Fisheries Technology Committee

ICES CM 1999/B:3

REPORT OF THE

JOINT SESSION OF THE ICES WORKING GROUPS ON FISHERIES ACOUSTICS SCIENCE AND TECHNOLOGY (FAST) AND FISHING TECHNOLOGY AND FISH BEHAVIOUR (FTFB)

St. John's, Canada
23 April 1999

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1. TERMS OF REFERENCE

In accordance with C. Res. 1998/2:10 a joint session of the Working Group on Fishing Technology and Fish Behaviour (WGFTFB) and the Working Group on Fisheries Acoustics Science and Technology (WGFAST) met under the Chairship of Mr J. Massé(IFREMER, France) in St. Johns, Newfoundland, Canada, on 23 April 1999 to:

a) review the problems encountered in fish stock surveys related to fish behaviour;
b) consider the possibility for a single approach by WGFAST and WGFTFB to behavioural studies;
c) draft Terms of Reference for a study group on the impact of fish behaviour on sampling in fish stock surveys.

2. MEETING AGENDA AND APPOINTMENT OF RAPPORTEUR

The Chair opened the meeting and appointed Dr. P. G. Fernandes of the Marine Laboratory, Aberdeen, UK, as rapporteur for the morning session and Dr. A. S. Brierley of the British Antarctic Survey, UK for the afternoon session. The following agenda was adopted:

1. Session on current research on fish behaviour related to fishing and survey operations;
2. Session discussing the reports of the WGFAST and WGFTFB on aspects of behaviour;
3. Discussion on the formation of a study group about behaviour and stock assessment surveys;
4. Recommendations.

3. SESSION ON CURRENT RESEARCH ON FISH BEHAVIOUR RELATING TO FISHING AND SURVEY OPERATIONS

3.1 A. BRIERLEY and P.G.FERNANDES. Plans to use an Autonomous Underwater vehicle to estimate avoidance of survey vessels by herring and krill

Vessel avoidance is likely to be a source of bias in acoustic surveys of pelagic fish and krill. Previous studies have indicated that vessel noise may be more important than visibility in this avoidance response. This presentation described plans to use Autosub, an autonomous underwater vehicle (AUV), to quantify the effect of survey vessel avoidance. The exact noise characteristics of Autosub have not yet been measured, but it is likely to be "quiet" as it has a DC brushless motor, no gearbox and sea water lubricated bearings (less power is dissipated therefore less noise is created). Autosub will be equipped with an autonomous EK500 scientific echosounder operating at 38 and 120 kHz; it will then be deployed in front of research vessels on survey, and any differences in quantities of fish/krill detected by AUV and RV will be used to estimate avoidance. Similar measurements taken during fishing operations may provide quantitative information on avoidance in conditions of high noise.

Autosub may prove to be an alternative platform for acoustic surveys; it is likely to be less invasive and is able to sample impenetrable environments such as the near surface (looking up from close to the seabed), deep sea and more significantly under sea-ice. In addition, it may facilitate sampling at times when conventional research vessels can not operate, e.g. during bad weather. As the use of AUVs becomes more routine, they are likely to provide large savings in operating costs compared to conventional platforms.

Discussion: The noise signature of AUV's is likely to be minor: noise measurements of the Norwegian AUV "Hugin" were not possible as they were drowned out by the noise of the supporting research vessel Johan Hjort. The colour of Autosub was considered by a number of participants to be a possible source of avoidance although this is likely to be very localised and, furthermore, is outweighed by the importance of a visible colour for vehicle recovery: measurement at night may reduce the problem.

3.2 F. GERLOTTO, P. BREHMER, L. GONZALEZ AND B. SAMB. Variability on avoidance reactions and catchability of fish schools: learning from fishery or effect of environment ?

The clupeoid *Sardinella aurita* is the dominant species in its ecosystem and occurs on both sides of the tropical North Atlantic. The environmental conditions in these Sardinella driven ecosystems are very similar and this is reflected in the acoustic typology of the fish: school shapes are very similar in Venezuela and Senegal and occur in similar proportions. One noticeable difference between the populations in Venezuela and those off the west coast of Africa is the fishing pressure: it is considerably lower on the western side of the Atlantic. This has led to the hypothesis that fish on the eastern side may have learnt from the increased predation pressure to avoid (fishing) vessels. Such avoidance could have a significant influence on the catchability coefficient applied to the analysis of these fish stocks.

