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Report of the Working Group on Ecosystem Effects of Fishing Activities

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1. Introduction.

1.1 Terms of reference

At the 1992 Statutory meeting it was decided that (C.Res.1992/2:4) the Study Group on Ecosystem Effects of Fishing Activities will be renamed the Working Group on Ecosystem Effects of Fishing Activities and will work by correspondence during 1993 with the purpose of meeting early in 1994, to:

a) analyze existing data on discards and offal to study temporal and spatial variations in the amounts that are produced by different fisheries and their utilization by, and effects on, different components of the system;

b) evaluate methods of assessing impacts of groundfish fisheries on the benthic infauna and epifauna with particular reference to P/B related approaches;

c) analyze existing survey data in terms of appropriate summary parameters for species assemblages, with a view to initiating a study of biodiversity and changes in community structure;

d) consider the attributes that would be appropriate to define indicator species for the evaluation of long-term impacts of fishing in order to initiate a review of information on a variety of marine species that meet these attributes;

e) develop a design and planning framework for establishing areas of appropriate size that are closed to all fishing in order to monitor the response of benthic communities in heavily fished areas and plan monitoring activities and process studies that could help understand the impacts of fisheries.

The present report contains an inventory of ongoing research related to ecosystem effects of fishing activities as reported by members of the Working Group. The scope of this research is wide and overlap with other Working and Study Groups is difficult to avoid. Additional information on the effects of physical disturbance of the seabed can thus be found in the report of the ICES Benthos Ecology Working Group (C.M. 1993/L:3) and projects aiming at quantifying the by-catch of marine mammals are presented in recent reports from the ICES Study Group on Seals and small Cetaceans.

1.2 Participation

The following individuals have contributed to the report:

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N. Daan	The Netherlands
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2. Ongoing research

2.1 Benthos

The effects of physical disturbance of the bottom fauna by gears in contact with the seabed is subject to several research programs. Most of these programs involve quantification of the direct impact in the path of the gear from direct observations and/or inference of the longer term impact from comparisons of fished and unfished areas, but some of the studies also aim at identifying the processes determining the longer term response.

At the Marine Laboratory, Aberdeen (SOAFD), an experimental study of suction dredging for cockles on the west coast of Scotland is planned to involve fishing of large replicated plots in order to examine the effects on and the recovery of non-target macrobenthic fauna. The study is scheduled to last for three years and will be conducted at two contrasting locations. Another study will address the effects of frequency and spatial scale of fishing disturbance in inshore waters. The aim of this experiment is to determine which processes are most important for determining the recovery rates of affected areas. The effect of the frequency and spatial scale of the disturbance on the recovery rates will be studied by comparing plots of different size disturbed at three different time intervals (e.g. every 7 days, 14 days and 28 days). Finally a model of the importance for benthic communities of the natural physical disturbance from waves and currents is being developed. This involves sediment transport equations to calculate erosion depth probabilities for different types of habitat and measured wave climatologies.

The Netherlands Inst. for Fisheries Investigations (RIVO) is studying the microdistribution of beam trawl fisheries in the North Sea in order to estimate the frequency by which the seabed is disturbed in various areas. Attempts will be made to relate the microdistribution of fishing effort to the experience of the crew and to the physical characteristics of the sea floor (e.g.) wrecks, stones, Offshore installations).

In relation to the establishment areas closed to fishing in the North Sea, several dutch institutes (Netherlands Institute of Sea Research (NIOZ), RIVO, RWS-North Sea Directorate, RWS-Tidal Waters Division, IBN, IKC-NBLF) are planning how to conduct studies of the effect of closing an area off the island of Texel. Six areas have been proposed of which one will very soon be selected. All of the areas are located in the Environmental Zone which harbours a number of different species assemblages. The Environmental Zone was established by the dutch government (Water Management Plan North Sea, 1991-1995) as a specially protected area in which stricter regulations on contamination and other human impacts on the marine environment have been implemented in order to secure its sustainable use and the recovery, preservation and improvement of ecological quality. In the Environmental Zone and adjacent areas on the dutch continental shelf, studies on spatial and temporal trends in benthic communities (macrobenthos and meiobenthos) are continued in order to further identify indicator species and to assess trends in benthic community parameters.

