Fisheries Technology Committee ICES CM 1999/B:1

REPORT OF THE

WORKING GROUP ON FISHING TECHNOLOGY AND FISH BEHAVIOUR

St John's Newfoundland, Canada
19–22 April 1999

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 INTRODUCTION

1.1 Terms of Reference

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Venue: St. John's Newfoundland
CANADA

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In accordance with ICES C.Res.1998/2:6 the Fishery Technology Committee recommends that: **The Working Group on Fishing Technology and Fish Behaviour** [WGFTFB] (Chairman: Dr. A. Engas, Norway) will meet in St John's, Newfoundland, Canada from 19-22 April 1999 to:

a) consider technical modifications to fishing gears and fishing operations to reduce their undesirable immediate and long-term physical and biological impacts including ghost fishing by lost gear;
b) review and consider recently developed methodologies to study physical impacts on benthos and benthic substrates;
c) review recent research on fish behaviour, evaluate implications for assessment surveys and assess possibilities for quantitative modelling;
d) review the mesh measurement procedure for the ICES gauge.

WGFTFB will report to the Fisheries Technology Committee at the 1999 Annual Science Conference.

Justifications:

a,b) Recent international research on both active and passive fishing gears indicates that they have measurable impacts on the ecosystem, in addition to the known effects on target species. By-catches of non-target species of fish, mammals and reptiles can be significant and some gears, e.g., beam trawls and dredges, disturb the sea bed and benthic populations. In some fisheries there is a need to reduce these impacts and hence to investigate technical and operational measures to achieve this end. Ghost fishing, especially by passive gear, may exist on a large scale and is a major issue for the conservation of certain vulnerable species. In 1998, the working group reviewed the technique which have been developed for improving the size and species selectivity of towed gears for demersal fish species and consideration of methods of ameliorating adverse ecosystem effects of gears will complement that review.

c) There have been many studies of gear selectivity and efficiency but only limited work on the combined efficiency of a survey vessel and survey gear. Investigation of the natural behaviour of fish can provide information on horizontal and vertical distributions and help explain reactions to vessels and fishing gear. These characteristics affect accessibility to survey gear and vulnerability to capture. The catching performance of the demersal survey gear affects estimates of population abundance and similar considerations apply to acoustic surveys for pelagic species. Several ICES countries are conducting, or have recently completed, significant studies in this area and the subject would benefit from a review of progress, an exchange of experience and an evaluation of objectives.

d) Methods of mesh measurement were examined recently by an EC funded group. They noted that the present instructions for using the ICES gauge do not specify a) the size of spring to be used according to the thickness and stiffness of the twine to be measured; b) the selection and number of meshes to be measured. The chairman of the group has requested ICES to review and revised the instructions.

Suggested work items for the FTFB Working Group

In addition to the above Fisheries Technology recommendations, the FTFB Working Group also made the following suggestions for work to be initiated prior to the next meeting in April 1999:

a) investigate the development of techniques to quantify fish behaviour from underwater videos and still photographs. (Action: B. McCallum, Canada, Dick Ferro, United Kingdom, Ingvar Huse, Norway).
b) review the methods of implementation of technical conservation measures. (Action: Norman Graham, United Kingdom)

2 SPECIAL TOPIC C: FISH BEHAVIOUR, IMPLICATIONS FOR ASSESSMENT SURVEYS, MODELING

Keynote Speaker: Dr. Steve Walsh, Canada. Fish behaviour and trawl catchability: the impact on abundance estimation

Abstract: In annual bottom trawl surveys, catchability is assumed to be a proportional relationship between catch-per-unit of effort (CPUE) and stock abundance and constant within and between surveys. Systematic variation in catchability is a common concern in commercial CPUE data but is normally assumed to be constant in annual survey data, because the same standard survey gear and sampling methods are used. This implies that the sampling gear always catches the same proportion of all fish accessible to it. It is now more apparent that when mobile and static fishing gears are used either as direct measurement sampling gears or as sampling tools in support of acoustic surveys, the quantity and composition of the catches can vary considerably due to changes in catchability, i.e. availability, accessibility and vulnerability of the target species. These changes can be independent of the size, structure and behaviour of the stock. When such systematic changes in catchability occur during annual surveys, there is often insufficient detailed knowledge to detect and model precisely these changes for use in the stock assessment process. Critical to this detection is the understanding and development of predictive models on how catchability relates to fish behaviour.

Several emerging technologies such as data storage tags, acoustic positioning tags, swimming flumes, mobile and stationary acoustic transducers, scanning laser systems and low-light underwater cameras are being used in the study of both natural and sampling tool-induced fish behaviour. Changes in fish behaviour in the pre-trawl zone, in the zone of the arrival of the vessel, and in the zone of the arrival of the sampling gear can affect the effective fishing height, effective fishing width, and selectivity of the trawl. In these zones of capture, several key factors such as sound, light, temperature and school density, can affect the catchability of both acoustic and trawl sampling tools with subsequent biases in estimates of fish abundance indices. This may explain why retrospective analysis of catchability coefficients have shown trends developing over time in survey catch-at-age data.

Discussion: Small fish were less likely to escape under the trawl when it was fitted with a rockhopper footrope than with roller gear, but there were also some interactive effects between fish behaviour & gear design (trawl type). Studying flatfish behaviour, especially night time responses, is quite difficult since they do not present good acoustic targets. It was pointed out that vessel avoidance may be laterally out of the gear path as well as downwards, and the concern was raised that this may vary from year to year, perhaps influenced by abundance differences. This points to a fundamental question: can bottom trawl techniques ever produce estimates of absolute abundance? Are there differences in behaviour between the sexes, or would observed sex ratios in survey samples be due to differences in distribution? In studies of herring assessment, vessel avoidance was the most significant factor and apparently affected estimates by a factor of two. Walsh believes that absolute abundance estimates are possible with cod, but must be based on combined acoustic & bottom trawl techniques and take advantage of an improved understanding of behaviour. He feels that purely pelagic species such as herring can be completely assessed with acoustic techniques. Absolute estimates are more challenging to obtain for purely demersal species, and even harder to reliably derive from mixed species surveys.

Fish behaviour, impact on survey results. Kathrine Michalsen, Norway

Abstract: For Gadoids in the Barents Sea combined bottom trawl and acoustic surveys are conducted, but the indices from these surveys are used independently of each other in the tuning of the VPA. It is assumed that both sampling gears cover the total horizontal and vertical distribution and that they therefore produce indices that are proportional to the true abundance. However, fish are mobile organisms and their horizontal and vertical distribution may change, during the day, between areas and years, as well as between different species- and age groups. In order to increase the reliability of the survey results we have to understand why the fish change their distribution. To do this more knowledge about individual behaviour is required. Results from the use of electronic data storage tags have shown that the extent of the vertical distribution may change over the year, where the fish are conducting more extensive migrations during Summer/Autumn than during Winter/Spring. For some of the fish a 24-hour cycle in the vertical migration pattern could be observed, but only for restricted periods. For several of the fish there was a tendency of staying in the pelagic zone during the day, but it could take five or six days between each days between each time they conduct these kind of movements. The collective pattern in diel vertical distribution observed by bottom trawl and acoustic techniques might not be caused by an identical pattern in vertical movements by the individual fish. Due to the horizontal migration pattern on north-east Arctic cod, the fish are experiencing lower temperatures during Summer/Autumn, when the mean temperature in the Barents Sea is relatively high, while they are experiencing the highest temperatures during Winter/Spring when the temperature in the Barents Sea is low.

Discussion: How are trawl survey swept area estimates treated together with acoustic estimates to yield absolute abundance? With information on vertical distribution swept area estimates can be added to the acoustic estimates above the fishing zone. In fact, neither technique is used in an absolute sense, instead these and others are used as inputs to VPA models.

Infrared illumination and an intensified video camera to observe fish behaviour in trawls at low light levels. Craig Rose, USA

(a brief video demonstrating the infrared observations was also presented)

Abstract: An intensified video camera was used with infrared illumination to observe walleye pollock (*Theragra chalcogramma*) during capture by a pelagic trawl. Pollock were observed with sufficient image quality to distinguish behaviours and characteristics. Maximum range was 2 meters from the camera. Comparisons of video determinations of a crowding index were made with the average catch rate from each tow. Catch rate was correlated with crowding; explaining 50% of the variability, but produced large errors in many cases when used to predict crowding.

Discussion: Behavioural studies in the laboratory conclude that there is no response to infrared (IR) radiation. However most IR sources do emit some radiation at visible frequencies so it is important to know the exact emission spectrum vs. the response spectrum for the subject species. The IR sources Rose used probably were visible to the fish, but he feels that they did not effectively illuminate the surrounding objects.

Electronic tags and fish behaviour. Geoff Arnold, United Kingdom

Abstract: Fish behaviour determines the distribution of fish populations and biases estimates of abundance from acoustic surveys and fishing surveys. Behaviour effects availability, accessibility and vulnerability of fish to survey trawls, all of which can readily be studied by use of electronic tags. Tags work independently of natural or artificial illumination, are not affected by underwater visibility and can be used to make quantitative measurements. Radio tags, which are most appropriate in freshwater, cannot be used in salt water. Acoustic tags can be used in both salt and freshwater and combined radio and acoustic tags (CARTS) are available for use with fish that move between the two environments. Radio and acoustic tags are both available in transmitting or transponding forms. Simple transmitting tags ('pingers') emit a regular pulse; transponding tags listen continuously, but only transmit a signal on receipt of an external signal from a sonar or other device. Both types of tag can be coded and fitted with sensors to measure environmental or physiological factors. Historically, coding has relied either on variation in pulse repetition rate or the use of different transmission frequencies. New coding systems are becoming available that use binary codes - pseudo random (PN) numbers - which allow the arrival time of the tag signal to be measured much more accurately and also enhance the signal-to-noise ratio. The resulting coding gain provides increased range and allows the tags to operate in noisier environments, as well as simultaneously track large numbers of fish. Data storage tags allow data to be recorded from individual fish for long periods (1-2 years) and stored indefinitely (10-20 years). Several quantities - e.g. depth, internal & external temperature and light intensity (for geolocation) - can be measured simultaneously; sampling rates can be pre-programmed to suit the application and the amount of available memory.

Movements of acoustically tagged fish can be studied in the vicinity of static fishing gear (e.g. gillnets and longlines) using an array of anchored hydrophones, which radio data back to a research vessel or shore station. Studies of natural behaviour and vessel avoidance can be undertaken in the same way, in a limited area. Studies of moving gear generally

require the mobility of a research vessel with a tracking sonar. Both approaches can provide quantitative estimates of gear efficiency as well as fish behaviour. Data storage tag programmes, which can be used to investigate problems of availability and accessibility ('natural' behaviour) over large areas, currently rely on tag recovery through a commercial fishery. Recovery rates vary considerably from <1% to 50% in certain cases, although 20-25% is more usual in European fisheries. Fishery independent data retrieval is an important goal for the future, although it is already possible to retrieve limited amounts of data via an acoustic link using CHAT tags (Communicating History Acoustic Tags). These tags are quite large and the system, which requires the fish to regularly return to a dedicated listening station with some precision, has so far only been used with large pelagic species. Satellite data recovery is possible with tags that detach from the fish at a pre-programmed time and pop-up to the surface, where they float upright with a radio aerial protruding into the air. Existing pop-up tags, which are large and can also only be used with large pelagic fish (e.g. tuna), use the Argos system and record limited amounts of temperature data. The satellite determines the pop-up position of the tag by Doppler shift measurements. Second generation pop-up tags, which are currently under evaluation, will be able to record the depth and geographical position of the fish at pre-programmed intervals and transmit this information via satellite. It may be possible in future to recover data via a cellular telephone system, in which case it will be possible to make much smaller tags that will be suitable for fish of the size commonly encountered in North Atlantic fisheries.

Discussion: The present range of CHAT interrogation systems is probably around 100 meters or less. Storage tags are available that can record tilt angle and depth, and the potential exists to record such parameters at high data rates.

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

Abstract: A new statistical technique was used to analyse data on the swimming endurance of Atlantic cod (*Gadus morhua*). This technique, referred to as failure time (survival) analysis, is a more robust statistical technique than conventional regression models. The results of the analysis showed that swimming speed is a critical factor affecting the endurance of cod. The close similarity between the model and empirical observations suggest that the endurance of cod measured under laboratory conditions closely approximates the endurance of cod swimming in the trawl mouth. The findings indicate that even subtle changes in the speed of a trawl relative to the water could dramatically affect the rate of exhaustion, i.e. the turnover rate, of cod swimming in the trawl mouth.

Discussion: Is there a pressure wave in front of the trawl that can assist the fish in staying out of the mouth? There is no evidence of such an effect. Wingers study found little effect on cod endurance of either body length or water temperature. Wingers study used an electrical stimulus to induce swimming in the flume, but trawl stimuli may induce avoidance responses at different levels of intensity. The lengths of the cod studied ranged from 40 to 86 cm. The temperatures in the test tank were kept at the ambient temperature of local seawater (range: 0 to 8 degrees C. during the study period) and the fish were exposed to the ambient photoperiod. Winger believes that the cod acclimated to these temperature changes with respect to swimming ability.

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

Abstract: The Lowestoft Laboratory has been using data storage tags to study migration and vertical movements of plaice (*Pleuronectes platessa*) in the southern North Sea for the last five years. Between December 1993 and February 1997 we released 303 hemispherical Mk 1 tags, of which 49 (16%) have been returned through the commercial fishery. These returns have produced 2383 days of data and the longest record was 224 days. Between October 1997 and February 1999 we released 382 smaller, lighter, cylindrical Mk 2 tags as part of an EC-funded project, which involves the Netherlands, Belgium and Denmark as well as the UK. Eighty-seven (87) of these tags (23%) have been returned through the fishery and have yielded 12,515 days' worth of data. The longest individual record is 471 days. Most of the Mk 1 tags were released in the Southern Bight, where the tidal streams are fast and highly directional. Most of the Mk 2 tags have been released in the Central North Sea, where the tidal streams are much slower, less directional and orientated east-west rather than north-south.

