Fish Capture Committee

ICES CM 1997/B:1

REPORT OF THE

STUDY GROUP ON UNACCOUNTED MORTALITY IN FISHES

Hamburg, Germany
12–13 April 1997

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

TABLE OF CONTENTS

Section **Page**

Section		Page

1. TERMS OF REFERENCE

According to the ICES resolution (C. Res. 1996/2:21) adopted at the 1996 Annual Science Conference, a Study Group on Unaccounted Mortality in Fisheries under the chairman-ship of Alain Fréchet was to meet in Hamburg, Germany 12-13 April 1997 to:

a) review and summarise any new work undertaken on the estimate of unaccounted mortality in fisheries;

b) develop priorities for future research.

The Study Group will report to the April 1997 meeting of the WGFTFB, and to the Fish Capture Committee at the 1997 Annual Science Conference.

Participants (in alphabetical order)

D. L. Alverson	USA (National Resources Consultants, Inc. Seattle)
M. Breen	UK (Marine Laboratory, Aberdeen)
A. Carr	USA (Division of Marine Fisheries, Massachusetts)
E. Dahm	Germany (Institut für Fischereitechnik, Hamburg)
S. J. de Groot	Netherlands (Netherlands Institute for Fisheries Research, Ijmuiden)
A. Fréchet	Canada (Maurice Lamontagne Institute, Mont-Joli, Québec)
A. Järvik	Estonia (Estonian Marine Institute, Tallinn)
O. Kaljuste	Estonia (Estonian Marine Institute, Tallinn)
K. Lange	Germany (Institut für Fischereitechnik, Hamburg)
N. Lowry	Denmark (The North sea Center, Hirtshals)
G.I.Sangster	UK (Marine Laboratory, Aberdeen)
A. V. Soldal	Norway (Institute of Marine Research, Bergen)
G. Thorsteinsson	Iceland (Marine Research Institute, Reykjavik)

2. INTRODUCTION

On April 12-13, the Study Group met at the Institut für Fischereitechnik in Hamburg. The meeting was opened by Alain Fréchet who welcomed all participants and set the agenda for the two day discussions. This was the second meeting of the Study Group, the first being held in Aberdeen, Scotland in 1995 (ICES CM 1995/B:1). Members of this study group have worked by correspondence during 1995 and 1996 (ICES CM 1996/B:5).

The session started with a review of the correspondence that was exchanged over the past two years and detailing links that were established with other Study Groups such as the Study Group on Ecosystem Effects of Fishing Activities, the Study Group on the use of Grates and other Sorting Devices and the Study Group on the use of Selectivity in Stock Assessments.

In order to present the review of recent work and research priorities in a consistant manner, these will be presented in the same systematic fashion as the partitioning of fishing mortality (F) was done and described in the report of the first meeting.

The overall impact of a fishing activity can thus be given as:

$F =$	F_C	(Landed catch) +
	F_B	(Illegal, misreported and unreported landings) +
	F_D	(Discard mortality) +
	F_E	(Escape mortality) +
	F_G	(Ghost fishing mortality) +
	F_A	(Avoidance mortality) +
	F_P	(Predation mortality) +
	F_O	(Drop out mortality) +
	F_H	(Habitat degradation mortality)

3. REVIEW OF NEW WORK UNDERTAKEN ON THE ESTIMATE OF UNACCOUNTED MORTALITY IN FISHERIES

A total of 29 project reports that involved 17 countries and three working papers were presented and discussed. A short summary of the findings is listed:

3.1. Landed catch (F_C)

This component is the most obvious and expected source of mortality in a fishery and is not addressed within this group. Most stock assessments are based on this sole source of information.

3.2. Illegal, misreported and unreported landings (F_B)

Illegal, misreported and unreported landings are, in certain fisheries, the main source of unaccounted mortality. Where available, these are included into the stock assessment process but this is not a common occurrence.

3.3. Discard mortality (F_D)

3.3.1. Selection and survival of haddock in longline fisheries (Norway)

The survival of 18 haddock torn off the longline hook at the sea surface during hauling were studied. Only one died during a 5 day observing period in which the fish were placed in a sea water tank onboard the research vessel. The work will be repeated next summer with a larger sample of fish and a longer observation period. The fish will be stored in net pens floating in sea water. The condition of these fish will also be monitored.

3.3.2. Selectivity and survival in *Nephrops* (Iceland) (this project has also habitat degradation estimates)

15 - 85% of the *Nephrops* were dead shortly after being brought onboard. More than 50% of the living discarded *Nephrops* died in the cage. Damage assessment related to individual survival was not evaluated. The otter boards of *Nephrops* (and other) trawls can plough up the grounds and damage the habitat, seining on the other hand is not degrading the habitat seriously.

3.3.3. Survival of fish and *Nephrops* (UK, Sweden, Norway) (this project has also discard mortality estimates)

Preliminary work was successful and improvements were made to the techniques to be used for collection of fish escapes from cod-ends and from square mesh panels. A viable technique for the collection, transfer and holding of *Nephrops* which have escaped from a trawl cod-end was developed.

