Development and Application of Bottom Trawl Instrumentation Systems
in Fisheries Resource Assessment

by

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ABSTRACT

Catch results from bottom trawl surveys conducted by the Resource Assessment and Conservation Engineering (RACE) Division of the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, are used to estimate the abundance of demersal fishery resources in the northeast Pacific Ocean and the Bering Sea. The magnitude and composition of bottom trawl catches is influenced, among other considerations, by the physical performance of the trawl. An understanding of the factors that affect trawl performance is essential for correct interpretation of trawl survey catch data, which in turn has an impact on the management of commercial fisheries. In order to study trawl performance, hydroacoustic net mensuration instruments were developed in 1974 and have been used since then by RACE biologists. These observations have revealed, among other things, that the horizontal opening of bottom trawls can vary a great deal and that the trawls can be quite erratic in terms of attaining and maintaining contact with the bottom during a tow. Programs aimed at the development of systems for specifically evaluating these two trawl performance parameters have been initiated, and preliminary results have been promising. Possible avenues for further development of trawl instrumentation are discussed.

INTRODUCTION

A major activity of the Northwest and Alaska Fisheries Center (NWAFC), National Marine Fisheries Service, National Oceanic and Atmospheric Administration (NOAA), is the assessment of the status of marine fishery resources within its area of jurisdiction. This area, comprising the waters within 200 nautical miles of the coasts of Oregon, Washington, and Alaska, accounted for 47% of all domestic and foreign catches taken in U.S. waters in 1977-80 and 41% of the dollar value. For these valuable resources to be effectively managed, accurate and timely information on their abundance, distribution,

and biological condition is essential. The NWAFC provides this information through analysis of commercial fishery data and from the results of research vessel surveys.

The Resource Assessment and Conservation Engineering Division (RACE) of NWAFC is responsible for conducting resource assessment surveys and for analyzing survey results. An idea of the magnitude of this work may be formed by considering that RACE plans to conduct 19 separate cruises in 1982, each lasting from 1 to 15 weeks, using three full-time NOAA research vessels and five chartered U.S. commercial fishing vessels. In addition, cooperative research will be carried out aboard Japanese and Soviet fisheries research vessels.

The bulk of this work is focussed on demersal fishery resources, using bottom trawls (Fig. 1) to sample these benthic organisms for measuring abundance and collecting samples to determine biological characteristics of the stocks.

Figure 1.

By making certain assumptions about the area of bottom swept by the trawl and about the proportion of organisms in the path of the trawl that are retained, it is possible to extrapolate from the catches landed to estimate the total standing stock in the overall area surveyed. Obviously,

the accuracy of these estimates rests on the validity of the assumptions made.

Taking the last assumption first, common practice is to assume that all of the animals in the path of the trawl will be captured. The validity of this assumption is difficult to defend. Unfortunately, it is very difficult to independently determine the true proportion captured, often referred to as the "catchability coefficient." Some animals will escape under the footrope or over the headrope, while other animals not originally in the path of the trawl will be "herded" into the trawl by the rigging of the trawl and the turbid sediment clouds generated by the doors as they move over the bottom. Dickson (1974)¹ reviewed the work of Harden-Jones and others and concluded that on balance it is not unreasonable to assume that the catch landed represents 100% of the animals in the path of the trawl itself. However, this question is by no means resolved.

A second major assumption in estimating the abundance of demersal fishery resources is that the trawl spreads and fishes properly during tows. Fortunately, it is easier to measure the physical aspects of bottom trawl performance than the catchability. Many marine electronics firms now produce and sell netsondes, which acoustically measure the height of a headrope-mounted transducer above the footrope, or the seabed, thus indicating the vertical opening of the trawl, and most of the vessels engaged in RACE surveys have such systems. While this information is useful, other trawl performance characteristics are more important in determining the accuracy of catch data from tows. Knowledge of the horizontal wingspread of the trawl is essential for calculating the area swept; and if the footrope of the trawl is even a few inches above bottom, many of the benthic organisms may not be captured. Conventional netsondes are not capable of measuring the horizontal spread of a trawl, nor are they capable of indicating whether the footrope is fully on the bottom or is just above the bottom.

