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FISH CAPTURE RESEARCH - NEEDS AND OPPORTUNITIES

by

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SUMMARY

Fish capture research is aimed at understanding how fishing gears work and the knowledge gained is now being applied to develop more selective nets and cod-ends and to assess the performance of sampling trawls. Progress on the main gear and behaviour research topics is reviewed briefly, including size and species selectivity, fishing effort measurement, mechanical performance, scale and computer modelling, instrumentation, escape reactions and survival of escaping fish. Aspects which need further study are identified. Although current emphasis is on applications, it is essential to continue basic studies in parallel to maintain the flow of ideas. In future, fish capture studies may have to include the wider economic, social and environmental aspects of fishing methods to arrive at effective conservation measures.

INTRODUCTION

Fish capture research is aimed at understanding how fishing gears work. Knowledge of the reactions of fish to gear and of the mechanical performance of fishing gears has developed steadily (Wardle and Hollingworth, 1993) and has now gained sufficiently wide acceptance to be applied in fisheries management and science, for example in the design of more selective cod-ends and of trawls for fish stock surveys. Emphasis in research work has shifted from fundamental studies to obtaining quantitative information for particular applications. To maintain the momentum gained in research however, it is essential to have a balanced programme of both basic and applied work. Without this the flow of new ideas will be inhibited. With the aim of stimulating debate, this paper briefly reviews the state of knowledge on the current themes of research in fish capture, discusses how these may develop and notes some longer term trends. Vessel design, although relevant to fishing gear development, is not considered.

The key to progress in unravelling the processes of fish capture was the development of suitable equipment and techniques - underwater TV, towed vehicles, SCUBA diving on gear and instruments to measure gear forces and geometry. The original justification for investment in this equipment was to increase commercial catch rates (Stewart and

MacLennan, 1987). It was also perceived that the knowledge gained might be applied to refine methods of stock assessment and to improve technical measures for fisheries management. Although emphasis has shifted to improving stock conservation, progress will still depend on the invention of new and more precise measurement equipment.

Fishing, like all basic production industries has become highly efficient in purely economic terms through the adoption of new technologies, for navigation, fish finding and capture. Capture efficiency has increased steadily, some stocks are over-exploited and the number of vessels and fishermen needed to maintain catch levels is falling. Bycatch levels in the mixed species demersal fisheries are high and there is an urgent need for fishing methods which are more selective in the size and species of fish retained. Conservation, rather than improved efficiency, has become the focus of fish capture research (MacMullen, 1986). It can be overlooked however, that improving fishing efficiency, eg by reducing fuel consumption, is also a form of conservation.

BASIC RESEARCH

Although fishing gear design and fish behaviour are often discussed separately, both must be considered when examining capture by a particular gear. The subject is multi-disciplinary and involves fish physiology and behaviour, hydrodynamics and engineering. Without drawing on all these subjects it is not possible to have a full grasp of the processes.

It has proved easier to quantify the mechanical performance of fishing gears than fish behaviour in gears (Ferno, 1993). This is mainly because the efficiency and selectivity of capture is highly variable, depending on biological, environmental and gear factors. More of the variables can be controlled in a gear engineering trial than in a fishing experiment. Output from behaviour studies has been essentially qualitative, describing how fish react to gears under various circumstances.

a) Behaviour

Principles of fish behaviour have been elucidated for mobile gears (Wardle, 1983), in particular the importance of the visual reaction, the role of the optomotor reflex and of swimming endurance. Although obtained mostly from observations in relatively shallow, clear water, these concepts have been found to apply widely. They account for observed events in fisheries, eg the large changes in efficiency between day and night fishing in the same area. There is still a need to develop quantitative relationships.

Efforts have been made to develop quantitative theories of fish behaviour in gears (Matuda, Liang and Sannomiya, 1993). The various stages in a capture process are described mathematically and linked. Flow diagrams can be helpful (Dickson, 1989) and this type of work should be pursued as it identifies areas in which knowledge is weak or absent.

Since it is possible to collect large amounts of data and to analyse these readily, there is interest in mathematical models for coping with the many variables encountered in both gear and behaviour studies. Models are usually the simplest equations which provide a statistically adequate fit to highly variable data. It is difficult to extrapolate these models and there is merit therefore in trying to fit equations which have physical significance and can shed more light on the problems.

Studies of fish reaction to the stimuli provided by fishing gears are supported by a knowledge of the sensory perceptions of fish - vision, hearing, smell - and on their swimming abilities and energy reserves (Wardle, 1987). Information on what can be detected by fish has been related to the visual aspects of gears and components, of the sounds generated by gears and of the chemicals emitted by baits. This is not an active area at present though there is a need to determine the visual capacities of the important marine fish, to investigate visual thresholds, pattern recognition and visual acuity.

