# HYDROACOUSTIC METHODS OF FISH SURVEY

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PROGRESS REPORT ON CONTRACT DO3/02/RHBNC/01 FOR THE PERIOD FROM MARCH 31ST - SEPTEMBER 31ST 1992.

Dr. A. Duncan & Dr. J. Kubecka: Hydroacoustic methods of fish survey (project 0250).

1. SUMMARY OF WORK UNDERTAKEN DURING THE REPORT PERIOD.

1.1 Chronology of work undertaken:

April 1992 - Start of seasonal monitoring of fish stock of River Thames in Chertsey Meads (=spring).
- Monitoring of salmon smolts behaviour after releasing into Thames.
- Intercalibration experiment with the Simrad EY 200 echo-sounder (Dr A Starkie, NRA Severn-Trent).
- Analysis of pulse width frequency distributions of single and multiple targets.

May - Monitoring of fish stock of River Thames in Chertsey Meads with the emphasis to spawning behaviour (1 - 2 surveys a week).

June - 24 hours monitoring of fish behaviour in River Thames (Chertsey) using the "river ladder"; also considered as summer monitoring.
- Calibration of beam pattern factor with SOAFD in Loch Duich.
- Short survey of Loch Ness, calibration with standard targets and measurement of target strength of Ness fish in situ.

July - Acoustic survey of Clifton and Culham reaches of the River Thames and Sutton Pools.
- Acoustic survey of Queen Elisabeth II Reservoir.

August - Acoustic survey of four Czech reservoirs where the fish stock had previously been estimated by classical net methods.
- Presenting of our results of acoustics surveys at the International Reservoir Limnology conference (Czechoslovakia) and the Unesco Ecotone meeting (Austria).

September - Acoustic survey of 40 km of the Vltava River in Prague
- Work in Alderhurst Pond: Tests on the influence of

separation distance between two standard targets and the ability of the dual-beam system to distinguish them as single targets. Comparison of pulse peak shape as measured in the pond and as described by dual-beam processor.

- Presentation of an invited paper in European Conference of Underwater Acoustics (Luxembourg).

## 1.2. Description of work undertaken

### 1.2.1. Spring survey of the River Thames at Chertsey Meads (April 15th to June 25th).

The aim of the study was to make several acoustic estimations of the fish stock of the River Thames between the Shepperton and Chertsey locks during a 24 hour cycle and to collect acoustic records of fish behaviour before and during the spawning of cyprinids. At the same time during these surveys, the conditions of background "noise" (acoustic volume reverberation) were compared with levels of turbidity and suspended solids of different particle size (<150, <100 and <33 µm) in order to estimate the possibility of any particle interference or sound attenuation that may occur in turbid rivers.

The fish stocks were estimated on nine occasions mostly both by day and night surveys. Preliminary observations indicate that night-time is better for acoustic surveys of fish in rivers for various reasons. We now have our "river ladder" operational and it was used for fixed station work over 24 hours at Chertsey Meads.

We failed to discover any spawning grounds occupied by actively spawning individuals, despite our daily observation of the Chertsey reach during the likely spawning period and despite frequent acoustic surveying and regular seining. The only evidence of pre-spawning behaviour were the dense aggregations of fish in certain areas of the stretch which were observed during the first two weeks of May. The first cyprinid larvae were caught by larval tow net on May 16th. Normal spawning behaviour in shallow areas with willow roots and macrophytes was completelly absent.

At the Queen Elizabeth II Reservoir inlet in the Walton reach, we surveyed acoustically the fate of salmon smolts after their release into river by Greg Arsmstrong and Michael Moore. Results showed dual beam sonar is useful for this purpose of following the spread of smolts in the river by mobile survey and, by fixed location, of seeing the smolts' avoidance of the protective inlet bubble screen.

### 1.2.2. The River Thames at Didcot

We repeated the 1991 acoustic survey of the River Thames in the Clifton reach during July-August 1992 in order to obtain comparable data with last year's survey in this area and to provide supplementary information for another research programme connected with a proposed reservoir.

1.2.3. The River Vltava at Prague, Czechoslovakia

Opportunity was taken to estimate acoustically the fish stock of the River Vltava above, at and below Prague during September in order to test the applicability of the dual-beam system and our procedures to a big continental river of this size (up to 300m wide). The Vltava in Prague also offers an interesting mixture of acoustic conditions: a low fish stock in the Vltava River itself above the city where it receives the cold clear water from the Czech reservoir cascade; then high fish stocks present in the warm, eutrophic Berounka tributary; in Prague itself and just below, with different levels of fish abundance according to the degree of river regulation present; and finally, below the Prague main sewage outlet, the heavily polluted river with its extremely high fish stocks and very high particle loadings.