Most of the fish tagged with Mk 1 tags have shown regular vertical movements with either a diel or a tidal periodicity. We have reconstructed the geographical tracks of these fish using a tidal stream simulation model and assuming the fish swam down current at a speed of 0.6 body lengths per second when in midwater. We have been able to independently validate a number of these track reconstructions using temperature and hydrostatic data recorded by the tags. All of the fish tagged with Mk 1 tags showed rapid north-south movements in the area of fast tidal streams extending along the east coast of England through the Dover Strait into the eastern English Channel. Several fish visited the spawning ground off Flamborough Head, as well as the spawning ground in the eastern English Channel.

The Mk 2 tag returns show that plaice in the Central North Sea exhibit far less vertical movement than those in the Southern Bight, even during the periods of autumn pre-spawning and spring post-spawning migrations. Recorded

hydrostatic data show that, whilst some fish move significant distances to spawn, they do not use the tidal streams when migrating in the German Bight and adjacent areas. Because of the absence of systematic patterns of vertical movement, it is not currently possible to reconstruct the geographical tracks of these fish in any detail. The contrasting patterns of vertical movement observed in the Southern and German Bights suggest that tidal stream transport is primarily an energy saving mechanism. The boundary between the two areas is marked by an average tidal stream speed of 20-30 cm s^{-1} and we hypothesize that fish of 40 cm and over cease to save energy when the average speed of the tidal stream drops below this speed.

We are now processing our data to provide the information our colleagues need to develop biologically realistic stock assessment models. We are assembling a fish behaviour data base, which - when combined with information from our tidal stream data base - will allow us to estimate the probability of rates and scales of population movement at different times of year. We will derive these estimates from individual movements calculated with an 'object-orientated' model, whose attributes will include size, sex, reproductive state, and growth rate. Our estimates of population movement will provide the input our colleagues need for their new compartmental assessment models.

Discussion: The presentation suggested there are several distinct plaice populations in the North Sea, raising the question of whether they are managed separately, which they are.

A comparison of two intragastric tagging techniques in Atlantic cod (*Gadus morhua*). Paul Winger, Canada
Abstract: Two methods of intragastric tagging were investigated in Atlantic cod (*Gadus morhua*) under laboratory conditions. These included forced implantation and voluntary ingestion of two different sizes of acoustic transmitters commonly used in the field. Dependent variables measured included: 1) duration of transmitter retention, 2) food consumption, and 3) level of mortality. The findings showed that fish which voluntarily ingested transmitters exhibited longer periods of intragastric retention, delayed onset of initial regurgitation, higher food consumption, and no mortality. Transmitter size had no significant effect on the duration of transmitter retention.

Discussion: Voluntary ingestion reduces the risk of damage to the swimbladder, but there may be difficulty in ensuring that the "right" fish gets the transmitter, and only a single transmitter. The retention of transmitters may be prolonged under colder temperatures.

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

Abstract: Fish behaviour may change from year to year, possibly altering the efficiency of survey sampling gear. Such a change in efficiency would be confounded with change in abundance as inferred from indices of abundance estimated with survey data. Experiments can be conducted to assess change in behaviour and estimate change in efficiency of sampling gear, but should the estimated change in efficiency be incorporated in the estimate of change in abundance? To do so would remove systematic error from the estimate of the index of change in abundance but would add random error through the uncertainty in the estimate of change in efficiency. If uncertainty were increased too much, the reduction in systematic error would lead to a worse estimate of change in abundance. A decision rule based on the Mean Square Error (MSE) was presented, along with an algorithm for detecting it. According to this rule, an estimate of change in efficiency would be applied only if it reduced the MSE of the estimate of the index of change in abundance. Two examples were provided, one demonstrating a choice to apply a correction for change in efficiency and one demonstrating a choice against such an application.

Discussion: Munro's experimental results showed that at-the-footrope capture probability for flathead sole as a function of size started at a low level, increased to a certain point, then fell again for larger fish. However, the mechanism is not understood, and this pattern has not been observed for other species.

Following these presentations, the Working Group broke into two subgroups for further discussion of the Special Topic. Steve Walsh, Canada, convened one subgroup to consider the topic "fish behaviour and stock assessment." The other subgroup addressed "fish behaviour and modelling" with Chris Glass, U.S.A., serving as convener. Following these discussions the Working Group reassembled and the two conveners presented reports on their respective meetings for consideration by the Working Group as a whole. Digests of these reports follow.

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) Echointegration 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) Echointegration 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.

Discussion of subgroup reports:

Many of these questions on fish behaviour have been asked for years. There has been some progress made in terms of qualitative description, but little new quantitative information has emerged. However, the technical and methodological tools are just now being developed that will allow quantitative study.

What do stock assessment biologists really want us to do? We need to articulate the areas where we see the potential for progress and develop research priorities in interaction with them. The awareness on both sides is developing, but we need clear collaborative direction.

Assessment is not the only area where this knowledge has value. Impact of fishing operations is also an important area. Assessment biologists need input from us on how fish behaviour studies help them produce better stock assessments. This can help identify priorities and allocate research resources. Can we identify particular studies that offer examples of actual benefits?

Such dialogues have occurred and are ongoing, but concerns were expressed that the profile and emphasis must be raised to a higher level.

3 STUDY GROUP ON METHODS FOR MEASURING THE SELECTIVITY OF STATIC GEAR

ARNE CARR, USA, STUDY GROUP CHAIRMAN.

Summary: The Study Group on Methods for Measuring the Selectivity of Static Gear (SGMMG) met on 17 - 18 April in St. John's, Newfoundland. Seventeen people were in attendance. The terms of reference for SGMMG are as follows:

a) write a manual of methods for measuring the selectivity of static gear;
b) review selectivity studies on fish traps, fyke nets and pots to determine whether the information available on techniques for studying the selectivity of these gears is sufficient to warrant inclusion in the methods manual.

The group heard the following presentations;

Gerald Brothers, Static gear selectivity in Eastern Canada.
René Holst, A herring size detection model for experimental gillnets used in the Sound.
René Holst, A longitudinal study of the selectivity parameters estimated from experimental gillnet catch data for herring, *Clupea harengus*.
Niels Madsen, Set-by-set analysis of gill net data.

The group developed the content of the manual. In regard to gillnet and longline selectivity, a detailed content format was organised which considered planning, protocol, parameters and data analysis. The content format followed that in the draft MANUAL FOR GILLNET SELECTIVITY by René Holst (Constat/DK), Niels Madsen and Thomas Moth-Poulsen (DIFTA/DK), and Paulo Fonseca and Aida Campos (IPIMAR/P). Specific issues were also identified that were considered critical to a selectivity manual.

SGMMG discussed the status and understanding of selectivity of fish traps, fyke nets and pots. The conclusion relative to the terms of reference was that work has been directed to the selectivity of this gear, although in some cases, the work is more comparative than selective in scope. The protocol for this work is important and it was agreed that these gears should have a statement of protocol, but it should be less in detail.
SGMMG will work on a first draft and try to develop it by the FTFB meeting in CY 2000. The group feels that it should meet at the time of FTFB in CY 2000 to review the draft.

4 REQUEST FOR ASSISTANCE FROM THE INTERNATIONAL BOTTOM TRAWL SURVEY WORKING GROUP. DAVID REID, UNITED KINGDOM

The International Bottom Trawl Survey (IBTS) has been using the GOV (Grande Ouverture Verticale) trawl as its standard sampling gear for years, but recently there have been more and more objections to it on various grounds. Other gears have been proposed and evaluated, and even adopted in some areas. West of Scotland and in Ireland the GOV trawl has limited utility due to the restricted bottom types on which it can be used. The WG/IBTS would like WG/FTFB to join them in a study group or some other ICES-sanctioned process to investigate or specify alternative gear(s), perhaps one for soft substrates and another for more challenging areas. It may be possible and most appropriate to pursue funding for an activity like this as an R&D project.

5 SPECIAL TOPICS A AND B: TECHNICAL MEASURES TO FISHING GEARS AND OPERATIONS TO REDUCE THEIR BIOLOGICAL AND PHYSICAL IMPACTS ON BENTHOS AND BENETIC SUBSTRATES, AND METHODOLOGIES FOR STUDYING SUCH IMPACTS

Keynote speaker: Dr Kent Gilkinson, Canada. Methods for quantifying benthic impacts of mobile bottom fishing gear in deepwater, offshore environments in the Northwest Atlantic

Abstract: It is well recognised that there are many facets to the issue of fishing impacts on marine ecosystems. Until relatively recently, impacts to the seabed from mobile bottom fishing gear has been a neglected area of study. Reasons for this may include: (a) our poor understanding of the role of benthos within marine ecosystems, in particular the link between benthic and pelagic systems and fish communities (b) few instances of significant, obvious effects on fisheries that can be directly related to physical disturbance of the seabed. To date, scientific studies have demonstrated that mobile gear can disturb benthic habitat and communities, with discernible effects depending on scales of resolution, habitat type and the kinds of organisms present. Limits of resolution with respect to physical and biological variables is critical since it determines the questions that can be posed regarding impacts as well as our ability to detect different types of impacts. The design and use of physical and biological sampling devices has direct bearing on resolution since the data collected are used in all subsequent impact hypothesis testing. Recent innovations in technology (sampling devices and navigation) continue to improve our ability to effectively sample species at different lifestages and to resolve habitat features at scales ranging from millimetres to kilometres. In 1990, the Department of Fisheries and Oceans (Scotia-Fundy and Newfoundland regions) initiated a long-term research program to investigate benthic impacts of mobile bottom gear types commonly used in Atlantic Canada. To date, three offshore impact experiments have been conducted or are in progress: two otter trawling experiments on sandy and gravel bottoms (Grand Bank, Western Bank) and a hydraulic calm dredging experiment on Banquereau Bank. Until very recently it has proven difficult, if not impossible, to conduct fishing impact experiments in deepwater, offshore environments, owing largely to limitations in the technology required for trawling and sampling within a precisely defined area of seabed. It was necessary to design sampling gear and navigation systems specifically for the deepwater, harsh environments in which our experiments were conducted. We use an epibenthic sled and a hydraulic, colour video grab to collect organisms and sediments and still photography (CAMPOD) and ROV-mounted video (BRUTIV) to obtain small- and large-scale images of the seabed. A variety of physical sampling devices (sidescan sonar, ROXANNE) are used to map large scale features of disturbance while an innovative acoustic imaging tool (DRUMS) is used to identify small scale (mms-cms) changes in sediment structure (i.e. habitat complexity) from fishing disturbance. An immediate challenge for those involved in this field of research is the interpretation of results of relatively short-term experiments in an ecologically meaningful context. This will become more critical as fisheries managers request advice on the effects of fishing on seabed habitat as it relates to fish habitat and production. Some general benthic research priorities include information on: (1) the relationship between seafloor habitats and fish communities (2) marine food webs (3) functional consequences of fishing disturbance (e.g. exchange processes between benthic and pelagic environments) (4) recovery rates in fishing disturbed habitats and (5) small-scale distribution patterns of fishing activities.

Discussion: At Montpellier there was a similar discussion in which it was concluded that fished areas adjacent to industrialised countries are swept by trawls around 3 or 4 times annually, and that it takes about 100 days for such areas to "recover." Research on the Grand Banks suggest that actually only a small portion of the total area of the Banks is trawled annually, although such grounds may be trawled at high frequency, suggesting that small-scale trawling frequency characterisations may be more appropriate than averaging over wide areas. Acoustic properties of trawled areas returned to pre-trawled conditions in about one year. It was pointed out that little research has been conducted on potential "beneficial" impacts of fishing that positively affect productivity of exploited species.

Review of impact studies. Bob van Marlen, Holland

Abstract: Three review papers on the topic of the impact of fishing gears were noted and discussed: Jennings and Kaiser, 1998; Lindeboom and De Groot, 1998; and the literature review section in the 1999 report of the EU-project REDUCE. The various methodologies for investigating this topic were summarised and the major results explained. General conclusions are that fishing practices have changed, and trawling intensity has increased. Demersal trawling has measurable direct mortality on benthic invertebrates and demersal fish. Demersal trawling increases feeding opportunities for scavengers. High demersal trawling intensity has long-term changes on benthic communities (fish and invertebrates), favouring short lived opportunistic species over long-lived sessile species.

Discussion: Studies were carried out with gear types representative of those used in the North Sea commercial fisheries. Many studies have been done on impacts and the time may be ripe to shift research effort away from further description of impacts towards ways in which gear can be modified to reduce impacts.

Physical impact of beam trawls on seabed sediments. Ronald Fonteyne, Belgium

Abstract: The paper deals with the impact on the seabed of modern, heavy beam trawls. A 4-m beam trawl equipped with a chain matrix was used in all experimental work. The effects of gear and vessel size on gear pressure were modelled. The changes to the seabed topography were observed by side-scan sonar and changes in sediment characteristics were measured using the RoxAnn seabed classification system. The results can be summarised as follows

1. The pressure exerted on the seabed by beam trawls is strongly related to the towing speed. As the speed increases the lift of the gear increases and the resultant pressure force decreases.
2. For the 4-m beam trawl studied the pressure exerted by the trawl heads varied from 17 to 32 kPa at towing speeds of 4 to 6 knots. Bottom contact was lost at a towing speed of 7 knots.
3. Although larger vessels use heavier gears, this is compensated for by larger sole plate dimensions and higher towing speeds.
4. Beam trawls leave detectable marks on the seabed. On a seabed consisting of mainly coarse sand the tracks remained visible for up to 142 hours whereas on sediments with mainly finer particles the tracks were completely faded after 37 hours.
5. The movement of the gear causes the suspension of the lighter sediment fraction. The suspended particles, however, settle down within a few hours.

Gear modification as a management tool to limit ecosystem effects of fishing. Peter Stewart, United Kingdom, presented by Dick Ferro

Abstract: The known impacts of the commonly used active and passive methods of sea fishing are summarised and techniques for reducing these impacts are discussed, with examples from particular fisheries. Studies of the processes of capture by mobile and static fishing gears are needed to provide a firm basis for modifying fishing gears to lessen the effects of commercial fishing on the ecosystem. Proven techniques are now available to improve the size and species selectivity of fishing gears for both target and non-target organisms. Given the variation in morphology and behaviour of marine species, successful approaches tend to be species and fishery specific. Reference is made to the selective effects of net construction and to escape panels, separator trawls, selection grids, square mesh netting, ghost fishing, scaring devices for sea mammals and to direct physical impacts on the sea bed. More selective fishing gears tend to be relatively complex and reduce catches of marketable fish, rendering them unacceptable to the fishing industry unless part of a management system of perceived mutual benefit. Further work is needed on methods of separating species in fishing gears in mixed fisheries, on acoustic scaring devices, and aspects of ghost fishing. Also, in order to achieve wider use of improved fishing methods more work is needed on the economic effects on fisheries of gear modified to reduce impacts.

