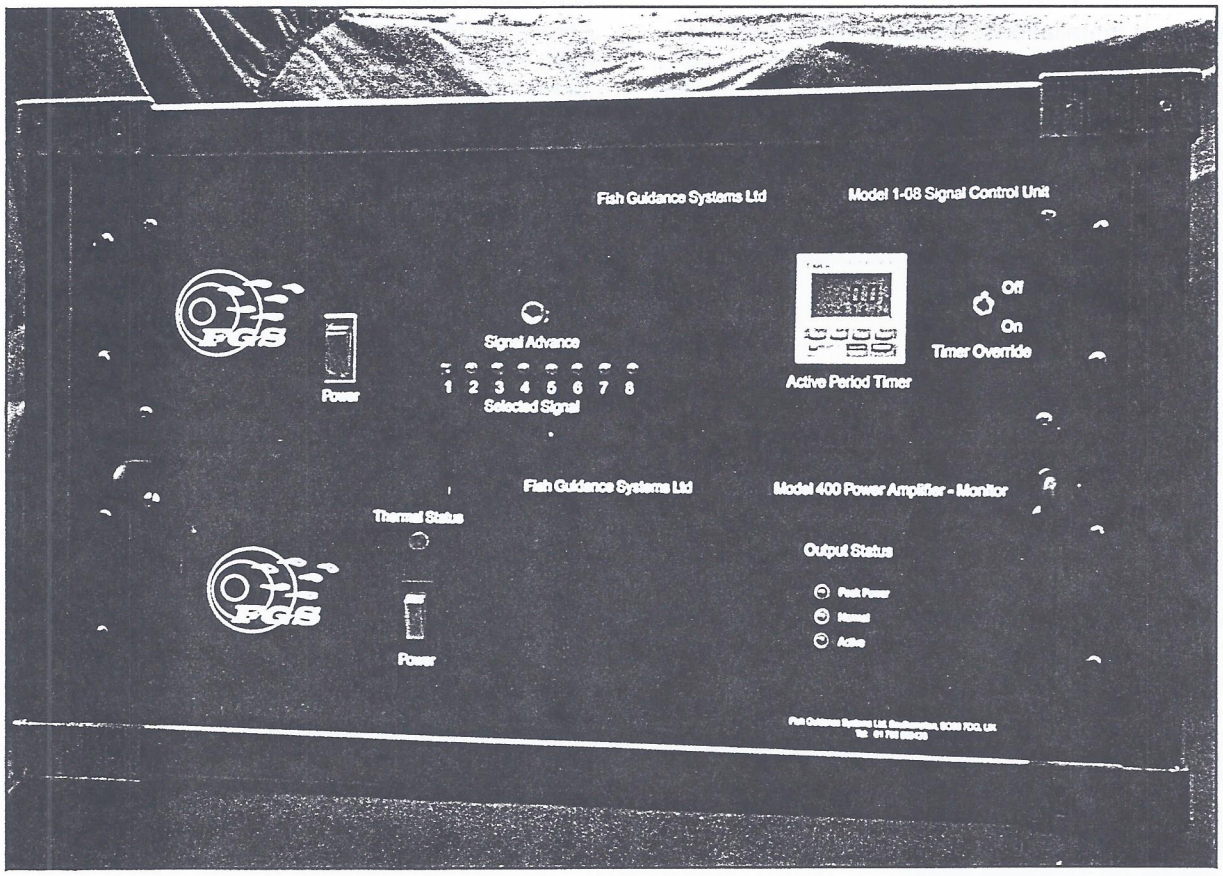
The FGS Model 1-08 Signal Control Unit & Model 400 Amplifier / Monitor



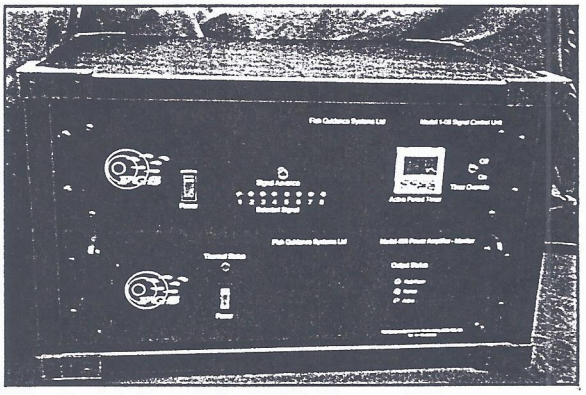
At the heart of the acoustic fish guidance system are the signal generator and power amplifier modules. The Model 1-08 Signal Control Unit and the Model 400 Amplifier/Monitor have been developed specifically for fish guidance applications.

The Model 1-08 Signal Control Unit

The Model 1-08 Signal Control Unit uses solid-state digital recording technology to hold and play back up to eight fish guidance signals. Each signal can be manually selected and run continuously, or a pre-timed sequence of signals can be selected. Multiple signals are used, for example, where it is required to deflect a resident, non-migratory population which, after protracted exposure, might become accustomed to a single signal: the signal sequence can be operated so as to minimise this effect. It also provides the opportunity to change the signal seasonally in order to provide optimum effectiveness for a sequence of species or life stages. The timer may also be configured to generate a programme of sound-on and sound-off periods, for example for night-time only operation.

