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REPORT OF THE
STUDY GROUP ON UNACCOUNTED MORTALITY IN FISHERIES

Aberdeen, Scotland

17-18 April 1995

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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TABLE OF CONTENTS

Page

1. TERMS OF REFERENCE 3
2. INTRODUCTION 4
3. THE IMPORTANCE OF UNACCOUNTED FISHING MORTALITIES 5
4. FISHING MORTALITY 5
   - 4.1 Present knowledge and relative magnitude of different components of F 7
     - 4.1.1 Landed catch, F_C 7
     - 4.1.2 Illegal and misreported landings, F_B 7
     - 4.1.3 Discard mortality, F_D 7
     - 4.1.4 Escape mortality, F_E 8
     - 4.1.5 Ghost fishing mortality, F_G 9
     - 4.1.6 Avoidance mortality, F_A 9
     - 4.1.7 Predation mortality, F_P 9
     - 4.1.8 Drop out mortality, F_O 9
     - 4.1.9 Habitat degradation mortality, F_H 10
   - 4.2 The condition of fish in relation to F 10
5. RESEARCH ON UNACCOUNTED MORTALITY 11
   - 5.1 Eastern North Atlantic 12
     - 5.1.1 Iceland 13
     - 5.1.2 Norway 14
     - 5.1.3 North Sea/Skagerrak/Kattegat 14
     - 5.1.4 The Baltics 16
   - 5.2 Western North Atlantic 16
     - 5.2.1 USA 17
     - 5.2.2 Canada 18
     - 5.2.3 Greenland 19
   - 5.3 Other concerns of new species and areas 19
6. CONCLUSIONS AND RECOMMENDATIONS 20
   - 6.1 Recommendations proposed 21
7. REFERENCES 21

TABLE 1 23

FIGURE 1 24

APPENDIX 1 25

APPENDIX 2 27

1. TERMS OF REFERENCE

According to the ICES resolution (C.Res. 1994/2:8:10) adopted at the 1994 Annual Science Conference, a Study Group on Unaccounted Mortality in Fisheries was to be established under the chairman-ship of Bjørnar Isaksen to meet in Aberdeen, Scotland, UK, 17 - 18 April 1995, to:

a) review for major fish stocks the relative magnitude of encounters, escapement ,or discards of fish from different fishing gears involved in exploitation of these stocks;
b) review for major fish stocks the potential of these fish to survive;
c) make conclusions available to ACFM and ACME.

The Study Group was to report to the Working Group on Fishing Technology and Fish Behaviour and to the Working Group on Ecosystem Effects of Fishing Activities.

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2. INTRODUCTION

On April 17-18, the Study Group met in the Marine Laboratory, Aberdeen. The meeting was opened by Bjørnar Isaksen who welcomed all participants and set the agenda for the two-day discussions.

During the morning session two presentations were made to the Study Group. Lee Alverson made a presentation of his work on discard mortality (Alverson *et al.* 1994), highlighting the extent of the problem globally as well as noting that much of the data relating to unaccounted fishing mortality was either limited for many fisheries or not available. This presentation was then followed by one on fish condition during the capture process by Frank Chopin (Chopin and Arimoto 1995). Models of the capture - escape process were presented in terms of how fish condition before, during and after escape may impact the probability of unaccounted mortality (Figure 1) (Chopin et al. 1995).

After these two presentations the Study Group focused on addressing particular issues of the terms of reference. The following items were discussed in particular:

(i) the importance of unaccounted mortalities;

(ii) different components of unaccounted fishing mortality, including several components that were not included in the original equation during the Montpellier meeting on methodology for survival studies last year (Anon. 1994a);

(iii) the relationship between fish condition and mortality and the possible consequences of targetting only healthy fish;

(iv) species of primary interest in the eastern and western North Atlantic and regional differences in terms of the magnitude of unaccounted fishing mortality problems;

(v) limitations of the validity of data due to technical constraints.

The following sections are a summary of both the discussions and conclusions of the Study Group with respect to the above mentioned points.

3. THE IMPORTANCE OF UNACCOUNTED FISHING MORTALITIES

By-catch and discard are effects of a species-specific management plan in a multi-species environment. In some instances fishing gear can be designed as a mono-specific gear, but examples are extremely rare, and nearly all fishermen use fishing gears and tactics that result in a multi-species catch. By-catch and discard practices are also a reflection and a function of the level of integrity of fishermen at sea without surveillance by observers or to their own perception of conservation. Fishing mortality can also occur through discards, disease, fatigue, stress, and injury; all of which can be reduced under normal conditions. Fish of a specific cohort may exhibit a large range of conditions in varying circumstances (or seasons); a fishing effort directed towards the healthier fish may have negative effects on the survivors. On the other hand, fish in better condition may show better chances of survival after encountering a fishing gear.

In the context of stock assessment of fish resources, it is becoming more urgent to include the monitoring of the condition of the fish. A stock might only be assessed in terms of numbers at age and biomass, but might also include an index of health condition.

