FISHERIES HYDROACOUSTICS AT THE PACIFIC BIOLOGICAL STATION IN NANAIMO B.C.

R. Kieser
Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

RESUME

Les méthodes hydroacoustiques constituent un outil important pour repérer et évaluer les poissons et le plancton. Divers appareils acoustiques puissants sont maintenant utilisés couramment par les pêcheurs, les gestionnaires et les scientifiques. Leur efficacité repose sur plusieurs principes fondamentaux qui rendent possible la télédétection de paramètres biologiques sous l'eau. Un certain nombre de techniques acoustiques sont utilisées régulièrement à la Station de biologie du Pacifique située à Nanaimo, et on en donne ici une brève description. On utilise, à titre d'exemples, un levé par intégration des échos de merlus du Pacifique et une expérience qui compare un dénombrement visuel et acoustique de saumons.

ABSTRACT

Hydroacoustic methods provide an important tool to detect and assess fishes and plankton. A variety of powerful acoustic devices are now in general use by fishermen, managers and scientists. Their success is based on several fundamental principles which make underwater remote sensing of biological parameters possible. A number of acoustic techniques, routinely used at the Pacific Biological Station in Nanaimo are briefly described. An echo integration survey of Pacific hake and an experiment that compares a visual and an acoustic count of salmon are used as illustrations.

Hydroacoustic methods play an important role in commercial fishing, fisheries management and fisheries research. The three endeavours rely on similar methods, but differ in the required accuracy, precision and timeliness of the results.

The most common acoustic device in fisheries is the vertically oriented sonar (echosounder), Fig 1. The usefulness of the echosounder and other hydroacoustic devices in fisheries is based on several phenomena:

1. Sound waves present the only form of energy that propagates in water with reasonable speed and relatively small attenuation and dispersion.
2. Fishes and plankton usually are the major scatterers in the water column.
3. Sufficiently reliable relations exist between the acoustic properties of fishes and some biological parameters of interest, e.g. fish target strength and fish weight or length.
4. Availabilty of hardware and trained personnel.

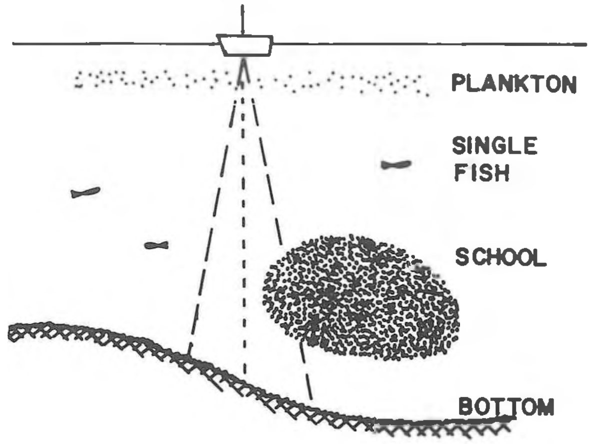


Figure 1. A vertically oriented sonar (echosounder), the most common acoustic device in fisheries.

It is important to note that alternate or conventional methods generally depend on direct visual observations or on some form of catching the fish. Visual observations are limited to clear water and short distances. Methods that rely on catching the fish are relatively labour intensive, slow and sample a small volume of water only. A typical trawl fishing operation is shown in Fig 2, it gives an impression of the coordinated and often large effort that is required.