The IMPACT programme which is being coordinated by RIVO and NIOZ considers the environmental impact of bottom gears on the benthic fauna. The IMPACT I programme (1992-93) involves 6 institutes in The Netherlands, Germany and Belgium, while the IMPACT II programme (1994-1996) will involve a total of 11 institutes in The Netherlands, Belgium, Germany, Ireland and UK. The latter programme will consist of four complementary subprojects: 1) Collection and analyses of historical and present-day data on catch and discard composition, vessel and gear characteristics and fishing areas. 2) Comparative field research to document the direct effects of different types of bottom trawl fisheries in the southern and central North Sea. 3) Analysis of fishing effects in previously unfished areas. 4) The fate of discards with special reference to their impact on the benthic ecosystem.

As a part of the IMPACT I programme NIOZ is studying the direct impact of 12m beam trawls on the bottom fauna in the Oysterground area and the impacts of 4m beam trawls and shrimp trawls in the coastal zone. The experiments are directed towards estimating the percentage of in- and epifauna caught in the trawl, the survival of species after being caught in the net and handled on board, the proportion of the individuals of various species injured after one passage of the beam trawl and after repeated trawling, the rate of influx of predators and scavengers towards the impacted area and the resulting rate of predation on the fauna which has been dug out of the sediment by the gears. In order to improve the estimates of the abundance of the larger sized benthic species a new benthos dredge has been designed.

Also within this programme the Fisheries Research Station in Oostende, Belgium, has studied the tracks of a 4 m beam trawl by means of side-scan sonar and *in situ* inspection by divers. Experimental fishing has been performed on sandy bottoms on the Flemish Banks. The side-scan sonar revealed detectable trawl marks for up to 52 hours after fishing. The divers, however, could not recover the tracks and no direct measurements of the penetration depth could be made. However, from the recordings of the side-scan sonar it appears that the penetration depth of the gear was less than expected and that the gear only penetrated the uppermost part of the sediment. The average pressure of the sole plates on the bottom was measured by means of instruments fixed to the beam trawl head and was found to vary between 0.1 and 0.3 kg/cm^2.

Finally, in Germany the Alfred-Wegener Institut für Polar und Meeresforschung, the Bundesforschungsanstalt für Fisherei (BFAF) and the Institut für Meereskunde, Kiel, perform investigations on the medium and long term changes in macrobenthos in relation to fishing. Two areas are studied in the North Sea. An area 20 nm west of Helgoland has been subjected to experimental beam trawling in order to study the recovery of benthic populations. A baseline study revealed that this area was uniform with respect to depth, hydrography and sediments. 99 taxa were found in 10 vanVeen grab samples and 12 epifauna samples obtained by dredging and otter trawling. The fauna included species such as *Aphrodite aculeata, Corystes cassivelanus* and *Pagurus bernhardus*, which have previously been reported to be strongly affected by heavy bottom gear. The other area is a

'quasi-protected' area close to the wreck of the 'West Gamma' platform which is situated 60 nm northwest of Helgoland. This area is expected to have been fished less intensively over the last three years than neighbouring areas. Analysis of species composition of the benthos in the vicinity of the wreck showed a north south gradient which seemed to reflect a gradient in sediment characteristics with coarser sandy sediment in the north and finer sand in the south. A total of 135 taxa were found in 32 grab samples and 8 dredge hauls. There was no relation between the number of species and individuals and the distance of the sampling station from the wreck.