For most installations, a single Model 1-08 unit, which will drive up to six Model 400 Amplifier/Monitor units, is adequate. For larger configurations, additional output amplification can be provided.

The Model 1-08, like the Model 400, is supplied in standard 19-inch rack-mount form, for installation in a 19-inch instrument rack or environmental housing.



Model 1-08 - Brief Specification

Type: solid-state digital recording on EPROM via 8-bit word
Max. output voltage: 1V RMS
Max. signal length: 32k words
Frequency range: 20 - 10k Hz
Max. No. pre-recorded signals: 8
Timer: any of 10 min on/off periods over 24 hour period or 1 hour on/off periods over 7 days
Power requirements: 240V AC, single phase, 0.5KVA

The Model 400 Amplifier/Monitor

The Model 400 is the power-house of the system, boosting the deflection signal for delivery to the sound projectors. Not just an amplifier, the Model 400 performs a series of essential monitoring functions to ensure the system's smooth performance. A number of LED indicators on the front panel of the unit display essential information about the operational integrity and function of the system, while further diagnostic information is provided for the benefit of our engineers.

One Model 400 unit is normally sufficient to power two Model 30-Series sound projectors, or up to eight Model 15-Series units.

As with the Model 1-08 Signal Control Unit, the Model 400 is supplied in rack-mount form, with internal cooling fans. Owing to high heat rejection, it is essential that the mounting rack or housing is well ventilated. In the event of overheating, however, the Model 400 has full thermal overload protection.

Model 400 - Brief Specification:

Power output:
455W RMS into 4 ohms
305W RMS into 8 ohms
Power bandwidth: -3 dB, 1Hz - 100kHz
Damping factor: >300
Slew rate: 70V / µsec
Input sensitivity: 500mV RMS
Input impedance: 100kohms
Signal-to-noise ratio: 110dB
Power requirements: 240V AC, single phase, 1KVA

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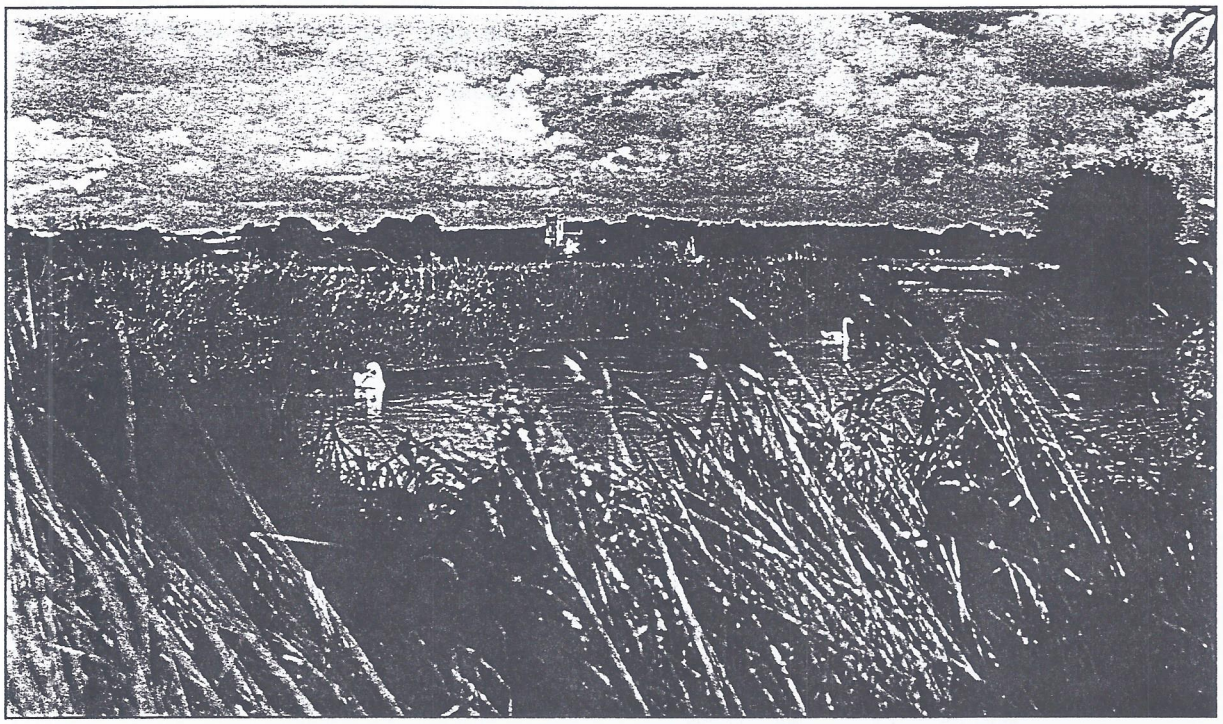
Fish Deflection Case History