4. FISHING MORTALITY

The Study Group has characterized F as the sum of all fishing-induced mortalities occurring directly as a result of catch or indirectly as a result of contact with or avoidance of the fishing gear. Longer term declines in the abundance of a stock or population may also occur as the consequences of gear-induced changes to the habitat F_H. Catch mortality should include all reported or estimated commercial landings F_{CL} plus landings from recreational fisheries F_{RL} and subsistence fisheries F_{SL}. Illegal and misreported landings F_B must also be considered as a potential component of the harvested and landed catch. All landings as noted above are also likely to have discard components F_D a portion of which is likely to die.

In addition to the catch and discard mortality, there is likely to be a death associated with fish which contact fishing gear but escape after being captured and subsequently die F_E, and fish which avoid the gear and yet die due to stress and injuries F_A. To this suite of mortality factors we must also add drop out deaths from nets and/or drop off from hooks F_O, death as a result from fish being caught in ghost fishing gears $F_{G,}$ and losses due to predation of fish that escape but would otherwise survive F_P.

Thus overall fishing mortality may be written as:

$$F = (F_{CL} + F_{RL} + F_{SL}) + F_B + F_D + F_O + F_A + F_E + F_G + F_P + F_H$$

In order to simplify this equation we have grouped all Fs associated with landed and reported catches (commercial, recreational and subsistence) under F_C thus reducing the equation to the form:

$$F = F_C + F_B + F_D + F_O + F_A + F_E + F_G + F_P + F_H$$

Contemporary information on some fisheries is available for landed commercial, recreational and subsistence fisheries and estimates of discard amounts and mortalities. In instances where no information is available on discard, mortality is presumed to be 100%. Additional estimates of mortality associated with contact and escapement from selected fishing gears are available for some species and are currently under active research in several countries. Almost no information is in hand for avoidance mortality, ghost fishing and habitat degradation. Finally, illegal fishing is frequently considered to be the largest source of unknown fishing mortality.

Note Because the calculation of the sub components of F may involve different age classes and thus different portions of the population, care must be taken to ensure the calculated Fs are associated with specific age classes impacted. For example, the calculation of F_D involves an estimate of weight or numbers of each age class discarded, multiplied by the expected mortality and divided by the relative number of the stock involved, expressed as an instantaneous rate.

4.1 Present knowledge and relative magnitude of different components of F

4.1.1 Landed catch, Fc

The Study Group did not discuss this component.

4.1.2 Illegal and misreported landings, F_B

The Study Group recognized that in some fisheries this maybe a major source of unaccounted fishing mortality. The Working Group on Northern Shelf demersal stocks has identified three forms of misreporting:

- misreporting of landings by area;
- misreporting of landings by species;
- under or non reporting of landings.

However, the magnitude of F_B may vary considerably with the Working Group on Northern Shelf demersal stocks estimating the level of misreporting to 10% of the landings for all species, while the Scottish Fishermen's Federation estimates these mortalities to 100-200%. The considerable range of values suggests that further research is necessary to quantify more precisely the levels of F_B.

4.1.3 Discard mortality, F_D

This was defined as mortality of fish actively released by fishermen after capture. The magnitude of this component of fishing mortality was demonstrated by reference to the data set from the North Sea (1991-1994) for all mobile gears for target species; haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), cod (*Gadus morhua*) and saithe (*Pollachius virens*) (Table 1). This type of mortality is usually regarded as high for nearly all gear types. Levels of discard mortality have been shown to exceed landed catch mortalities in many fisheries (Alverson *et al.* 1994), and escapement mortality has also been shown to be significant.

The reasons why fish might be discarded include:

- the vessel quota for a species has been reached;
- the fish are under minimum landing size;
- the fish are of legal but non-marketable size (occurs when vessel quotas are restrictive);
- the fish are damaged, and so are of low marketable value;
- the fish are in excess of the requirements of processing vessel (high-grading);
- the fish belong to a by-catch speciesand/or are non-marketable.

4.1.4 Escape mortality, F_E

This was defined as mortality of fish that escape from fishing gear after having encountered the gear. While there have been collected data sets for some species like haddock, whiting, saithe, cod and shrimp the escape mortality values for other species is not available. Furthermore, the validity of the present escape mortality data is limited by the number of experiments that have been conducted for most species. In addition, the following limitations on the existing data sets were noted:

1. a lack of knowledge on the physiological condition prior to capture. This may limit correlating results between experiments;
2. very few experiments are carried out on fish escape mortality at different life stages for most species and gears;
3. no experiments is carried out on pre and post spawning fish for all species and gear types;
4. no standardized experimental protocols for escape mortality experiments;
5. the short period of time during which escape mortalities have been carried out (lack of time series) should be considered as a limiting factor in terms of the confidence that can be placed in the results collected to date. One example of how escape mortality can be used in terms of stock assessment is given in Appendix 1 (Sangster and Lehmann 1995).

4.1.5 Ghost fishing mortality, F_G

The Study Group recognized that ghost fishing may be a significant problem for gill- and entangling nets and to some extent pots. Further research is necessary to identify the extent to which lost fishing gears continue to fish and the level of mortality associated with these gears. It was recognized by the Study Group that recent work on ghost fishing was available for some species, and that some effort be placed on determining whether the magnitude of ghost fishing in terms of fishing mortality could be reliably calculated.