Discussion: Canada will introduce minimum toggle length in shrimp trawl footropes to reduce turbot bycatch. Separator trawls are also receiving attention, but cost and complexity are concerns that may inhibit acceptance by industry.

New European research into the impact of lost nets. Philip MacMullen, United Kingdom

Abstract: Two studies of ghost fishing phenomena in European waters were described. The first, with the acronym FANTARED 2, is supported by the European Commission and involves seven partners: Norway, Sweden, UK, France, Spain and Portugal. It aims to identify and quantify the impacts of static gear lost in European waters and the means by which any adverse impacts can be mitigated. The second study involves UK interests only and concerns trap fisheries for shellfish.

The FANTARED 2 research programme has established a methodology to identify the factors most likely to predispose a métier to gear loss. The programme involves establishing industry liaison groups to identify grounds where net loss is

common and to help steer the research work. The fishing areas will be surveyed by means most appropriate to the depth and ground conditions at each. The areas targeted are mainly in deep water (<800m) and wrecks and reefs. Lost nets will be retrieved and assessed for age, physical condition and fishing potential. Experimental nets will be deployed and assessed over a two-year period to determine their evolution under a wide range of conditions. Estimates will be derived of the likely losses of commercial species in each métier studied and these estimates will be compared with the targeted catches by the métiers concerned. Potential mitigating measures will be reviewed and an assessment made of their appropriateness to those European métiers where 'ghost' catches may be having a significant impact on commercial stocks. After cost/benefit analyses of the options, a series of recommendations will be agreed in consultation with the industry liaison groups.

The work on shellfish traps is more limited in scope than FANTARED 2 but the two research programmes have many features in common.

Discussion: How are net losses quantified? Experience has been that fishermen are willing to voluntarily report losses, and these correlated well with patterns of net purchases, replacement, etc. A challenge is to convince fishermen that such studies are not a threat.

What proportion of red king crab (*Paralithodes camtschaticus*) were injured by passage under bottom trawl footropes? Craig Rose, USA

Abstract: The rate of injuries sustained by red king crabs during passage under the footropes of bottom trawls is an important factor needed to account for unobserved mortality of these crabs due to encounters with bottom trawls. Red king crabs were recaptured and examined for injuries after passing under each of three trawl footropes representing those used in the bottom trawl fisheries of the eastern Bering Sea. These injury rates were compared with those of crabs passing under a floated footrope which minimised contact with crabs. After accounting for handling injuries, injury rates of 5 - 10% were estimated for the crabs passing under the commercial trawl footropes.

Discussion: Crabs with many atomised legs have shown good survival under stressful conditions.

Model experiments for the analysis of the interaction between fishing gear elements and the over-dragged sediment. Uwe Richter, Germany, presented by Ronald Fonteyne.

Abstract: The task of the international research project TRAPESE exists in the modelling and simulation of the mutual influence of fishing gears towed along the bottom of the sea and the over-dragged sediment. The target is the creation of a methodology for estimating the consequences of technical fishery activities at the sea bottom. Apart from theoretical analyses using methods for hydraulic and soil mechanics, model experiments for the quantitative evaluation of influence parameters can help focus full-scale experiments in this area. The theoretical analyses and model experiments were conducted primarily by the University of Rostock. For the time being the available results represent a further contribution to the present level of knowledge about the interaction between fishing gear elements and the bottom of the sea. Validating the results from the model tests is the responsibility of project partners from Belgium and the Netherlands.

Discussion: Absence of upwards forces exerted by gear drag and flotation can be accommodated by the modelling technique.

Bivalve dredge selectivity and impact

Bill Lart, United Kingdom

Abstract: Currently most of the UK dredge fisheries for scallops are unregulated by technical measures prescribing design features of the dredge. A study was conducted to gain an understanding of the mechanisms by which these dredges select scallops. Three aspects of dredge design were investigated for their effects on size selection: the spacing of the teeth on a bar at the lower front of the dredge, ring size in the "chain mail" forming the aft portion of the collection bag, and the mesh size of the netting in the upper/forward portion of the bag. Two levels of each of the three factors were used in all eight possible combinations in order to examine the extent and significance of these factors on selectivity and catch per effort. In the commercial fishery, multiple dredges are towed from bars towed from booms either side of the vessel and this practice was employed for this experiment. The dredges were deployed in three groups of two dredges on each bar with a space between each group to minimise interference. The experimental and control dredges were rotated among the various positions along the bars over the course of the study, which ran for four days with 6 hauls per day.

The results indicate that ring size and tooth spacing had a significant effect on discard rate contributing 11% arid 3.5% respectively to discard rate reduction. No significant reduction was found in the catch per haul of these scallops in the

larger ring size but larger tooth spacing resulted in significant reductions in terms of weight and numbers of around 10%. Ring size and possibly tooth spacing had an influence on selectivity. No effect was found for mesh size and no significant interactions among the three factors were found.

Computer aided design software was used to simulate interactions between the scallops and likely selection features of the gear, while varying the size and shapes of those features. These results suggest that there may be scope for further increases in ring size while still retaining100mm scallops.

Discussion: Adductor muscle energy charge is an index of a discarded scallop's vitality & likely survival.

Ghost fishing: Lost gillnets and unaccounted fishing mortality in the Greenland halibut fishery. Dag Furevik, Norway, presented by Ole Arve Misund

Abstract: In the gillnet fishery off the coast of Norway gillnets are lost from time to time but the magnitude of these losses is unknown. Further, the change in fishing capacity over time for lost gillnets is difficult to estimate. During a retrieval cruise using a heavy bottom grapnel system to recover lost gillnets, four fleets of recovered Greenland halibut gillnets were examined, with 27, 47, 30, and 30 nets in the four fleets respectively. Fish in these recovered nets were counted and classified as live, freshly dead, old, and unidentifiable. By assuming the maximum time a caught fish could remain in the "live" or "fresh" condition was one week, and knowing the time of loss of the gillnets, it was possible to estimate the catch rates. These were projected to be 9.8 to 18.7 tonnes of Greenland halibut per year per fleet.

Discussion: Norway has been conducting gillnet cleanup operations for about 8 years at a cost of around NOK 2.5 million/year. Losses are due to currents submerging the marker buoys and buoy lines being cut by other trawlers. Canadian ghost gillnet studies have shown similar estimates of ghost-fishing catch rates. Cleanup operations are coordinated to avoid gear being actively fished. Each year about 5,000 lost gillnets are recovered.

Possibilities for discard reducing in the shrimp (*Crangon crangon*) fisheries by means of electric pulses as an alternative stimulation. Hans Polet, Belgium

Abstract: In Belgium brown shrimps (*Crangon crangon*) are caught in the coastal zone by small beam trawlers with a maximum engine power of 221 kW (300 hp). Each vessel tows two beam trawls with a legal minimum cod-end mesh opening of 20mm. Once on board, the catch is processed with a rotating shrimp riddle that separates the commercial shrimp from the by-catch. Besides marketable fish, this by-catch often contains high numbers of undersized fish and a wide variety of benthic species, which is the catch fraction to be returned to the sea.

Several attempts have been made to reduce this by-catch by means of sieve nets or sorting grids. These methods are based on selection through net meshes or bar openings. The success will depend on the size of the animals and behaviour will play only a minor role, which is a problem in the shrimp fishery since the shrimps have a comparable size to the main part of the discards. An ideal selectivity device would induce a different behaviour between the target species (brown shrimps) and the non-marketable animals. The possibilities of electric pulses to reach this goal are being investigated in the present project. The project started in November 1997 and the first project phase, consisting of only lab-experiments to study behaviour and survival, was recently concluded. The aim of the project is to reduce the by-catch of juvenile flatfish, non-commercial fish species and benthic organisms and to reduce seafloor disturbance by reducing the bottom contact of the fishing gear.

With an electric pulse of 60 V and a frequency of 5 Hz brown shrimp will jump out of their resting position in the sand into the water column to a height between a few centimetres to 50 centimetres. Following species stayed on the bottom without moving under the influence of the pulses: plaice, sole, turbot, *Myoxocephalus scorpius, Agonus cataphractus* and shellfish species. Other species like dab, *Callionymus lyra, Cilliata mustela, Gobius spp* and several crab species like *Liocarcinus holsatus* and *Carcinus maenas* started a nervous movement but stayed very close to the bottom.

It is the intention to use this difference in behaviour to increase the selectivity of the groundrope. The bobbin rope will be altered to reduce bottom contact and avoid mechanical stimulation and to give the non-reacting species the opportunity to escape underneath the belly of the trawl. The electric pulses will be used as an alternative stimulation to bring the shrimps into the water column and within the reach of the net.

Survival experiments with animals in an electric field have been carried out for all species mentioned above and the survival was 100 % in all cases.

The second phase of the project, which started early this year, will focus on sea trials and further lab experiments with electric pulses with other characteristics.

Discussion: Most of the non-shrimp organisms stayed in their resting positions when experiencing the electrical stimulus, although some were seen experiencing tremors at a frequency similar to the pulse. Power is supplied either by cable from the vessel or by a battery pack attached to the beam.

Effects of cutting holes in lower panel of a beam trawl. Bob van Marlen, Holland

Abstract: Trials were conducted on RV TRIDENS in October 1997 and October 1998 to investigate whether the capture of benthic organisms could be reduced by cutting large meshes in the lower panel of a 12-m beam trawl. The 1997 experiments in which relatively small holes were cut out did not show any effect, and in 1998 it was decided to take bigger steps. The result was that some benthic species were indeed released more from the trawl (*Pagurus* spp. L.; *Acanthocardia echinata* L.; *Artica islandica* L. and *Aphrodita aculeata* L.) The penalty however was a significant reduction in target flatfish species, particularly sole, and to a lesser extent plaice and turbot. Further research is advocated to find a configuration that releases benthos without causing these losses in the target species.

Discussion: Most mortality of benthos was suffered by animals hit and passed over by the gear, not the ones picked up into the net, so allowing all of these to escape will have little beneficial impact. Sole very actively plunged downwards once over the footrope, even at the high towing speeds (4.5 kn) used in the studies. Belgian studies of large release openings for benthos showed similar results, and suggested that benthos "floated" down towards the codend. Holes cut into the after parts of the net might be more effective at releasing benthos, but at high risk of losing fish.

Effects of shrimp-trawling on abundance of benthic macro-fauna in a Swedish fjord. Mats Ulmestrand, Sweden, presented by P.-O. Larsson.

Abstract: The Gullmar fjord on the West Coast of Sweden has been protected from trawling since 1990. A large-scale experiment replicated in time and space was performed during 1996-97 to evaluate the potential effects of a resumption of shrimp trawling on the abundance and total biomass of benthic macro-fauna.

Samples were taken at six sites during four replicate times in July-November 1996. Three of these sites were thereafter trawled weekly until November 1997. Samples were taken at all sites at four times during the period July-November 1997. (In total 480 samples). This sampling design tests the hypothesis that the temporal variability in mean abundance and biomass of fauna in trawled areas will be different from areas that are not trawled.

Of the tested variables, the number of echinoderms was significantly affected by trawling. More specifically, the number of brittlestars, mainly *Amphiura chiajei* decreased by, on average, 30% in trawled sites whereas the number at the control sites did not change. Total abundance and total biomass were not significantly affected by trawling, although there was an overall tendency for a reduction at all sites during the experiment. The abundance of individual species generally decreased. After trawling, a larger number of species decreased in abundance at trawled sites than at control sites. However these differences were not consistent among sites. Except for the echinoderms, the power to detect trawl effects was very low for the total number of individuals, total biomass, and abundance of the major phyla (power <0.1). This indicates that the effect of trawling was very small compared to the natural variability.

The results of this experiment differ in many respects from most previous experiments on effects of trawling and dredging on benthic fauna. Compared to previous studies, the most striking difference is the relative weakness of observable effects of trawling on individual taxa. Most analyses in this study show strong temporal variability among trawled sites and among control sites, emphasising the need for replicated treatment sites or at least replicated control sites in order to logically interpret potential trawling effects.

A study of the gross effects of water jet dredging for razor clams in some Western Isles populations. Dr. Norman Graham, United Kingdom

Abstract: The effects of water jet dredging for *Ensis* spp. on the seabed and benthos were examined through experimental fishing. Immediate physical effects were apparent, with the dredge leaving visible trenches in the seabed. While these trenches had started to fill after five days, and were no longer visible after 11 weeks, the sediment in fished tracks remained fluidised beyond this period. The majority of the infaunal community is adapted morphologically and behaviourally to a dynamic environment, and other than initial removal through dispersal, is not greatly affected by the dredge. Species that are likely to be affected (e.g. *Echinocarium cordatum, Arctica islandica*, and other large bivalves) were very rare in infaunal samples, but present in dredge catches, where damage was noted, and ranged on average from 10 □ 28%. Epifauna were scarce in the study area, and unaffected by the fishing, except that epifaunal scavenging species were attracted to the fished tracks. On the evidence of the present study it would appear that there was little difference between the biological impact of hydraulic and suction dredging, although the latter may have a greater physical impact (larger trenches).

Discussion: There is potential to reduce damage rates by employing lower water pressure in the jetting system but this was not tested here. Clams suffering damaged shells or injuries to the foot that inhibited burrowing were very quickly consumed by crabs, otherwise they escaped. Local legislation prohibits the vessel towing itself against an anchor.