Sea trials were carried out in the summer of 1996 off the West coast of Scotland. Problems were experienced with the performance of the fishing gear and the lack of fish on the grounds. This limited the amount of data which was collected during the sea trials. Some data was collected on the selectivity of haddock, witch and *Nephrops*.

Triplicated *Nephrops* survival figures were obtained for deck discards, cod-end escapees, and control groups. The mean mortality figure obtained for discards (67%) was close to the figure which is currently in use by ICES Nephrops discard assessment group (75%). Mortality of escape groups was between 6 and 28%. The figures for 60 mm square and 100 mm diamond mesh were similar. The selectivity of these two cod-ends for *Nephrops* was also similar, although the square mesh had a lower selection range.

Damage assessment for escaped and discarded Nephrops showed that the injuries most likely to be fatal were punctures to the cephalothorax and abdomen. These types of injuries were significantly more common in discards than in escapes and resulted in lower discard survival rate. *Nephrops* discards also showed a high level of physiological disruption (dehydration, etc), but all individuals that encountered the fishing gear showed physiological stress.

These results provide support for aims towards the reduction of discards by the development of selective gear. However, the actual fate of escapes and discards is not confirmed by these experiments, only that they have the potential to survive in a " sheltered " environment. The effects of predation related to ability to find shelter cannot yet be assessed.

No survival or damage figures were obtained for fish in this phase of the experiment. However, development of the techniques increase the likelihood that the data will be collected in 1997. A working technique for collection of escapes through a square mesh panel was developed for the first time and data will hopefully be collected for these categories in 1997.

3.3.4. The effects of different fishing gears on the North & Irish sea Ecosystems: IMPACT II (Netherlands, Belgium, Germany, Ireland, UK)

The survival experiments were conducted on both sole and plaice. Low mortalities were observed in the trawl. The effects of the fishing gear were correlated with changes in benthic communities.

3.3.5. *Lophius* (Monkfish) survival (USA)

Eleven out of 53 survived the fishing tows after being placed first in a livewell aboard the boat and then transfered to cages on the seabottom for a 24 hour total experimental period. Survival was best in colder water and air temperature (just above freezing). A thermocline was detected in June and could have reduced survival to 18%. Another factor that could have affected the resultant survival may be a greater tow depth and subsequent decompression.

3.3.6. Undersized crab survivability project (Canada)

The testing has indicated that mishandling undersized crab such as dropping and holding them on deck for long periods of time, will result in high mortality rates. When crabs are when dropped from heights as low as four feet, the mortality will range between 83 - 100%. Crabs that are slid down a chute to below deck will have a mortality between 46 - 79%.

Some crab may die due to being subjected to temperature changes or moulting when the pots are being hauled, even if they are returned immediately to the water.

The most desirable method of handling and discarding crab would be to use a chute to slide the catch onto a picking table and to then return them to the water as quickly as possible (at least under 10 minutes).

3.3.7. Survival of trawl-caught and discarded sablefish *Anoplopoma fimbria* (USA)

The first field season was designed to evaluate the usefullness of a sea-bed caging method (e.g. developed by Pikitch *et al.* 1996) for estimating short-term mortality of discarded sablefish (*Anoplopoma fimbria*). Sablefish were placed into cages and returned to the sea-bed for periods of 1,2,4 and 6 days. At least two caging days were necessary to detect most trawl-enduced mortality. Results of the control group (self-caught sablefish) suggested that confinement within the cages caused mortality when trapped for four days or more.

Factors affecting survival of discarded sablefish were fishing depth, body size, deck exposure and air temperature. Because this was not a pilot study designed to evaluate the method, levels of most variables did not emulate the commercial fishery (e.g. towing duration and catch size) and other potential explanatory variables were held constant. Future experiments will evaluate survival over a wide range of fishing conditions.

Two-day survival was low (less than 20%) when deck exposure exceeded 20 minutes. This work was conducted during summer months when both air and surface water temperatures were high.
3.3.8 Demersal Longline Survival and Stress (USA).

A study to determine the survivability of cod and haddock in the demersal longline fishery is being invetsigated. After passing through an automated discarding device, the "crucifier", the cod and haddock are tagged and held for 72 hours in wire mesh cages which are returned to the bottom. Control fish are caugth in fish traps. Both are observed after seventy two hours and the mortality rates noted. A study of the blood chemistry of the cod and haddock is also being undertaken to determine what physiological processes are occuring in association with capture stress.

3.4. Escape mortality (F_E)

3.4.1. Selection and mortality in Nordic trawl fisheries (this project has also discard mortality estimates)

This was a cooperative project involving Northern European countries (Sweden, Denmark, Faroe Islands, Iceland, Finland, Norway and Greenland) to study the mortality in their most important trawl fisheries. Several sub-projects included:

- Survival of herring in the Baltic Sea
- Survival of cod and haddock in the Barents Sea
- Survival of saithe close to the Faroe Islands
- Survival of shrimp (escapes and discards) in Iceland
- Survival of cod in the Baltic Sea

3.4.2. Survival of young gadoids in shrimp *(Pandalus)* trawl fisheries (Norway)

No mortality was found among the young gadoids during the observation period, except for one haddock in the control group. Few visible skin injuries and scale losses were observed for cod. Whiting and haddock had a significantly higher incidence of these two factors. No correlation was observed between fish size and scale loss. It is suggested that the survival of o-group gadoids be studied in more detail.