1.2.4. Other localities

We made the most of an excellent opportunity to recalibrate the directional beam patterns of all our and the NRA transducers at the Loch Duich acoustic facility belonging to the Aberdeen Fisheries Laboratory of the Scottish Office Department of Agriculture and Fisheries.

During his attendance at the Second International Conference on Reservoirs and Water Quality in Czechoslovakia organised by his home Hydrobiological Institute, Dr Jan Kubecka demonstrated our acoustic equipment. Opportunity was taken of having this equipment in Czechoslovakia to survey acoustically four water reservoirs which have been thoroughly and extensively surveyed for fish by netting. This will enable him to compare dual beam acoustics and classical fish netting in these drowned valley reservoirs so different from the London reservoirs. In all of the Czech reservoirs, both horizontal and vertical echo-sounding were employed.

2. Recommendations

2.1 That the NRA think about and prepare for the practical application of dual-beam acoustics in their strategy for surveying fish stocks in large lowland rivers. Our Interim Reports provide enough evidence to demonstrate that the dual-beam system and the procedures developed by Dr Jan Kubecka and myself provide practical means for such surveys of large rivers and are a better tool for the job than large-scale electro-fishing. There is less than a year left of our contract (JULY 1993) and the NRA needs to take advantage of our present expertise to prepare for the future.

2.2 In our March 1992 Report, I recommended that we train a young British national in dual-beam acoustics and our procedures for river acoustics. This could easily be done during the remaining period of our contract. An NRA Fellowship would have been an ideal way to support someone for about a year but I understand from Maxine Forshaw that these have been temporarily frozen until 1993. An alternative suggestion is that the NRA establish a post under Dr Alan Butterworth in Thames Region for a young candidate with an appropriate eductional background to tackle acoustics. This person could be seconded to us at RHBNC for training until July 1993. During this year, there would be the possibility of earning small contracts within the NRA Regions for routine fish surveying work as needed. We know such work exists but we cannot satisfy the demand without taking time from our main contract work.

3. Results of interest for NRA

Since the March 1992 Interim Report, our BioSonics echo-sounding equipment has been used as a normal practical tool for fish stock assessment in different localities. Under all the conditions encountered, it had proven itself to be powerful equipment of scientific calibre for the estimation of fish from diverse water bodies, from large lowland rivers to the deep Loch Ness. According to one of the leading specialists in underwater accoustics, Dr. K. Foote, our relationship between the number of targets and the number of fish caught in River Thames (by net) and in the River Wey (by electro-shocking) is probably the best recorded to date.

4. Future planned work

4.1 The processing of the tapes data accumulated from the 1992 season and some modification of the standard procedures involved in this.

4.2 Completing the seasonal monitoring of the fish stock in the River Thames at Chertsey Meads with an autumnal and a winter survey, covering a day and a night.

4.3 A brief winter fish behavioural study using the "river ladder" as a fixed station.

4.4 Upgrading the portable model 105 echo-sounder for 200 kHz frequency which involves calibration and consultation at the Biosonics headquarters in Seattle USA.

4.5 This will be followed by repeating the work on side aspect measurement of fish target strengths for 200 kHz that was done earlier with 420 kHz frequnecy (September 1991 Interim report). We will try to include as many European species of riverine fish as possible.

4.6 An optional activity which is dependent on progress in item (7) is a 24 hour echo-sounder monitoring of a salmon migration.

4.7 Starting preparations for writing the final report.

6. Factors that might affect completion

None foreseen at present

Appendix:

A copy of a paper presented at the European conference on Underwater Acoustics and already published by the Commission of the European Communities in book form.

European Conference on

# UNDERWATER ACOUSTICS

*Edited by*

M. WEYDERT

*Commission of the European Communities, Brussels, Belgium*

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# ECHO COUNTING OR ECHO INTEGRATION FOR FISH BIOMASS ASSESSMENT IN SHALLOW WATERS

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SUMMARY

As acoustic conditions for assessment of fish population densities deteriorates in rivers and shallow lakes, the errors associated with classical echo-integration techniques increase concomitantly. Under such conditions, dual beam echo-counting was found to be more robust than echo-integration. The proportion of fish multiple targets found in several lowland rivers and shallow lochs was low enough for dual beam echo-counting of single targets to be acceptable when operated with short ranges, narrow sound beams and short pulse widths. Corrections for volume reverberation can be applied to both echo-integration and echo-counting for comparable results.