4.1.6 Avoidance mortality, F_A

This is mortality directly or indirectly associated with stress, fatigue, and injuries of fish actively avoiding the gear. The Study Group was not aware of any literature on this type of fishing mortality and felt that in terms of the other components it would probably be low and difficult to measure.

4.1.7 Predation mortality, F_P

Gear-induced mortality, in which predators take fish either directly from the gear (seals stealing fish from gill nets) or indirectly due to reduced capacity to escape predators after escape or discard. It is measurable for some gears and species, but is probably low relative to other types of escape and discard mortality, and should not be given immediate priority.

4.1.8 Drop out mortality, F_O

This is mortality due to capturedfish dying and dropping out of the gear but are not a part of the catch brought on deck. Examples are fish washed out of the codend during trawling or haulback, or fish lost from hooks and gillnets.

4.1.9 Habitat degradation mortality, F_H

The Study Group was not aware of any work done on the impact of habitat degradation that could be directly translated into a measurable and reliable component of fishing mortality. This subject should not be given immediate priority. (Habitat change may have a cascade effect on other components of F.)

4.2 The condition of fish in relation to F

The Study Group recognized that the relative and absolute magnitude of all these components of fishing mortality would be significantly affected by the condition of fish prior to capture. Thus the reliability of estimates of all forms of unaccounted fishing mortality are directly related to pre-capture condition. In addition, experiments in which escape or discard mortality are estimated through holding fish for extended periods, the conditions of holding, transfer, and observation may also affect fish condition. Indirect estimates of escape and discard mortality through tag and release may also affect mortality.

The impact of a number of F partitions presented at the Study Group may be greatly increased for fish displaying poor condition. Condition indices can be used as an indicator of the stress level of both the environment (food, temperature, predators, etc.) as well as the physiology of the individual fish. Fulton's K factor and the HSI have been shown to be in synchrony with the collapse of the cod resource in the northern Gulf of St. Lawrence.

It was noted that as part of the stock assessment programme in Canada that some measure of the condition of fish is being used as a measure of the health of the fish stock in the northern Gulf of St Lawrence. Health indicators such as Fulton's K factor[(1)] and the hepato-somatic index (HSI)[(2)] have been monitored on a seasonal basis from both commercial fisheries and research vessel surveys, where

$$K = 100 \cdot \frac{S_W}{(L)^3} \qquad \textbf{(1)}$$

K = Fulton's condition index

S_w = Somatic weight (g) (total weight less the gonad and stomach content weights)

L = Fork length (mm)

$$HSI = \frac{l_w}{S_w} \qquad \textbf{(2)}$$

HSI = Hepato-somatic Index

l_w = liver weight (g)

The Fulton's K condition factor is an indicator of the protein energy content of the fish whereas the HSI is an indicator of the lipid energy content of the fish. As such these two reservoirs of energy contribute to the majority of the total energy reserves of fish.

However, it was recognized that these indices are measures of condition over a long term period (> months) and would not in isolation be sufficient for determining the physiological condition of fish immediately prior to the capture process or to determine the effect of handling stressors associated with experimental design. For these reasons it was considered important to have some reliable estimate of physiological condition associated with pre-capture condition and the change of physiological condition associated with experimental design.

5. RESEARCH ON UNACCOUNTED MORTALITY

Unaccounted fishing mortality, comprising of the components listed in Section 4, has been researched for a few species and gear types, but a large amount of additional research is required if these components are to be properly quantified and prioritised.

5.1 Eastern North Atlantic

In the eastern North Atlantic, further research on unaccounted mortality is needed in the cod, haddock, whiting, saithe, and Nephrops (*Nephrops norwegicus)* trawl fisheries. Additional species of concern include hake (*Merluccius merluccius*), red fish (*Sebastes sp.*), herring (*Clupea harengus*), mackerel (*Scomber scombrus*), Atlantic halibut (*Hippoglossus hippoglossus),* Greenland halibut (*Reinhardtius hippoglossoides)*, monkfish (*Lophius piscatorius*), spur dogfish (*Squalus acanthias)*, plaice (*Pleuronectes platessa)*, lemon sole (*Microstomus kitt*), deep water shrimp (*Pandalus borealis*) and scallop.

Discard in the shrimp trawl fishery was a concern, but with the introduction of the "Nordmøre" grid, non-target species bycatch and discard have been reduced considerably. In other trawl fisheries discard rates remain substantial. Discard rates have been established for cod, haddock, whiting, saithe, and Nephrops, but further investigation of discard survival for each species is warranted.

Escapee mortality rates for the above finfish have been determined for trawl fisheries off the west coast of Scotland. Triplicated cage experiments by Sangster and Lemann (1994) showed a range of results for the mortality of 15-38 cm haddock and 17-35 cm whiting. The mortality rates for the haddock and whiting experimental groups were 33-52% and 40-48% (70 mm cod-end), 18-21% and 22-27% (90 mm cod-end), 17-27% and 23-33% (100 mm cod-end), and 11-15% and 14-17% (110 mm cod-end) respectively. The mortality rates of the controls were 0% for both species. These percentages relate only to the numbers of mortality from the total escapees in a particular cod-end mesh size category, regardless of fish length. Further analysis of the data revealed that the mortality of the smaller cod-end escapees was much higher than for larger fish of either species. Similar experiment by Soldal *et al.* (1993) gave mortality rates from 5 to 10% for haddock generally bigger than those in the earlier mentioned experiment. This suggests that survival may be a more complex function of fish length. An expansion of this work to look at this is therefore worthy.