3.4.3. Cod-end Selectivity and Fishing Mortality (Denmark, U.K.)

Survival of fish which escaped from the cod-end was estimated for three diamond mesh sizes (70, 90, 100 mm nominal). A hoop-supported cod-end cover was used to capture the escapees and transfer them to sea-bed holding cages. The majority of fish mortality occurred within the first eight to ten days, irrespective of mesh size. In most cages, deaths of the smaller fish (both haddock and whiting) occurred earlier than for larger ones.

The results showed that the survival rate appeared to be age and size related. Smaller fish were more likely to die than larger fish of the same age. This effect was clear for ages 0 and 1; there were insufficient fish in older groups to show this clearly. Overall, fish under 1 year old had a low survival rate, one year olds had a moderate survival rate and older fish had a high survival rate. Some caution needs to be exercised in interpretation of these results. Although all of the control groups survived, they consisted primarily of slightly larger fish and contained no fish under one year old. An experimental effect acting on the small fish therefore cannot be eliminated.

The relationship between survival and mesh size was analysed on the basis of survival by length group. This was necessary given the above result, that survival is age and size related. The results tended to suggest that given that a fish escapes, the probability of it surviving is not strongly dependent on the size of the mesh through which it escapes. However, this conclusion should also be treated with caution as there was insufficient data to thoroughly test the hypothesis for each length group due to the variability in the data.

The survival results from this experiment are consistent with results obtained from a similar experiment (Sangster *et al*, 1996).

A qualitative list of injuries sustained by the mortalities and survivors from the survival experiment was obtained showing a variety of damage forms, including skin damage, fin rot, snout necrosis, liver damage, eye injuries and gill damage. Possible causative mechanisms in the fishing capture process and experimental procedures were described for each injury.

The injury to skin sustained by fish escaping from trawl codends was assessed. The fish were obtained using the same technique and cover used in the survival experiment. The fish were sampled from the cover anaesthetised and stained to highlight areas of damaged skin tissue. A photographic record was mad of each side of the fish, and these were analysed in detail using an image analyser. The degree of skin damage was shown to exhibit a symmetrical distribution with respect to each side of the fish and to increase towards the tail of the fish.

The severity of the total skin damage to the fish was examined with respect to mesh size and fish length and girth. The resulting multivariate model indicated that for a fish of a given size the total expected damage would be less if it had escaped through a larger mesh, and for a given mesh size the amount of damage would be less for a larger fish. These relationships, although statistically significant, were not strong due to the degree of variability in the data. However, if skin damage is a good indicator of the of the potential to survive, this does agree with the survival results showing that larger fish have a greater likelihood of survival.

3.4.4. Mortality of Baltic cod escaping trawl codend under commercial fishing conditions (Finland, Denmark, EU)

New methodology was developed in 1994-1996 for collecting escapees under high catch rates (or during long hauls). Initial results of this pilot study were published (see attached report). The actual investigation will be conducted in 1997-1998 together with Swedish and Danish Scientists.

3.4.5. Stress and Mortality of Fish Captured by Sweeping Trammel net (Japan)

The stress and mortality of fish captured by sweeping trammel net will be studied. This will include the type of entangling or the manner in which fish are gilled. Experimental catagories will be compared to control fish caught by hook and line.

3.4.6. Relationship between physiological / physical condition of captured fish (Japan).

Investigations of how various physiological indices change seasonally and their relationship to escape mortality indices (weight, length, hepato-somatic index, gonado-somatic index, whole body energy, cortisol variables) in relation to season, mortality duration and survival after release from gill nets.

3.4.7. The effects of trawl exclusion devices on bycatch and benthos on prawn and finfish fisheries. (Australia)

Three inclined grids (Super Shooter, Nordmøre grid and AusTED) were extremely effective at excluding large animals such as sea turtles, large sharks and large rays. They were also effective (between 0 - 39%) at excluding some of the small fish catch, especially when used in combination with other bycatch reduction devices such as a fisheye or square mesh window.

Another objective of this research project was to describe the damage and survival to fish escaping from bycatch reduction devices. These two studies were made using square mesh cod-ends. Damage to fish was assessed by collecting escapees from a 38 and 45 mm square mesh cod-end. A fine mesh cod-end cover and a large, water-filled scoop was used to bring the escapees onto the boat with minimal damage. Most escapees from the 45 mm diamond and square mesh cod-ends suffered minimal damage, but those from the 38 mm square mesh cod-ends were more severely damaged.

The survival experiments also compared the effects of fish survival from a 45 mm diamond and 45 mm square mesh cod-ends. Escapees were retained in fine mesh cod-end covers and transfered into sea cages or swimming pools. Their survival was monitored for eight to ten days. The survival rates obtained were higher in the pool experiments than the sea cages showing that for most of the species tested, more than 80% of the escapees survived.

3.4.8. Mortality of walleye pollock escaping from the codend and intermediate section of a pelagic-trawl during commercial fishing conditions. (USA, Finland)

This work has just begun and no results are available.

3.4.9. Practical applications of fishing and handling techniques in estimating the mortality of discarded trawl-caught halibut (USA).