Underwater observation of nets has focused interest on visual reactions (Main and Sangster, 1981), partly because divers and underwater vehicles can operate only in limited depths and above threshold light levels. Although some work has been done in conditions of near darkness, there is a need to explore more fully what happens in darker and more turbid water. Flash photography has been used to assess reactions in darkness but turbid water presents a greater problem. Acoustic methods seem appropriate; tagging has been used in conjunction with acoustic scanning but this is a costly approach (Arnold *et al.*, 1990). It may be that when visual detection is not possible, mobile gears will act more like sieves, but this possibility needs to be investigated. Fish may move randomly when touched by the gear, which has implications for size selection. It would be useful to estimate the proportion of fishing time spent under low light conditions (as defined by the visual abilities of the fish).

Most of the work on the reactions of fish to fishing gears has been on single boat trawls. This gear is relatively stable during a haul and easier to study than the seine net and pair trawl. Divers have observed fish in seine nets in shallow water but little is known of the reactions of the main commercial species in normal fishing depths. Size selection takes place throughout the process of herding by towing wires and bridles and during entry to nets when escape under the groundline and over the headline can take place. There appear to be differences between gear types in the selectivity of the whole system which can lead to larger numbers of small fish entering some nets. Fish in the mouth of a seine net for example, should be less tired than in a trawl and larger fish may escape more readily from the cod-end. Although it is possible to bring independently powered and towed vehicles close to these other nets, an additional vessel is required and the exercise is costly and difficult to execute. Self-contained cameras mounted on and near the nets may be a practical way to make observations.

Differences in reaction between species are potentially of great importance as such behaviour may be used for separation in mixed fisheries and hence reduce the mortality of non-target species. Separator trawls have been constructed (Main and Sangster, 1982) and shown to work in certain fisheries but commercial and research interest has declined. Perhaps more effort should be directed to looking for aspects of behaviour which can be used in separating gears?

The need to reduce the high mortality of juvenile fish caused by fishing has directed study to the behaviour of fish in cod-ends. The reasons why fish leave a cod-end need to be clarified. Visual stimuli appear important for inducing fish to pass through the meshes provided they have the energy reserve to make the attempt (Glass, Wardle and Gosden, 1993). Cod-ends should be designed to provide the correct stimuli, then water speed and temperature will determine whether a fish has the ability to escape. More work is needed in this area to define the limiting conditions for various species.

Accurate measurements of cod-end selection parameters are needed by both fishery managers and stock assessment scientists. Improved methods of measurement have been devised: the non-obstructing hooped cover and the twin trawl (with a small mesh cod-end on one side) but data analysis needs refinement (Millar, 1992). This is a current theme for the ICES FTFB working group and progress is likely. Ideally, a measurement technique is needed which does not involve the use of small mesh covers since these may influence fish reaction and give biased results. It may be possible to apply pattern recognition techniques to extract from video records information on the size distributions of the fish entering cod-ends. This approach will however, require considerable development work.

The survival rates of fish which escape from nets through meshes are critically important. These fish may suffer scale damage and subsequently die. If so, mesh regulations have little justification for conservation of the stocks. Effort in this area is expanding internationally (Sangster, 1992) and techniques of investigation are being devised to retain and study fish which escape during a haul. The question of survival of fish which escape during hauling, including those at the surface, has yet to be addressed. This work should continue to reach substantive conclusions.

Fish behaviour around static gears merits more study. Most data on set nets, for example, relates to catch comparisons (Reis and Pawson, 1992) and more needs to be known about the environmental conditions under which fish approach and enter nets. Visual methods are very restricted in range and since nets are long, the chances of collecting enough observations to make adequate assessments are slim. Acoustic methods would probably be more productive. Baited traps and long-lines have been given more attention (Olsen and Laevastu, 1983) and there is scope for studying the dispersal of the attracting chemicals.

b) Gear Performance

Existing instruments enable the mechanical performance of gears to be measured fairly thoroughly (MacLennan, 1982). Any new gear or variant can be assessed in detail and the shape and drag of the gear related to water speed. Much has been learnt about the shape, resistance and manoeuvrability of nets and the operation of otter boards. It has not proved easy to transfer this information to the fishing industry. One consequence is that vessel towing power and gear resistance are still often not well matched. The recent EC supported exercise on comparing the performance of different types of otter board (Anon., 1993) has made a serious attempt to make technical information available and may help communication in future.