River Frome Salmon Smolt Census



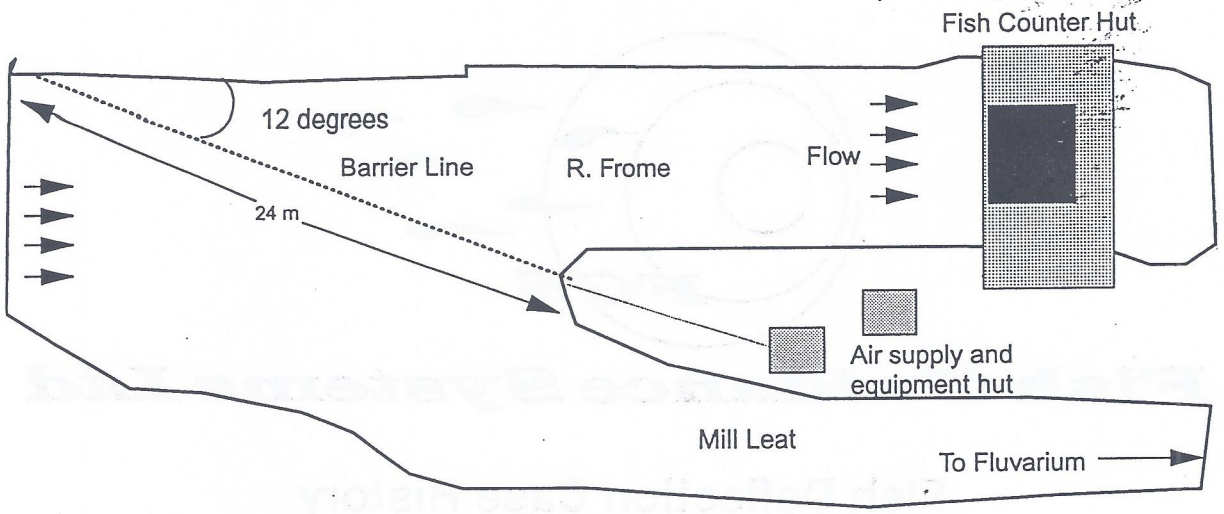
Background

Stocks of Atlantic salmon *(Salmo salar)* in Britain have declined in recent years, for a variety of reasons. Effective management of salmon stocks requires a knowledge of the population statistics so that the population dynamics can be fully understood.

Conventionally, these statistics have been obtained from catch records, redd counts, juvenile surveys and from electronic adult fish counters in rivers. Little attention has been paid to enumerating the smolt lifestage. Being the final riverine stage before migration to sea, counting the size of the smolt run provides necessary information to distinguish where in the life cycle impacts might be occurring.

As part of research into salmon population dynamics, scientists at the Institute of Freshwater Ecology's River Laboratory in Dorset, England, wanted to establish a facility to divert salmon smolts from the River Frome, which passes through the Laboratory's land, into a mill leat which supplies its experimental Fluvarium. The Fluvarium has two glass-sided channels, in which it was possible to place a video system and electronic counters to monitor the passage of smolts.

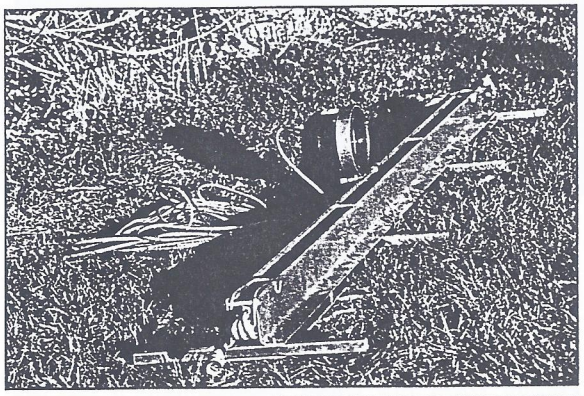
An acoustic deflection system was set up to divert fish from the main river.



Note: barrier line has eight Series 15 Sound Projectors

The Main River Diversion

The smolt diversion acoustic barrier is based on a SPA line, comprising eight FGS Model 15-50 Sound Projectors, hybridised with a BAFF system. The principle of the BAFF, a completely novel, patented system, is that the sound is coupled to an air-bubble curtain which constrains the horizontal dispersion of the sound field. Hence, it is possible to achieve a guiding wall of sound along a pre-determined line, without the usual problems of uneven sound dispersion over uneven topographies in water. In the case of the River Frome, the barrier line is arranged to create a funnel, leading into the mill leat entrance. The angle of the barrier was designed to ensure that the fish were diverted sideways at a rate within their swimming capacity. Water velocity at the barrier face is around 1-1.2ms^{-1}.



A combined BAFF and Sound Projector Unit

The project was subsequently expanded at the request of the National Rivers Authority to incorporate a number of different diversion techniques, including the use of SPA (Sound Projector Array) and BAFF (Bio-acoustic Fish Fence) systems and a simple bubble curtain.

The aims were extended to include evaluation of the various methods for smolt diversion, for potential application to water pumping stations, fish farms, hydro-electric installations and irrigation canals, as well as for smolt census. Only the main river diversion scheme, for which the preliminary 1995 findings are available, is covered here.