Other fisheries show low escapee mortality. Experiments on redfish and saithe have shown that those sorted out at fishing depth stand the selectivity process well (Jacobsen *et al* 1992, Jacobsen 1994). In the shrimp trawl fishery, shrimp escapees show low mortality whilst discarded shrimp show high mortality (Thorsteinsson, 1995)

In the extreme ends of the mortality rates are cod and herring. Cod seem to manage a selectivity process exceptionelly well, with a reported mortality of almost nil (Jacobsen 1994, Soldal and Isaksen 1993, DeAlteris and Reifsteck 1993, Suuronen *et al.* 1994). Herring escaped from codends seems on the other end to suffer a quite high average mortality (60%) (Suuronen *et al.* 1993). As for haddock, the herring experiments have indicated a size dependant mortality (Suuronen *et al.* 1995)

5.1.1 Iceland

Small fish have always been discarded in Iceland. In recent times many regulations have been enforced in order to improve the selectivity of the fishing gears and protect "nursery" areas. These regulations have not eliminated the small fish discards.

Due to lack of cod quota, some vessels operating in mixed species fisheries might discard cod or land it illegally. Fish of inferior quality, mainly caught in gillnets, might be discarded as the vessel owners/fishermen want to get the highest possible price for their low quotas.

Some promising young year classes of haddock have not entered the fishery as strongly as expected. This could be explained by discards and discard mortality of young fish combined with unaccounted mortality of fish escaping through the cod-end meshes. The Polish chafing gear generally used by Icelandic trawlers may increase this kind of mortality. This unaccounted mortality should be investigated with reference to the rigging of the cod-end.

Scallop dredges used in the fishery for Chlamys may break shells on the bottom without catching them. Experiments have shown that the catchability of the dredges is low. That means that a good deal of the shells are escaping under the dredge where they might be crushed by the gear. This presumed mortality should be investigated to improve dredge design, if necessary.

5.1.2 Norway

The fishery for gadoid species with moving gear (trawl/Danish seine) is currently under harsh regulation, with closure of fishing grounds if catch rates of protected species below minimum landing size (MLS) exceeds 15% in number (of total catch). To avoid closure, work on improving selectivity in this gear should continue together with mortality studies of escaped fish both below and above MLS.

A discard in the summer pelagic longline fishery for haddock is currently under investigation, both to give the level, as well as to estimate survival of fish knocked off the hooks.

Although the introduction of the "Nordmøre" grid in the shrimp trawl fishery has reduced the bycatch of non-target species considerably, there are still problems with small fish (<15-20 cm). During autumn when 0-group gadoid species settle on the bottom, the catch of juveniles often exceeds legal level (10 juveniles/10 kg shrimp), and major shrimp grounds may be closed for months. Selective experiments to solve this problem are needed, together with further research on whether 0-group juveniles survive the selection process.

Given a fixed quota on shrimp in some areas shrimpers tend to size-sort shrimp on deck to maximize the catch value (high grading). Since shrimp tend to survive an escapement process better than those discarded (Thorsteinsson, 1995), effort should be made to improve the size selective properties of shrimp trawls.

5.1.3 North Sea/Skagerrak/Kattegat

The Norway lobster (*Nephrops norvegicus*) is a commercially important species for most of the countries around the North Sea. The Nephrops live hidden in burrows; they are only catchable when they are available for trawls on the sediment surface. It has been shown that the Nephrops' activity depend on a number of factors (light intensity, temperature, oxygen saturation, life-cycle stage) which affect their behaviour and thus the availability for the fishery. Generally, the activity increases with the Nephrops' size, although berried females may remain in their burrows for up to a year while large males live on the sediment surface most of the time. Because of these differences in catchability between different categories of Nephrops, the fishery mortality will vary between the categories as well. Unaccounted mortality may also occur from fishing activity when they are soft after moulting and especially vulnerable.

All recent roundfish mortality work has beenconcentrated on the fate of cod-end escapees from demersal trawls on fishing grounds where relatively "clean" catches are taken and where mortality rates can be quite low. Conversely, the Nephrops fisheries are examples where cod-end catches may regularly contain a lot of damaging abrasive materials (eg. shells, stones, and various crustacea) mixed with important juvenile human-consumption species of roundfish. This abrasive debris would undoubtedly damage on contact both roundfish and Nephrops and affect their chances of survival; (a) after escape from the cod-end, and (b) after being discarded by the crew from the vessel's deck. Therefore, mortality rates of roundfish and Nephrops could be high in these fisheries, but this has never been investigated and quantified in a commercial situation.