This study was conducted aboard seven commercial groundfish fishing vessels off Kodiak, Alaska. Results showed that the mortality of halibut caught in trawls can be reduced by modifying fishing and handling practices. A conclusion from this study revealed that current sampling practices by fishery observers does lead to overestimates of mortality when used in the International Halibut Commission model.

3.5. Ghost fishing mortality (F_G)

3.5.1. FANTARED: Incidental catches in ghost fishing gill nets (U. K., Spain, Portugal)

See Kaiser *et al.* (1996)

3.5.2. Ghost Fishing Function of Lost Crab Pots (Japan)

The development of the ghost fishing function of crab pots has been studied based on diver observations.

3.5.3. Lost gillnets - unaccounted mortality (Norway)

This work involves the use of different methods for the acoustic location and density of lost gillnets. This work also estimated their fishing capacity potential.

3.5.4. Ghost Fishing in Demersal Gill Nets (Ireland).

This work investigated the impact of ghost fishing by demersal gill nets used in the Irish southern shelf fishery. The gears were monitored using a combination of period observation by divers and period hauling and inspection, depending on the depth of the fishing site. Inshore nets were found to be fouled by epifaunal organisms, mostly brown crab and spider crab. This reduced the vertical height of the nets from 4.8m to 1m after five months. Offshore nets experienced little fouled, however there was still a reduction in headrope height to less than 2m. Brown crabs were again the most numerous organisms caught, with smaller numbers of spider crabs. Larger numbers of finfish were caught, primarily dogfish, but also gurnard, whiting, cod and pollack.

It was concluded that the catching efficiency of demersal gill-nets deployed in an inshore environment may decline rapidly, while those in deeper offshore environments, being less affected by storms and wave action, apparently retain their catching efficiencey for a longer period. These netshowever are more likely to be daamged by encounters with other fishing gears; the effect being to reduce the catching efficiency quite drastically. As these nets are not fished inshore environments they are unlikely to paso any threat to diving birds.

3.6. Avoidance mortality (F_A)

No information on current research has been received on this topic.

3.7. Predation mortality (F_P)

3.7.1. Vulnerability to predation of small cod after severe exercise (Norway)

0-group cod were forced to severe swimming exercise by a scaled-down model trawl in flowing water. These fish were transfered to a tank holding large predator cod. In the first experiment using a trawl, no increased risk of predation was observed among the exhausted fish. In a second experiment which used a treadmill, an increased risk of predation was observed to that of control (unstressed) fish.

3.7.2. Effects of prawn trawling on the Far Northern Great Barrier Reef (Australia)

Discard studies obtained data on the time taken to sort the commercial catches from vessels working near the Green Zone. This data was an essential pre-requisite for designing experiments to replicate the survival of bycatch deck discards from this same fleet. The towing duration averaged around 160 min. The average sorting time was 38.8 min. Subject to this information, 40 min was used to keep animals on deck during starfish survival experiments common with the commercial practice. After collection, animals were introduced into seawater tanks. After 72 h of monitoring, 45% were floating and 85% were alive.

The diets of 12 species of tropical seabirds were investigated in two areas off the northern Great Barrier Reef. This data was collected with particular reference to the depths of trawler bycatch discard. The avian species whose diets included at least 20% discard taxa are *Sterna bergii, S. dougalli* and perhaps *S. anaetheta*; between 5 and 19% - *Hydroprogne caspia, Anous stolidus, Sterna bergalensis, Sula leucogaster* and *Fregata ariel*, less than 5% - *Sterna sumatrana*; and none - *Fregata minor, Sula dactylatra* and *S. sula*. There was a marked contrast in *Sterna bergii s* diet in closed and open trawling seasons: in the closed season only 5% of the prey were benthic species, whereas in the open season they made up 70% of the diet. Differences in the diets of birds from areas open and closed to fishing were less marked, probably because birds from the closed zone can forage in adjacent areas open to trawling. About half the bycatch discarded by the trawlers is of a size suitable for one or more of the seabirds. Most of this deck discard floats; some of it for up to six hours. *S. bergii, S. leucogaster* and *F. ariel* are actively opportunistic, feeding around trawlers, but *S. anaetheta* and *S. dougalli* may be passive discard feeders, feeding on floating discards away from the site of dumping. The provision of discards has not changed the size ranges of prey taken by any of the species. It may, however, have increased an overlap in the diets of the various seabirds and changed some feeding strategies. There is little evidence that discards have directly affected breeding cycles or nesting periodicity. Nevertheless, most species breed mainly in late summer and the largest quantities of bycatch are discarded in March, immediatly post-fledging. This may lead to juvenile birds becoming conditionned to feeding on discards and may reduce juvenile mortality rates

3.8. Drop out mortality (F_O)

3.8.1. Performance of the New England Hydraulic dredge for the harvest of Stimpson s surf clam (*Mactomeris polynyma*). (Canada)

The New England hydraulic dredge was used to determine the harvesting of Stimpson s surf clam, (*Mactomeris polynyma*) and its immediate impact on the mollusc population. Of the clams remaining on the bottom, almost two-thirds were damaged by the dredge. A small percentage of other mollusc species that were not harvested were also damaged. More than 20% of the clams harvested by the dredge showed signs of damage. Although survival experiments were not carried out during trials at sea, it is expected that mortality of any clam with a broken shell is 100%.