A new methodology to study physical impact of towed gears on benthos and benthic substrates. Francois Theret, France

Abstract: The presentation of a new method to study the impact on the benthos of towed fishing gears is given here. It aims at perfecting a procedure (that can be generalised) dedicated to the assessment of the impact of a trawl on a defined zone so as to predict *a priori* the impact of a new type of trawl, or in case of a negative impact, to define the characteristics of suited trawls. The point is to tow standard devices instead of the real trawls, and to quantify the impact of these standard devices on the benthos. Then, to demonstrate that any type of towed fishing gear can be adjusted according to these standard devices so as to know the impact of any kind of trawl on the zone investigated. Some work remains to be done to validate this method which will be tested next year in Brittany.

Discussion: The authors feel that this approach is very versatile and applicable to all trawl types so long as a good description of the trawl is available. The model only considers mechanical impacts and downwards forces. However there is lateral translation of substrate, hydrodynamic forces that disperse substrate surficial materials, and potential predation or other biological impacts which are not considered by the model. The model is dynamic but cannot accommodate transient effects such as the build-up of material in front of the otterboard causing the door to then "skip" or "hop," and so on.

Two FAO activities aimed at reducing environmental impact of fishing operations on the marine environment: John Willy Valdemarsen, UN/Italy.

Abstract: Within the framework of the Code of Conduct for Responsible Fisheries has FAO supported by its member countries, recently initiated several activities aimed at assisting developing countries to improve the sustainability of their fisheries. Concerning impact on the environment of fishing operation, two major activities are in the process of being implemented;

- an international Plan of Action on reduction of incidental catch of seabirds in longline fisheries
- a global project aimed at reducing the impact of tropical shrimp trawling fisheries on living marine resources through the environmentally friendly techniques and practices.

The plan for reducing incidental seabird catch by longlines have been developed by expert and has recently been adopted by FAO member states. The Plan, however is a voluntary instrument and it is left to the individual States to take the required actions.

The global tropical shrimp project is in preparatory phase, is mainly funded by the Global Environment Facility and with FAO as the executing agency. 13 developing countries from four regions participate in the preparatory phase of the project. Overexploitation of shrimp resources and catch of juvenile food fish are most likely priority areas to be solved in a main phase project.

Recent regulations to prevent deterioration of *Lophelia perlasa* coral reefs off Western Norway. Ole Arve Misund, Norway (accompanying video presentation)

Abstract: In May 1998 a remotely operated vehicle was used to survey areas containing reefs of the deep-water coral *Lophelia perlasa* on the continental slope off Western Norway. Redfish (*Sebastes viviparus*) were abundant on the reefs, and sea trees (*Paragorgia* spp.) were also observed on the reefs. On adjacent areas exposed to bottom trawling with heavy rockhopper ground gear the reefs appeared to have been demolished. A recently-enacted regulation by the Royal Norwegian Ministry of Fisheries makes it a crime to intentionally damage such reefs, and a specified area has been closed to on-bottom fishing with towed gears.

Discussion: It is not known how long it will take for such areas to recover, but it is probably a very slow process. Projects to evaluate this are anticipated. The British offshore oil industry has organised cooperative projects to assess such areas prior to initiating development work. Similar reefs are known in other areas but comparable controversies have not yet developed.

Following these presentations, the Working Group broke into two subgroups for further discussion of the Special Topic. One subgroup convened under Ronald Fonteyne, Belgium, to consider methodologies for conducting fishing impact studies. The other addressed means for reducing biological and physical impacts and was convened by Philip MacMullen of the U.K. Following these discussions the Working Group reconvened and the two conveners presented reports on their respective discussions for consideration by the Working Group as a whole. Summaries of these reports follow.

Impact methodology subgroup

The group prepared lists of relevant gear types and components, their impacts on the substrate, their impacts on benthos, the relevant gear and operational parameters, and important environmental parameters.

- Passive gears were characterised as follows:
  Gear components - anchors, lead-lines or groundlines, netting, hooks, and pots.
  Effects on substrate - pressure, penetration, material dispersal, and shearing.
  Effects on benthos - impact damage and shearing.
  Gear or operational parameters affecting impact - weight, dimensions, design, mode of operation, and frequency.
  Environmental parameters affecting impact - substrate composition, tides or other currents, bottom topography, depth, and patterns of natural disturbance.
- Active gears were characterised as follows:
  Gear components - otterboards, beam trawl heads, sole plates, sweeps, bridles, and other rigging, tickler chains or chain matrix, ground gear, teeth or blades, netting, clump weights, and jets or suction.
  Effects on substrate - pressure, penetration, flattening, reduced habitat complexity, shearing, functional effects on bottom chemistry, material dispersal, and fluidisation.
  Effects on benthos - impact damage, shearing, abrasion, disturbed normal activities, increased vulnerability to predation or competition, and sediment injection.
  Gear or operational parameters affecting impact - weight, dimensions, design, mode of operation, and frequency.
  Environmental parameters affecting impact - substrate composition, tides or other currents, bottom topography, depth, patterns of natural disturbance, and redox status and properties.

  From these lists of factors, two tables were prepared associating each impact category with methodologies suitable for laboratory or field research and the parameters to be studied for each.

Methodologies for studying physical effects

	Methodology		
Item	Laboratory	In situ	Properties or features
Penetration depth	Towing basin (laser)	Side scan sonar Reineck boxcorer Direct observation	Parallel lamination Compactness, porosity x-ray photography
Pressure force	Towing basin (laser), dynamometer	Instrumented trawlheads Warp loads	
Sediment displacement	Towing basin	Direct observation Side scan sonar	
Sediment suspension		Sediment traps Transmissometer Direct observation	
Sediment characteristics		RoxAnn Sediment samples	E1/E2
Sediment topography		DRUMS	Removal of emergent organisms
Chemical functional effects		Chemical analysis	
Sediment compaction	Pore water pressure	Pore water pressure, penetrometer	
Sediment fluidization	Pore water pressure		

Methodologies for studying biological effects

	Methodology	
Item	Laboratory	In situ
Impact damage	Survival in tanks	Samples by divers/grabs Visual inspection, followed by survival tests
Shearing, snagging, and abrasion	Survival in tanks	Samples by divers/grabs Visual inspection, followed by survival tests
Stress		Stress indicators ATP/ADP ratio
Displacement		Sampling & visual inspection
Vulnerability		Sampling & visual inspection Predator observations
Disturbance		Sampling & visual inspection
Injection & pressure-related injuries		Sampling & visual inspection Survival tests

Biological and physical impacts subgroup

The group acknowledged their limited competence and emphasised the need for participation by ecologists and other specialists. They identified the value of a "risk assessment" approach, and the need for making information available to scientists and industry, categorised by gear types. They also pointed out the need to determine objectively whether or not a problem truly exists, and the need to present positive solutions. They concluded that this is a continuing topic that may need to be addressed at future meetings.

General - Broad access to information is desirable. This might include web sites or a video library, perhaps active links between the two. There could be a role for ICES in this. Publicity or educational campaigns to heighten awareness of all aspects of these issues could be valuable.

Gillnetting - Nets or critical components could be made from biodegradable materials. Increasing catching efficiency could facilitate reducing effort, thus the amount of material lost annually. Locating devices have shown their worth, and close tending by the vessels also reduces loss rates. Putting boat identification on the gear can be used to penalise losses, while deposits can be used as incentives to avoid loss and/or encourage recovery. Retrieval projects have been useful.

Towed gears - Various topics were identified for further research and development. Wheels could be used on beam trawls. Devices could be used to reduce the friction or compression forces against the seabed, or reduce the weights on the groundrope to the minimum possible. Alternatives to mechanical stimulation have been identified and could be explored further. Otterboard designs that feature minimal ground force and shear can be utilised or developed. Sweep contact can be reduced, for example by employing semi-pelagic rigging systems. Alternative groundgears have shown potential. Other efforts in the general area of gear engineering or catching efficiency could be valuable.

Plenary discussion:

There was general agreement that gear impact should be an ongoing topic for the Working Group. A need was identified for a manual of methods for conducting impact research, but concerns were raised that at the present state of development of this research area it would be premature to consider preparing one. A proposal was made to form a small discussion group to propose some aspect of this issue as a topic for future Working Group meetings. It was pointed out that the ICES Consultative Committee has already specifically identified this subject as one of the areas of responsibility of WG/FTFB. Much discussion centred on the need to involve the Working Group on Ecosystems Impacts or other experts, and Phil MacMullen has volunteered to present our discussions on ecosystem impacts to the ICES study group on ecosystem analysis if a clear mechanism or mandate for so doing can be identified.

6 INTERNET COMMUNICATIONS: OPTIONS FOR THE FTFB WORKING GROUP.

PETER MUNRO, USA

Abstract: An HTML web site for the WG/FTFB was presented to provide the Working Group with a presence on the Internet. The site is in skeletal form: navigation and layout structures are complete and essential elements of content are represented by appropriate pages, but the content for each page has yet to be filled in. Help was sought for tracking down content, an appeal was made for one or two of the more experienced members of the WG/FTFB to volunteer to help the web steward. Comments on the web site were invited from group members. An automated e-mail mailing list has been established to provide Group members with a forum for Internet discussion. The mailing list is served from a computer at the Alaska Fisheries Science Center in Seattle. A strategy for organising the mailing list and procedures for maintaining it were presented. Certain policy issues for the web site and mailing list are not yet resolved and comment and discussion on these issues were invited from the Group.

Discussion: The broad potential of a website was acknowledged. It was suggested that a small group of interested members assemble with Peter Munro to provide guidance on site policies and content.

7 SPECIAL TOPIC D: ICES GAUGE

Review of the mesh measurement procedure for the ICES gauge. Ronald Fonteyne, Belgium

Abstract: The mesh measurement procedure for the ICES gauge dates from 1961 and has not been modified since, despite the fact that fishing gears and netting materials have evolved considerably afterwards. Prior to the WG/FTFB meeting a review of problems encountered, and possible solutions, was discussed by a group of interested WG members via e-mail. The major questions concerned the spring or measuring force of the ICES gauge, the number of meshes to be measured, and techniques for selecting them. It was acknowledged that from an engineering point of view there should be some relationship between the measuring force and the twine size, but if the major concern is selectivity then a constant measuring force seems to be more appropriate. The 4-kg spring force currently specified, however, is rather large for fine netting as used in gillnets for example, while it is inadequate to completely stretch meshes of heavy netting. Other twine characteristics, such as flexural stiffness, affect the ability of a mesh to be stretched or opened, and hence have an influence on both mesh measurement and selectivity. The discussion group came to the conclusion that to solve the problem of the measuring force, a more profound discussion is needed of mesh selection and the mechanisms involved. This should enable the WGFTFB to modify current mesh measurement practices with respect to the netting materials now in use. The group agreed that the ICES procedures for the selection and the determination of the number of meshes to be measured is quite clear and seems to be in little need of modification.

Discussion: The view was expressed that it is desirable for scientists and inspection services to use the same technique since scientists' advice is considered in setting the mesh sizes to be enforced. However, if this is done then this will at the outset constrain the technique in favour of simplicity of design and use, and away from destructive testing, pre-measurement of multiple technical parameters, complex measuring patterns, etc. Industry involvement in development of a new instrument and method is important. It was pointed out that the force exerted by an escaping fish (whatever it may be) is independent of the material, justifying the designation of a constant measuring force. Other factors besides material properties affect the resistance to opening, such as towing speed and codend fullness. It was pointed out that there is a need for a standard technique for measuring other components and features of fishing gears such as grids. An EU project is presently being prepared to develop a new technique, offering an opportunity to consider these factors and participate in a program of research and development.

8 POSTER SESSION

Codend selectivity in Portuguese waters on board commercial vessels- preliminary results. Paulo Fonseca and Aida Campos, Portugal (poster withdrawn and replaced with a distributed paper.)

Abstract: A codend mesh selectivity project partially funded by the EU has started in 1998 bringing together three institutes, IPIMAR (Portugal), IEO (Spain) and IFREMER (France). The aim of the project is to collect new data allowing for the characterisation of the selection properties of trawls towards the most valuable commercial species in Region 3 waters. For this effect a given number of surveys, depending on each country, is to be carried out onboard commercial trawlers representative of the different métiers.

The present paper addresses only the results of the first survey carried out in Portuguese waters (ICES Division IXa). Last Fall. Two different métiers are found in the Portuguese trawl fisheries, the first aiming at crustacean species while the second targets fish species.

During the experiments (using the hooped covered codend method) the catch of a considerable number of commercial species presented a distribution (both in number and length class range) allowing for their characterisation in terms of retention by different codend mesh sizes (55, 70 and 80mm for crustacean, and 65, 80 and 90mm for fish, full mesh size). Nevertheless, due to their size structure, it was not always possible to derive selection curves for all species and mesh sizes, even when considering that the curves presented resulted from pooled data.

For the crustacean trawler species caught were the rose shrimp, *Parapenaeus longirostris*, the red shrimp, *Aristeus antennatus*, the scarlet shrimp, *Plesiopenaeus edwardsianus*, and the Norway lobster, *Nephrops norvegicus*. Furthermore, in this métier, two fish species were also caught, the European hake, *Merluccius merluccius*, and the blue whiting, *Micromesistius poutassou*, the latter having almost no commercial value, being discarded most of the time.

In the fish trawler, the commercial catch was constituted by the European hake, the horse mackerel, *Trachurus trachurus*, the mackerel, *Scomber scombrus*, the pouting, *Trisopterus luscus*, the common octopus, *Octopus vulgaris*, and the common squid, *Loligo vulgaris*.

In spite of the commercial importance of all the species referred to, with the exception of blue whiting, the results obtained for the cephalopod species must be stressed, since the selection of these species through codend mesh sizes is poorly understood in Portuguese waters. In fact these are the first results ever obtained.

***In situ* measurements of seabed disturbance by beam trawlers. Ronald Fonteyne, Belgium.**

Abstract: The aim of the study is to assess the seabed disturbance caused by 300-hp and 1200-hp beam trawlers, the two most important vessel classes in Belgium. The trawlers used in the experiments were equipped with 4 m and 10-m chain matrix beam trawls for the 300- and 1200-hp vessels respectively. The 4-m beam trawls weighed 2200 kg (1500 kg under water), the 10-m beam trawls 6100 kg (3900 under water). The measurements were made on the Goote Bank on the Flemish Banks, a tide dominated area with medium to coarse grained sand.