Long time series on landing per unit of effort (kg/trawling hour) from Skagerrak/Kattegat log book data show a drastic decrease from more than 10 kg/hour in middle of 1980s to about 3 kg/hour in recent years, while the trawling effort has increased by more than 200% during the same period. The stock has undoubtedly declined. Regular measurement on catches from the commercial trawl fishery shows that more than 70% in numbers are undersized and thus discarded. The discard mortality from the trawl fishery is uncertain, but the Nephrops Assessment Working Group assumes it to be 75%. This high discard rate and assumed mortality shows that the mesh size in use (70 mm diamond mesh) does not correspond to the minimum landing size (40 mm carapace length) and that the current trawl fishery probably generates a high mortality on small, undersized Nephrops if the assumption on discard mortality is right. A preliminary mesh assessment (Anon. 1994 b) indicates that a change to 60 mm square meshes in 8 m of the extension piece and cod-end would give a long term gain in landings by about 60%, if it is assumed that all the escapees survive. This underlines the need for research on discard mortality and escape mortality to get reliable forecasts on the long term yield in landings.

5.1.4 The Baltics

The two Baltic cod stocks are both in poor condition at present. From a peak catch of close to 500.000 tonnes in 1984, a continous decline ended below 50.000 tonnes in 1993. The SSB is far below MBAL, according to ACFM. This has caused a concern, which is shared between fishermen, biologists, and managers. Experiments are initiated to improve selectivity in trawls and to study survival of escapees from cod-ends. Further experiments are planned, and discard rates and survival will also be studied.

5.2 Western North Atlantic

In the western North Atlantic, the following commercially important species are problematic relative to fishing related mortality: Atlantic cod, haddock, pollock, turbot, N halibut, yellowtail flounder (*Pleuronectes ferruginus)*, American plaice (*Hippoglossoides platessoides*), red fish, whiting, summer flounder, sea scallop (*Placopecten magellinicus*), and surf clams (*Spisula* spp.).

A mixed trawl fishery for squid (*Loligo* sp.) Atlantic mackerel, and butterfish is also important and of concern because of a large discard of scup (*Stenotomus chrysops*) and black seabass. Discards of up to 50% of the catch have been reported; little is known of the discard and escape mortality.

Catch reports and sea sampling are providing information on most trawl and other gear catches and discards, but little is known on fishing related mortality components such as on discards escapees preyed upon and drop out.

Although some initial data are available in the trawl fishery on the discard and escape mortality for cod, yellowtail, plaice and summer flounder, more investigation is required if the mortality components are to be understood and identified as to the degree of impact. Besides discard and escapee mortality, an understanding of mortality associated with predation, habitat, and drop out may also be important.

On the remaining species listed, including turbot, yellow tail flounder, redfish and sea scallop, little information on fishing related mortality is available on any fishing gear types. Of particular importance for these species would be discard, escape and predation mortality. Not listed are some pelagic species (eg sea herring and Atlantic mackerel) which may also be problematic, but currently to a lesser degree.

5.2.1 USA

The escapement of juvenile scup, winter flounder (*Plerunectida sp.*) and Atlantic cod from diamond (60 mm) and square mesh codends was investigated by using a simulation apparatus (Reifsteck and DeAlteris 1990, DeAlteris and Reifsteck 1993). While the first experiments on scup gave significant higher survival for square-mesh escapees, later experiment gave high survival and no significant difference for fish escaped from both codends. The flounder and Atlantic cod experiments gave all high survival rates.

Some work has been completed on deck discard mortality and escape mortality in the bottom trawl fishery (Robinson *et al. 1993)*. The species this work has targeted include Atlantic cod, American plaice and yellowtail flounder. The data include two seasons, summer and winter. An investigation on summer flounder has only focused on deck discard mortality in nearshore, shallow water during summer.

Experiments on attempting to mitigate trawl discard mortality of Atlantic cod and American plaice have been undertaken in concert with codend escapee mortality investigations. Three deck-treatment scenarios were used; dry deck, water spray, and awash down hose in a confined deck area. The results suggest that efforts, in regard to these species, should be directed to increasing the escapement of undesired fish in situ; this produces the least mortality.

5.2.2 Canada

Few examples of studies aimed at estimating unaccounted fishing mortality exist in eastern Canada. Some work has been done to estimate survivorship of invertebrates (mostly crabs) after being caught by commercial gear and prior to be released. During the fall of 1994, an undersize crab survivability project was carried out in Conception bay, Newfoundland. The project was designed to subject crab to various procedures that simulate handling techniques commonly used on 13 to 20 mcrab vessels, to determine the effect of handling practices on crab mortality. Survivability tests included dropping crab from distances of 120 cm to 214 cm and sliding crab into baited holding pots, and returned to sea floor. Weekly, the holding pots were retrieved, baited, and set. The results indicated that 83 to 100% of the crab died when dropped, and 46% of the crab died when sled. Both the holding times onboard and the height from which the crab were dropped or sled increased the mortality rates.

The bycatch of crab in gillnets directed to Greenland Halibut in the Saint Lawrence Estuary has been examined with the goal to estimate the survivorship once the fishermen have manipulated the crab out of the gillnets. Some attempts have been made to reduce the amount of crab bycatch either by fishing on greater depths or by allowing larger clearence of the gillnet to the bottom.

A field experiment has been conducted a few years ago on the survival of Atlantic Halibut in waters off Nova Scotia (Neilson et al. 1989). The time of exposure of halibut on the deck of a fishing vessel and survival at various light and temperature exposures were assessed. There is no direct effort currently done to estimate unaccounted fishing mortality in groundfish species in eastern Canada.