In response to these concerns, the Conservation Engineering Task within RACE undertook in 1974 to develop trawl mensuration instruments for measuring these and other parameters. The original objectives were to determine the variability of trawl performance during survey operations and to assess the desirability of routinely incorporating trawl instrumentation into sampling operations. Since then, variability in gear performance has been measured and documented, problem areas have been identified, and development of new instrument systems has been initiated. The goal of this report is to describe the instrumentation systems that have been developed, to summarize some of the significant findings that have been obtained, and to identify some of the problems that need further attention.

Current Trawl Instrumentation Systems

A number of experimental trawl instrumentation systems had been developed prior to the involvement of RACE in this area (see the section on Trawl Gear Instrumentation in H. Kristjansson (editor), *Modern Fishing Gear of the World 3*, 1971²). However, because of their limitations with respect to measurement capabilities, data storage, and portability, as well as transmission problems and/or technical complexity, none of these systems were considered satisfactory. Further, many of these systems were designed for conducting detailed engineering studies of trawl performance, which lay outside the scope of RACE's needs. Consequently, in 1974, the Applied Physics Laboratory of the University of Washington, Seattle, was contracted to design and construct a suitable prototype system.

Consultations were held with the design engineers to outline the parameters needing measurement and the operational conditions expected, with compromises reached to stay within available funds. The general goal was to develop a system that would measure and record the desired parameters while withstanding the severe conditions encountered during trawling operations. It also needed to be relatively simple to operate and maintain. The resulting system (Acker and Brune, 1974³) is shown schematically in Figure 2.

Figure 2. Schematic drawing showing relative locations of instrumentation system components.

It measures acoustically and records on data cassettes the following parameters: headrope-to-bottom distance (D_2), the footrope-to-bottom distance (D_1), the horizontal opening, or wingspread (W), and the headrope-to-footrope distance (S). The system consists of a headrope unit (HRU) (Figure 3) which keys the other units and houses the cassette recorder on which all the data are stored, two wing units (WU) (Figure 4), a footrope unit (FRU) (Figure 5), a battery charger, and a cassette playback unit (Figure 6), which displays the data digitally and can be linked directly to a computer for further analysis.

Figure 3. Headrope unit from net mensuration instrument (NMI) system.

Figure 4. Wing unit from NMI system

Figure 5. Footrope unit from NMI system.

A complete set of observations is made and recorded every 3.3 seconds. All measurements are recorded in feet, with 1-foot increments in the wingspread measurements and $\frac{1}{2}$ -foot

steps in all other measurements, except the footrope-to-bottom distance measurements, which are in increments of 0.1 foot. Vertical openings less than 4.5 feet or greater than 100 feet will not be recorded, nor will wingspreads greater than 180 feet.

Figure 6. Cassette readout unit from NMI system.

Subsequent refinements of the original system include: substitution of an acoustic link between the HRU and the WU's for the original hard-wired link, reduction in size of individual units, and an acoustic telemetry link with the surface for real-time readout onboard the fishing vessel.

Early results with the net mensuration instruments (NMI), as well as a more detailed description of system function, are described in Wathne (1977).⁴ Highlights of this report will be discussed here. He found that the physical performance of the trawls was more variable than might have been expected. On one survey, of 38 tows for which data were recorded, 11 (29%) were abnormal in that the trawl was off bottom for a substantial part of the time. During the abnormal tows, the trawl either reached bottom late (standard sampling tow duration is 30 minutes), or it fished normally early in the tow but then came off bottom before the tow was completed (Figure 7), or it never settled and spread properly at all. Without the NMI data, these tows would have been considered normal and the catch data from these faulty tows would have entered the data set, introducing errors in subsequent analysis. During the 27 tows when the trawl performed properly, within-tow variability was very low. The vertical openings during these tows fluctuated less than ± 1.5 feet. However, between-tow variability for the normal tows was somewhat greater, with average horizontal openings ranging from 36 to 48 feet and vertical openings between 4.5 and 5.5 feet. A plot of wingspread versus depth of tow (Figure 8) suggests that wingspread increased with depth, and vertical openings decreased with increases in wingspread.

Figure 7. Graph of NMI data showing gear leaving bottom about 12 minutes before hauling started.