Before fishing the area was checked by side-scan sonar for possible earlier traces of fishing and boxcorer sediment samples were taken along the track to be fished. Next the fishing track was trawled four times. Immediately after fishing, the area was again observed with the side-scan sonar and from the recordings the exact positions for a second set of boxcorer sediment samples on the fishing traces were read. Side-scan sonar observations continued until the fishing traces had completely disappeared.

The persistence of the fishing traces was determined from the side-scan sonar recordings. The penetration depth was estimated from the comparison of the sediment samples before and after fishing using lithological descriptions (porosity and packing) and X-ray photographs.

Depending on the hydrographical conditions the fishing traces persist for up to 142 hours (1200 hp trawler). The traces from the sole plates are more distinct and last longer than those from the chain matrix. The penetration depth of the 10-m beam trawls varied from 1 to 5 cm. There was a good correlation between the lithological analysis and the X-ray photographs.

This study is made in the framework of the EU sponsored project "Trawl Penetration in the Seabed" (TRAPESE). Partners in this project are:

University of Rostock (coordinator)
Centre of Agricultural Research Ghent - Sea Fisheries Department
Netherlands Institute for Fisheries Research RIVO-DLO
Netherlands Institute of Applied Geoscience TNO

Grand Banks otter trawling experiment. D.C. Gordon, Jr., K.D. Gilkinson, E. Kenchington, J. Prena, P. Schwinghamer, T.W. Rowell, D.L. McKeown, W.P. Vass, K. MacIsaac, C. Bourbonnais, and J.Y. Guigné, Canada. No abstract.

Banquereau hydraulic clam dredging experiment K.D. Gilkinson, E. Kenchington, D.C. Gordon, Jr., K. MacIsaac, C. Bourbonnais, D. Roddick, S. Naidu, D.L. McKeown, W.P. Vass, G.B. Fader, and M. Lamplugh, Canada. No abstract.

Western Bank otter trawling experiment. E. Kenchington, K.D. Gilkinson, D.C. Gordon, Jr., K. MacIsaac, C. Bourbonnais, D.L. McKeown, W.P. Vass, G.B. Fader, and M. Lamplugh, Canada. No abstract.

Impacts of otter trawling on infaunal bivalves living in sandy bottom habitats on the Grand Banks. K.D. Gilkinson, P. Schwinghamer, D.C. Gordon, Jr., J. Prena, T.W. Rowell, D.L. McKeown, W.P. Vass, K. MacIsaac, C. Bourbonnais, M. Paulier, and S. Hurley, Canada. No abstract.

Escape of fish species and fish of different size under the groundrope - a crosscheck to the bagnet method by alternate hauls with different roller gear E. Dahm, Germany. No abstract

Modelling trawl performance during the retrieval period. C.W. West, J.R. Wallace, and T.A. Turk, United States.

Abstract: Observations of sampling trawl performance made during a multi-vessel groundfish trawl survey raised concerns that the trawls might be continuing to fish during the retrieval period, after the end of the sampling period but before coming off bottom as the gear was recovered. Using records of times and positions at critical moments during and following each sampling tow, a simple geometric analysis was used to estimate the distance over the bottom that was covered by the gear during the retrieval period, and the speed at which the trawl moved over the bottom. This analysis found that the distances swept were substantial and systematically increased with the depth of the tow. The effective trawl speed approached or even exceeded the towing speed specified by the sampling protocols, and this varied systematically among the participating vessels. Neglect of these effects could increase the impact of depth-related bias and inter-vessel variability on survey results.

Video presentation: Effectiveness of selectivity grid in salmon seines. S.T. R. de Silva, Canada. No abstract.

Following the Poster Session the Working Group reconvened in plenary session for a group discussion of the posters presented:

Several comments concerned the poster on sampling hauls: the delay in coming off bottom could lead to errors in the effective tow duration, and that the shorter the sampling tow, the greater the impact. It was pointed out that such lag, if undetected, could explain observations of apparently higher catching efficiency during shorter hauls (the "catch by surprise" hypothesis).

Following that was a general discussion of the poster session concept and its relevance to the Working Group: How can we make poster presentation more appealing to authors? Are members satisfied with the approach? It was pointed out that posters take time to prepare. The idea of a dedicated poster session and discussion period was endorsed. Is it harder to get travel support when the presentation will be in poster form vs. lecture or written? At one meeting, posters were keyed to particular sessions and attendees were specifically referred to the appropriate posters during a viewing period. There is a need for the authors to at least provide a handout to go with each poster.

In conclusion, the Working Group endorsed the concept of a poster session featuring a convener, and each poster should have an accompanying handout.

9 SUGGESTED WORK ITEMS

Techniques to quantify fish behaviour from underwater videos and still photographs.

B. McCallum, Canada, D. Ferro, UK and I. Huse, Norway

Abstract: At the 1998 meeting of the Fishing Technology and Fish Behaviour Working Group in La Coruna it was decided to set-up a group to investigate the development of techniques to quantify fish behaviour from underwater videos and still photographs. It was decided to approach this task in two phases. The first phase was to collect all pertinent information about who is doing what in the analysis of fish behaviour using video and still photographs. The second phase will seek to identify the opportunities presented by commercial software packages which may or may not have been developed specifically for fish behaviour. A detailed questionnaire and preliminary list of analytical tasks was developed and distributed within the FTFB membership in the Spring of 1999. While some detailed and thoughtful replies were received, response to the questionnaire was generally low and it was therefore recommended that this FTFB suggested work item be extended for a second year such that:

- The questionnaire can be recirculated within the FTFB and to selected university and/or commercial interests. A detailed list of analytical requirements can be completed.
- A list of relevant commercial software packages can be developed and these packages will be evaluated for their utility to the analysis of fish behaviour.

Discussion: Digital camera and recording technologies offer great potential to facilitate digital image analysis without the need to transform or digitise the data. Software exists for quantitative behavioural analysis with little further

refinement needed. Point was made that quantitative image analysis is applicable to impact research as well as behavioural studies.

Methods of implementation of technical conservation measures. Dr. Norman Graham, United Kingdom
Abstract: Internationally, much effort and resources have been dedicated to investigating methods of reducing the quantities of discards through gear related measures. The list of possible gear solutions is extensive. The utilisation of such measures as management tools has been identified as being highly variable. In order to estimate the use, a detailed questionnaire was sent to various countries and management regions. The majority of replies (twenty received from seventy posted) received concerned shrimp & groundfish fisheries. In management regions where financial incentives form an important role in harvesting practices, the use of more selective fishing methods is common. These incentives, which generally relate to access to fisheries, take several forms. For example, in many of the tropical shrimp fisheries the use of Turtle Excluder Devices (TEDs) is commonplace. Essentially this is a direct consequence of a US import embargo of shrimps from countries with high by-catch rates of endangered species. In other areas, strict harvesting policies in relation to discard rates have facilitated the use of more selective gears. In Norway, for example, if discard rates exceed a certain percentage of the catch (15% by number), then large areas available for fishing are closed down. This has resulted in the use of full square mesh cod-ends and grid systems. Some examples of voluntary use have been noted but so far this seems to be the exception rather than the rule. This has occurred due to the reductions in time and labour when sorting target species from by-catch e.g. in shrimp fisheries. The exclusion of potentially dangerous animals such as sharks has also encouraged voluntary use. It is intended to continue collecting further data.

10 NEW BUSINESS

ICES Five Year Plan. Ole Arve Misund, Chairman Fisheries Technology Committee. Comments were offered on the ICES five year plan for the Fisheries Technology Committee.

Discussion: A suggestion was made to revise the survey topic and justification statements to emphasise understanding and improving the capture performance of survey gears and relevant fish behaviour issues. Concern was expressed regarding the specific identification of particular Study Groups, Working Groups, etc. in the "Activities" statements. Since WG/FTFB members often work closely with industry in developing technical measures it was recommended that this be specifically acknowledged.

11 RECOMMENDATIONS FOR THE 2000 FTFB WORKING GROUP MEETING

WG/FTFB has been invited to hold its next meeting in IJmuiden, the Netherlands, 17-20 April 2000.

The format of the WG/FTFB meeting will be same as this year (1999).
Recommendations for **Special Topics** for the 2000 meeting of the WG/FTFB:
1) **Review and consider recent research into unaccounted mortality in commercial fisheries.**
Proposed by G. Sangster and A. Carr.

Justification:

Several countries are conducting or have recently completed significant studies in this area and the subject would benefit from a review of progress and an evaluation of the results obtained. The last review of significant studies occurred in 1996 by the ICES Study Group on Unaccounted Mortalities. A review of more recent work will determine the need for revision and update on planning and methodology for studying this subject.

2) **To review ongoing work for reducing unintended effects on the seabed and associated communities of fishing operations and gears, including ghost fishing.**
Proposed by P. MacMullen. (MacMullen and Carr will be conveners.)

Justification:

All fishing activities have influences that extend beyond removing target species. The approach recommended by FAO is that responsible fisheries technology should achieve management objectives with the minimum side effects and that they should be subject to ongoing review. WG/FTFB members and others are currently undertaking a range of research programmes to provide the means to minimise side effects.

Study Group:

It was recommended that a Study Group be formed under the Chairmanship of (to be named) to meet in IJmuiden simultaneously with the WG/FTFB to advise on improvements and further standardisation of current mesh measurement practices in view of the netting types now in use in ICES member countries. Proposed by Fonteyne.

Justification:

In 1998/99 the WG/FTFB established the need to refine mesh measurement methodologies to take account of the wider range of twines and netting types used in the fishing industry since 1962 when the current ICES and wedge gauge methods were adopted. Modern twines vary significantly in e.g. thickness and stiffness and it is known that these characteristics affect both mesh size measurement and selectivity. At the same time two other international bodies (CEN and EU) and the fishing industry (both fishermen and netmakers) have agreed that there is a need to consider the adoption of a standard mesh measurement method for use by the fishing industry, enforcement agencies, and scientists. The SG will initially consider whether the current definition of mesh size is still appropriate for scientific and industrial purposes, taking account of the need in stock assessment for the selection factor (L50/MS) to have a consistent meaning. The SG will compile an inventory of commercially available netting associated with the selectivity process, identifying the fisheries in which they are used. The SG will then consider the need to define groups of netting types for which the same measurement conditions (e.g. tension) can be applied. Finally the SG will agree on the specification of a suitable mesh mesh measurement methodology and the conditions under which mesh measurements for all fishing gears in ICES areas are made.

Suggested work items:

In addition, the FTFB Working Group also made the following suggestions for work to be initiated prior to the next meeting in April 2000:

- techniques to quantify fish behaviour from underwater videos and still photographs (Action: B. McCallum, Dick Ferro, and Chris Glass)
- implementation and acceptance of gear-related technical measures (Action: Norman Graham)
- prepare a Web-based manual concerning fishing gear measurement and observation devices for use in fishing gear research and development (Action: Bavouzet, Carr, Hall, and McCallum)

Other recommendations and issues:

A proposal was made for WG/FTFB to hold a joint session with WGECO, with Dick Ferro as co-chair. This can be a recommendation from the Working Group to the Fisheries Technology Committee. Jack Rice (ricej@dfo-mpo.ca) is chairman of the Ecosystem Working Group and should serve as the contact point for future discussions.

WG/FTFB recommended that the Chairmen of the FTC and RMC initiate a dialogue to take forward the work described in the recommendations of the Study Group on the Use of Selectivity and Effort Measurements in Stock Assessment (SGSEL).

Justification:

The report of the SGSEL (ICES CM 1998/B:6) makes clear recommendations for further work. Members of the group felt that it was important to establish a forum where fishing technologists and stock assessment scientists can work together to improve the exchange of information and ideas and to undertake specific analyses. One possibility is to establish a more broadly-based study group which could deal with a wider range of issues related to technical conservation measures in fishery management.

The Working Group wish to continue receiving National Progress Reports on a voluntary basis.

At the meeting's close the Chairman of the Working Group expressed his thanks to the keynote speakers, the subgroup conveners, the organising committee, and the Rapporteur, with special thanks to Peter Munro for his work (both to date and to come in the future) developing and maintaining the FTFB Web page.

1999 CANADIAN NATIONAL REPORT (S.J. Walsh)

ICES WORKING GROUP ON FISHING TECHNOLOGY AND FISH BEHAVIOUR

Newfoundland Region

Greenland Halibut (Turbot) otter trawl selectivity: Four experiments were carried out onboard the M/V "Northern Osprey" in NAFO division OB from August 24 to October 15, 1998. The objective of the experiments was to investigate ways of reducing the retention rate of small turbot in the trawl. The alternate hall methodology was used during the first three experiments. The number and size of turbot caught and meshed in a standard turbot trawl with a 145 mm mesh codend and 160 mm mesh in all other parts was compared to that of an experimental trawl with 80, 120, 200mm mesh in the first lower belly, and lower wings. Twenty-three valid pairs of sets were successfully completed. During the fourth experiment the standard trawl was rigged with trouser codends. One leg contained a 145mm mesh, while the other had the same mesh size, and a 145 mm mesh plastic-coated panel (exit window) inserted in the top panel. Ten valid sets were completed. The number and size of turbot caught in the standard codend were compared to that of the experimental codend.

Salmonid recapture technology for aquaculture operations: Experiments were carried out in Bay D'Espoire to develop technology to recapture salmonids, which escape from sea cages. The first experiment had a net wall around a single cage and both ends of the wall attached to a small mesh trap. The second experiment was a modification of the first by adding a leader in front of the trap. The second experiment was a modification of the first by adding a leader in front of the trap. The third experiment had the wall of netting removed, and a leader attached to the small mesh trap extended 80 meters long between the sea cages. The experiments were carried out during July and August 1999. Contact person: Gerald Brothers, coordinator-Conservation Technology, Program Planning and coordination Division, Fisheries Management Branch, department of Fisheries and oceans, P.O. Box 5667, St. John's, Newfoundland, Canada, A1C-5X1. Telephone +1709 772-4438, Fax +709 772-2110, e-mail: brothersg@dfo-mpo.gc.ca

Vessel-trawl avoidance studies: the avoidance behaviour of a dense aggregation of cod to vessel noise and bottom trawls was studied during the Canadian Integrated Trawl-Acoustic survey in the Gulf of St. Lawer4ence, may 1998 in collaboration with scientists from the Quebec region. During this survey, new trawl/acoustic investigations on fish reaction to the vessel noise and fish availability to the acoustic sampling volume and the sampling trawl were carried out using two vessels. Preliminary observation suggest the vertical distribution of cod was influenced by light intensity whereby fish were closely aggregated, by day, tight to the bottom and by night the aggregation began to disperse up from the bottom in the water column. However, a comparison of bottom trawl catches showed that catches were significantly higher at night than by day, the opposite of what was expect4ed given the changes in fish density as view on the EK500. Contact: Stephen J. Walsh, Northwest Atlantic Fisheries center, Department of Fisheries and Oceans, P.O. box 5667, St. John's Newfoundland, Canada, A1C-5X1. Telephone 1 709 772 5478; Fax 1 709 772 4188; email: walsh@athena.nwafc.nf.ca.