5.2.3 Greenland

In the Greenland shrimp fishery, discard of small redfish and Greenland halibut has been identified as a major problem. Discards, which are mainly composed of these two species, are previous estimated to 10-30% of total shrimp catches, which equals or exceed the actual catch of these species in the directed commercial fishery (Riget et al.1988, Pedersen and Lehmann 1989). Much research effort has been put into investigations with the objective to reduce by-catch of undersized fish and shrimp by means of grid devices and mesh selection (Valdemarsen *et al.* 1993).

5.3 Other concerns of new species and areas

Most of the components of fishing mortality using stationary gear is poorly understood. The landed catch is the best known component. Mortality associated with discard, predation, ghost fishing and drop out are potentially serious, and research is necessary to quantify the extent of the problem.

Two other concerns relative to this mortality issue are fishing effort directed at new species and areas and habitat. New or increased efforts on species not previously subjected to direct effort are developing in response to the decline of traditional fisheries. It is important to define fishery-related population parameters, including fishing mortality, for these species during the developmental stages of these fisheries to support the design of management strategies to prevent overfishing.

Some evidence exists concerning the alteration of benthic habitats by bottom trawls, which can effect substrate and associated benthos. Formal investigation of the effects is limited and the direct and indirect effects on larval and juvenile finfish are unknown, but possibly a very important component of fishing-related mortality.

6. CONCLUSIONS AND RECOMMENDATIONS

The Study Group notes that a large number of unknowns exist regarding the true magnitude of fishing mortality (F) for many important marine fisheries. These unknowns include; illegal fishing, discards and their survival, escapement mortality, as well as predation and habitat losses. Thus, the quantification of the various components of unaccounted fishing mortality is essential to the robustness of the estimate of F and the understanding of the full scope of fishing impacts. The application of experiments designed to measure discard and escapement mortality under varying conditions, form an important addition to existing knowledge of the consequences of fishing at the stock and ecosystem levels.

The Study Group also notes that while some of the unaccounted mortalities represented were significant in relation to landed catch, research to identify the level of unaccounted mortality for different species and gear types has been extremely limited. There are significant gaps in our data with respect to discard, escape mortality and ghost fishing, as well as large variations in estimates of level of misreporting. The magnitude of the problem is not matched by the existing level of research effort. In many instances escape mortality figures have been based on a single non-commercial fishing experiment, and further research should be carried out to determine whether these mortality rates change with seasonal condition of fish. No research has been carried out on fish in spawning condition.

The Study Group also notes that identifying each of the various components of F has two potential benefits:

(i) It would allow a more apropriate measure of F for each gear type for stock assessment purposes allowing the possibility of "withdrawal" qoutas to be allocated to each gear type based on the magnitude of the level of unaccounted mortality in relation to reported catch.

(ii) Measurement of each component of F would assist decision making in terms of directing technological research to reduce those components considered to be unacceptably high to reduce resource wastage.

It was also recognized by the Study Group that some components of F were difficult to measure and may be quite low for many species and gear types. Consequently, most of the technological research effort should be applied to measurement and reduction of discard, escape mortality, and ghost fishing.

6.1 Recommendations proposed

(i) The Study Groups reaffirms the reccomendations made by the 1994 ICES Sub Group on Methodology of Fish Survival Experiments (Anon. 1994a, see appendix 2).

(ii) The Study Group recommends to expand the scope and amount of unaccounted mortality research on major commercial species and commercial fisheries to obtain estimates of escape mortality, discard mortality and ghost fishing mortality (gill nets and pots). (Nephrops trawl fishery was specifically identified to require further investigation).

(iii) The Study Group recommends to study the applicability of various condition indices that may be used to determine physiological condition prior to capture as an indicator of stress and injuries that fish incur during encounter and escape.

(iv) The Study Group ask ACFM to provide guidance with respect to the most appropriate format for presenting data relating to the various F components.

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TABLE 1.

Discards For North Sea

The current discard figures for all gears for haddock, cod, whiting and saithe are shown in table 1.

Year	Species	By Numbers	By weight
1991	haddock	53%	31%
	whiting	58%	42%
	cod	46%	17%
	saithe		
1992	haddock	64%	41%
	whiting	58%	41%
	cod	62%	25%
	saithe		
1993	haddock	72%	51%
	whiting	70%	48%
	cod	42%	16%
	saithe		
1994	haddock	67%	45%
	whiting	65%	44%
	cod	83%	45%
	saithe	30%	18%