Figure 8. Wingspread versus towing-depth relationship for the 400 mesh Eastern trawl, reported in Wathne (1977).⁴ Curve fitted by inspection.

Analyses of NMI data from other surveys using different types of trawls showed similar findings: on a substantial number of tows, trawls did not reach bottom when expected or stay on bottom as long as expected, and during normal tows within-tow variability was low while between-tow variability was quite high.

In 1979 the NMI were used during a cruise dedicated to gear performance experiments aimed at isolating the effects on trawl behavior of various elements of the towing situation (West, 1981)⁵. It was found that different trawls of the same design had slightly different characteristic vertical openings and that vertical openings increased when fore-to-aft tensions in the trawl were reduced by modifying the rigging and other components. Wingspreads increased with

towing speed and depth. During 12 out of the 75 experimental tows, the trawls did not settle and spread properly.

Over the years, guidelines have been developed empirically within the fishing industry that suggest the correct amount of towing warp to be deployed at any particular depth (Fig. 9) to ensure optimal trawl performance.

Figure 9. Plot of recommended scope versus towing depth values prepared for NOAA's ship Miller Freeman, using 1-inch diameter warps and 3,000 lb steel V-doors.

One of the experiments described by West examined the effects of exceeding the values specified by these guidelines, and it was found that wingspreads were reduced when excessive warp was deployed.

While the NMI were vital for demonstrating variability in wingspread and bottom contact, due to their complexity they were too unreliable for routine field use. RACE's experiences with the NMI demonstrated the need to routinely monitor trawl performance during resource assessment surveys, but more reliable systems were needed for routine use by unskilled personnel. The decision was made to develop new instrumentation systems that would look specifically at bottom contact and wingspread only. By reducing the number of tasks that the new systems would be expected to perform, system complexity could be reduced, consequently increasing system reliability. A corollary benefit would be lower acquisition and maintenance costs.

The first problem to be approached was the development of an on-bottom indicator (OBI). Factors considered in the design of this system included: minimal expense, the use of off-the-shelf components wherever possible, maximum reliability, and ease of operation. The system consists of a 27 kHz acoustic pinger which is attached to the footrope of a bottom trawl, a mercury tilt switch encased in an armored housing below the footrope (Fig. 10), a receiving hydrophone to be towed from the ship, and a shipboard receiver-amplifier.

Figure 10. Tilt-switch and pinger for on-bottom indicator system.

In operation, (Fig. 11) the tilt switch hangs below the footrope whenever the trawl is off-bottom, switching the pinger on, which pulses at about 1-second intervals. Pinger signals are picked up by the hydrophone and sent to the receiver for amplification. The receiver filters out noise other than the 27 kHz signals and activates an electronic "peeper" while it is receiving these signals.

Figure 11

This feature was added to avoid the masking of the pinger signals by ambient noise. Whenever the footrope is on bottom, the pinger is switched off. In preliminary tests, a prototype has performed satisfactorily and will undergo extensive field tests in spring and summer 1982. If these tests go well, plans are underway to equip all RACE survey vessels with these systems during bottomfish surveys. In this way, hopefully, the problem of off-bottom tows will be reduced, and perhaps fewer "water hauls" will enter the data base.

The other problem, variability in wingspread, is a bit more difficult to deal with, but preliminary tests of a system have yielded promising results. Two of the NOAA research vessels used for trawl surveys are equipped with third-wire netsondes, which have proven to be relatively reliable systems. The approach was to take advantage of these pre-existing systems by designing accessory units that would measure wingspreads acoustically and display the data on the netsonde paper recorder. Once again, design objectives were low cost, high reliability, and ease of operation and maintenance. A contract was awarded to Pacific Digital, Inc., of Seattle, to design and construct a prototype system. The netsonde wing unit (NWU) system consists of two wing transducers (Fig. 12), one attached to each upper wingtip of the trawl, and a battery charger/test unit.

Figure 12. Wing units for netsonde-linked wing-spread measurement system.

The port wing unit is the "master" and is linked to the netsonde headrope transducer circuitry via a connecting wire (Fig. 13).

Figure 13.