## 1. INTRODUCTION

According to fisheries acoustic theory, echo-integration (EI) is the only reliable technique for assessing fish abundance and biomass and the dual beam echo-sounder was developed mainly to estimate the average back-scattering cross section of in situ fish for scaling the output from echo-integrators (Ehrenberg, 3, 4; Burczynski, 1; Johannesson & Mitson, 5). This optimal combination of single target echo-counting (EC) and echo-integration including mutiple targets cannot always be applied for fish stock assessment in shallow waters. This paper considers these problems which were encountered during hydroacoustic surveys in rivers and shallow lochs during 1991.

## 2. METHODS

Hydroacoustic surveys using Biosonics Dual-beam echosounders for horizontal beaming were carried out in reaches of the River Thames near Didcot, with 12 fixed stations, and near Old Windsor, with 2 fixed stations. Both of these reaches of the River Thames were very similar ecologically to that described in Mann (7), with widths of between 50-80 m and maximum depths of 3-4 m. The River Wey was also surveyed on four occasions at sites above and below the Woking Sewage Outfall where it was 9-16 m wide and 1.5-2.0 m deep. At the same time, the sonar surveys were accompanied by fish surveys, either by seining of the insonified area (on 11 occasions) or by mark-recapture censuses of the insonified fish within net enclosures of 0.2-0.25 ha (3 occasions) (River Thames) or by continuous fish removals (River Wey). Although 15 species of fish were recorded, 20-80% of the catch were roach (*Rutilus rutilus*), bleak (*Alburnus alburnus*) and dace (*Leuciscus leuciscus*) and these were considered to be the main fish species recorded by sonar. Also in 1991, three shallow lochs (3 m) in the Orkney Main Island were surveyed by mobile sonar techniques and horizontal beaming with the transducer mounted on scaffolding in front of the boat. The Lochs of Harray, Swannay and Boardhouse are inhabited mainly by brown trout (*Salmo trutta*).

During the fixed location studies, the transducer was mounted on a right angled frame which permitted horizontal sounding across the river at a known water depth, usually in mid-water. Biosonics Models 105 and 102 Dual-beam echo-sounders operating with a frequency of 420 kHz were used with either a circular transducer (6°/15°) or an elliptical one (3°-7°/10°-21°). Normally, pulse widths of 0.4 - 0.6 ms were used with a trigger rate of 5 - 10 per second. All echoes were recorded on tape in a Technics SV260 portable audio tape recorder and analysed using Biosonics Model 281 Dual Beam processor and Biosonics Model 221 Echo Integrator. Echoes were "filtered" by setting noise thresholds during processing according to the ambient noise levels observed on a Tek222 portable oscillioscope in situ and on the software oscilloscope during analysis. It was usually possible to detect targets bigger than -

61dB in ranges up to 10 m from the transducer. Calibration of the 40logR receiver channels was carried out with Dunlop Long-life ping-pong balls (Burczynski & Dawson, 2) and a 21 mm Tungsten Carbide calibration sphere (MacLennan & Simmonds, 6).

3. RESULTS & DISCUSSION

Four sets of conditions were encountered during the 1991 surveys which affected processing of the taped data:

(1) Conditions favourable for fish population assessments using both echo-counting and echo-integration processing.

(2) Conditions under which it was impossible to apply echo-integration. These were encountered during mobile surveys with horizontally-operating sonar in the Orkney lochs where no way was found to prevent the echo-integration of *Potomogeton perfoliatus* and *Elodea canadensis* plants which formed extensive sublittoral weed beds. Apparent "biomasses" of up to 3 $kg.m^{-3}$ were estimated by EI processing. By Taking advantage of the much greater wide beam response of the plants, it was possible to distinguish between fish and plant targets during dual-beam echo-counting and this gave estimates between 300 and 900 $fish.ha^{-1}$ which are in agreement with catches of anglers and by gill nets (Duncan & Sinclair, pers.commun.).

(3) Conditions under which echo-integration processing was difficult either due to the generation of clouds of bubbles by passing boats or due to variation in the range of the bottom or water surface reverberation during mobile echo-sounding in shallow waters. These two unfavourable conditions can only be resolved for echo-integration by consecutive re-processing of the data with a manually tracked bottom whereas dual-beam echo-counting automatically eliminates both kinds of noises via the setting of appropriate pulse width criteria and appropriate ratios between narrow to wide beam voltages.

(4) Sites with dense shoals of fish and the dominance of multiple targets which prevents the use of dual-beam echo-counting for fish population assessment. Such dense shoals were only rarely encountered during late autumn, probably preparation for the over-wintering 'sleep'.