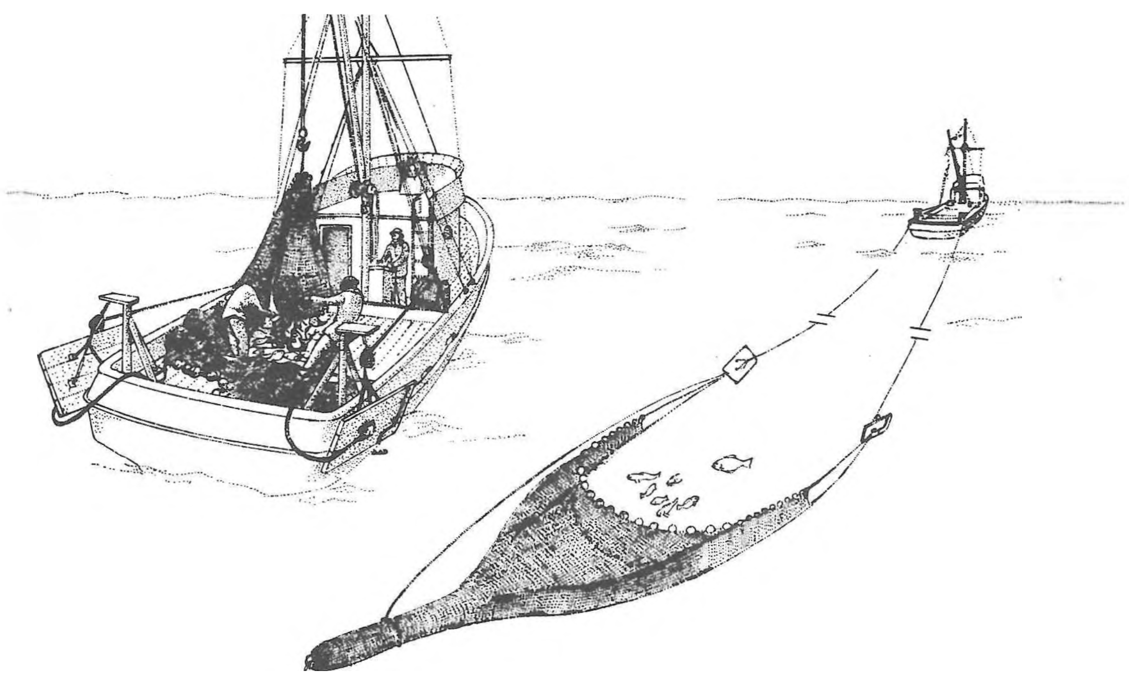


Fig. 2. A typical trawl fishing operation.

The following activities highlight the acoustic methods that are currently used at the Pacific Biological Station (PBS):

- Echo counting: This method determines fish number density from a visual count of the echo traces on the echogram, Fig 3. Alternately the resolved single fish echoes can be counted from an oscilloscope that is connected to the echosounder's receiver output, Fig 4.