Observations of fish avoidance were made with an omnidirectional sonar in Venezuela and the Ivory Coast of west Africa using the same research vessel ("Antea"). Preliminary results indicate that the avoidance response in the Ivory Coast was indeed greater than that in Venezuela. This was reflected in trawl catches: in Venezuela *S. aurita* contributed to over 80% of the catch; whilst in west Africa this species only contributed to 15%.

Discussion: Similar inferences had been drawn from studies with a submersible in the Barents Sea where cod are suspected of learning to avoid trawls. The distinction between adaptation through genetic evolution and learning is often difficult to separate: it is usual therefore to consider the response as a function of both processes. Finally a cautionary note on the calculation of fish speed was expressed with regard to taking into account local currents.

3.3 G. ARNOLD. Availability and accessibility of demersal fish to survey gears : Population-wide patterns of behaviour.

The Centre for Environment Fisheries and Aquaculture Science (CEFAS) continues to have success in the deployment of data storage tags. The work has proceeded in two phases of an EC funded programme: in phase one, tags recorded temperature and pressure every 10 minutes and lasted approximately nine months; a total of 303 tags were deployed on plaice (*Pleuronectes platessa*) in the southern North Sea and 49 were recovered providing almost 2500 days of data (maximum of 224 days); in phase two, approximately 400 new tags were deployed which record data every four minutes for up to two years (1.5 MB); to date, 87 tags have been returned providing 12500 days of data (maximum of 471 days).

Analysis of pressure data revealed distinct and repeated patterns of behaviour linking vertical movement to both tidal and diurnal cycles. The fish are seen to vertically migrate into pelagic water (vertical movement takes approximately half an hour) where they use tidal streams to augment their horizontal movement. The tidal models used to reconstruct the fish tracks can be validated by reference to temperature readings (which are significantly different from the southern N. Sea to the Channel) and by reference to the state and timing of the tide (which is evident in the fine scale analysis of the pressure data). These horizontal movements have revealed a distinct corridor of migration from the southern North Sea to the eastern approaches to the English Channel. The migration patterns can then be used to assess the influence on catch per unit effort with regard to the availability of the stock.

The project aims to deploy tags on cod and other species soon. The vertical movements of these animals are important for studies of their target strength. Preliminary observations suggest that these fish are only neutrally buoyant at the top of their range such that when they undertake rapid vertical movements their tilt angle and swim bladder volume may alter considerably.

3.4 I. MACQUINN and Y. SIMARD. An adaptive integrated acoustic/trawl survey on Atlantic cod

A presentation was made of preliminary results from the High Priority National Hydroacoustic Project integrated survey conducted in southern 4R in May 1998. This survey was designed as an operationally useful mixed acoustic/trawl groundfish survey which would produce absolute abundance estimates of groundfish (mainly cod and redfish) for a given area and to study factors affecting the geographic and vertical distribution of the target species aimed at improving the precision and accuracy of these estimates. The survey protocol involved conducting an initial acoustic survey with systematic transects between the 150 and 300 m depth contours to locate a significant cod concentration. An experimental area was then defined for the mixed acoustic/trawl experiment which would encompass the cod concentration and which could be completed within a 24 hr period. The area backscatter from the initial survey was stratified into low, medium and high densities for the allocation of the trawl stations. The systematic acoustic transects were resurveyed alternately with the 10 selected trawl stations.

Trawl data showed that the vast majority of the fish in the area were cod, with an increase in the percentage of redfish with depth. There was also a pattern of larger cod (45-48 cm) in the southern and the northern ends of the area, with smaller cod (40 cm) in the central zone. Trawl catch rates showed that the majority of these cod were in the south and in the north, with low catches in the central area. The stratified mean density of cod gave a biomass estimate of 4200 t for the area.

The acoustic data showed two centres of biomass, one in the southern zone and the second at the northern extremity of the area, similar to the pattern from the trawl catches. There were visible differences in the vertical distribution between transects conducted in day versus at night, cod being distributed up to 50 m off the bottom at night, and within a few meters of bottom in the day.