When activated by a pulse from the third wire transmitter, the port wing unit's transducer fires a 180 kHz signal across to the starboard transponder, which in turn transmits at the same frequency back to the port wing unit. The port wing unit then returns a signal to the netsonde, and the wingspread measurement is displayed on the netsonde's paper recorder in analog form (Fig. 14).

Figure 14. Paper recording of netsonde data with wingspread measurements appearing as a dashed line.

By switching itself on and off periodically, the NWU creates a characteristic dashed line on the paper recorder, making the wingspread measurements easily distinguishable from other marks on the paper. Interface circuitry is included to prevent interference with the operation of the host netsonde system, even in the case of NWU malfunction or failure of the connecting wire. Test circuits built into the battery charger facilitate trouble-shooting.

Preliminary tests of the NWU system have demonstrated that the electronic and hydroacoustic functions are satisfactory, but some problems have arisen due to the attachment of a hard wire to the trawl. Since attaching and removing the wire at the beginning and end of each tow was unworkable, it was semipermanently attached to the headrope and allowed to roll up onto the net reel with the rest of the trawl. When setting the trawl, it was then necessary to plug a jumper from the netsonde headrope unit into one end of this wire, and another jumper from the port wing unit into the other. (The starboard wing unit has no hard wire link). Unfortunately, these jumpers had a tendency to come unplugged, so two alternative remedial strategies are being evaluated. Design work was initiated to replace the hard wire with an acoustic link, and in the meantime, the plugs were redesigned. The acoustic link method promises to be easier to use, while the hard wire method uses less power, requires less complex electronics, and should be more reliable. It appears from preliminary

testing of the redesigned hard wire that the unplugging problem has been alleviated. The data acquired so far with this system have already proven to be useful (Fig. 15), and accelerated field testing is scheduled for the summer of 1982.

While the on-bottom indicator (OBI) and the netsonde wing unit systems represent progress towards the goal of reliable trawl performance instrumentation, neither system is entirely satisfactory.

Figure 15. Plot of response of trawl opening dimensions to changes in towing speed and scope.

Some way of making a permanent record of OBI data is needed and interfaces linking the OBI system to other trawl instrumentation such as a netsonde would be desirable. The netsonde wing unit system displays its data on the netsonde's paper recorder so a permanent copy is made, but in a format that is inconvenient to handle or prepare for computer analysis. Further, the accuracy of the NWU system's measurements is limited by the accuracy of the host netsonde.

Avenues for Further Research

One advantage of working with new technology such as trawl instrumentation is that opportunities for pursuing new ideas are wide open. The original NMI have been useful in demonstrating avenues for further research and development.

In the near term, RACE gear specialists plan to take advantage of recent advances in micro-processor technology to expand the capabilities and improve the reliability of the NMI, or a similar system. If reliability can be improved, a portable, self-contained system that gives a comprehensive description of trawl performance and records it in a computer-compatible format will be very useful. Real time shipboard read-out would be advantageous as would adding the capabilities for automatic recordings of such

environmental parameters as water temperature, salinity, and depth.

The OBI is just the first step in analyzing footrope contact. RACE gear specialists suspect that the footrope in the vicinity of the wingtips does not always fully contact the bottom even though the center of the footrope may be on bottom. A system that could record footrope contact at a number of points simultaneously could be very useful, especially if it had real time display capability.

It has been suggested that the failure of trawls to settle and spread properly and stay on bottom may be due to currents acting on the gear. A reliable system for measuring the water velocities affecting the trawl could help further our understanding of this problem.

There is the further, and perhaps most difficult to study, problem of catchability of the trawls. A technique for assessing the catchability of species in the path of the trawl would be enthusiastically received.

Summary

Trawl instrumentation systems have been developed to analyze the performance of bottom trawls used during resource assessment surveys, with the goal of improving the accuracy of abundance estimates derived from survey catch data. Data from these systems have revealed that trawl performance can be quite unpredictable. Specialized instrument systems have been developed with promising results to specifically monitor especially troublesome aspects of trawl behavior such as footrope contact with the bottom and wingspread. Further research is needed to develop systems for simultaneously monitoring footrope contact with the bottom at several points, trawl speed through the water, and catchability.

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