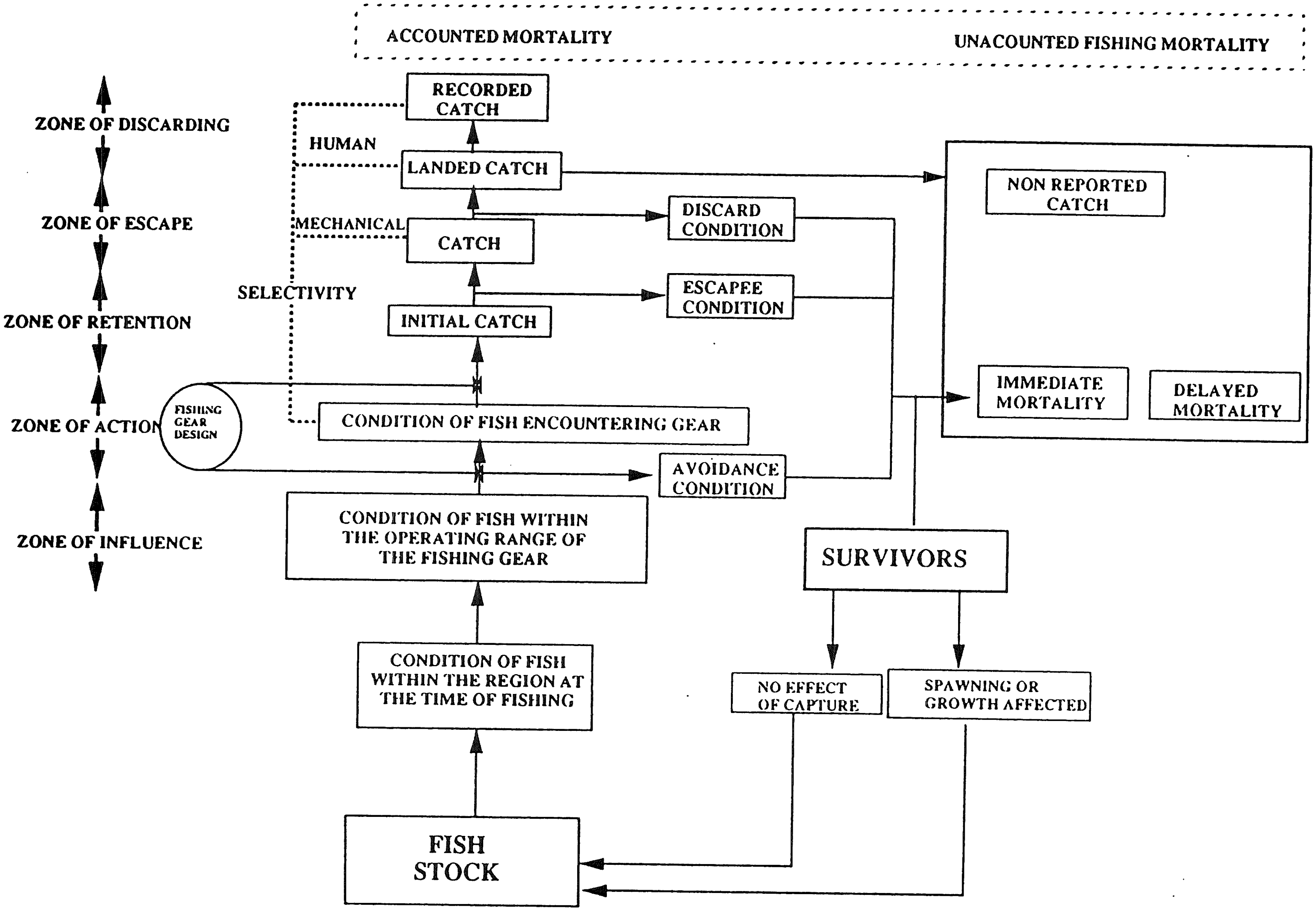
Data Collection.

Data is collected regularly for all the above species. Staff sample regularly on commercial fishing vessels during normal operations, and make note of total discards and sample for length frequency distributions.

The staff have developed a good working relationship with the skippers and crews of the fleet, therefore the data can be regarded as representative of true commercial conditions.

Data is collected by a limited number of countries, namely Scotland (ICES Areas IV& VIa) and Northern Ireland & Eire (ICES Areas VIIa).

FIGURE 1.



The condition of fish escaping from fishing gears (Chopin, INOUE, ARIMOTO in press)

APPENDIX 1.