In Northern Ireland interest on the impact of fishing on benthos is centred on the impact of Queen scallop trawling on *Modiolus* communities in Strangford Lough. Strangford Lough's depth and shelter means that the fine muds on the bed of the Lough are relatively stable. This has allowed the formation of extensive *Modiolus* beds which form a suitable substrate for many species more usually found on firmer substrate. Strangford Lough has been proposed as a likely Marine Nature Reserve and the *Modiolus* associated communities have been identified by local environmental groups as having great conservation value. In 1990 the Department of the Environment (NI), Countryside and Wildlife Branch initiated a survey of Strangford Lough in order to map the extent and scale of the otter trawl fishery for Queen scallop on the *Modiolus* communities. The study used underwater video, grab sampling and side-scan sonar techniques. The side-scan sonar showed that most of the impact resulted from the action of the trawl doors on the seabed and suggested that sediment structure was changed in the areas most intensively impacted. Qualitative benthic infauna samples have yet to be worked up. The Aquatic Sciences Research Division (DANI) has begun further research in this area will include monitoring of the recovery of previously trawled areas. Other work will be centred around quantifying the rate of the impact and accompanied by studies of species and community level responses to disturbance.

MAFF (Conwy) is studying the effects of beam trawling on benthic communities at a site off the north Wales coast where benthic communities are relatively undisturbed by fishing. Benthos samples taken before and after repeated beam trawling along the same track, indicated a significant decrease in the density and biomass of sessile animals after fishing. Analysis of dogfish and gurnard stomach contents showed that the proportion of certain animals in their diets increased after beam trawling. Species in the by-catch showed a wide range of survivorship, e.g. 90% of the starfish, 48% of the swimming crabs and 0% of the dragonets survived after 72h in running sea water. In 1993 two cruises will be devoted to an experimental programme in which the effects of the frequency and intensity of beam trawling on the benthos and movement of predators into the fished area will be studied. The programme will monitor changes in benthos community structure over a period of several years.

The Marine Laboratory, Port Erin, Isle of Man will commence a study on the effects of commercial scallop dredging on benthic communities on the scallop grounds of the Isle of Man. The results will be compared with studies of the benthic communities in a zone where scallop fishing is excluded.

In France, IFREMER is conducting a multidisciplinary research programme in the Bay of Saint-Brieuc (north coast of Brittany) to assess the effects of bottom fishing gears on benthic communities and commercially exploited resources. An intensive fishery for scallops (*Pecten maximus*) started 30 years ago, but today with the declining scallop stock fishermen have diversified their activities. Approximately 300 small vessels are now fishing within the bay using bottom trawls, scallop and clam dredges. The research programme aims at evaluating the short and long term impacts on the macrobenthos and sediment with special attention to the impact on the commercially exploited resources. Data collected by divers and underwater video and by sampling of the benthos have been used to assess the short term impact of the various gears. The long term changes of the sediments in the bay will be assessed by comparing recent data collected by side-scan sonar, underwater video and bottom samples with a sedimentological map established just before the scallop fishery started. Another study will consider how trawling and dredging may contribute to the dispersion of the

introduced *Crepidula fornicata* pest.

At the Institute of Marine Research, Lysekil, Sweden, the non-catch mortality generated by the fishery for *Nephrops* is being studied.

In Canada, the Bedford Institute of Oceanography and the Northwest Atlantic Fisheries Centre of DFO have for the past three years collaborated in a research program directed at evaluating the impacts of mobile fishing gear on the seafloor and benthos. This has included the analyses of previously collected side-scan sonar records for evidence of bottom disturbance by fishing gear, the development of new equipment to study the seabed and its fauna (towed platform, epibenthic sled, video grab, and high resolution acoustic systems), and three controlled experiments on the impacts of otter trawls (one nearshore and two offshore).

Analyses of the available side-scan sonar records from the Scotia-Fundy region showed that less than 2% of the records contained any evidence of physical disturbance from mobile fishing gear. Most of the observed disturbance was due to groundfish trawls and was restricted to areas of low sediment transport. About 15,000 km of side-scan sonar records from the Grand Banks were also reviewed. Less than 10% of the total length of these records showed any evidence, even slight, of disturbance caused by otter trawls. The south and eastern areas of the Banks were more intensively trawled than other areas, but even in these areas over 90% of the line segments with trawl tracks were in the $<5\%$ disturbance category and less than 1% were in the heavy disturbance ($>25\%$) category. In the Bras D'Or Lakes approximately 240 km of survey lines were covered using a high-resolution side-scan sonar and a bottom profiler.