Acoustic Modelling

A potential problem of placing the acoustic diversion system close to the entrance to the mill leat, was of the underwater sound field spreading to block fish entry to the leat. To minimise this risk, acoustics engineers from Subacoustech Ltd undertook a planning exercise, using the PrISM acoustic model. The results (see figure) showed that a well confined field could be generated with the appropriate sound projector spacing.

Diversion Efficiency

It will be some time before the smolt barrier has been comprehensively tested, but observations made by IFE scientists during the 1995 spring smolt run, indicated a high diversion efficiency. During the peak run on 5th May, some 575 smolts were observed to be successfully diverted by the barrier, while approximately 50 were seen to pass below the barrier over the same period. This represents a diversion efficiency of around 92%. The barrier extends over only 90% of the river width.

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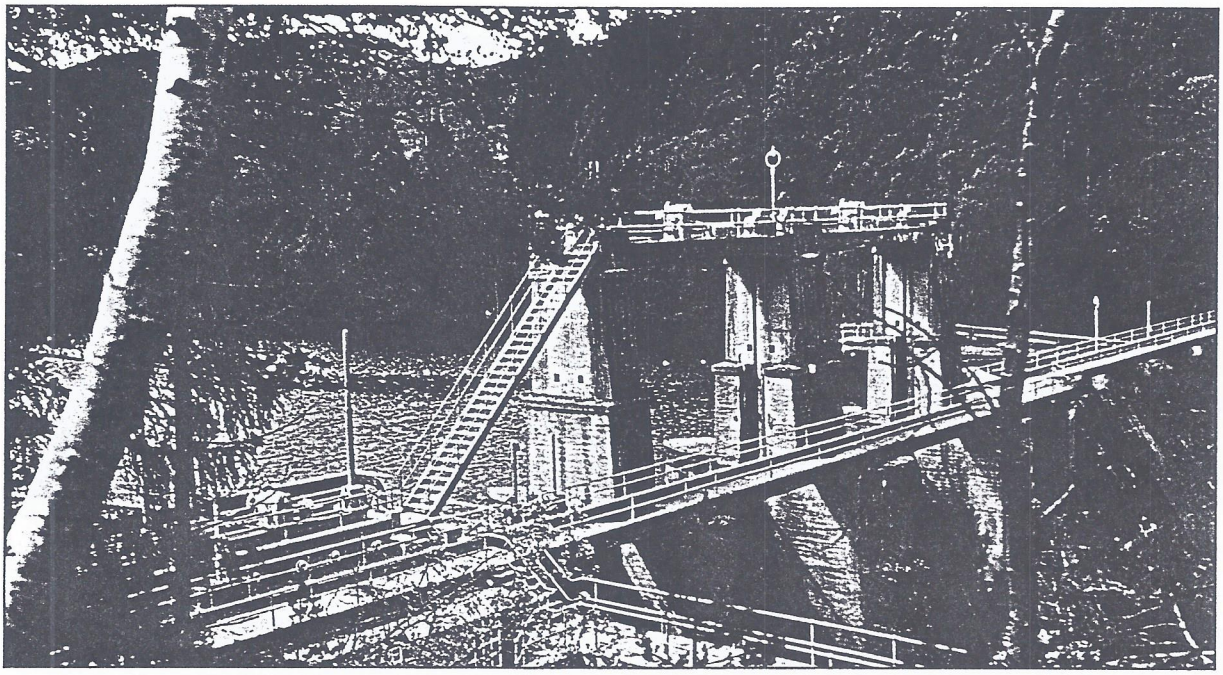
Fish Guidance Systems Ltd

Fish Deflection Case History

Dunalistair Hydro-electric Dam



Background

The majority of hydro-electric power stations in Britain are located on upland river/ reservoir systems that are home to Atlantic salmon *(Salmo salar)* and/or sea trout *(S. trutta).* The life cycle of these species is divided between river and stream waters and the sea. The adults spawn in upland nursery streams and the young spend 1-3 years in the river system before migrating to sea as the "smolt" stage. After spending one or more years at sea, the adults return to the river and must negotiate weirs, dams, fish ladders and other impediments to return to the spawning grounds, so completing their life cycle. Some adults return to the sea and are known during this phase as "kelts".

Both descending smolts and kelts are at risk of entering the turbines of a hydro-electric station but are normally prevented from doing so by metal smolt screens - perforated grids placed across the flow to divert them safely.

The Problem

Smolts screens present difficulties for the operators of hydro stations, as they rapidly become blocked by debris. This results in loss of generating flow and the need for around-the-clock cleaning and maintenance. Scottish HydroElectric therefore commissioned trials of an acoustic guidance system to see whether the conventional smolt screens could be replaced by an acoustic field, with the attendant advantages of low maintenance and unrestricted flow.