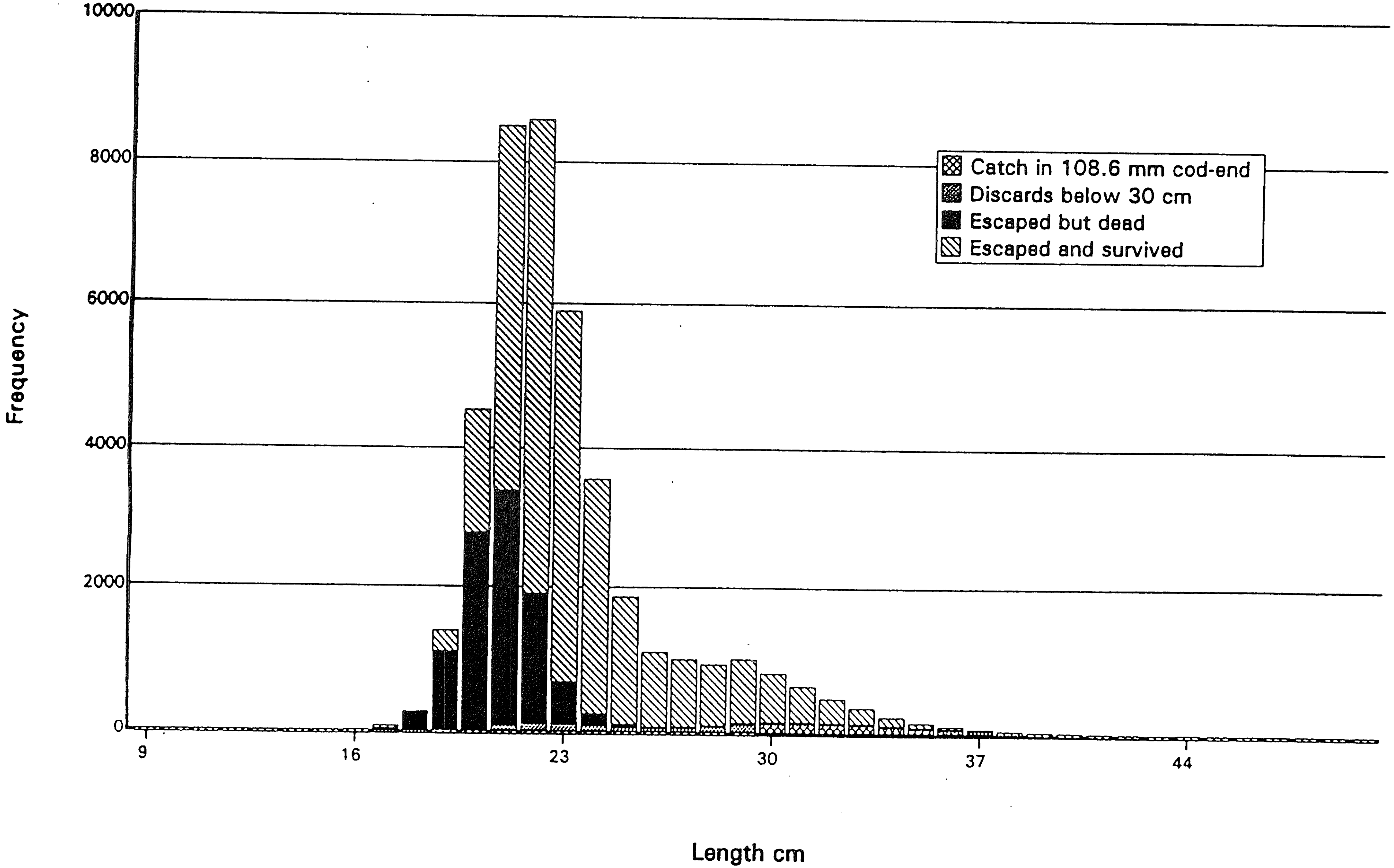
AN EXAMPLE OF THE USE OF THE RESULTS FROM AN ACTUAL SURVIVAL EXPERIMENT.

(Sangster and Lehmann, 1995)

The resultant survival/mortality data obtained from a haddock survival experiment, where cod-end escapees were held in cages on the seabed over a period of 60 days, were applied to selectivity data from the same fishery and obtained at the same time. The resultant probability of mortality at lenght from the survival experiment was applied to the cover data from the selectivity experiment and furthermore, the codend catch was separated into those fish above and below minimum landing size MLS. This provided four categories of haddock data; (1) fish landed > MLS, (2) fish discarded < MLS, (3) fish escaped and survived and (4) fish escaped but dead. These data sets were used to construct Figure A (page 17) which shows the fate of the haddock population from a specific fishery which entered the cod-end. The Figure shows quite clearly the relative magnitude of haddock mortality for this mesh size of cod-end and the size range of dying fish. It must be noted that a knife edge breakpoint in the MLS was used whereas this may not necessarily be the case in the fishing environment. Also there may be some degree of mortality caused by the holding of the fish in the cages through stress and lack of food but it is expected to be low. Further studies will investigate age and length in relation to mortality after cod-end escape. This analysis of survival experiment data can be applied to any species under similar investigation.

This will have some impact in the context of the stock assessment process. Once the experiments will be conducted, it will be possible for stock assessment biologists to adjust the estimated fishing mortality, for fish > MLS landed in order to take into account the fish above MLS which have escaped and died because of the passage through the fishing gear. If discards levels at age are available it will be possible for stock assessment biologist to adjust again for fish < MLS which have escaped the fishing gear and died afterwards.

FIGURE A. Fate of haddock population entering cod-end



APPENDIX 2.

Recommendations given by the

SUB-GROUP ON METHODOLOGY OF FISH SURVIVAL EXPERIMENTS
Montpellier, France 22-23 April 1994 (C.M. 1994/B:8)

RECOMMENDATIONS

The Sub-group on fish survival recognize:

- the lack of knowledge of the unaccounted mortalities associated with the fishing processes and their impact on stock assessment and the ecosystem;
- that limited methodology and results exist for various fishing gear species.

The Sub-group recommends that:

1. The fate of fish that encounter each phase of the fish capture process must be understood.
2. Impacts of unaccounted mortality be investigated based on biological and economic consequences.
3. Selectivity studies require a complementary understanding of survival.
4. Efforts be made on the development of methodologies to obtain results for fisheries of commercial importance.
5. More research is needed to identify the factors causing stress* and mortality of fish during the capture process.
6. Research should be aimed at identifying and correcting the damaging mechanisms of fishing gear.

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* Stress assessment is a tool that assists in determining causal factors of mortality and aids in mitigation.