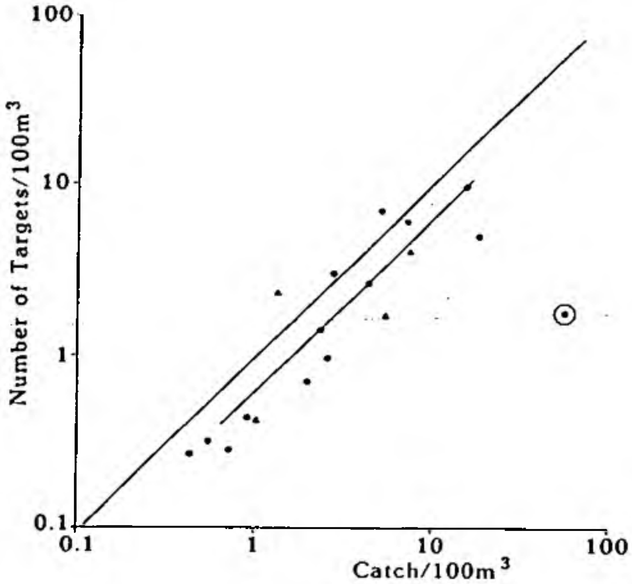
The Dual-beam processing procedure provides so much information about each individual echo record that it can be used for a powerful "filtration" or elimination of interfering echoes for the purpose in hand. As the echo-integration procedures are rather sensitive to such interferences, it seemed worth-while to test whether or not dual-beam echo-counting would provide satisfactory estimates when used with fairly narrow beam transducers and short pulse widths, that is reducing the sampling volume. The results of this study are given in Fig. 1 which shows the relationship between single target densities and fish densities in the Rivers Thames and Wey which can be described by a statistically significant regression :

$$Y = 0.62.X^{0.997} \quad (d.f.\ 1,15;\ F\ 80.7;\ P\ 0.0001)$$

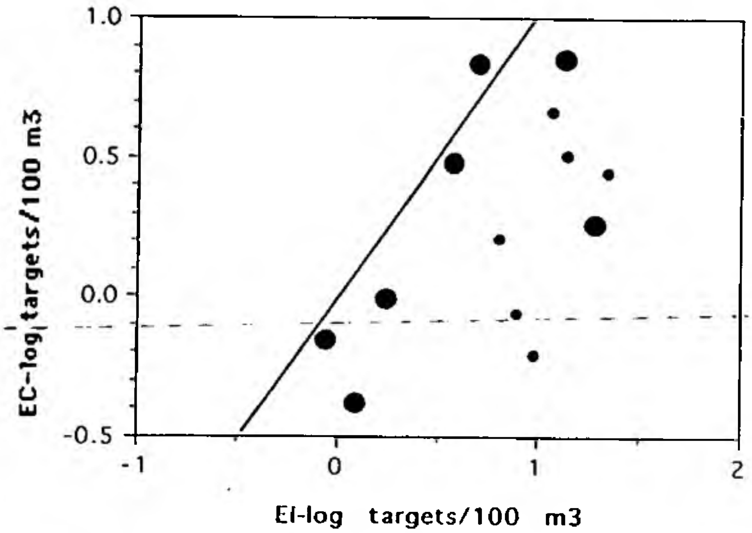
where Y is target numbers/100 $m^{-3}$ and X is fish/100 $m^{-3}$),

Fig. 1 shows that the densities of acoustic fish targets are only about 62% of netted or electro-fished fish densities. There may be various reasons for this shift from the 1:1 line: (1) Fish may show a behavioural preference for micro-habitats near the surface or near the bottom both of which are badly sampled by the techniques employed. (2) The presence of multiple targets which are eliminated during dual-beam echo-counting procedures. (3) Volume reverberation within the rivers exerts an influence that increases the "weighting" of the wide beam echoes and "places" the target further from the acoustic axis. Some of these effects can be counteracted with the aid of the flexible processing software.