Although cod off bottom are available to the acoustic technique, fish close to bottom in the so-called "dead zone" are undetectable, therefore the acoustic estimate must be biased downward. However, the sample volume of the dead zone can be estimated and is a function of depth. A correction was applied to the acoustic biomass estimates in which the unsampled fish density in the dead zone was extrapolated by a linear inference to the fish density immediately above this zone. This resulted in an average correction to the transect biomass estimates of 21 and 9% for day and night transects, respectively.

The cod biomass was estimated by two methods using the acoustic data. The first method involved first classifying the backscatter into 3 major groups using information from the trawl catches and visual patterns on the echograms: cod (cod >80%), cod and redfish (30%<cod<80%) and redfish and cod (cod<30%), attributing the backscatter within each class to the two species from the proportions in the corresponding trawl sets, and estimating the mean cod and redfish densities within the area from the weighted transect backscatter means. This resulted in a total cod biomass estimate for the experimental area of 4600 t. The dead zone correction increased this estimate to 5300 t, or by 15%. The second method involved kriging of the acoustic data within various layers off bottom, and using the relationship between the proportion of cod and redfish in the trawl catches and depth to proportion the backscatter to species. This technique resulted in a total dead-zone-corrected biomass estimate of 4300 t and showed that, on average, 50% of the biomass was above the headrope height of the trawl (approx. 4 m) during the acoustic data collection. The trawl biomass estimates would therefore be negatively biased due to this diel vertical migration, although it was noted that most of the trawl sets that were conducted in high cod-density stations were in daytime (06:00 and 20:00) and therefore may not be severely biased. The trawl estimates were very similar to the dead-zone-corrected kriged estimate, although they were 1100 t less than the dead-zone-corrected mean transect estimate.

Although these analyses are preliminary, it is clear that the major potential source of error in trawl survey estimates would be due to their diel vertical migration where on average 50% of the cod were above the headrope height over a 24 hr period and were therefore unavailable to the gear. For the acoustic estimates, the combined day/night dead zone correction was in the order of 15%, and can be estimated assuming a linear relationship between the cod density in the dead zone and the density in the zone immediately above it. Two large aggregations of fish were observed by both methods: one in the northern part of the area and one to the south. A correction for the acoustic "dead zone" was made by extrapolation: the fish density in this one was assumed to be the same as that in the layer of equivalent size immediately above it.

The trawl survey biomass estimate was 4235 tonnes and the acoustic estimate was 5308 tonnes (4600 tonnes without the dead zone correction). The difference is thought to be driven by the availability of the fish to the trawl: at night the fish move up into the pelagic layer of the water column, beyond the 0-4 m layer where the trawl operates. This was reflected in the trawl catches which were significantly lower at night.

K. MICHALSEN gave a short presentation on the combined acoustic and trawl surveys of groundfish in the Barents Sea. The fish were found to be herded by the vessel such that the effective fishing height of the trawl was much higher than its headline height. Differences were observed in the occupation of the dead zone: by day the large cod and haddock were pelagic and small cod occurred predominantly in the dead zone; by night the situation was reversed. This observation of diurnal migration was confirmed by analysis of data storage tags on cod. Movements of individual fish were often rapid and residence not always predictable: in one case a fish remained on the bottom for approximately six days.

A. BERTRAND gave a short synopsis of his work looking at the longline tuna fishery in the French Polynesia. Acoustic surveys were conducted over longline sets and revealed that the availability of fish to hooks was not consistent over the area: this change in availability invalidates the measurement of catch per unit effort producing a negative bias in the population estimate. An estimate of 170,000 tonnes was derived from the acoustic survey.

J. MASSÉ gave a short presentation of echograms from combined bottom trawl and acoustic surveys in the Southern North Sea. Fish species that are typically regarded as pelagic (herring and sprat) were predominantly found in the area accessible to the trawl, whilst demersal fish such as cod and whiting were found further up in the water column beyond the headline height of the trawl. It is not possible to conclude that it was similar the previous years because a change in behaviour seems to have occurred and has been observed recently in other areas (Bay of Biscay, Spain and Portugal), .

The group was reminded of two forthcoming events relevant to the subject of combined acoustic and trawl surveys:

i) Theme Session at the ICES Annual Science Conference (Stockholm, September 1999) entitled "Application of acoustic techniques to bottom trawl surveys" (co-convenors J. Massé and O. R. Godp);

ii) A planned conference on bottom trawl surveys at the Alaska Fisheries Science Centre in Seattle (dates to be decided, contact david.somerton@imr.no).