Applied fishing gear research: Projects carried out by the Canadian Centre for Fisheries Innovation and MUN fisheries and Marine Institute 1) design, construction and testing of deepwater turbot Trawl in partnership with the fishing industry; 20 underwater observations of shrimp around/in shrimp pots to determine effectiveness of gear in small-boat fishery; 3) underwater camera observations of yellowtail flounder trawl, modified to reduce cod bycatch in partnership with the fishing industry; and 4) testing of groundfish trapping system for deepsea fishing in partnership with the fishing industry. Contact: Mr. Glenn Blackwood Canadian Centre for Fisheries Innovation P.O. Box 4920. St. John's, Newfoundland, Canada A1C 5R3 Tel: 1 709 778-0542; Fax: 1 709 778-0516; email: Glenn.blackwood@mi.mun.ca.

Crab Pot Selectivity: The preferred size of snow crab (*Chionoecetes opilio*) to be landed has a carapace width of 4 inches or greater and many crab with a carapace width between 3 ¾ and 4 inches are being caught. The crab pots were fitted with a plastic collar to prevent crab with carapace widths of less than 4 inches from entering 3 ¾ and 4 inches can be reduced significantly. *Shrimp Pot Design (to reduce by-catch of crab):* The shrimp pots being used in exploratory fishing trials in Newfoundland for Pink Shrimp (*Pandalus borealis*) have a by-catch of snow crab. To reduce the by-catch of crab the pots were fitted with a plastic rim that the crabs could not climb over to get into the pots. *High Lift Bean Trawl*: The Department has introduced the use of beam trawling for shrimp (*Pandalus borealis*) into the Province over the past two years and fishermen have now adapted this harvesting method in a commercial fishery in Fortune Bay. The Resource Development division is undertaking a project to improve the headline lift of these nets to improve the catch rates through flume tank testing and fishing trials. Contact: Brian Johnson Project Coordinator Department of Fisheries and Aquaculture P.O. Box 8700 St. John's Newfoundland, Canada A1B 4J6 telephone 1 709-729-3717; Fax 1 709-729-1884; email: bjohnson@mail.gov.nf.ca.

Novia Scotia Region

New Projects: Gear Selectivity Training Program Description. Training Fishermen in Selectivity Projects. A comparison of composite diamond/square mesh codends. Comparison of selectivity between Scottish seining and trawling. Contact: David Taid Nordsea Limited, 84 Thronhill Drive Dartmouth Nova Scotia, Canada B3B 1S3 Tel. 902-468-1355; Fax 902-4668-3004; email: davetait@istar.ca.

ICES FTFB Working Group, St. John's Newfoundland, Canada, 19-22 April, 1999

Progress Report – Norway

Fish behaviour in relation to capture:

Sounds generated by fish are recorded, and the project will investigate the potential of using such sound to manipulate fish behaviour and improve gear selectivity.

Fishing gear technology:
Fishing grounds and technologies that may form the bases for a fishery for Gonatus fabriici are being investigated. Catch rates of trawl were too low for a commercial fisher.

Selectivity In Trawl:
Sorting grid in the trawl fishery for Norway pout and blue whiting has been tested. The catches of juvenile haddock were reduced by 75%, and losses of target species were 10-33%. The performance and selectivity of a new sorting grid have been investigated. In comparison with the sort-X grid which is mandatory in the Barents Sea, the new grid is smaller, has better handling properties, causes less damage to the gear and gives similar selectivity parameters. Experiments with sorting grid in trawling for mackerel gave promising results in term of capacity and size selectivity.

Survival and bycatch:
As part of a multi-national project sponsored by the EU, mortality of juvenile haddock escaping through the meshes of a *Nephrops* trawl has been studied and shown to be low.

Ecosystem effects of fishing:
Ghost fishing has been studied by observing catches in gillnets soaked for several months. After 6 months, both live and dead fish were still observed in the nets. In a longline experiment, various mitigation measures have been shown to give reduced bycatch of seabirds, reduction in bait loss and higher catch rates of target species. ROV-observations of deep-sea coral reefs demonstrated damages of the reefs caused by trawling.

Effects of stimuli:
Observations of gillnets showed increasing number of fish around nets baited with bait bags. However, results from fishing experiments did not show increased catch rates by using bait bags.

Using light stimulus in addition to baits in pots did not increase catch rates of cod. The design of the entrance and the position of the bait bag were shown to be important parameters affecting the catching efficiency of pots.

Interactions between oil industry and fisheries:
Investigations in the vicinity of oil platforms in the North sea were conducted to study their potential as sites for commercial fishing. Catch rates of gillnets set close to the platforms were several times higher than those of nets set at greater distance.

WG ON FISHING TECHNOLOGY AND FISH BEHAVOUR – St. JOHN'S, APRIL 1999
REPORT OF ACTIVITIES – BELGIUM

Agricultural Research Centre – Ghent
Sea Fisheries Department
R. Fonteyne and H. Polet

Selectivity and discards reduction

The study on the development of environment friendly fishing methods for brown shrimp (*Crangon crangon*) in the Belgian coastal waters was continued. The main aim of this study is to develop a shrimp trawl that (a) fishes in a species and length selective way, (b) reduces the unwanted by-catches, (c) thus reducing the impact of this coastal fishery on the environment and (d) improves the quality of the catches. The selectivity experiments going on in the margin of this study were finished. Cod-end as well as whole trawl selectivity was studied. The experiments with a sorting grid were partially successful. Significant reductions of benthic organisms, undersized shrimps, flat- and roundfishes in the catches were recorded. The 0-age group flatfish still occurred in high numbers in the catches. The project to use electrical pulses as an alternative stimulation in the shrimp beam trawl was continued and offers good perspective. This project aims at the development of a shrimp trawl that increases the species and length selectivity of the groundrope. In the first project year only lab experiments were carried out to study the behaviour and survival of all organisms that occur in the commercial catches of the shrimp fishery.

The EU-project "Economic consequences of discarding in the Crangon fisheries" was concluded and aimed at the determination of the biological and economic impacts of the discarding of juvenile round- and flatfish in the *Crangon* fisheries in EU-waters. It ran in co-operation with the University of Lincolnshire and Humberside (co-ordinator) (Grimsby), Danish Institute for Fishery Research (Charlottenlund), BFAFI (Hamburg) and CEFAS (Lowestoft).

A new EU-project Fair PL-98-4164 "Nephrops trawl discard reduction using activating selection grids" was started to study the possibilities of sorting grids in the *Nephrops* fishery to reduce discarding.

Related to selectivity was the MESH project in which mesh measurement methodologies for fisheries inspection and research were evaluated. The Sea Fisheries Department acted as co-ordinator of this EU Concerted Action in which all EU fishing nations were represented.

Ecological effects of fishing activities

The EU-project FAIR PL97-3809 "Reduction of adverse environmental impact of demersal trawls" was continued and runs in co-operation with the Martin Ryan Marine Science Institute '(Galway), the Rijks Instituut voor Visserij Onderzoek (Ijmuiden), the Nederlands Instituut voor Onderzoek van de Zee (Texel), Rijkswaterstaat Directie Noordzee (Den Haag) and the Bundesforschungsanstalt für Fisherei (Hamburg). The main objective is to assess methods to reduce the adverse impact of demersal trawls on benthic marine organisms through changes in net design and alternative methods of stimulation.

The physical impact of beam trawl was further studied in the frame of the EU sponsored project TRAPESE (Trawl Penetration in the Seabed). The other partners are the University of Rostock (co-ordinator), RIVO-DLO and the Netherlands Institute of Applied Geoscience TNO. In-situ measurements were made involving side-scan sonar and RoxAnn observations of fishing tracks. The penetration depth was determined by comparing lithological characteristics and X-ray photographs of boxcorer sediment samples taken on the track before and after fishing.

NATIONAL REPORT FOR DENMARK: LIST OF RELEVANT PROJECTS AND CONTACT PERSONS

PRESEMO: Predictive selectivity model (EU project). David Wileman, DIFTA.

BACOMA: Improving technical management in Baltic cod fishery (EU project). Niels Madsen (DIFRES), DIFTA, and R. Holst, ConStat.

Size selectivity and relative fishing power of Baltic cod gillnets (EU project). David Wileman, DIFTA, and R. Holst, ConStat.

Development and testing of grids for the North Sea and Skagerrak shrimp fishery (EU project). Niels Madsen, (DIFRES), DIFTA.

Greek gillnet fishery. David Wileman, DIFTA, and R. Holst, ConStat.

Establishment of a herring size selection model for experimental gillnets. Søren Poulsen and J. Rasmus Nielsen, DIFRES, and R. Holst, ConStat.

Longitudinal study of gillnet selectivity for herring. J. Rasmus Nielsen and Søren Poulsen, DIFRES, and R. Holst, ConStat.

ISDBITS EU Study: Inter-calibration of the new standard TV3 bottom trawl with the old trawl on national basis used in the Baltic International Bottom Trawl Survey (BITS). Participants: Denmark, Sweden, Germany, Finland, Russia, Poland, Latvia, and Estonia. International coordinator: J. Rasmus Nielsen, DIFRES.

Inter-calibration between two sizes of small TV3 bottom trawls used in surveys by two small survey vessels in near coastal waters. Søren Poulsen, DIFRES.

EUROGRID (EU project). Kurt Hansen, DIFTA.

Fish and *Nephrops* survival after escaping (EU project). David Wileman, DIFTA.

Selectivity in the pelagic Baltic cod fishery (EU project). Niels Madsen, DIFRES and DIFTA.

Grids in industrial Norway pout trawls. Niels Madsen, DIFRES and DIFTA.

PROGRESS REPORT THE NETHERLANDS, 1998-1999

Fishing gear technology related projects carried out at RIVO-DLO, by B. van Marlen.

1. Project CETASEL (AIR3-CT94-2423, Prevention of by-catch of small cetaceans in pelagic trawls by technical means)

Project finished with final report, revised in April 1999.

2. Concerted Action SELDAT-2 (FAIR-CT98-4044, Selectivity Database)

The new project was scheduled to run between September 1998 and November 2000. Difficulties arose during the negotiations with DG-XIV. The total costs were reduced substantially and a new budget plan had to be made. The problem of finding a hosting organisation was solved eventually. The project has not started yet and the idea exists to postpone the time schedule with one complete year.

3. Concerted Action MESH (FAIR-CT96-1452, Evaluation of Mesh Measurement Methodologies for Fisheries Inspection and Research)

The last meeting was held in Ostend, Belgium in May 1998. The Final Report with conclusions and recommendations was discussed and completed. A further debate was held through e-mail after the termination of the project.

4. Project: Separation of mackerel and horse mackerel in pelagic pair trawling.

Further trials at sea were conducted in the fall of 1998 on the commercial pair trawlers IJM-203 and SCH-22. The emphasis was on the possibility of aimed fishery using more advanced echo-sounder equipment (SIMRAD ES-500).

5. Project: TRAPESE (Study 96/006, Trawl penetration in the sea-bed).

The first trip to measure the penetration depth was made onboard cutter OD-1 in the spring of 1998 in collaboration with RV ZIRFAEA. A second trip on the OD-1 was made in August 1998 on a different fishing ground. The objective was to sample sea bed sediment material before and after passage of a 12m tickler chain beam trawl to determine the penetration depth, but the second trip failed to produce results due to bad weather conditions. The work was repeated recently in the second week of April 1999 with better results. Side-scan sonar pictures were made and BoxCorer sediment samples taken, still to be analysed. A third project coordination meeting was held in January 1999 in Ostend. The idea to continue this research in a follow-up project was investigated.

6. Project: REDUCE (FAIR-CT97-3809, Reduction of adverse environmental impact of demersal trawls)

Technical trials were carried out on RV TRIDENS in March 1998 with an improved version of a 4.5m waterjet beam trawl in collaboration with BFAFi-Hamburg. Underwater observations showed that the system worked, but the catches fell short of the standard trawl. Also the effect on the benthos by-catches was analysed. The second REDUCE-meeting was held in Hamburg in June 1998. Further experiments with the jet trawl were carried out in November 1998. The first week was lost due to storms, and the second week allocated to further modifications on the jet system brought closer to the ground rope. Model tests were carried out in the Hull Flume Tank in December 1998 with participants from Ireland, Belgium, and The Netherlands. A prototype sparker is under development, and a series of tests are to be conducted before the summer of 1999.

7. Project: DISCRAN (Study 98/012, Reduction of discards in *crangon* trawls)

The project started in March 1999 to run for two years. It is a follow-up from Study 94/044 RESCUE. The objective is to develop selectivity devices appropriate to the European shrimp fishery in order to reduce discarding of undersized shrimps and (predominantly) juvenile flatfish. The EU developed recently ideas to make sorting grids or sieve nets mandatory in the year 2000. Flume tank trials on sorting grid and veil designs will be carried out in the SEAFISH tank in June 1999.

10. Project: Reduction of impact and discards in the cutter fleet (at national expense)

In October 1998 experiments were continued on RV TRIDENS with modified gears to reduce the impact and by-catch of benthos. Large meshes were tried behind the footrope to release benthic species during trawling, whilst maintaining flatfish catches. Three configurations with more large holes cut out (i.e. 10, 14 and 19) were tried, after comparing the two nets unmodified. The results were presented at the FTFB-WG meeting in St. John's, April 1999. The conclusions

are that a) the large holes can release some benthic species, particularly the heavier ones, b) where such release was found, catches of sole were negatively affected, and c) further gear adaptions are necessary to overcome this problem. Further alternatives were investigated in January-February 1999 on RV ISIS (release holes with netting sheet underneath, 8m beam trawls) and in March 1999 on RV TRIDENS (release holes and alternative chain arrangement, 12m beam trawls). The results still need to be analysed and reported. Prior to the sea trials designs of release holes and alternative chain rigs were tested at model scale (1 to 5) in December 1998 and March 1999 in the SEAFISH tank in Hull.