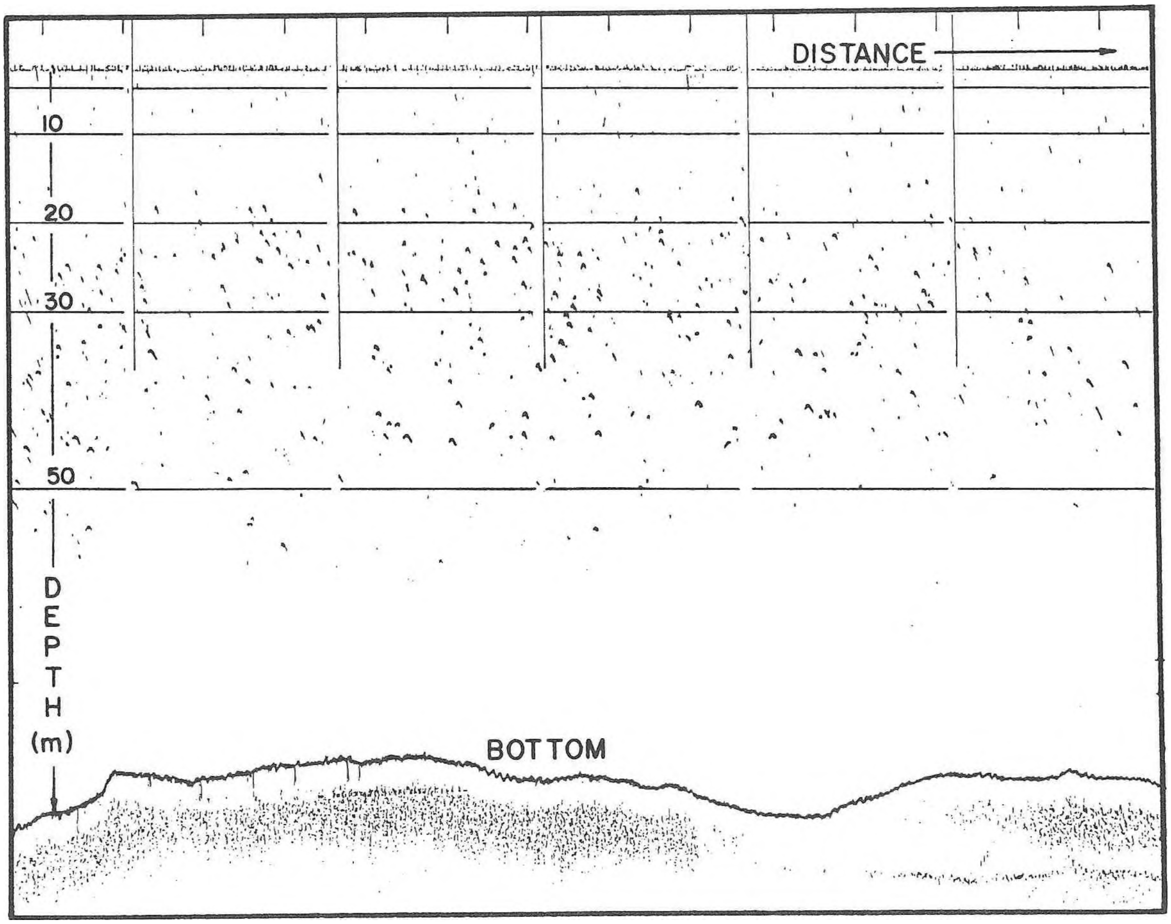


Fig. 3. The echogram gives a visual presentation of the echo returns as a function of depth and distance travelled. The depth below the transducer and the distance travelled are marked on the vertical and horizontal axis respectively. The bottom is shown as an irregular dark line. The single fish echo traces indicate a light layer of fish at about 30 m depth.

- Echo integration: This method determines fish biomass density from a measurement of the mean acoustic backscattering strength.
- Single beam target strength analysis is used to determine fish size.
- Acoustic fence: This device counts the number of fish that migrate up or down stream, Fig 5.

More sophisticated methods have been developed at the University of Washington, Seattle, Wa. and elsewhere. These include:

- Acoustic doppler measurements to detect fish movement and tail beat frequencies.
- Special beam forming and signal processing schemes to extract fish target strength.
- Swimbladder resonance measurements correlate with fish size.
- Multi-frequency measurements to provide an indication of the insonified fish species.

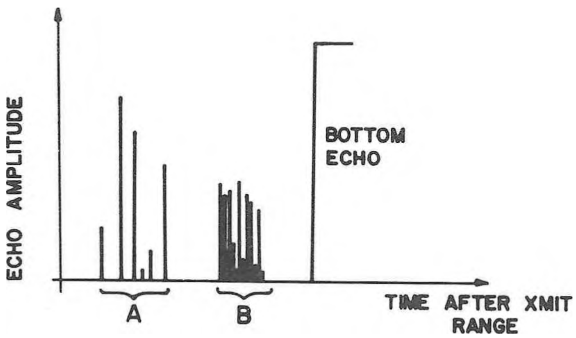


Fig. 4. Oscilloscope display of the echosounder receiver output. 'A' are resolved single fish echoes, 'B' are nonresolved echoes. The bottom echo saturates the receiver.

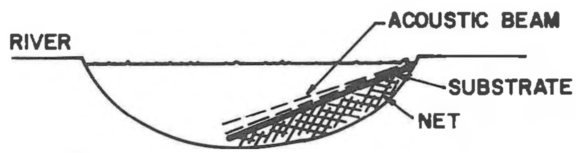


Fig. 5. The acoustic fence is deployed perpendicular to the shore. It crosses the migration path of the salmon, which often is near the shore rather than in the middle of the stream. The sketch shows the acoustic beam. Fish are guided through the beam by a net that is suspended from a pipe, just below the beam.

Generally acoustic methods provide a powerful tool for low resolution remote sensing of fishes and plankton. Ranges may be as large as many hundred meters for a 10 kHz Sonar which may have a range resolution of the order of one meter.

Increased resolution can be obtained at higher frequencies but the maximum range will be reduced.