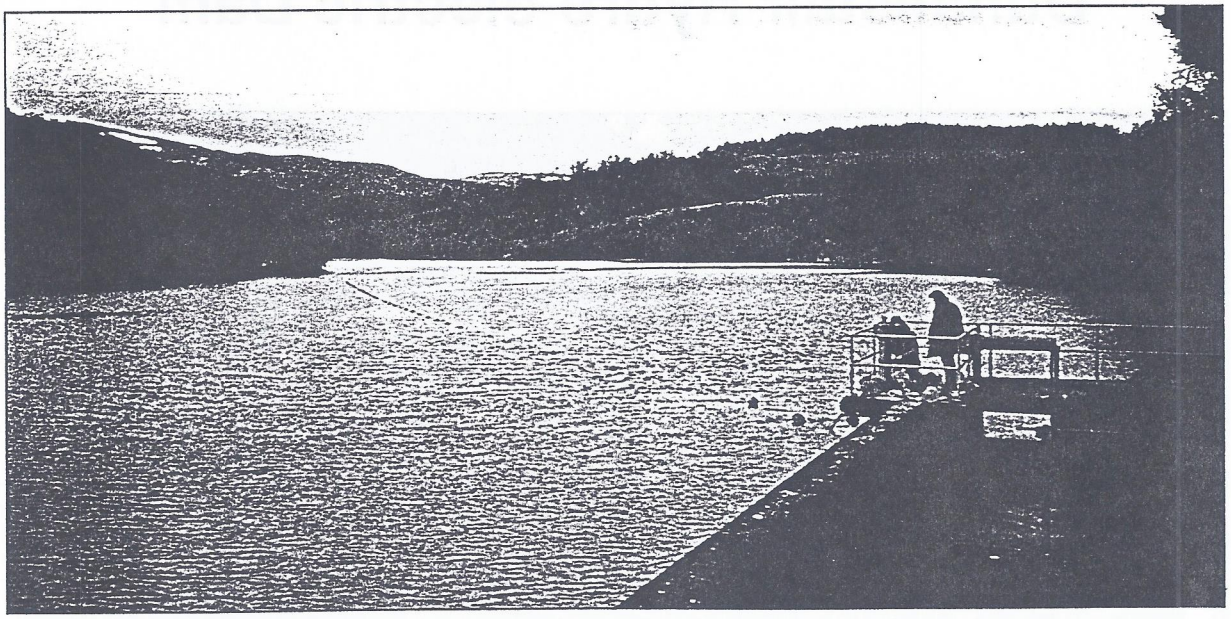
The Site

Dunalistair Dam is located in the Central Highlands of Scotland in Perthshire, on the River Tummel system. Water impounded behind the dam is fed to the turbine hall further downstream by an aqueduct, in which the conventional smolt screens are fitted. These serve to divert the smolts and kelts back to the original course of the river. On the opposite side of the dam is a pool-and-traverse fish ladder, which allows adults to ascend the dam, and some of the smolts to descend. A third route for downstream fish passage is the trash chute, which allows debris to pass over the dam.

Fish Diversion Trials

Trials of the system's efficiency for smolt diversion are being undertaken by scientists from Fawley Aquatic Research Laboratories. In order to do this, fish traps are placed in the fish return path from the smolt screens, in the fish ladder and in the path of the trash chute, allowing daily tallies to be made of the smolts passing in each direction.

For testing purposes, the sound system alternates between sound-on and sound-off periods of 1-2 days. The sound signal used is one developed and tested on smolts in a salmon farm.



Buoys supporting the SPA Array

The Sound System

The aim with the sound system was to divert smolts and kelts from across the whole width of the river into the small opening at the top of the fish ladder. This required an "acoustic funnel", a 200m guiding wall of sound which would deflect the smolts across the river. Preliminary investigations revealed that water was deeper on the side of the fish ladder, leading to a risk of enhanced sound propagation into the critical area for guidance. Acoustics engineers from Subacoustech Ltd conducted an assessment using the PrISM acoustic model and devised a suitable arrangement to avoid this problem. This involved a SPA (Sound Projector Array) line of 64 FGS Model 15-100 units, suspended at 1m below the water surface. The shallow deployment was to limit the spread of sound, but hence required the large number number of units to cover the 200m span. To our knowledge, this is the largest SPA array ever deployed for fish guidance.

The electronic amplifier and signal generator units were located in an environmental housing at one end of the array.

The trials are in the early stages at present and consequently, results are not yet available for publication.