4. SESSION DISCUSSING THE REPORTS OF THE WGFAST AND WGFTFB ON ASPECTS OF BEHAVIOUR

4.1 O. MISUND. The ICES Strategic Plan

The objectives for the ICES Strategic Plan were presented by the Chair of the Fisheries Technology committee; these will be submitted to the forthcoming ACFM meeting. The group considered the general layout to be acceptable but thought that WG FAST's remit in particular could be extended into other areas such as: "Understanding marine ecosystems", particularly with regard to mapping habitats and studying life history; and "Understanding human impacts" with regard to looking at ecosystem effects.

The Chair asked the group for comments on wording of the two specific sub-objectives that were of most relevance and some suggestions were made; the final version is as follows:

Develop improved technical measures for fishery management.

Fishing gears are selective in the size and species composition they retain. Nevertheless fishing gears often capture a bycatch of fish which are either of the wrong size or species from the point of view of marketing or conservation. Improving the gear selectivity is important in the choice of appropriate fishing regulations to better manage fisheries.

An understanding of fish behaviour during fish capture is essential in the design of appropriate gears for given target species. Understanding behaviour also assist in developing gears with specific conservation needs either to prevent unwanted bycatch of small or non-target fish.

Activities: WGFTFB meets annually to review relevant studies of fish behaviour and consider development of selective gears with reduced impact on marine ecosystems, Study and topic groups consider specific subjects.

Improve the accuracy and precision of abundance survey methods

Acoustic methods are widely used in fishery science, particularly to estimate pelagic fish abundance. As technology advance continually, it is important that new methods are developed and deployed for scientific applications. These will improve the accuracy and precision of existing surveys, and offer new methods for investigating plankton, studying fish behaviour, enhancing trawl surveys and identify species before capture.

Fishery independent estimates of abundance are essential in stock assessment. The importance of surveys has increased as fishery catch and effort statistics have declined in quality. Further development of survey gears is essential to improve abundance estimates. There is also an increasing need to quantify the capture of non-commercial species as the interest in an ecosystem approach to fishery management develops.

Activities: WGFAST and WGFTFB meets annually to address topical issues, and also to have a joint session. Special study and topic groups consider specific subjects.

4.2 W. WEST. FTFB report on Fish Behaviour Research, Modelling, and Assessment Surveys

Fish behaviour, its implications for assessment surveys, and an assessment of possibilities for quantitative modelling, was the subject of a Special Topic of the WGFTFB. A keynote speaker, Steve Walsh, had been invited and gave a paper entitled "Fish behaviour and trawl catchability: the impact on abundance estimation". A number of additional papers germane to the Special Topic were presented:

Fish behaviour, impact on survey results (Kathrine Michalsen, Norway);

Use of infrared illumination and an intensified video camera to observe fish in trawls at low light levels: an application toward measurements of fish crowding in trawls (Craig Rose, USA);

Electronic tags and fish behaviour (Geoff Arnold, United Kingdom);

The importance of towing speed on the swimming endurance of Atlantic cod (*Gadus morhua*) (Paul Winger, Canada);

Behaviour and spatial dynamics of fish populations: an update on the Lowestoft data storage tag programme (Geoff Arnold, United Kingdom);

A comparison of two intragastric tagging techniques in Atlantic cod (*Gadus morhua*) (Paul Winger, Canada);

Correcting abundance indices for behavioural effects: A decision rule based on the mean square error (Peter Munro, USA)

Following these presentations, the Working Group broke up into two subgroups for further discussion: One on Fish Behaviour and Stock Assessment, under the Chairship of Steve Walsh, and another on Fish Behaviour and Modelling, chaired by Chris Glass. These subgroups then reported to the WGFTFB for discussion.