3.9. Habitat degradation mortality (F_H)

3.9.1. The seamount fauna off Southern Tasmania: Impacts of trawling, conservation and role within the Fishery Ecosystem (Australia).

This work has just commenced and no results are available.

4. PRIORITIES FOR FUTURE RESEARCH

The following section will attempt to highlight limitations the Group has identified in current understanding of the various sub-components of fishing mortality. Where methods of study have been developed, practical difficulties and potential shortfalls of these are noted and, where applicable, potential for improvements suggested.

4.1 General

Under the approach of the Precautionary Principle, a better understanding of the overall mortality resulting from a fishing activity is essential for good fisheries management. The assessment of fisheries stocks and the establishment of a reference catch level should include estimates of the total fishing mortality, including all subcatergories of F. The overall mortality associated with a particular gear could be used to prioritise its impact on a given stock, in comparsion to alternative capture methods. For example, an increase in mesh size is usually accompanied by an increase in effort, such an initiative may be detrimental to a fish stock if escapement mortality is high.

The Study Group acknowledged that there has been limited advancement of definitive information on most components of fishing mortality since the last meeting. The research carried out over recent years has concentrated primarily on the estimation of mortalities associated with pelagic and demersal towed gears. Estimates of mortality resulting from the use of static gears remain lacking.

It was decided that because of this lack of information it would be unreasonable to prioritise any particular subcomponents of F within particular fisheries. However, it was recognised that illegal, misreported and unreported landings (F_B) and discards (F_D) are likely to be of most importance in the majority of fisheries. With respect to fisheries using mobile gears it was agreed that escape mortality was also likely to have a significant impact.

The Group recognises that practical attempts to estimate the magnitude of individual sub-components of mortality need considerable investment, in terms of personnel and resources. A greater commitment from the scientific community and its funding authorities is required to achieve viable data in more fisheries.

Although there has been notable advancement in methods used for acquiring data for some mortality categories, eg escape mortality, most still require development. Particular effort is needed to insure that the data collected is a realistic reflection of the actual situation in commercial fisheries.

A potentially large impact on juvenile fish has been identified by escape survival studies. Future work in all areas should attempt to account for mortality in juvenile age groups, and identify fisheries in which the juveniles form a high proportion of the fished population.

The incidence and fate of fish that have multiple encounters with fishing gear is unknown. This is maybe most serious with mobile gear. Issues critical to this situation include species, size, degree of injury or stress and time between encounters.

A systematic review of past research in gear performance may provide simple estimates of sub-components of F.

The Study Group recognised that most work to date has attempted to estimate the magnitude of mortality and little effort has been invested in identifying its causes. It is important that the causes of mortality in each subcomponent of F are understood in order that improvements to capture techniques may be devised in attempt to reduce their impact upon a fishery. This work should identify potentially fatal injuries and their causative mechanisms. It is clear that this will a comprehensive approach, including post mortem, histological and pathological investigation and assessment of the physiological impact of injuries on individual fish. The pre-capture condition of fish should also be assessed with respect to its influence on an individual's survivablilty and the injuries it may sustain.

The following sub-components of mortality, identified at the previous meeting in 1995, are reviewed for specific points:

4.2 Illegal, misreported and unreported landings - F_B:

The Group is not aware of any significant advances in this category in recent years. In most fisheries little definitive data exists on the magnitude of this sub-component.

Discussion within the Study Group acknowledged this sub-component is likely to represent a significant proportion of total fishing mortality in some fisheries. This is recognised as a global problem and thought to relate especially to stocks that are under extreme pressure.

Recommendation: *The critical need for accurate data on this issue is re-emphasized. The suitability and quality of the techniques to acquire this data in each fishery need to be reviewed.*

4.3 Discards - F_D:

Recent improvements have been made in the acquisition and quality of data on discards in some fisheries (Alverson & Hughes, 1996); however it remains lacking in many other fisheries. As highlighted in the review, knowledge of discard rates in certain fisheries has improved, however the survival of these discards is largely unknown.

Most fisheries have a minimal utilization of discard generated in the fish capture process. This waste of discarded biomass is potentially avoidable and could be utilized in more beneficial ways. For example, major discards in the penneaid shrimp trawl fisheries are potentially useful in the production of fish meal for aquaculture.

Recommendation: *In fisheries were significant discarding has been identified, but cannot be resolved, efforts should be made to account for this mortality sub-component in stock assessment and management, and constructive utilization of the discarded material implemented.*

4.4 Escapees Mortality - F_E

Selectivity studies have been conducted for many years and the development of survival investigations has evolved primarily from this discipline. However, there is still a need to incorporate the estimation of survival more directly in the calculation of fishing gear selectivity. Selectivity of a gear, in terms of its use as a conservation tool, is useless if escaping fish do not survive.

In addition, there is a need to develop compatible data sets, that can both utilise existing survival data and be applied directly to stock assessment and management. For example, it is necessary to improve the current estimation of fleet selectivity.