There are several flume tanks in ICES member states. The cost of conducting model/full scale performance comparisons on nets has inhibited detailed investigation of the modelling rules. Work on modelling otter boards has been successful but the more complex rules for nets need to be well understood to maximise the value of flume tanks for gear development. Recent work, supported by the EC, has been very encouraging and there is scientific merit in pursuing this topic as it is likely to clarify many aspects of gear performance and modelling.

Computer modelling of nets (Ferro, 1989) is also useful since it highlights areas where knowledge is limited or inadequate. Present models are based on wind tunnel or flume tank measurements of netting resistance and use a lot of computer time to evaluate the shape of a net under tow. More effort in this area should also be productive of basic ideas.

Net design programmes for computers emerged from these studies and are gradually being adopted by net makers. ICES played a part in setting agreed standards for specifying nets (Anon., 1989).

The materials used in fishing gears are of great economic importance to the industry. An understanding of the properties of the materials is essential to gear research and most institutes have devoted some effort to this area. Major changes are likely to come from manufacturers of twines aiming at stronger, thinner yarns which absorb little sediment. The gauges used to measure mesh size - wedge or ICES gauge - have limitations; the former in controlling the applied force and the latter in dealing with heavy twine. A new design is needed. The increasing use of heavy twine in cod-ends to reduce selectivity indicates that a method of determining twine thickness at sea will be needed. Some work has been done on this topic in relation to fresh-water fisheries (Williamson, 1993). It is a sensible course of action for institutes to have a small programme of work on materials to maintain awareness of developments.

c) Instrumentation Requirements

Underwater vehicles are probably the most important devices available at present for fish capture work (Urquhart and Stewart, 1993). More manoeuvrable and smaller versions would help. A two-stage RCV may be an option, with a smaller vehicle tethered to the headline which carries a control package with a cable link to the vessel for power. Use of self-contained camera and recorder systems, especially if miniaturised, would enable more to be learnt about encircling gears.

A long range spreadmeter (up to 1,000 m) for use on seine nets and pair trawls is till required. A simple and reliable device for measuring the angle of attack of otter boards is another requirement. Several ideas, including flow direction indicators and flux gate compasses, have been tried with limited success. Acoustic devices to measure cod-end diameter are under development and means to measure mesh opening in situ in a cod-end would be useful. Photogrammetry can be applied to obtain precise descriptions of net shape (Kroeger, 1992).

Acoustic scanners for use in poor light conditions are available but expensive. Both electronic and mechanically scanned versions are available but have not been widely used in fish capture work. The up-date rate of mechanical scanners is rather low for tracking fish in mobile gear but can be used around static traps.

APPLICATIONS

1. Fisheries Management

Fisheries regulations aim to conserve the stocks by reducing fishing mortality. The present approach is mainly to restrict fishing effort and mesh sizes to aid the escape of small fish.

Fishing effort is currently estimated from vessel size, engine power and time spent fishing. Restrictions on vessel design encourage the adoption of more efficient methods of capture to limit loss of catch and also encourage the building of "rule-beaters" - vessels specially constructed to avoid the regulations. It is the fishing gear however, and not the vessel which actually catches the fish and it would be more accurate to define effort in terms of gear size and performance. Work is needed to compare gear performance and catches by different methods to assess how much the fishing effort exerted by a vessel can vary depending on the gear used. With such information, fishing effort could then be more accurately estimated by considering the combination of vessel and gear.

Minimum mesh size regulations have been applied for a long time to limit the retention and discarding of small fish by mobile gears. Although effective in selection experiments this regulation is often ineffective in the fisheries. Mesh size is only one of the factors determining mesh opening and it is easy to reduce mesh opening by altering cod-end geometry (Stewart, 1991). Adequate opening can be achieved by altering the cod-end shape, using square mesh or rigid grids. All these methods reduce discarding but complicate the gear to some degree. Enforcement of gear regulations is a problem and compliance appears to depend on the economic pressures on a fisherman. If the loss of marketable fish resulting from proper use of a selective cod-end is deemed too great, there is a temptation to alter the cod-end to retain these fish. This aspect of management needs to be considered when new rules are mooted (MacLennan, 1990).

Demersal gill nets are inherently more size selective than towed gears. The publicity given to sea bird and sea mammal by-catches in surface drift nets has given a misleading impression of the by-catch levels in demersal set nets which are normally much lower. There would appear to be a case for encouraging the wider use of this gear type. This would only be feasible if it could be demonstrated that the by-catch of sea birds and mammals was very small and if reserved sea areas could be created from which mobile gears were excluded to prevent conflicts. Research will be needed to investigate and minimise by-catch levels. The economics of larger scale fishing with demersal set nets is in doubt. These nets are usually deployed where fish concentrate naturally and such opportunities are limited. What is a limiting fish density for the profitable use of set nets? Some economic investigation may be worthwhile.