Fish behaviour and stock assessment

1) Is absolute abundance estimation possible? Examples were presented of various resource assessment survey programmes characterised by whether they are used to produce estimates of absolute or relative abundance, with a brief discussion in each case of the implications of fish behaviour.
   a) Absolute abundance indices
      i) Egg surveys for North Sea mackerel – sampling gear is assumed to be non-selective, with no concerns about possible avoidance behaviour or other behavioural effects.
      ii) Barents Sea capelin survey
         (1) Echo integration techniques used to estimate biomass
         (2) Pelagic trawls used to sample acoustic targets for size/age composition
         (3) Assumption is made that both the acoustic technique and the pelagic trawl are non-selective, implying no concerns about vessel or gear reactions

   b) Relative abundance indices
      i) Many pelagic species in various regions worldwide
         (1) Echo integration techniques used to estimate biomass
         (2) Pelagic trawls used to sample acoustic targets for size/age composition
         (3) Assumption is made that both the acoustic technique and the pelagic trawl are non-selective, implying no concerns about vessel or gear reactions
      ii) Semi-pelagic species, e.g. cod, haddock, pollock, blue whiting, redfish
         (1) Acoustic techniques and/or swept-area bottom trawl assessment techniques used to estimate biomass
         (2) Trawl catches are used to allocate acoustic energy among size(age) and species
         (3) General acknowledgement that sampling trawls may be length and/or species selective
         (4) Awareness that vessel and warp avoidance by fish in the pelagic zone may increase the effective height of the trawl, leading to overestimates of biomass in the bottom zone and underestimates for the pelagic zone.
         (5) Horizontal avoidance may also be a problem.
      iii) Flatfishes
         (1) Bottom trawls or beam trawls used to estimate biomass
         (2) General acknowledgement that sampling trawls may be length and/or species selective
         (3) Horizontal avoidance may also be a problem.

2) Non-selective sampling trawls – Is this a fruitful concept ? The group concluded that a non-selective trawl gear is not possible at our present state of knowledge. However, obtaining the knowledge needed to develop a non-selective gear would also make it possible to convert catches from a selective gear back into characterisations of the true population.

3) Quantitative estimation of survey catchability and correcting survey estimates of catch-at-age data. A key question is: Is it sufficient to make measurements or estimates of trawl selectivity and efficiency on a one-time basis and

assume that these do not change from survey to survey ? Even if definitive, universal calibration factors are not achievable there may be value in using approximations, as is being done in some Norwegian surveys.

4) Effect of environmental variables and their interactions with trawl efficiency.
   a) Variations in light levels and currents can affect accessibility and vulnerability to both acoustic and trawl sampling gears.

   b) In some species there are diurnal changes in size stratification and the occupation of different depth zones by different size classes, e.g. large fish on the bottom and small fish off bottom during the day, with the opposite distribution at night. In such cases, day-only (for example) surveys will underestimate the smaller categories, which can be troublesome if this situation reverses for some reason. Barents Sea cod were cited as an example, where these large-fish/small-fish day/night bottom preferences have been observed changing in response to fish density.

5) Sources of bias
   a) Pelagic species
      i) It is known that variations in tilt angle and reactions to survey vessels or sampling operations can affect target strength, but different institutes have demonstrated varying levels of concern ranging from none to great.
      ii) The basic gear-related assumption for acoustic surveys is that the catch represents the species and size composition of the selected acoustic targets or aggregations. Recent results (e.g. from use of the MultiSampler) show that conventional pelagic trawl catches do not represent such factors as within-school size stratification. Other studies have shown that size- or species-related gear avoidance does occur, as well as selectivity within the gear.
   b) Semi-pelagic species
      i) Effective sampling height: In Norwegian studies an upwards-looking acoustic transducer was attached to the headline of the sampling trawl to characterise fish abundance in the zone above it.
      ii) Studies in the Barents Sea and Bering Sea have employed stationary transducers to evaluate fish responses to vessel and/or gear passage in an effort to quantify avoidance behaviour and the effective sampling height.
   c) Semi-pelagic and demersal species - There is a need for effective methodologies for studying horizontal avoidance behaviour, herding by doors and rigging, etc. Submersibles, towed vehicles, autonomous underwater vehicles (AUV's), underwater cameras, and scanning laser systems have been used on a limited basis or have been proposed as potential methods. AUV's are less obtrusive than submersibles or towed systems and are probably more cost effective.