The research carried out over the past few years has concentrated primarily on the estimation of mortalities of escapes from pelagic and demersal towed gears. The Group is not aware of any current work considering the survival of escapes from static gears. However the practical difficulties in attempting this are recognised.

Current techniques do not adequately reflect conditions encountered by fish in the commercial fishing environment. For example, factors such as catch size and composition, tow length, season, water temperature, depth and time of day may prove to be influential, but have not yet been investigated.

All present techniques to investigate escape survival collect fish in covers. This is the only practical technique currently available. However, it also has the potential to inflict additional injury and stress.

Recommendations: *Future work on survival of escapes in mobile gear should include whole gear selectivity and survival. Present methodologies have focused on cod end mesh survival studies. New technology will be required to obtain realistic data of the effects of the whole gear.*

4.5 Ghost Fishing Mortality - F_G

The review highlights the considerable potential for mortality from the loss of fishing gears. This is especially true for static gears, which have been shown to continue fishing for long periods of time.

Escapes from ghost fishing gears have been observed by divers and ROV studies. However, the fate of these escapees is unknown and there have been no attempts to investigate this.

Recommendations: *The potential for mortality from ghost fishing can be reduced by minimising the loss of gears. Greater accountability for lost gears (i.e. tagging of gear) may be a profitable direction. In areas where there are large densities of lost gears, recovery should be considered. Development of bio-degradable gears should be investigated to reduce the duration of ghost fishing by lost gears.*

4.6 Avoidance Mortality - F_A

The Group recognise that this category primarily concerns mobile gears, namely trawls and seine nets. Of these encounters, the greatest potential for mortality is likely to arise from enforced swimming ahead of the main body of the net and then passing over the headline or under the ground gear. In particular, the impact of heavy ground gears, for example beam trawls, hydraulic and scallop dredges and certain otter trawls may be substantial.

4.7 Predation Mortality - F_P

The Group now recognises that Fp should be considered as a subset of every other sub-components of F (excluding Fc). The potential magnitude of Fp may vary considerably with respect to each sub-components of F.

In some fisheries there is a suspected high magnitude of this sub-component. For example, observation of predation by marine mammals has been reported in trawling and static fish traps (Lien, 1996)

Attempts have been made to mimic the effects of predation after encountering stress or trauma. Due to great practical difficulties, these have not attempted to mimic natural conditions, i.e. they are confined to tank experiments. The Group recognise this as the single greatest limitation in correctly estimating this factor.

4.8 Drop Out Mortality - F_O

Dropout mortality is recognised as a potential problem in most gears, but there are great difficulties in its estimation. In some fisheries, catastrophic events may cause major mortality in this category . For example, in the Pacific walleye pollack fishery the codends of pelagic trawls are known to burst due to large catches. In addition, losses can occur from gears with full codends coming fast on the bottom and the collapse of purse seines in herring fisheries.

4.9 Habitat Mortality - F_H

Currently the information on habitat impact has been mostly qualitative, with little attempt to quantify the direct effects upon fish mortality. These effects are likely to be perceivable only on a long term basis. However, there is evidence of a direct short term effect upon spawning grounds in some species, in particular herring, and *Nephrops* burrows.

4.10. Standardisation of Methods

The Group recognises the need for standardisation of methods in the estimation of individual sub-components of F. Although, it is appreciated that the current status of this area of investigation is very much in development. This makes it impossible to recommend a standard method for investigation of the many fisheries and sub-components of F. The Group would like to recommend a number of key factors that should be considered by future researchers.

The calculation of any sub-component of F requires the evaluation of two factors: a) the number of fish experiencing potentially fatal interaction with fish gear and b) rate of mortality of these fish. Although these may be calculated separately, care must be taken to ensure compatibility between them and that their results are considered in combination . For example, selectivity should be integrated with survival studies and future definitions of selectivity must include survival potential of escaping fish.

In the calculation of both factors, the experimental techniques used must accurately reflect the conditions experienced by fish during the commercial fishing process. An account should be made of any existing differences, for example, catch size and composition, tow length, season, water temperature, depth and time of day.

With respect to estimating mortality rates it is essential that the following points are considered and accounted for:

- The potential for mortality as a result of the experimental method. This includes the collection of escapees and their captivity during the observation period and is best accounted for with the careful experimental design and effective use of controls. Future investigations should also consider the impact of apparently sub-lethal stresses in individual fish due to the experimental method. The potential for these to cause death, in combination with injuries and traumas received during the capture process, should be assessed.

- Care must be taken to avoid rapid changes in environmental conditions, particularly depth, temperature and salinity, during the transfer of fish from the area of capture to the observation site.

- Stocking density and feeding rates (if provided), and other aspects of fish husbandry, should be carefully regulated to ensure no undue stresses are experienced by the escapees.

- Containment of fish within cages during the observation period of survival investigation usually results in the exclusion of predators. In addition, the fish can be provided with food. The provision of these beneficial conditions are likely to underestimate the true mortality rates. However, predation within observation cages has been observed, eg Sculpin upon shrimp (Thorsteinsson, 1995). It is recommended that potential predators, or cannibals, are excluded from cages, as it will prove difficult to determine whether such predation is an accurate representation of true F_P.