In collaboration with the Acadia University, the impacts of otter trawls on the intertidal sediments of the Minas Basin (11 m tidal range) have been investigated. Experimental trawl tracks were made at high tide and observations of effects were made at low tide when the intertidal area was exposed. Door furrows and roller marks remained visible for 2-7 months. No significant impacts were observed on either benthic diatoms or macrobenthos (dominated by polychaetes). Nematode numbers were initially depressed in the door furrows but recovered with time.

Cruises were conducted in 1991 and 1992 to locate suitable sites for the main offshore trawling impact experiments. For these experiments, an attempt was made to select sites which: 1) had never been trawled (or dredged), or had not been trawled in recent years, so that benthic communities were in a "natural" state; 2) could be protected from mobile gear disturbance for the duration of the project (at least five years); 3) had sediment types and benthic communities representative of large areas of the shelf; and 4) had uniform conditions of depth, sediment type, etc. to reduce sampling variance. Two general areas were investigated, one on Western Bank on the Scotian Shelf and another on the Grand Banks.

Western Bank is a nursery area for haddock and has been closed to trawling since 1987. The area is, however, still open to scallop dredging and considerable physical disturbance by scallop dredges was detected by side-scan sonar.

The Grand Banks site, which had been selected in consultation with the fishing industry, was finally chosen for the controlled trawling experiments. The site is 10 times 10 nautical miles square and is centred at 47^{0} 10' N, 48^{0} 17' W with an average depth of 137 m. It has not been subjected to heavy trawling in the past decade, and now is closed to all mobile gear for an indefinite period. Side-scan sonar survey records of the "Closed Area" show no signs of physical disturbance from fishing gear, although there is some evidence of iceberg scouring. The sediments, consisting mainly of fine sands, harbour an abundant and diverse community of benthic organisms, including a well-developed epibenthic assemblage.

Two controlled trawling experiments, conducted in collaboration with the Atlantic Geoscience Centre, were carried out on the Grand Banks site in July 1993. One experiment involved the laying down of a single 60 km long trawl mark crossing a variety of bottom types, depths, and energy levels. The objective is to determine the rate of physical degradation of the trawl mark in these various sediments and energy regimes. The other, and main experiment, involved the repeated experimental trawling (12 passes each) of three randomly oriented 200 m wide and 13 km long corridors within the "Closed Area". Side-scan sonar, video, and biological sampling surveys were performed before and immediately after experimental trawling in the experimental corridors and once in the parallel control corridors. A second cruise, one month later in August, will evaluate residual impacts over the short-term. This will be followed by further sampling at three months (October) and at one year post-trawling. It is intended to continue annual sampling for up to five years if longer-term impacts are demonstrable. In subsequent years, experiments to evaluate the impacts of different levels of trawling intensity and frequency are being considered.

2.2 Fish

Studies of the discarding of commercial and non-commercial species of fish from the major fisheries have indicated that considerable amounts can be involved. Apart from the regular discard sampling programmes undertaken by SOAFD and RIVO plans have therefore been made by a number of laboratories to collect and/or analyze additional information on discards. BFAF has intensified the collection of discard data from the cod and flatfish fisheries, DIFMAR is now collecting information on discarding in the Danish North Sea gillnet fisheries and IFREMER is in the process of quantifying the amounts of discards from the main artisanal trawl and gillnet fisheries in the Western Channel.

A joint project by SOAFD and DIFMAR will utilize discard data collected between 1987 and 1991 to estimate the amount and species composition of discards of non-commercial species of fish from scottish and danish demersal trawl fisheries. The results will consist of total catch and length composition of species such as grey gurnard, dab, rays, long rough dab and flounder by quarter, area and vessel category.

A joint project is being undertaken by MAFF (Lowestoft) and RIVO aimed at quantifying the fishing mortality of dabs, gurnards and rays in the North Sea by comparing estimates of the total amounts discarded from dutch beam trawlers with survey estimates of biomass.

The longer term impact of fishing is being studied by SOAFD. Data from ground fish surveys are being analyzed in order to reveal changes in the structure of the fish community in the north western North Sea. Analysis of data from the time period 1972 to 1991 has not revealed any effects which could be linked to fishing. In order to detect such effects longer time period seems to be required and for this reason data from the 1930's to the present are in the process of being entered into the computer and analyzed. Another study addresses how changes in the stock biomass and age structure of cod, haddock, whiting and saithe in the North Sea have affected the total consumption of their various prey.