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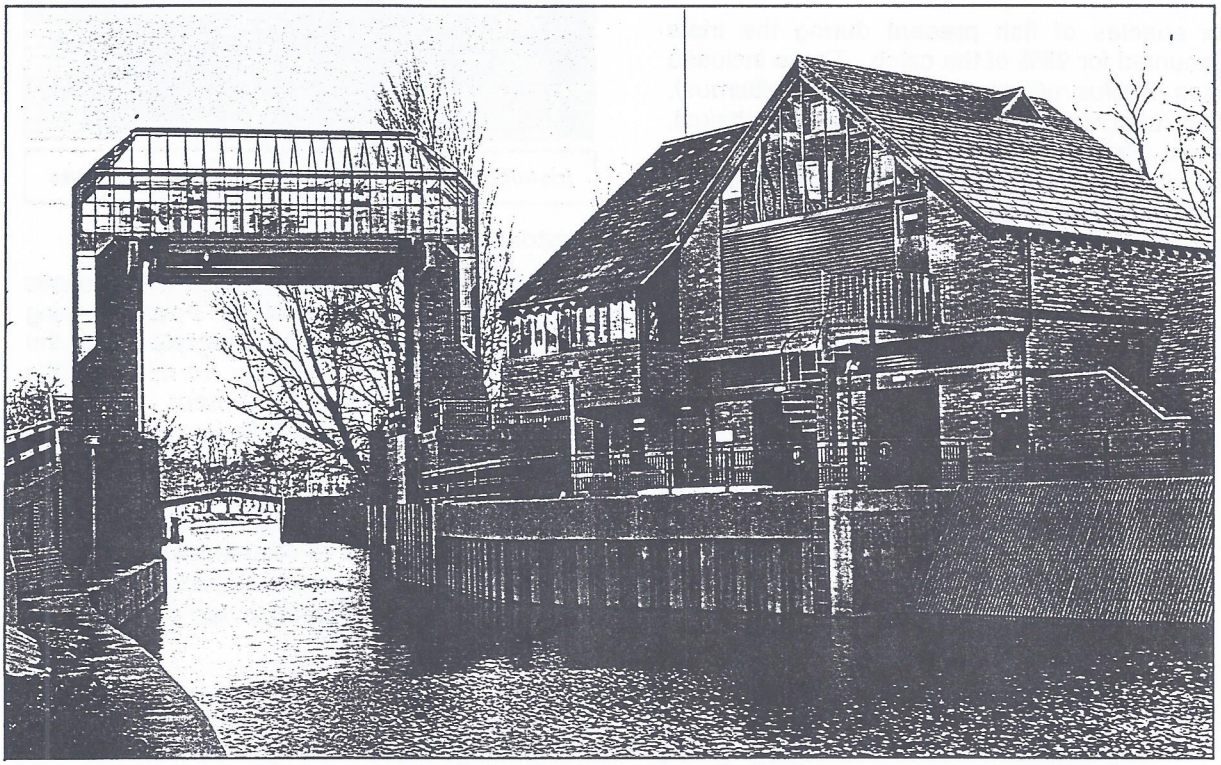
Fish Deflection Case History

River Foss Pumping Station, York



Background

The National Rivers Authority's Foss Pumping Station in York is part of a flood alleviation scheme designed to protect the historic centre of the city. The scheme functions by means of a barrier - not unlike the Thames Barrier - which closes off the lower end of the River Foss under flood conditions. This prevents water from the River Ouse backing up into the River Foss, with the risk of flooding the City. The pumping station then discharges water from the River Foss into the River Ouse, across the barrier.

The Problem

Operation of the scheme has led to a certain number of coarse fish from the River Foss being drawn into the water pumps and damaged.

The pumping station has eight pumps, rated at $3.8 m^3 s^{-1}$, giving a total capacity of $30.4 m^3 s^{-1}$.

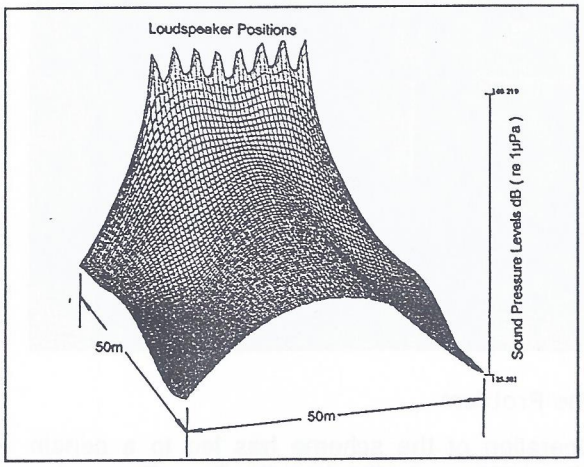
As the pumps are operated once a month for testing purposes, damage to fish is not just confined to flood events. Physical screening to prevent fish entry would have led to the risk of screen blockage and would have exacerbated the flood risk. The National Rivers Authority therefore wished to investigate the use of acoustic fish screening, which carries no blockage risk.

Trials of an Acoustic System

A series of trials was performed at the pumping station by scientists from Fawley Aquatic Research Laboratories, over the autumn and winter of 1993-4. A single sound projector was used in one pump chamber at a time, connected to an amplifier and signal generator. The signal used was one which had been developed and tested in the laboratory on a variety of coarse fish species. For trial purposes, the pump was operated with and without the sound system operating. Any fish drawn in by the pumps were collected by a net placed in the pump outlet, and compared for sound-on and sound-off periods. The pump chosen for each trial pair of periods was altered on a random schedule.

Trial Results

Six species of fish present during the trials accounted for 98% of the catch. These included roach *(Rutilus rutilus)*, bleak *(Alburnus albumus)*, dace *(Leuciscus leuciscus)*, chub *(L. cephalus)*, perch *(Perca fluviatilis)* and common bream *(Abramis brama)*. The overall reduction in fish catch attributed to the acoustic deterrent system was 80%. The system was also shown to be effective over the whole size range of fish present (20-150mm). Water temperature during the trials was <1°C. These low temperatures may have limited the ability of fish to swim away from the pumps.