6) Cost/benefit analysis – Stock assessment biologists can provide valuable information regarding which issues are most critical from their standpoint. This can be weighed against the costs of the research needed to obtain the answers, and research priorities can then be efficiently assigned. Alternatively, such determinations may provide a motivation for adjusting assessment methodologies, or developing new ones, when a particular issue scores badly in such cost/benefit analyses.

Fish behaviour and modelling

1) Definition of the zones of capture.
   a) Zone 1 includes the natural behaviour and distributions of schools/individuals that are as yet undisturbed by either vessel-propagated noise or the trawl gear.
   b) Zone 2a includes the behaviour of fish in response to vessel propagated noise.
   c) Zone 2b includes the behaviour of fish in response to the trawl warps.
   d) Zone 3 includes the behaviour of fish in the region between the trawl doors and wing-ends of the trawl net.
   e) Zone 4 includes the behaviour of fish in the region between the wing-ends and cod-end.

2) This capture zone framework was used to characterise our present state of knowledge
   a) Zone 1: Several emerging technologies are currently being used or proposed to monitor the natural behaviour and distributions of fish in the pre-trawl zone. These include laser scanning systems, data storage tags, radio-acoustic buoy arrays, and stationary acoustic transducers. We would like to find a means of quantifying the proportion of fish that are available to the sampling gear. We suspect that many environmental and physiological factors may affect the behaviour of fish in this region.

b) Zone 2a: A considerable baseline of data now exists on the noise signatures of different vessels. However, it was agreed that data on the impact of such noise on fish behaviour remains limited. Emphasis was put on the need to:
   i) reduce variability in vessel noise,
   ii) manufacture quieter vessels,
   iii) study learning in fish,
   iv) conduct comparative studies between different vessel sizes/powers (i.e. noise envelope),
   v) quantify the effect of shipboard lights, and
   vi) increase general awareness of needs for research in this area.

c) Zone 2b: Very little work has been conducted on the behaviour of fish in response to trawl warps. Given that the warps themselves are known to produce a "hum" while passing through the water, it was suggested that further work should be directed toward studying the hearing capability of different species, and their behavioural responses to such stimuli.

d) Zone 3: A substantial collection of qualitative observations (video and still photography) of fish behaviour exists within this zone of capture. The group agreed, however, that most of this research has been collected during the day only with very few night time observations. It was further suggested that increased effort should be directed toward gathering quantitative estimates of fish behaviour. The group agreed that the potential sources of variability are high in this region.

e) Zone 4: The group agreed that the greatest volume of data on fish behaviour exists within this zone of capture. While much of the data is quantitative, it has only been collected for a few commercially important species. Emphasis was put on the need to study other species.

3) The same zone framework was used to characterise future research needs.
   a) All zones:
      i) Emphasise the quantification of fish behaviour,
      ii) Direct our attention to those species and areas which are most important to surveys,
      iii) Develop new techniques to quantify fish distribution and reaction behaviour, and
      iv) Reduce all aspects of variability, but in order to do that we need to know the causes.

   b) Zone 1:
      i) Encourage the continuation/expansion of current initiatives to assess natural behaviour
      ii) Promote increased understanding of spatial variability and distribution of fish,
      iii) Promote the collection of fisheries independent data

   c) Zone 2a: Need to describe and quantify the reaction behaviours of fish in this region

   d) Zone 2b: Need to describe and quantify the reaction behaviours of fish in response to warps

   e) Zone 3:

      i) Need to know the number of fish by size and by species which enter between the doors
      ii) Need techniques to quantify aspects of fish distribution
      iii) Need to quantify reactions of individuals/schools throughout the entire herding process

   f) Zone 4: must improve our detailed knowledge of avoidance behaviours in the vicinity of the net mouth.

4) The group agreed that "predictive" behavioural models remain presently unattainable for capture zones 1 through 3. The obstacle at this time appears to be a lack of fundamental knowledge of fish behaviour in relation to different variables (e.g. environmental, physiological, or gear related). It was suggested that the wealth of video/still photography at many institutes could be analysed to help address this need.

The group agreed that the feasibility of a predictive model for zone 4 is a likely possibility. Some preliminary efforts to date have already been devoted to this area.