Our work at PBS has focussed on improving acoustic estimation procedures and on demonstrating their usefulness to fisheries and fisheries management. To achieve these objectives we have pursued four major goals:

1. Set up a versatile, calibrated fisheries acoustic system.
2. Develop real time data analysis methods to obtain feedback during the experiment.
3. Develop hardware and software to record digitized echo returns and to analyse them on a central computer.
4. Identify fisheries situations where acoustic methods are appropriate and demonstrate their relevance.

At present our major effort is directed towards digital data analysis and experiments.

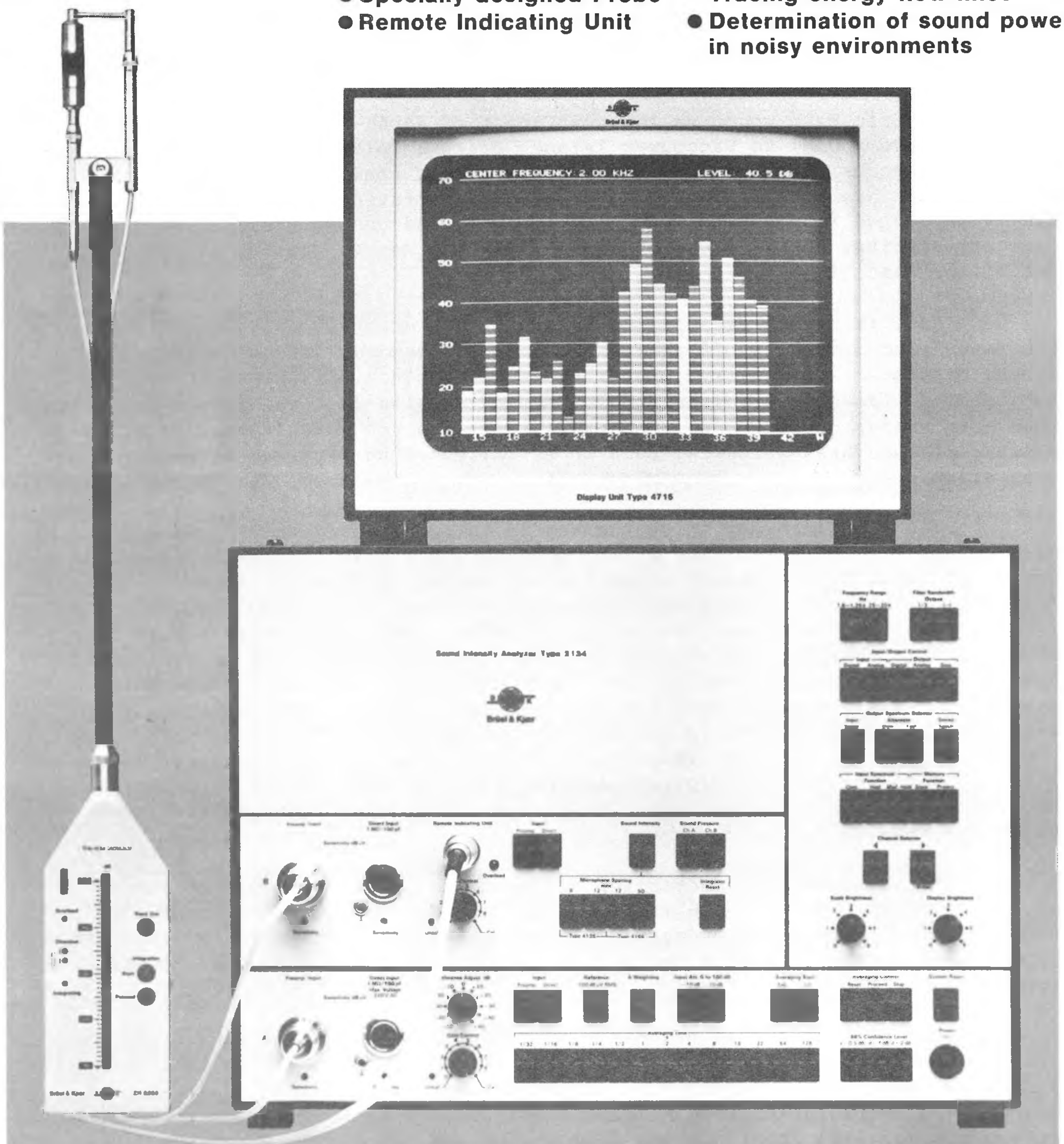
Sound Intensity Analysing System 3360

The 3360 System includes:

- Analyzer
- Display Unit
- Specially designed Probe
- Remote Indicating Unit

Applications:

- Location of noise sources
- Mode studies
- Tracing energy flow lines
- Determination of sound power in noisy environments



MONTREAL
90 Leacock Road
Pointe Claire, Que H9H 1H1
Tel (514) 695-8225

OTTAWA
7 Slack Road, Unit 4
Ottawa, Ont. K2G 0B7
Tel.: (613) 225-7648

TORONTO
71 Bramalea Road, Suite 71D
Bramalea, Ont. L6T 2W9
Tel.: (416) 791-1642

LONDON
23 Chalet Crescent
London, Ont. N6K 3C5
Tel.: (519) 473-3561

VANCOUVER
5520 Minoru Boulevard, Room 202
Richmond, B.C. V6X 2A9
Tel. (604) 278-4257

To illustrate our work I will describe an acoustic survey that was designed to determine the offshore hake biomass and its distribution and an experiment that compares acoustic estimates of the number of salmon in a lake with a visual weir count.

A TYPICAL OFFSHORE HAKE SURVEY

The successful estimation of a fish stock often depends on a detailed knowledge of the fish's life cycle. In many cases there is only a short time during which a particular fish stock can be acoustically assessed. At other times the fish's proximity to the surface or to the bottom or a mixing of species may make an estimate impossible.

Pacific hake occur on the west coast of North America from Santa Cruz, California, (36° 50'N) to Vancouver Island, British Columbia, (49° 00'N). Like many other species hake are best estimated in their spawning/feeding aggregations. These are pelagic and quite characteristic, thus signals are readily separated from surface and bottom echoes and can be distinguished from plankton, herring, rockfish and other species that may be present in the same area at the same time.

Hake is the target species for a large, international joint fishery that takes place annually off the west coast of Vancouver Island during July through September. (A similar joint fishery takes place off the coast of Washington.) Canadian trawlers and Polish and Russian factory vessels catch and process in excess of 30,000 tons of hake. Management of this fishery requires an estimate of the total resource, such an estimate can be obtained by echo integration.

The echo integration system was installed onboard the Canadian Research Vessel G.B. Reed. Its major components are shown in Fig 6. A single transducer is used to transmit a short pulse and to receive the echoes. It is mounted in a torpedo shaped towed body which is towed by an armoured cable that also provides the connection to the echo sounder. The echo sounder output is displayed on a chartrecorder and an oscilloscope and is recorded on analog tape as a backup. The same signal is also connected to the echo integrator which measures the average echo power for a specified number of depth slices. This measurement is proportional to the average volume backscattering strength. A printed output is available, it can be scaled to present fish biomass. These data are stored on 1/2 in. digital magnetic tape and are processed by the onboard computer to yield estimates of fish surface density and total biomass in the survey area.

The system is characterized by the following parameters: Frequency 38 kHz, pulse length .6 ms, pulse repetition 2 Hz and transducer full beamwidth between half-power points 10 degrees. The receiver has a 'time-varied gain' that compensates for the spreading and absorption losses that the acoustic pulse experiences in the water.

During late August and early September 1983 we have surveyed the shelf area off Vancouver Island that extends from the 48-th to the 49-th parallel and out to the 300 m depth contour. The survey encompassed ~8500 km^2 and was covered by a rectangular transect grid of ~1800 km length. The average spacing between the parallel transects was 4.7 km. The nominal survey speed was 17 km/hr.