11. Project: Electrical stimulation (at national expense)

Further work was done in collaboration with the private company VERBURG-HOLLAND B.V. at Colijnsplaat and paid by the Ministry of Agriculture, Nature Management and Fisheries. An extended series of comparative trials on 7m beam trawls (electrified vs. conventional tickler chain) was done in June, August, September, November and December 1998 for a period of 9 weeks in total on RV TRIDENS. The results were analysed in SAS and presented in a national report. Sole catches were of the same order of magnitude for the electrified net, plaice catches lower, and also the catch of benthic organisms. Further trials are to be carried out in April 1999 on RV TRIDENS, aimed at increasing the catch rate for plaice and at investigating survival of discards.

ICES FISHING TECHNOLOGY AND FISH BEHAVIOUR WORKING GROUP

St John's, Newfoundland, 19-22 APRIL 1999

Portuguese Report of Activities from 1998

by Paulo Fonseca and Aida Campos

Portuguese Institute of Fisheries and Sea Research (IPIMAR)

1) Characterisation of the fishing fleet

The characterisation of the different segments of the fishing fleet is of major importance for the adoption of correct management procedures, in order to adapt fishing effort to the stocks. Most often existing databases are not fully actualised regarding alterations on deck layout and equipment, and even on decommissioning. Therefore, there is an urgent need to go through all the available information and confront it with results from *in situ* (fishing harbours) inventories.

The work started by the purse-seine fleet, whose main catch is the sardine, *Sardina pilchardus*,
The database from the Portuguese Directorate-General for Fisheries and Aquaculture (DGPA) was consulted, as well as the information on each vessel existing in the Directorate-General for Vessels Inspection. Additionally to the technical characterisation of vessels data on catches between 1989 and 1997 was also obtained along with prices of first sale. All this information is under analysis and before the end of the project it is intended to design a new more efficient vessel for this fishery, not only in terms of the fishing operation but also concerning the handling and preservation of catches.

2) Codend selectivity experiments

A codend mesh selectivity project supported by EU has started during 1998. This project, involving Portugal (IPIMAR), Spain (IEO) and France (IFREMER) is intended to provide new data allowing for the characterisation of the selection properties of trawls used onboard commercial vessels.

During the Portuguese surveys, both in the crustacean and in the fish trawlers, a considerable number of commercial species were caught in relatively high number, thus allowing for their characterisation in terms of their retention by the different codend mesh sizes. However, due to the size structure of the catches, it was not always possible to derive selection curves. For the crustacean trawler these species were the rose shrimp, *Parapenaeus longirostris*, the red shrimp, *Aristeus antennatus*, the Scarlet shrimp, *Plesiopenaeus edwardsianus*, the Norway lobster, *Nephrops norvegicus*, the Hake, *Merluccius merluccius*, and the Blue whiting, *Micromesistius poutassou*, while in the fish trawler the commercial catch was mainly constituted by the Hake, the horse mackerel, *Trachurus trachurus*, the mackerel, *Scomber scombrus*, the pouting, *Trisopterus luscus*, the common octopus, *Octopus vulgaris*, and the *common squid, Loligo vulgaris*.

3) Experimental fishing and topography in the continental slope

Considering that the major part of the commercial fish stocks in Portuguese waters are submitted to a heavy exploitation pattern, the importance of investigating the hypothesis of initiating an aimed fishery to deep-water species has been gaining an increasingly interest in recent years. Therefore, the IPIMAR has been participating in international projects with the aim of studying the biology and dynamics of those species. However, these aspects are only part of the actions that should be undertaken. The tests of different types of fishing gears, longlines, gill-nets, and eventually traps, besides trawl gears specially designed to the match topography and depth of these bottoms is of the utmost importance. Furthermore, there is a need for a more complete fishing oriented cartography of the continental slope. During 1998 the construction of the fishing gears took place, as well as the acquisition of an echosounder for bottom cartography. The beginning of the experimental work is scheduled to start in the summer of 1999.

4) Square mesh window experiments

Considering the success achieved by the use of square mesh windows for some mixed Irish and UK trawl fisheries, and most recently for the Baltic cod fishery, it was decided to investigate the use of such devices in Portuguese waters. Square mesh panels were tested in the upper belly and on the upper panel of the codend of a fish trawl The main species captured were the European hake, *Merluccius merluccius*, the horse mackerel, *Trachurus trachurus*, the blue whiting, *Micromesistius poutassou*, the chub mackerel, *Scomber japonicus*, the boarfish, *Capros aper* and the rose shrimp, *Parapenaeus longirostris*. Blue whiting was the only species which showed an active escape behaviour, with a considerable amount of fish crossing the square mesh window (about 24% when it was installed on the trawl upper belly and over 60% when used on the codend top panel). Furthermore, given the fact that the rose shrimp presented an escape of 14% when the window was installed on the upper belly, although in this case the escape behaviour was a passive one, the eventual use of such selective device in the Portuguese fisheries seems to be ruled out for the moment.

GEAR RELATED RESEARCH IN 1998. NATIONAL REPORT. SWEDEN

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1. Improving Technical Management in Baltic Cod Fishery (BACOMA). EU-project. Contact person: P-O Larsson or Vesa Tschernij.

2. Size Selectivity and Relative Fishing Power of Baltic Cod Gill Nets. EU-project. Contact person: P-O Larsson or Vesa Tschernij.

3. Selective whitefish grid system for demersal towed gear fisheries in the North Sea and adjacent waters. EU-project. Contact person: P-O Larsson or Vesa Tschernij.

4. Selectivity Database (SELDAT). EU-project. Contact person: P-O Larsson or Vesa Tschernij.

5. Evaluation of mesh measurement methodologies for fisheries inspection and research (MESH). EU-project. Contact person: P-O Larsson or Vesa Tschernij.

6. Development and testing of grids for the Skagerrak and North Sea shrimp fishery. EU-project. Contact person: P-O Larsson or Mats Ulmestrand.

7. A study of roundfish and *Nephrops* survival after escape from commercial fishing gears. EU-project. Contact person: Mats Ulmestrand.

8. Environmental effects of shrimp trawling in the Gullmar fjord. Contact person: Mats Ulmestrand.

9. Selectivity experiments with vendace trawls in the northern Baltic Sea. Contact person: Vesa Tschernij.

10. Experimental study of the selectivity of eel-pots in a population with a known size distribution and under semi-natural conditions. Contact person: Håkan Westerberg.

11. Behaviour studies of fish in relation to fixed gears in the Baltic Sea. Contact person: Håkan Westerberg.

12. Experiments with acoustic fishing for whitefish (Coregonids) in the Baltic Sea. Contact person: Håkan Westerberg

ICES FISHING TECHNOLOGY AND FISH BEHAVIOUR WORKING GROUP
ST. JOHN'S, NEW FOUNDLAND, CANADA, 19-22 APRIL 1999

UK (Scotland) – Report of Activities in 1998

FISH BEHAVIOUR EFFECTS ON SELECTIVITY

Four different approaches were used to confirm the significant slowing effect of winter (7 deg. C) relative to summer (12 deg. C) water temperature on the ability of haddock to escape cod-ends.

COD-END SELECTIVITY
A twin trawl experiment was conducted during June 1998 to determine the effect of a square mesh window in relation to position and panel mesh size on the selectivity of a 100mm diamond mesh cod-end. Two different positions were assessed with an 80mm square mesh panel, one at the start of the extension and one in the cod-end. The effect of a 100mm panel in the cod-end was also studied. With the 80mm panel in the forward position no significant difference in selectivity was evident when compared to the standard cod-end. The 80mm panel inserted in the code-end significantly improved selectivity but the results with the 100mm panel were inconclusive.

Further analysis using nested modelling techniques to determine a model of cod-end selectivity for haddock is continuing, based on the initial findings presented last year. Inputs include mesh size, twine diameter, number of circumferential meshes and season of year.

GRID SELECTIVITY
In collaboration with several other institutes FRS commenced two new FAIR projects. **Eurogrid** aims to develop a selective whitefish grid system for towed gear fisheries in the North Sea and adjacent waters while **Netrasel** has a similar objective for species separation and Nephrops size selectivity in the North Sea and Aegean Sea.

SELECTIVITY DATABASE
FRS together with several partners completed a feasibility study on establishing such an international enterprise and is also involved in a new FAIR concerted action project commissioned to bring this about.

FISHING EFFORT
A study of trends in Scottish fishing methods (1982-1996) was published in June 1998.
A concerted action project in collaboration with fisheries economists to study the effectiveness of effort control in the EU Common Fisheries Policy is now in its second year.

SURVEY GEAR
New deep water scraper gear to sample monkfish and other demersal species down to 1000 metres depth on the continental slope west of Scotland was tested and the inaugural survey successfully completed.

OIL INSTALLATION/FISHING GEAR INTERACTION
Following an ad hoc survey of net manufactures and gear providers a report listing mean and maximum rope, wire and chain diameters and weights of components used in Scottish towed gears was submitted by FRS for inclusion in a handbook to be published jointly by the Scottish Fishermens Federation and UK Offshore Operators Association.

FISH SURVIVAL AND DAMAGE AFTER COD-END ESCAPE
This EU funded project continued into its third and final year in collaboration with Denmark, Sweden and Norway. An acoustic mechanism attached to the net allowed the cod-end cover to be closed at pre-determined trawling duration's and released from the gear after collecting fish escapes for a set number of minutes. Analysis of the data sets gave high haddock (89-97%) and whiting (90-100%) survival with the shortest sampling time (15 minutes). Haddock survival was reduced significantly to 68.5% in one tow with a 30 minute cover sampling period. The results also revealed that tow duration had no significant effect on survival for either species.

PHYSICAL AND MATHEMATICAL MODELLING
The SFIA flume tank was used to study pulsing in a half scale cod-end. The towing bridle was attached to a hydraulic pump and the amplitude and frequency of the pump was varied for a range of catch sizes and towing speeds. The resulting cod-end motion was measured and video taped. A cruise on FRV *Clupea* also investigated the relationship between code-end pulsing, vessel motion, sea state and towing speed. Accelerometers measured vessel motion during the fully instrumented trials and cod-end motion was recorded on videotape using mini TV systems and/or RCTV. Initial analysis suggest that there is a very strong correlation between the frequency of vessel motion and that of cod-end pulsing.

An EU funded project on developing a predictive model of cod-end selectivity is in its third and final year.

Progress Report to the ICES Fish Technology and Fish Behaviour Working Group, April 1998.

UNITED STATES
NORTHEAST

Massachusetts Division of Marine Fisheries
Conservation Engineering Program
H. Arnold Carr
Michael Pol

The primary focus of the program was on four issues: a) a raised sweepless trawl for the whiting *Merluccius bilinerais* fishery; b) modifying the longline catch process to reduce the mortality of juvenile bycatch discard; c) examining the behaviour of scup *Stenotomus chrysops* and a long-finned squid *Loligo* sp. In the mouth of the trawl; and c) gaining further observations of rockhopper and roller gear on rocky bottom.

A fall whiting fishery of the southern New England coast has been only opened as an experimental fishery in recent years. The fishery is only permitted to function if the vessels use a raised footrope trawl. This trawl has a chain sweep with dropper chains. The objective is to reduce the bycatch of demersal regulated species (primarily flatfish *Pleuronectiformes*) to a level of 5% or less by weight. A second generation raised footrope trawl that eliminates the chain sweep was designed and tested last spring in the flume tank at the Memorial University in St. Johns, Newfoundland. Three vessels were then permitted to use this net arraignment in the fall whiting fisher. The vessels increased the size of the dropper chains and fished with satisfaction. A second, more comprehensive use of this sweepless trawl is planned for the fall fishery this year.

The demersal longline fishery, though generally considered low in discard mortality when compared to the mobile fishery, has a recognised problem with the handling of the juvenile cod *Gadus morhua* and haddock *Melanogrammus aeglefinus* bycatch. A program has been approved to examine methods to reduce the mortality. These methods include modifying the hauling process on these small boats, constructing a land-based copy of a longline hauler to further examine the catch process, and to further examine means to reduce the hooking of juvenile cod and haddock. This multiple effort is being undertaken with a combined team of fishermen and researchers.

The squid fishery has a perceived problem with a bycatch of scup. The scup stock is at an extremely low state, but there is a good recent year class that holds promise. MaDMF and the Manomet Center for Conservation Sciences teamed to examine the behaviour of the two species and to use differences in behaviour to modify squid trawls so that they would reduce the bycatch of scup. Four to six inshore boats are rigging modified trawls to further examine the problem during the spring fisher. The two species show a difference in the way they enter the mouth of the trawl and that difference appears to be vertical in nature. Several nets using a means to vertical separate the two species will be tested.

The impact of mobile trawl gear on the seafloor has become a major issue in the United States. A five day cruise was undertaken for the purpose to video rockhopper and roller gear currently in use in the New England groundfish fishery. Good video was obtained on a variety of sea bottom. The video will be made into a 15-20 minute program that will comment on the effects of trawling on the sea floor.

Manomet Center for Conservation Sciences
Marine Division
Dr. Chris Glass

Bycatch Reduction Program

Behavioural studies on the reaction of squid (*Loligo* and *Illex* sp0 to trawl gears was continued during 1998. Bycatch rates were quantified in inshore and offshore *Loligo* fisheries and in inshore *Illex* fisheries. Bycatch rates vary between fisheries but over 30% by weight is discarded at sea by boats targeting *Loligo* squid in Nantucket Sound. The main bycatch and discard species comprise flatfish, scup and butterfish. Behavioural analysis of squid reactions to trawl gears shows classical herding behaviour and considerable swimming endurance in the forward part of the net. Loligo was also shown to rise when dropping back towards the codend and in some cases to turn and rise on tiring. This species-specific behaviour has enabled squid to be separated from the main bycatch species. An experimental separator trawl and a raised footrope trawl was fished on chartered commercial boats during spring 1999. Using the separator trawl, 90% of all non-target bycatch was directed to the lower codend while over 95% of all squid was caught in the upper codend.