Techniques to separate species are urgently required in the mixed species demersal fisheries managed by quota allocations. The discarding of over-quota species is inevitable unless grounds are closed or the act of discarding is heavily penalised. Wider trials of existing separator trawls and study of other separation methods, eg using square mesh panels and grids, is justified. Due attention should be given to the feasibility of devising and enforcing regulations for such complex devices.

The current concern of conservationists over by-catches of sea birds and sea mammals may lead on to increased public interest in all the activities of the fishing industry, particularly when other species are affected. It is likely that more investigation of by-catches and discarding will be required and more effort devoted to developing capture techniques which minimise these effects. The effect of fishing gear on the flora and fauna of the sea bed (Bergman and Hup, 1992) is also a developing issue. Some fishing gears, such as beam trawls and dredges, do disturb the sea bed significantly. Worthwhile studies of the subject are inevitably expensive since they must be designed to cope with the high natural levels of variability of populations in time and place. It is likely that more work will be required in this area to provide a basis of information enabling discussion to proceed probably towards the restriction of gear sizes and types permitted in sensitive areas.

Recent experience has shown that fisheries management needs a multi-disciplinary approach to address the economic, social and environmental aspects as well as the purely technical. Fishermen are driven by short term economic pressures and fishery managers take a longer term view aiming at stability. Bio-economic issues need to be considered when devising management strategies. Fisheries laboratories rarely have any expertise in economics and might find it difficult to deal with the "softer" science approach used in economics. Useful dialogue between fish capture experts and economists might be established by considering fishing operations at the level of the single vessel or method (van Marlen, 1988) rather than at whole fleet level.

2. Fisheries Science

Stock abundance surveys require consistent sampling methods to produce reliable indices. Although a sampling trawl may be constructed to meet rigid specifications, its catching efficiency will vary according to how it is used and on the environmental conditions (Hagstrom, 1992). Towing speed and light level will have significant effects on catch rates. There is a need to monitor the shape and towing speed of survey gears to reduce variability and to investigate the influence of other factors. These ideas are being adopted in surveys and should improve the quality of the data collected.

Cod-end selection data are needed for all the important species and gears in the major fisheries to assess fishing mortality fully. Seasonal variations need to be determined and the effects of gear changes introduced by fishermen need to be monitored. It should be noted that the selection data emerging from experimental work, albeit on commercial vessels, describes ideally rigged cod-ends whereas those in use in a fishery may be less than ideal. What is needed is an estimate of the cod-end selection parameters of the gears actually used by a fleet. Consideration should be given to obtaining such estimates.

3. Fisheries Development

The information obtained by scientists on fish behaviour and gear performance is available to the fishing industry as reports and especially as video-films. Since fishermen have traditionally adapted their gear to maximise efficiency in any fishery, the new information will assist the process. Any measures which increase capture efficiency may be applied to reduce costs rather than increase catches and this is important when total catch size is limited by quotas.

The equipment and techniques developed for scientific purposes can be used to investigate questions of interest to the fishing industry. The small size of most of the enterprises inhibits expenditure on R&D and there is a reliance on Government agencies for such work. Exploratory fishing in deep water and the testing of new gears are examples.

New materials for gear construction are of value. Stronger twine leading to reduced gear drag and more durable twine would reduce costs. Bio-degradable materials for set nets to deal with the "ghost" netting problem would also be welcome. The cost of fuel is not a problem for the fishing industry at present, but in the longer term it is likely to reappear. This should stimulate interest in low drag nets, better matching of vessels and gears and static methods of fishing.

CONCLUSIONS

This text has dealt mainly with the continuation of existing themes in fish capture research but some trends have been noted which may come to dominate future work. The economic, social and environmental factors influencing the implementation of new fisheries regulations should be considered to ensure that decisions are taken which will be effective in practice. The technical means to reduce fishing mortality are available but the real constraints are economic and social. Conservation issues may become even more important if public concern about the wider impacts of fishing increases. In future, multi-disciplinary studies of fishing methods may be encouraged to provide fishery managers with the breadth of information needed to develop effective measures of control acceptable to the industry.

The demand for data to support conservation measures will, in the short term, require sustained activity on cod-end mesh selection and fishing effort measurement. The pressure to concentrate on these areas of applied science should not be allowed to starve activity in basic science. Modelling of fish capture processes, mathematical modelling of selectivity and gear shape and scale modelling should all continue as this work will pose new questions and increase understanding. Progress will depend on the provision of new and more precise instrumentation.

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