- The potential importance of physical condition prior to capture of individual fish has on their catchability, survivability and on the health of the surviving population has been identified in (Chopin & Arimoto, 1995). Future studies should investigate this and determine the seasonal variation in the condition factors used.

5. CONCLUSION AND RECOMMENDATIONS

The Study Group reaffirms the recommendations made by the 1994 ICES Sub Group On Methodology of Fish Survival Experiments and the 1995 Study Group an Unaccounted Mortality in Fisheries.

The Study-Group on Unaccounted Mortality in Fisheries recognises:

- a continuing need to increase the awareness of fisheries managers, fisheries scientists and the fishing industry to the potential importance of Unaccounted Fishing Mortality;

- little or no data exists on the magnitude of each sub-component of fishing mortality as defined by 1995 Study Group an Unaccounted Mortality in Fisheries;

- illegal, misreported and unreported landings (F_B) and discards (F_D) are likely to be of most importance in the majority of fisheries. With respect to fisheries using mobile gears escape mortality is also likely to have a significant impact.

- while advancements have been made in the development of techniques to investigate the magnitude of some sub-components (namely, discard, escape and ghost fishing mortalities), further investment in the development of these techniques, and those for previously univestigated areas, are required if accurate estimates of fishing mortality are to be achieved.

The Study Group recommends:

A concerted effort is untaken to raise the awareness and understanding of Unaccounted Mortality in Fisheries among fisheries managers, scientists and the fishing industry.

A data base should be constructed, co-ordinated by the FTFB Working Group, to collect and collate any available data on all sub-components (except landed catch, illegal, misreported or unreported landings) of fishing mortality and used to identify future research priorities. This would be made available to the Methods Working Group and to the Stock Assessment Working Groups of ICES.

The mortality due to illegal and misreported landings has been identified by the Group as causing particular concern. It is recommended that immediate action be taken to estimate its magnitude and account for it in the relevant fisheries.

In addition to estimating the magnitude of mortality in all the sub-components of F. The Group strongly recommends identification of the causes of mortality in each case. Such knowledge is essential if the fatal mechanisms are to be identified and mitigated.

6. REFERENCES

ICES C.M. 1995/B:15 Ref. G

ICES Journal of Marine Science, 54. In press

Industry Development Division. Project Summary. Undersized crab survivability project. Fisheries and habitat management. DFO Nfld. region. IDD No. 3

Anon. (1993) Selectivity of Fishing Gears in Irish Waters. EU Contract BIO/ECO 1993/11 - Final Report.

Alverson, D.L, S. E. Hughes. 1996. Bycatch: from emotion to effective natural resource management. Reviews in Fish Biology and Fisheries. 6:443-462.

Breen, M. and G. Sangster, 1997. The injuries sustained by haddock (*Melanogrammus aeglefinus*) escaping from trawl codends and the implications of these to survival. Working paper

Bullimore, B., P. Newman, S. Gilbert, K. Lock, 1996. Study on the effects of fish (crustacea / mollusc) traps on benthic habitats and species: " Ghost Fishing " by lost pots. EU Study Contract 94/076 16p.

Erickson, D., E. Pikitch, E. Babcock, J. Walace, T. Builder, P. Crone, J. Brodziak and J, Rogers 1996. Survival of trawl-caught and discarded sablefish (*Anoploma fimbria*): evaluation of a sea-bed cage method. Cruise Report. National Marine Fisheries Service. Northwest Fisheries Science Center, Newport OR 97365

Kaiser, M.J., P. Bullimore, P. Newman, K. Lock, S. Gilbert. 1996. Catches in " Ghost fishing " set nets. Mar. Ecol. Progress Ser. 145 (11-16)

Lambert, J. and P. Goudreau. 1996. performance of the New England Hydraulic Dredge for the harvest of Stimpson s Surf Clam (*Mactomeris polynyma*). Canadian Industry report of Fisheries and Aquatic Sciences No. 235 28 p.

Lien, J. 1996. A review of present knowledge of collisions with fishing gear and the use of sound to prevent or reduce the entaglement of large cetaceans in fixed fishing nets and traps, and comments on working with fishermen on marine mammal problems. U.S. Marine Mammal Comission, Seattle Washington, U.S.A. March 1996.

Lowry, N. G. Sangster and M. Breen, 1996. Roundfish and *Nephrops* survival after escape from commercial fishing gear E.C. Study Contract 1944/005. DIFTA.

Pikitch, E.K. D.L. Erickson, G. Oddsson, J. Wallace, and E. Babcock. 1996. Mortality of Trawl-caught and discarded Pacific halibut (*Hippoglosus stenolepis*). ICES CM Doc. 1996/B:16

Sangster, G.I., Lehmann, K. and Breen, M. (1996). Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh cod-ends. *Fisheries Research.* **25(3-4)**, 323-346.

Thorsteinsson, G. 1997. Discards and survival of *Nephrops norvegicus* in Icelandic waters. Working paper.