4.3 F. GERLOTTO. FAST report on behavioural considerations

1) The work of the FASTWG has confirmed that fish behaviour is one of the most important potential sources of bias in fisheries acoustics, from several points of view:

a) directly, due to the existence of relationships between the spatial position of fishes, the stimuli produced by the research vessel and the characteristics of the individuals, due to avoidance reactions;
b) indirectly, on species identification through the avoidance of fishing gear, etc.;
c) randomly, by the existence of adaptive functions related to the environmental changes.

2) The main characteristics of fish behaviour as studied through acoustics may be:

a) Predictable (tilt angle, shadowing, etc.);
b) Species specific (school shapes, migrations, etc.);
c) Responsive (induced by environmental variability).

3) These characteristics allow new insights into the dynamics of fish stocks, and contribute to such innovations as automatic species identification, recognition of stock status (cluster, schools) etc. Moreover, some behavioural characteristics are highly favourable to acoustic surveys:

a) aggregative behaviour (decrease sampling effort, multi-species mixing);
b) fish identification;
c) trophic relationships, etc.;

4) Acoustics may provide to itself, as well as to other research fields valuable information about behaviour, which allows to correct the acoustic data and sampling strategies in real time. Moreover, it is able to provide to other areas of fisheries biology a unique data source on fish behaviour in relation to:

a) catchability and availability to fishing gear;
b) reactions relative to the environment;
c) monitoring of behavioural changes;
d) the definition and following of populations (stocks);
e) adaptation to exploitation;
f) trophic relationships.

5) Acoustic methods and instruments presently exist which allow for an exhaustive spatial and temporal observation which, thanks to dynamic 2D and 3D visualisation, allow for:

a) the reduction of bias from sonar data;
b) the detailed description of spatial behaviour in relation to any environmental element.

From these points, FAST concluded that the studies presented during the meeting confirmed the results of the questionnaire on the sources of uncertainties presented in 1998, and concluded that the effect of fish behaviour is certainly one of the priority research field to be considered in the future. Consequently, the FAST W.G. recommended that fish behaviour be studied along three lines:

- Adaptation of fisheries acoustics to monitor and quantify the effects of fish behaviour on biomass estimation;
- The use of acoustic observations of fish behaviour to help understand fish stocks;
- The development of new methods, tools and models to resolve fish behavioural effects on biomass estimation;

In addition, the FAST recommends two special topics for the next FAST meeting:

- consider the effect of fish avoidance on the results of acoustic surveys;
- consider acoustic bottom type classification methods, in order to evaluate the impact of bottom types on the distribution of fish

5. DISCUSSION ON THE FORMATION OF A STUDY GROUP ABOUT BEHAVIOUR AND STOCK ASSESSMENT SURVEYS

J. Massé (Chair) began the discussion by observing that both WG agree on the importance of fish behaviour impact on most of the results and data collected. This first conclusion leaded to another point: how should the two W.G. take this result into consideration ? J. Massé asked if the two W.G. had an interest in participating in a Study Group (SG) on acoustics and fish behaviour. They expressed interest, particularly for a SG to address the influence of behaviour on stock assessment surveys. Nevertheless general opinion seemed to be that assessment scientists would not have the time to become involved. FAST/FTFB should be pro-active in setting up the SG. This latter point of view was generally supported. Suggestions for the remit of the proposed SG were then made:

- to examine surveys of various species to see where main sources of error lay, and address these sources
- to examine the components of techniques practised by the group that contribute to assessment (e.g. survey technique, fishing selectivity), and focus on reducing biases of these
- to identify points of common interest in the behaviour area common to both FAST and FTFB, and improve them.

The suggested SG should have very fixed goals that can be achieved within the two to three year lifespan of the group. The SG could not expect to address the whole subject of "behaviour", and additional reviews would be unnecessary since both FAST and FTFB had already done this independently.

An earlier example of collaborative SG between two WGs was described, and the point made that ICES had not been particularly satisfied with the outcome. It was suggested that in light of this, formation of a SG should be delayed until the Living Resources and Fishing Technology Committees had liased. It was suggested that FAST/FTFB should first encourage dialogue between the Fisheries Technology and Living Resources Committees so that behaviour is recognised as a source of error to wider audiences than just FAST/FTFB.