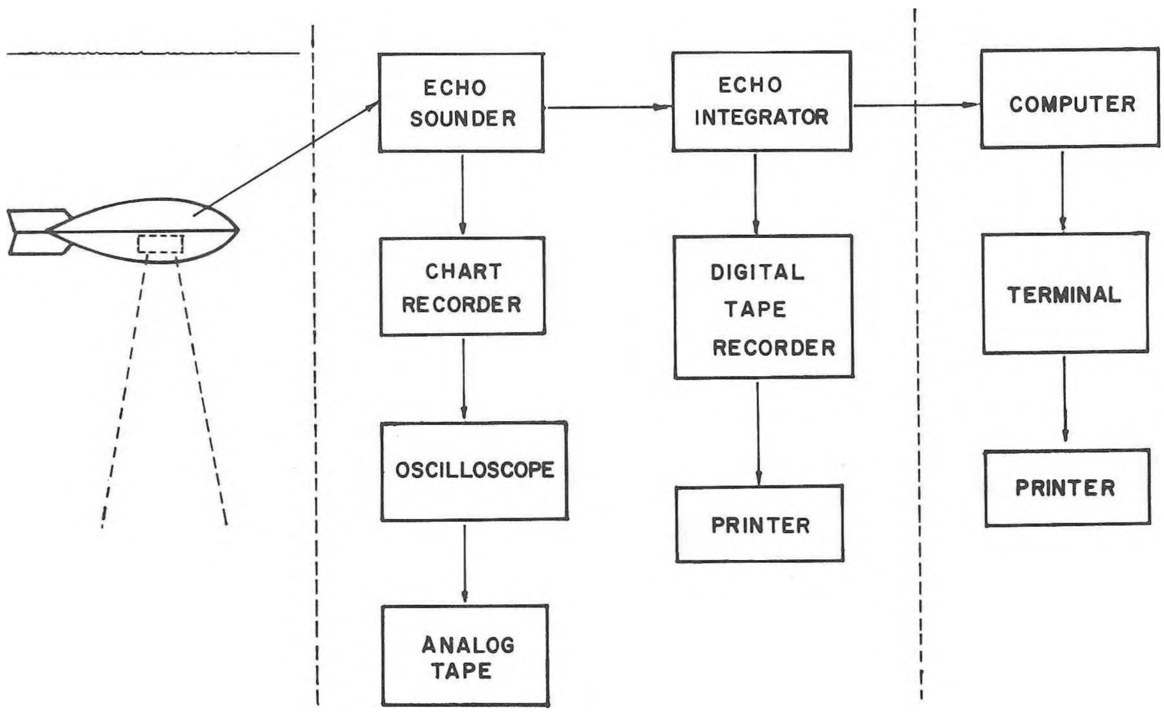


Fig. 6. The echo integration system. The transducer is mounted in a torpedo shaped body and towed from the stern of the vessel. The echogram, the oscilloscope and the printed output from the echo integrator provide immediate feedback on systems performance and fish densities. The computer is used to produce fish surface densities and biomass estimated.

The echo integrator output was processed to yield an estimate of the average fish surface density (kg/m2) every six minutes. This was plotted on a daily basis as a bar graph along the transects, Fig 7. A map of the biomass distribution in the area results when the transects and densities are plotted on a hydrographic chart, Fig 8.

The total fish biomass for all species in the survey area was estimated as 280,000 tons. The species composition has been obtained from a careful visual interpretation of the echograms and from the net catches that were made by a second vessel. Based on this additional information the total hake biomass was estimated as 140,000 tons.

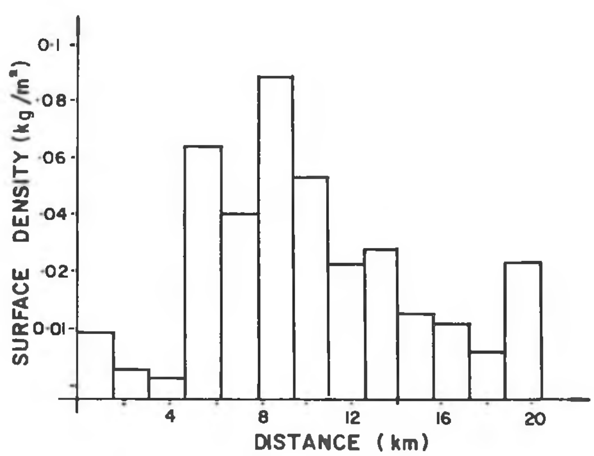


Fig. 7. A plot of surface density versus distance gives an impression of the fish distribution along the transect.