Studies with the raised footrope net were incomplete but indicate that bycatch levels are much reduced as compared to standards nets. These results suggest that bycatch can be reduced to minimal levels either by fishing with a simple raised footrope net or by fishing with a separator net with differential mesh sizes in the top and bottom codends to selective for larger marketable bycatch species in the lower codend and squid in the top codend. Further studies will be carried out in 1999 – 2000.

Multispecies Groundfish Fisheries
Experimental fishing trials were carried out on commercial boats in the Gulf of Maine during fall and winter 1998/1999. An experimental trouser trawl was employed to assess the effectiveness of different codend configurations in reducing bycatch and discard of undersized yellowtail founder and cod. Various composite mesh codends have been compared with the standard 6" square mesh codend. This work will continue throughout 1999-2000 but results are beginning to show significant reduction in undersize yellowtail flounder and for flatfish as a whole. There has been no significant reduction in catches of cod. Analyses and sea trails are continuing.

Other Projects
Manomet continues to investigate bycatch reduction in New York Bight sturgeon fisheries. Investigations of an experimental gillnet designed to reflect the acoustic signals of Harbour Porpoises are planned for 1999 in the Gulf of Maine.

SOUTHEAST
University of Georgia Extension Service
Brunswick, GA Station

Dave Harrington, Lindsey Parker, Richard Vendetti

Shrimp Trawl Gear Development – TEDS and BRDs

The prohibition of soft TEDs in 1996 and the implementation of bycatch reduction devices (BRDs) had major impacts in the southeastern shrimp fishery. Shrimp losses experienced by some trawlers using BRDs led to a lawsuit between Georgia fishermen and regulatory agencies. The prohibition of soft TEDS challenged the ability of shrimpers to work in certain areas and conditions.

TEDs
As approximately 40% of the industry depends on soft TEDs, Georgia extension agents worked with the NMFS to redesign soft TED panels. A series of re-certification trials coordinated by the NMFS were conducted using the R/V *Georgia Bulldog* as the testing platform. *Bulldog* captain Lindsey Parker collaborated with NMFS specialists to restructure the Morrison TED, formerly built entirely of eight inch webbing, into an eight inch panel with four inch sides. He also drafted proper installation procedures. This TED passed certification trails and is now called the Parker TED. Other work with NMFS agents trained sixteen leading east coast netmakers in construction and installation of the new design. Captain Parker also was instrumental in redesigning the Andrews bottom exiting soft TED preferred by many Gulf of Mexico shrimpers.

TED evaluations to reduce unacceptable shrimp losses that delayed authorisation of the redesigned Andrews TED will continue. Current goals in TED research are to re-certify a soft TED for use in the Gulf of Mexico and to improve the Parker TED for achieving satisfactory turtle exclusion rates in additional trawl types.

BRDs
Considerable effort has been expended in determining the causes and events during a trawl operation which result in excessive shrimp losses from BRDs. Over 20 hours of underwater videos were obtained by Georgia and Texas extension agents on a Texas shrimp trawler using the most common Louisiana/Florida fisheye BRD. Several haulback events and trawl rigging configurations which lead to shrimp loss were identified. A video was produced showing these critical phases and distributed throughout the south Atlantic and Gulf of Mexico along with measures successful fishermen have taken to reduce shrimp loss.

Due to the high degree of cooperation by the southeastern shrimp trawl industry in conducting comparative tows and characterisation tows, the role of the University's research vessel has evolved from the early 1990s. the R/V *Georgia Bulldog* is now primarily used to refine gear through video observation. The development of a 'continuous feed' submersible video camera system is the primary reason for this evolution. Successfully conducted for the first time in April 1998, researchers aboard the Bulldog now have the capability of viewing 'live' the behaviour of marine species as they interact with the trawl. Trawl behaviour is also documented. This methodology reduces the speculation involved in comparative tow analyses. Specialists are currently working on improving this technique using multiple cameras and pan, tilt and zoom technology.

To develop new or improved BRDs, extension agents have aided fishermen in attaining testing permits and grants. This year, the Gulf and South Atlantic Fisheries Foundation awarded grants to five south Atlantic shrimp fishermen to test new BRD designs. Several prototype projects were also funded in the Gulf of Mexico. We will be coordinating this BRD development work for the Foundation.

Most of the new BRDs are designed to move the escape hole further forward in the codend and away from the tie-off to ameliorate shrimp losses. Some incorporate the exits into the TED. Fishery dependent tests conducted last year using one of these prototypes (Wheeler BRD) showed stable shrimp catches but widely varying fish reductions. The device is a TED/BRD combination with a piece of rod (the same as the TED's bars) used to frame a hole above the TED. This design offers fish an opportunity to exit the net after they pass through the TED while they 'draft' in the areas behind the TED's grid where water flow is reduced. Three modifications of escape openings will be tested.

Another device is the Webbing Panel BRD. It is essentially a webbing panel much like a soft TED, but it is much smaller than a soft TED and is positioned behind the hard TED. The front edge of the panel is sewn into the bottom of the TED extension and angles back to an apex where a hole is cut in the top of the shrimp net webbing to allow fish to escape. Research this year will

build on the work funded by the Foundation in 1997. Bycatch reductions after 19 tows were as follows: Weakfish 38%; All Fish 55%; Spanish Mackerel 75%; Shrimp 12%. The tests and subsequent underwater video camera footage taken aboard the Bulldog has identified three components where improvements could lessen shrimp loss; (1) the integrity of the escape opening, (2) the amount of webbing in the panel, and (3) the attachment point of the panel's apex.
Successful devices developed through the process using preliminary testing and submersible videos are expected to be submitted for certification trials during the 1999-2000 season.

NORTHWEST
Alaska Fisheries Science Center
National Marine Fisheries Center, Seattle, WA
Research on Survey Trawls 1998
Dave Somerton, Peter Munroe, Ken Weinberg

Groundfish assessment Program – Dave Somerton, Program Leader

1. Footrope experiments:
Analysis of footrope capture and escape data has proceeded. Data were collected using secondary nets. Statistical tests based on maximum likelihood estimation and variants of the logistic function were used to distinguish four distinct capture processes. The inferred footrope capture processes differ from the mesh capture process in important ways and are as much a function of fish behaviour as fish size. The estimation and testing methods were applied to data for the standard NMFS survey trawl sued in the eastern Bering Sea. (In hope of achieving a 100% capture rate this net was designed to tend bottom very closely.) Four out of five species had a probability of capture near unity across all sizes. Yellowfin sole (*Limanda aspera*) had length dependent capture with considerably lower capture probability than other species at the same length. These differences suggest that yellowfin sole behave differently in front of the footrope. (Peter Munroe, Dave Somerton, and Ken Weinberg).

2. Effects of artificial light on footrope capture probability:
Further experiments were done to assess the effect of artificial light on footrope capture processes. Secondary net methods were used to collect the data. The experiment was conducted on the standard net used in NMFS surveys in waters characterised by rough bottom, a polyethylene, high-rise, four-seam trawl with rubber bobbin roller gear. On every tow cameras and lights were attached to the net such that a very large portion of the footrope was illuminated. Lit and unlit tows were done side by side. Data are being analysed with log odds ratios methods. Initial analyses indicate that escapement increased substantially for those tows with the lights on. (Ken Weinberg, Steve Srjala, Peter Munroe, and Dave Somerton).

3. Effects of tow duration on observed CPUE:
Experiments have been conduced in the Bering Sea, using the standard NMFS survey trawl, in which 15 and 30 minute tows were conducted in pairs along closely positioned parallel tow paths. Paired, area-swept CPUEs were used as a measure of duration effects, species by species. Effects have been detected using linear models of the log of paired CPUE ratios: 30 minute tows appear to have higher CPUEs for some flatfish species. Crab species showed higher CPUEs for 15 minute tows. There are hints that the effects may be due to changes in fishing efficiency due to variations in towing speed and not due to duration, but this has not yet been fully investigated. (Pam Goddard, Steve Syrjala, and Robert Otto).

Alaska Fisheries Science Center
National Marine Fisheries Center
Dr. Craig Rose
Fisheries Coordinator

Studies on fish behaviour in fishing gear and bycatch reduction at the Alaska Fisheries Science Center in 1998 have included:

Flexible grates, constructed of Fiberglas rods with neoprene spacers, were tested for effective size selection of pollock against similar sized square and diamond mesh panels. The grate performed similarly to the square mesh panel. The selectivity patterns of all three panels, installed as top panels in a four-seam codend with the side panels tapered, indicated that approximately 60% of the pollock did not encounter the panel in a way that would effectively test their ability to escape.

A device to sort large halibut from sole catches was tested under commercial fishery conditions, excluding 94% of the halibut, while retaining 50 – 80% of the target species. The design, selected from proposals by sole trawlers, consisted of a circular, rigid grate (15.25 X 15.25 cm square openings) in the intermediate tilted back 28 degrees from vertical with an escape tunnel at the top. A diverter forced fish to encounter the lower half of the grate first. The study was done in cooperation with the Groundfish Forum, an organisation of groundfish trawlers.

University of Washington, FRI

Selectivity and Mortality of Walleye Pollock Escaping from Pelagic Trawl Meshes:

Ellen Pikitch (Wildlife Conservation Society, Marine Conservation Program), Dan Erickson (University of Washington, School of Fisheries), Petri Suuronen and Esa Lehtonen (Finnish Game and Fisheries Research Institute), Chris Mitchell (Alaska fisheries Development Foundation), Craig Rose (National Marine Fisheries Service, Alaska Fisheries Science Center), and Chris Bublitz and Cat Klinkert (University of Alaska, Fishery Industrial Technology Center),

The second of two field seasons was completed during 1998 off Kodiak Island, Alaska to study mortality of walleye pollock passing through pelagic-trawl meshes. Escapement was observed using underwater video. Pollock actively escaped through top-panel meshes (93-mm square) as far as 20 m ahead of the catch bulge. Escapees were herded towards a caging system by a top-panel cover that was designed in cooperation with Roger Larsen (University of Tromso) and Mike Stone (Victory Fishing Gear International). The caging system, designed by researchers at the Finnish Game and Fisheries Research Institute (see Lehtonen *et al.*, 1998, Fisheries Research 38:303-306) was used to collect escapees at any moment during a tow. The caging method was modified during this study to (1) herd escapees using a top-panel cover instead of a full-codend cover, (2) observe activity inside of the caging system in real time, and 930 activate gate closure and cage detachment from the wheel house using a third-wire system. A "control" group was collected by purse seine. Although many pollock that escape through trawl meshes survive, our results suggest some level of mortality (preliminary results: 36% to 68% mortality after 14 caging days). Mortality was inversely related to body size. Underwater observations clearly showed that trawling and the escape process caused injuries. Yield per recruit modelling should be conducted to determine the potential impacts of these results. For instance, we showed that the smallest fish experienced the highest escape mortality. This size of pollock also succumbs to high natural mortality.

Mortality of Trawl-Caught and Discarded Sablefish: Dan Erickson (University of Washington, School of Fisheries), Richard Methot (National Marine Fisheries Service, Northwest fisheries Science Center), and Ellen Pikitch (Wildlife Conservation Society, Marine Conservation Program).

Three field trials were conducted to estimate survival of trawl-caught and discarded sablefish (*Anoplopoma fimbria*) off the Oregon coast. A sea-bed caging method developed for estimating discard survival of Pacific halibut (see Pikitch *et al.*, ICES CM 1996/B:16) was used for this study. Trawl-caught sablefish were placed into cages and returned to the sea bed. Cages were recovered 2 to 3 days later. When surface water temperatures were less than 15 degrees C, survival was: (1) greater than 70% under the least damaging or stressful conditions, (2) somewhat constant to 20 minutes deck exposure, then decreased as time on deck increased, (3) similar between day and night tows, and 94) inversely correlated with towing duration (1 to 5 hours) and capture depth (180 to 550 m). Almost all discarded sablefish died when surface-water temperatures were approximately 20 degrees C, regardless of fishing depth, deck exposure duration, and towing duration.

Use of side scan sonar for assessing bottom impacts of beam-trawling in Tokyo Bay:

Yoshiki Matsushita (National Research Institute of Fisheries Engineering), Dan Erickson (University of Washington, School of Fisheries), and Hiorki Ueda (Sea Corp.)

Field trials took place during March 1999 in Tokyo Bay to evaluate the effectiveness of using side scan sonar for quantifying beam-trawl tracks on the sea bed. This bay is shallow (< 15m) and the bottom consists of silt/mud. Visibility is extremely poor within Tokyo Bay, hence underwater observations could not be effectively used for assessing Impacts of trawling to the substrate. Side scan sonar (100 and 500 kHz) was used to map an area measuring approximately 700 m by 400 m. A series of bottom tows were subsequently made within this area using a beam trawl at speeds ranging from 3 to 5 knots. The beam-trawl frame penetrated the sea bed approximately 13 cm (estimated by measuring the length of 8-mm twisted nylon line secured to a side beam that was penetrated by silt). Unfortunately, side scan sonar provided few images of beam-trawl tracks immediately after towing was completed. Although we are currently analysing the data, it appears that only a small percentage of the total trawl line was distinguishable. Hence, side-scan sonar (100 and 500 kHz) may not be effective for measuring trawling impacts on soft, muddy, shallow bottom such as that found in Tokyo Bay.

Effectiveness of an artificial-longline bait for catching Pacific cod: Dan Erickson (University of Washington, School of Fisheries), Susan Goldhor and Radu Giurca (Center for Applied Regional Studies), Hal Cook (MARCO Marine), Chris Mitchell (Alaska Fishery Development Program), and Ellen Pikitch (Wildlife Conservation Society, Marine Conservation Program).

Field trials will be conducted during the summer of 1999 to test the catchability and species/size selectivity of an artificial bait made of Alaska seafood processing wastes (i.e., walleye pollock). This bait will be fished on longlines in the Gulf of Alaska; target species will be Pacific cod.

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