Nevertheless, "behaviour" is taken into account by FTFB WG as part of the fishing technology perfecting, while the FAST WG consider "behaviour" according to both a bias in acoustic survey results and a knowledge provided by the tool itself. A Theme Session addressing the question of how behaviour influences assessment/management, to be jointly proposed by FAST and FTFB, was suggested as an intermediary step. This would serve to bring people from wider disciplines together. This idea was well supported, but several people believed that, in addition, FAST/FTFB should anyway convene a SG now to address some specific behaviour issues jointly. Together these two WGs have the ability to make recommendations that may reduce substantially biases in some aspects of surveys, recommendations which are at present not being implemented. A SG on a topic of common interest to both groups could improve surveys soon. Some members argued that as behaviour is such a big topic, even a joint SG may not be adequate, perhaps the subject deserves a WG in its own right. This was, however, not deemed a sensible suggestion at a time when ICES was generally rationalising WGs.

It was suggested, as another way to develop this common research, that a more general discussion on the topic should be favoured, and especially outside the FTC. There was a consensus of opinion that there ought to be more dialogue between the Fisheries Technology and Living Resources Committees. One way to achieve this in the short term would be to ensure that potential clashes in the programme for the forthcoming Annual Science Meeting were avoided so that members of each were not prevented from attending the other's sessions.

The group made some proposals on the basis of its discussions. These were:

- **Study Group** *The effect of fish avoidance on direct assessment methods*

  The group voted against establishment of this SG immediately, agreeing that the topic warranted study, but that the organisation of such a S.G. should be deferred.

- **FTFB/FAST Joint Session** *Visualisation and measurement of behaviour*

  This was endorsed by the group. Also it was agreed that next year the FAST and FTFB Chairs should attempt to make the agendas of their respective WGs more conducive to exchange between sessions.

- **Theme Session** *Impact of fish behaviour on living resource management*

  This was supported by the group. It was suggested that P Freon and D Skagen might be appropriate Chairs.

Jacques Massé was elected Chair for the Joint Session in 2000 (21 April) to be held in IJmuiden in the Netherlands.

6. JOINT SESSION RECOMMENDATIONS

The WGFAST and WGFTFB Joint Session made the following recommendations:

1. The WGFAST and WGFTFB Joint Session should meet in Ijmuiden, Netherlands on Friday 21 April 2000 to:

a) present common interest studies between FAST and FTFB members
b) consider as a special topic, tools and studies about visualisation and measurement of behaviour
c) reconsider the creation of a study group on the effects of fish behaviour on direct assessment methods.

Justification:

a) The relevance of the FAST/FTFB Joint session was confirmed as being the best way to confront respective experiments according to fish capture and acoustics and have mutual benefits. All subjects which might be of both concerns will be preferably presented to this session.

b) Behaviour is generally considered as a predominant factor affecting surveys results (with bottom trawl, acoustics, pelagic trawl, ...), biomass estimates and fishery management. As it is difficult to quantify such a factor, a special attention is asked to members on the availability of visualisation and measurements tools. This will take into account the different approach like acoustics, tagging experiments, laser, video, etc.

c) The relevance of such a Study Group was admitted but was finally deferred. To be efficient, very fixed goals that can be achieved within the two to three year life span of the group must be defined. The 2000 FAST/FTFB Joint session must be the right platform to create a Study Group with precise objectives and target participants.

2. The WGFAST and WGFTFB Joint Session suggests a special Theme Session for the next Annual Conference (2000) about "Impact of fish behaviour on living resource management" (P Fréon and D Skagen were suggested to be Chairs).

Justification:

Members argued that behaviour has certainly a great influence on survey results and fishery management as well. This subject is taken into account by FTFB WG as part of the fishing technology perfecting, while the FAST WG consider "behaviour" according to both a bias in acoustic survey results and a knowledge provided by the tool itself. To reduce substantially biases in some aspects of surveys, a dialogue between the Fisheries Technology and Living Resources Committees must be encourage so that behaviour is recognised as a source of error to wider audiences than just FAST/FTFB. A Theme Session addressing the question of how behaviour influences assessment/management, jointly proposed by FAST and FTFB, could be a first step to bring people from wider disciplines together.

7. CLOSURE

The Chair thanked the staff of the Department of Fisheries and Oceans, St. Johns, for their hospitality, and members of the Working Group and Study Groups for their efforts and contributions.

8. PARTICIPANT LIST

See in Appendix 1

APPENDIX 1 - LIST OF PARTICIPANTS

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