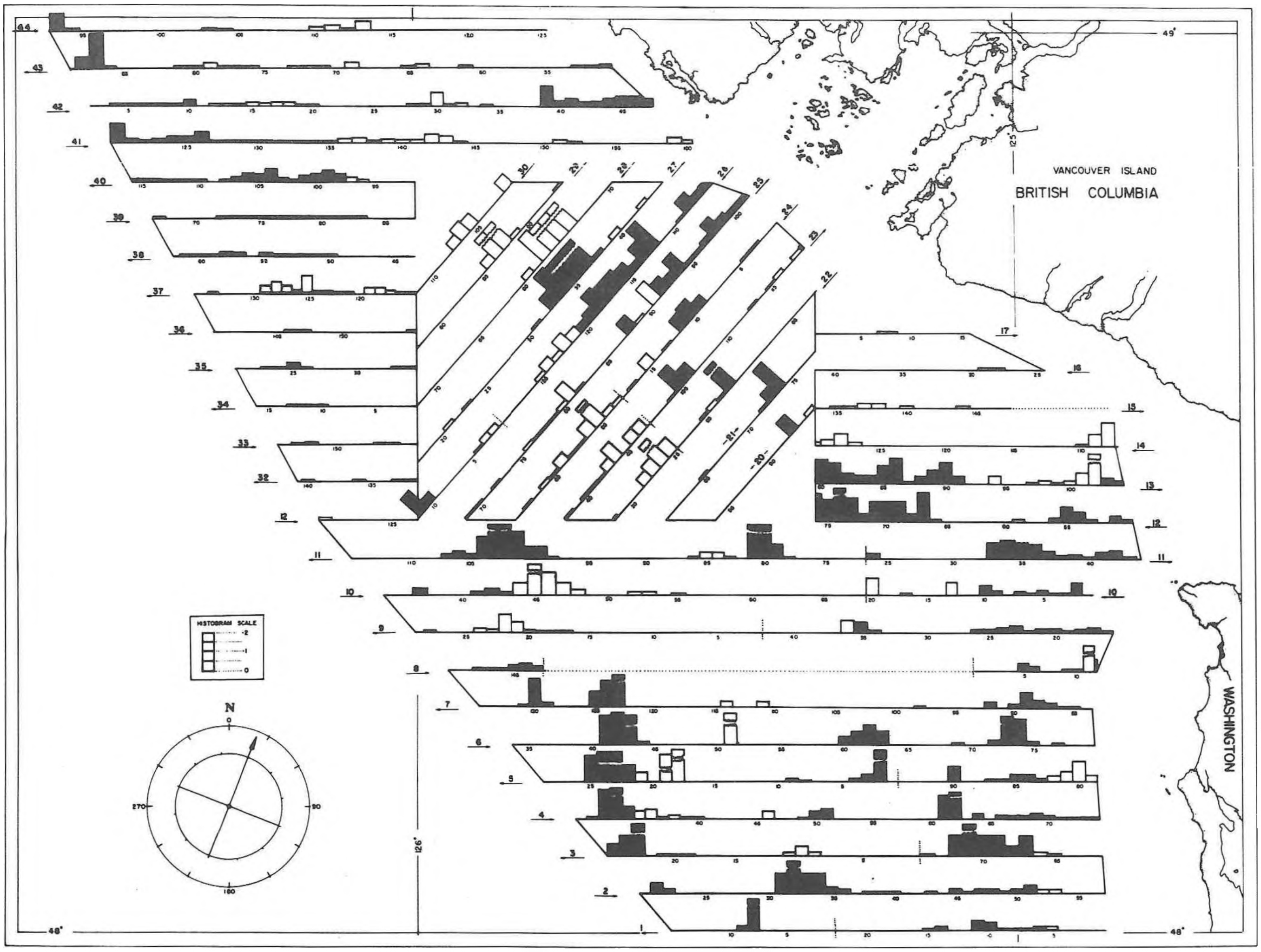


Fig. 8. The biomass distribution is shown by plotting the surface densities along the transects on a hydrographic chart. The scale used for the bars is shown above the compass rose, those that exceed .2 kg/m^2 are broken. Solid bars indicate hake, all other fishes are represented by open bars.