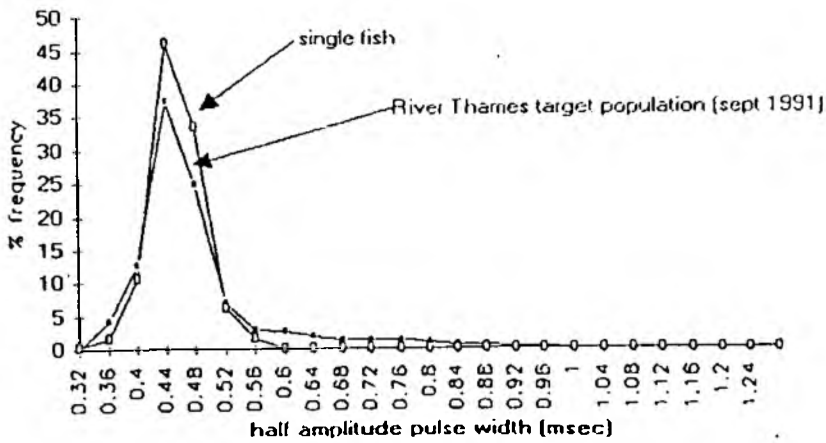
The extent to which the presence of multiple targets contribute to the above lower target




1. The relationship between acoustic densities of single targets and fish densities in the Rivers Thames (dots) and Wey (triangles) during 1991. One line shows the 1:1 relationship and the other the regression $Y=0.62.X^{0.997}$. Encircled dot refers to a night sample.




2. The relationship between acoustic densities of fish targets processed by echo-counting and by echo-integration. Large dots refer to the River Thames and small dots to the River Wey. The line shows the 1:1 relationship.




3. Frequency distribution of half-amplitude pulse widths for a fish population in the River Thames near Didcot (black squares) compared with a single perch of 120 mm length (side aspect) (empty squares).

densities is illustrated in Fig. 2. In this figure, EI densities show a 1:1 correspondence to EC densities for fish densities up to 5 ind./100 $m^{-3}$ but not at higher densities where EC estimates are lower. The 20logR receiver channels used for the EI densities were not calibrated for system performance for each estimate and these are based upon values for source level and receiving sensitivity supplied by the manufacturer.

Another possibility is to widen the dual-beam processing limits of the 40logR data by setting very wide limits of pulse width criteria and of the pulse width search window in order to collect all the recorded voltage peaks and their widths and without eliminating any multiple echoes. Fig. 3 illustrates a typical example of a frequency distribution of half-amplitude pulse widths estimated for the fish population of the River Thames compared with the pulse width frequency distribution of a single fish (120 mm perch; side aspect) held in acoustic under defined experimental conditions. In both cases, most of the targets had pulse widths which fell between 0.36 - 0.56 ms (with a nominal pulse duration set at 0.4 ms). This means that pulse widths larger than 0.56 ms are taken to be multiple targets. The pulse width frequency distribution was analysed on 7 occasions. It was found that between 10-18% of acoustic targets were multiple ones with half amplitude pulse widths of more than 0.56 mS ; the mean was 13.4% with a standard deviation of ±2.7 . This estimate of the proportion of multiple targets present in rivers can probably be used to correct the EC density estimates of single targets. Future studies will incorporate tests of the system performance whilst multiple targets are being recorded.

Volume reverberation together with bottom or surface reverberation caused by side lobes form another very important interference in turbid lowland rivers insonified by high frequency sonars. It is important to recognise that the mode of interference differs in echo-counting and echo-integration. In dual-beam echo-counting, reverberation increases the wide beam voltage thus resulting in a loss of some marginal target records by "moving" them beyond the nominal beam angle. In echo-integration, reverberation increases the total estimate of "acoustic biomass ". Methods for correcting these interferences are being developed for both echo-counting and echo-integration processing.

## 4. ACKNOWLEDGEMENTS

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## 5. REFERENCES

(1) Burczynski, J. 1979. Introduction to the use of sonar systems for estimating fish biomass. FAO. Fish.Tech.Paper 191. 89pp.

(2) Burczynski, J & J. Dawson. 1987. Dual-beam techniques for fish sizing and quantity estimates. Biosonics Applic.Memo 104. 8pp.

(3) Ehrenberg, J.E. 1973. Estimates of the intensity of a filtered Poisson process and its application to acoustic assessment of marine organisms. Univ.Wash.Sea Grant Publ. WSG. 73-2. 135pp.

(4) Ehrenberg, J.E. 1974. Two applications for a dual beam transducer in hydroacoustic fish assessment systems. Proc.Conf.Engineering in the Ocean. 152-5. IEEE, New York.

(5) Johannesson, K.A. & R.B. Mitson. 1983. Fisheries Acoustics. FAO. Fish.Tech.Paper 240. 249pp.

(6) MacLennan, D.N. & E.J. Simmonds. 1992. Fisheries Acoustics. Chapman & Hall. 325pp.

(7) Mann, K.H. 1964. The pattern of energy flow in the fish and invertebrate fauna of the River Thames. Verh.Internat.Verein.Limnol. 15:485-495.