Appendix 1:

Target and bycatch species catches (metric) tonnes retained, discarded and unaccounted for by fishery in the Bering Sea/Aleutian Islands. Data based on National Marine Fisheries Service (NMFS)

FISHERY (mt)	Biomass (mmt) [1]	Rock Sole 1.6	Atka Mackerel 1.2	Flounders 1.25	Turbot[2] 0.77
BT-Atka Mackerel	Retained	10	47,824	1	2
	Discarded	90	11,704	4	284
	Unaccounted	#N/A	#N/A	#N/A	#N/A
BT-Pollock	Retained	1,217	0	481	173
	Discarded	6,660	5	1,031	585
	Unaccounted	#N/A	#N/A	#N/A	#N/A
BT-Pacific cod	Retained	265	378	161	103
	Discarded	5,141	2,764	2,401	172
	Unaccounted	#N/A	#N/A	#N/A	#N/A
MWT-Pollock	Retained	22	0	155	64
	Discarded	2,018	41	2,411	558
	Unaccounted	#N/A	#N/A	#N/A	#N/A
BT-Rock sole	Retained	16,527	7	3,239	2
	Discarded	23,013	8	4,010	1,168
	Unaccounted	#N/A	#N/A	#N/A	#N/A
BT-Pacific Ocean perch	Retained	4	1,701	112	706
	Discarded	59	1,215	140	1,200
	Unaccounted	#N/A	#N/A	#N/A	#N/A
LL-Sablefish	Retained	0	0	0	235
	Discarded	0	0	1	1,035
	Unaccounted	#N/A	#N/A	#N/A	#N/A
BT-Yellowfin sole	Retained	3,042	0	2,629	0
	Discarded	4,505	0	7,057	5
	Unaccounted	#N/A	#N/A	#N/A	#N/A
LL-Pacific cod	Retained	0	4	10	224
	Discarded	18	17	196	715
	Unaccounted	#N/A	#N/A	#N/A	#N/A
LL-Halibut	Retained	0	0	0	0
	Discarded	#N/A	#N/A	#N/A	#N/A
	Unaccounted [4]	#N/A	#N/A	#N/A	#N/A
	Retained Catch (mmt)[5]	**0.021**	**0.050**	**0.007**	**0.002**
	Discarded Catch (mmt)[5]	**0.042**	**0.016**	**0.017**	**0.006**
	Stock Use Efficiency	**0.337**	**0.760**	**0.282**	**0.209**

NOTE: BT=Bottom Trawl; MWT= Midwater Trawl; LL=Longline; POT=Pot

[1] Biomass is exploitable sector
[2] Turbot includes Greenland Turbot and Arrowtooth Flounder
[3] Total Catch equals the sum of landings across all stocks for each fishery
[4] Halibut unaccounted for mortality is due to ghost fishing.
[5] Retained and Discarded Catch is summed across all fisheries for each stock.
[6] The percentage of a species catch actually landed.
[7] The percentage of the multiple species catch actually landed.
[8] Total catch and discard values for the rockfish fishery are too small to reflect numbers.

From: Alverson, 1996.

Bycatch

and International Pacific Halibut Commission (IPHC) stock and bycatch assessments, 1993. Biomasses across top of table are expressed in million tonnes. See text for explanation of stock use efficiency and ecological use efficiency.

Pacific cod 0.66	Pollock 6.7	Pacific Ocean Perch 0.3	Rockfish 0.5	Sablefish 0.037	Yellowfin Sole 2.5	Halibut 0.0015	Total Catch	Ecological Use [3]Efficiency
2,111	37	321	23	4	0	0	50,333	0.771
2,001	104	527	48	0	0	207	14,969	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
7,607	81,045	10	0	1	113	0	90,647	0.810
4,697	7,254	89	1	1	409	468	21,200	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
47,769	2,440	294	2	3	4	0	51,419	0.522
6,925	26,947	741	22	0	814	1,081	47,008	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
1,592	1,178,743	7	0	0	23	0	1,180,606	0.957
6,863	40,556	178	3	0	516	521	53,665	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
2,527	1,252	1	0	1	2,478	0	26,034	0.321
5,581	17,251	14	4	3	3,793	121	54,966	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
714	144	13,635	70	50	0	0	17,136	0.737
260	1,377	1,673	60	5	0	121	6,110	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
16	0	0	248	1,958	3	0	2,460	0.617
15	0	2	316	23	88	49	1,529	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
3,477	1,351	0	0	0	70,294	0	80,793	0.603
5,290	14,079	5	1	0	21,610	603	53,155	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
61,290	253	2	17	61	0	0	61,861	0.894
4,127	1,798	5	34	12	11	392	7,325	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	
0	0	0	0	0	0	1,724	1,724	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	51	#N/A	
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	51	#N/A	
0.127	**1.265**	**0.014**	**0.000**[8]	**0.002**	**0.073**	**0.002**		
0.036	**0.109**	**0.003**	**0.000**	**0.000**	**0.027**	**0.004**		
0.780	**0.920**	**0.815**	**0.424**	**0.979**	**0.728**	**0.326**		

$$\text{Ecological Use Efficiency} = \frac{\sum RetainedCatch}{\sum RetainedCatch + \sum DiscardedCatch}$$

$$\text{Stock Use Efficiency} = \frac{\sum RetainedCatch}{\sum RetainedCatch + \sum DiscardedCatch}$$

Appendix 2:
From: Lowry et al., 1996.

100 mm diamond