The accuracy of these estimates has been inferred from detailed considerations of the measurement process. An accuracy of 20% is expected for the measurement of the total acoustic backscattering strength from the insonified volume. Major sources of uncertainty occur when the measured backscattering strength is converted to a biomass estimate. Typical sources are: extrapolation from the insonified volume to the total volume of interest, fish target strength and species identification. The absolute acoustic biomass estimates may be accurate to within a factor of two, for this reason the better relative estimates are used whenever possible. It is important to note that comparable nonacoustic estimates have equal or larger errors.

The above estimates are valuable for the manager and biologist, and are used to manage the hake stock, to maximize the catch and to protect the fish stock from overfishing.

COMPARISON OF HYDROACOUSTIC ESTIMATES OF SALMON WITH A WEIR COUNT

Fisheries hydroacoustic methods are frequently employed but seldom verified. We have conducted an experiment that compares various acoustic estimates with each other and with an independent weir count, thus providing a direct indication of the accuracy of hydroacoustic estimation methods. The experiment was conducted in Long Lake near Smith Inlet B.C. A sockeye salmon run ascends the Docee River and reaches Long Lake during July. For many years a weir has been operated across the river to obtain a visual count of the total number of salmon that migrate into the lake. The salmon remain in the lake before they migrate into the tributaries where they spawn in the gravel beds. There is a period of several weeks when essentially all fish have been counted across the weir, yet none have appeared in the rivers that feed the lake. At this time the entire stock is in the lake. At night the fish are distributed in the water column and can be assessed acoustically. The acoustic gear was installed on a small skiff and eight surveys were carried out on four consecutive nights (July 31 - Aug 4, 1982).

Our comparative study has used the following methods to estimate the total fish population in the lake:

1. Weir count:
The fence was operated by fisheries management personnel who visually counted the number of salmon that migrated upstream into the lake.

2. Echo trace counting:
The single fish echo traces were counted from the echograms that were recorded during the surveys. A simple model was developed to estimate the number of fish per cubic meter from the trace count. An estimate of the total number of fish in the lake was derived.

3. Echo pulse counting:
The echo traces that were analysed above often include many successive echo returns. A pulse count is easily obtained from the digitized echo returns and can be converted to a fish number density. It yields a second estimate of the total number of fish in the lake.

4. Echo integration:
The same echo returns were used to measure the average volume backscattering strength for the depth interval of interest. This measurement provides an estimate of the fish biomass per cubic meter, which was extrapolated to obtain the total fish biomass in the lake. A fish target strength of -32 dB/kg was used for the analysis. The measured average fish weight of 2.9 kg was used to calculate the total number of fish in the lake.

The total number of salmon that was estimated by each of the four independent methods is given in the following table. The last row gives estimated accuracies for the population estimates that are based on detailed considerations of the measurement process.

Visual	Acoustic			
Weir count	Trace count	Pulse count	Integration 20logR	
200	120	121	197	10^3 # of fish
			571	10^3 kg of fish
±10%	±20%	±20%	±50%	Est. accuracy

Considering the expected accuracy of the various methods we have to conclude that the acoustic estimates agree with each other. There, however, is a discrepancy between the acoustic counting data and the visual fence count. Two possible reasons for the difference are: The fish might have avoided the noisy survey vessel or their distribution in the lake might have been less homogeneous than assumed. The data are insufficient to resolve the problem.

The different types of analyses presented above are frequently used by themselves but seldom on the same data set. A major point of this experiment was the comparison of the various methods with each other and with the independent estimate that was obtained from the weir count.

Recent developments in instrumentation and data processing have transformed fisheries acoustics into a field with new possibilities. Acoustic methods have reached a stage where they can compete with and supplement conventional fisheries sampling methods. Exciting new methods are now within reach of fisheries research which will lead to a better understanding of the fundamental acoustic processes and of fisheries biology itself.

ACKNOWLEDGEMENT

The hake survey and the salmon experiment were carried out by the hydroacoustics group at PBS under the direction of T. J. Mulligan. L. W. Barner and R. M. Hungar assisted in all phases of this work, their contribution is gratefully acknowledged.

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