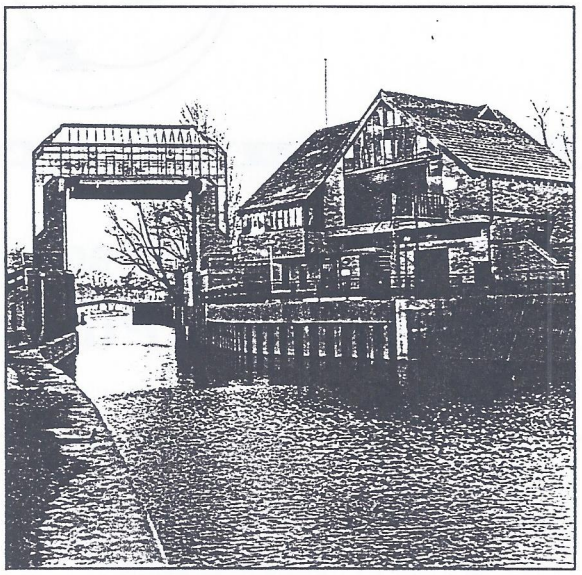


Example of PrISM Sound Model for the Foss

Full System Installation

Following the success of the trials, FGS were commissioned to build and install a full acoustic deterrent system to cover all 8 pump chambers. Various configurations were examined using the Subacoustech PrISM acoustic model. The challenge was to find an arrangement which yielded a smooth sound gradient, increasing towards the pump chambers (see figure).

The one chosen and installed comprises 8 Model 30/300 sound projectors driven by 4 Model 400 Amplifier/Monitors and a Model 1-08 Signal Control Unit.



Installing FGS 30-600 Sound Projector at Foss

Customised Instrumentation

As with many of our installations, the acoustic deterrence system fitted at the Foss Pumping Station was required to be integrated with the existing station Control Room. To minimise the intrusiveness of the equipment, the main electronic package was installed in the basement of the building, with only a master control console being fitted into the Control Room. The console was designed to complement the existing control systems. A PLC (Programmable Logic Controller) is used to enable individual amplifiers to be brought into operation for pump testing purposes.

Airborne Noises

A particular concern at the Foss site, which is located in the city centre of York, and close to a large hotel complex, was that airborne noise from the system might cause a nuisance. The system, however, is inaudible in air when the pumps are operating and has given rise to no noise problems.

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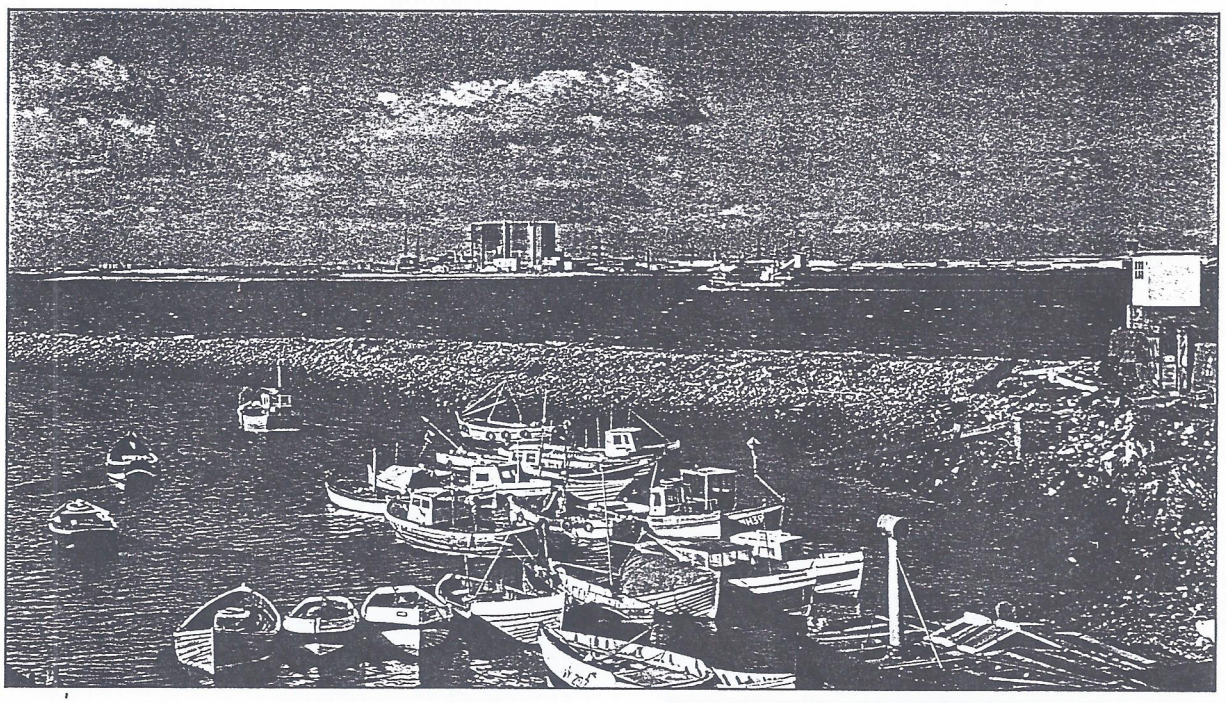
Fish Deflection Case History

Hartlepool Nuclear Power Station



Background

Large thermal power stations require huge flows of water for cooling purposes. Those sited on the coast normally use seawater, abstracting and returning millions of gallons per hour. It is not surprising to learn that marine life becomes caught up in the flow, and must be filtered out to prevent blockage of the fine heat exchanger tubes within the plant. Large rotating band or drum screens perform this function.

Fish form one of the most important groups of marine organism affected. While the impacts on fish ecology and the fishing industry from this cause have been shown to be minor, the quantities involved can, on occasions, overwhelm the screening systems, reducing the water supply, in extreme cases causing the station to cease generation.

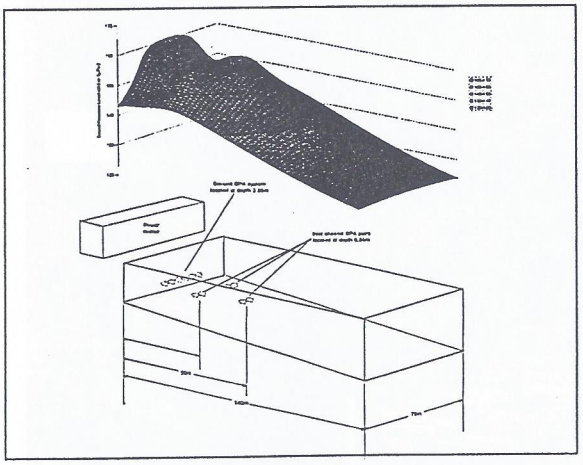
Nuclear Electric plc maintains a policy of continuous environmental improvement and has undertaken studies over many years to reduce the entrainment of fish into cooling systems. In 1995, they commissioned a trial of an acoustic fish deterrent system at Hartlepool Power Station, located on the Tees Estuary, in NE England.

The Site

Hartlepool is a directly-cooled, nuclear power station which abstracts its cooling water (CW) from the neighbouring Seaton Channel, within the Seal Sands nature reserve (a designated Site of Special Scientific Interest). The CW intakes are located on a wharf bordering the Channel; water enters them via a short (50m) dredged area connecting to the Seaton Channel.

The Sound System

The aim was to create a gradient of deterrent sound, increasing inshore towards the intake openings. The initial design involved a SPA (Sound Projector Array) line which used six FGS Model 30-600 sound projectors aligned along the intake wharf. A further two units were placed in the 50m intake channel, to ensure that under Low Water conditions, when water was confined to the dredged channel, fish would be repelled before they entered the high velocity region in front of the intakes. The suitability of this design was confirmed by acoustics engineers from Subacoustech Ltd, using their PrISM acoustical model (see figure). In fact when sound measurements were taken, it became apparent that background noise levels close to the intakes were uncommonly high, due to vibrations from the CW pumps. The configuration was therefore revised to boost the mid-intake channel sound signal levels by placing a further four sound projectors alongside the first two.



Example of the PrISM Sound Model for Hartlepool Power Station

System Trials

Scientists from Fawley Aquatic Research Laboratories conducted performance trials of the acoustic deterrent system. Fish catches were compared for alternating sound-on and sound-off days, over a 44-day period during March and April 1995. The signal used was one which had been developed in laboratory trials for use as a broad-spectrum marine fish repellent. The fish were collected from the CW filter screens of the power station, by day and night, and analysed for numbers, weights, sizes and species composition.

Findings

The results of the trials showed a marked reduction in fish catch when the acoustic deterrent system was operating. Sprat *(Sprattus sprattus)* and herring *(Clupea harengus)* formed over 80% of the fish numbers caught; whiting *(Merlangius merlangus)* were also numerous. In total, 48 species were recorded. For the majority of species, it is convenient to divide them into swimbladder and non-swimbladder species; the presence of a swimbladder generally conferring on fish a greater sensitivity to sound pressure. The percentage reductions in numbers with the sound system operating were as follows ($p<0.05$):

Sprat	-	*60%*
Herring	-	*80%*
Whiting	-	*54%*
S/B spp.	-	*55%*
Non S/B spp	-	*16%* (n.s.)

Concern for Seals

The Seaton Channel / Seal Sands Nature Reserve provides an important local habitat for the grey seal. Just prior to the proposed acoustic deterrent system trials, the seals had bred successfully within the Channel for the first time in living memory. Consequently, it was essential to ensure that the seals were not disturbed by the foreign underwater signals. English Nature were consulted and the local INCA (Industry Nature Conservation Association) group brought in Dr Susan Wilson, a seal specialist from Northern Ireland, to monitor the behaviour of seals during the trials. It was agreed that, in the event of signs that the seals were being disturbed by the sounds, the test programme would cease immediately.

The monitoring programme revealed no adverse behavioural changes in the seals, which occasionally approached the buoys marking the sound projectors, and the programme was completed successfully.

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