At the Instituto Español de Oceanografía, Santander, data from bottom trawl surveys in the Bay of Biscay are being analyzed in order to reveal changes in the distribution and abundance of benthic invertebrates and fish of no commercial interest in areas of high fishing activity. It is also planned to quantify the amount discarded from the commercial fleet and the influence of the discards on the diet of scavenging species.

2.3 Sea Birds

Additional work has been carried out on the importance of discards and offal for scavenging sea birds in the North Sea.

Several members of the working group have been involved in a project organised by NIOZ aimed at studying seabird feeding on discards in winter in the North Sea. Observers were placed on board five research vessels during the International Bottom Trawl Survey in February 1993. Good coverage of the entire North Sea was obtained although the waters off Norway, and those within 10 km of coasts were not covered as fully as others. Seabird densities were assessed using standard techniques, and counts were made of birds following the research vessels on 834 occasions, covering 148 hauls. Counts were also made at 108 commercial trawlers encountered during the survey. Fish were discarded experimentally on 101 occasions. About 6500 fish or other bits of potential food were measured and identified prior to throwing overboard, and their fates were recorded. About 86% of the experimental discards were picked up and about 83% swallowed. Offal and roundfish were handled and consumed more successfully than flatfish or benthos.

At the Inst. für Vogelforschung "Vogelwarte Helgoland" additional work has been started on the utilization of discards of fish, offal and invertebrates by seabirds in the North Sea and in the inner German Bight. Data from research surveys have been used to derive an estimate of the total amount discarded from the german sole fishery. In June and July seabirds near Helgoland consumed 51% of the fish discarded, while a similar investigation in November and February showed that 79% of the discards were consumed. A positive correlation was found between the catch of fish and the numbers of ship-following birds. Additional projects will use aircrafts and fisheries inspection vessels to map the distribution of fishing vessels in the German Bight and to estimate the numbers and species composition of birds in association with beam and otter trawlers in the Bight.

A joint project by JNCC, SOAFD and DIFMAR will identify the areas in the North Sea where industrial fisheries and seabirds may directly compete by quantifying the spatial and temporal overlap of seabirds, their suspected prey (i.e. sandeel, sprat and juvenile herring) and the industrial fisheries on these species. In order to allow further investigations of the relationship between seabird breeding success and the abundance of their food the surveys for sandeel around Shetland and to the north and west of Scotland will be continued.

The BFAF is investigating the by-catch of fixed gears in the Baltic. In 1991 and 1992 a total of 3 cruises with commercial vessels participating in the driftnet fishery for salmon revealed a by-catch of a few seabirds, of which only one was dead. The western Baltic is an overwintering area for many seabirds. Since 1991 the by-catch in the coastal winter gillnet fishery has been investigated during five cruises. A lot of seabirds, mainly eider ducks (*Somateria mollissima*), are caught at certain fishing grounds. Experimental fishing has been performed with a newly developed gillnet designed to minimize the by-catch of seabirds without reducing the catch of fish.

Further data on the incidental by-catch of seabirds in gillnets will be collected by DIFMAR and by the Norwegian Institute for Nature research.

The Canadian Wildlife Service's (CWS) responsibility for managing migratory marine bird populations have shown the need for quantification of anthropogenic influences such as marine transport and fisheries on seabirds. CWS in eastern Canada has undertaken a number of studies which assess the impacts of traditional fisheries and aquaculture on birds. Two such initiatives are: a model of food demands of western Atlantic and Arctic sea bird populations, and an assessment of the by-catch of seabirds in the gillnet fishery in Newfoundland.

The first initiative, the model of energy demands of seabirds in eastern and Arctic Canada, integrated data from intensive studies at breeding colonies with extensive data on pelagic distributions of seabirds using bioenergetics equations as a bridge. In this model data were run independently for small geographic cells then aggregated into oceanographic zones. Food requirements for the area under study averaged 1000 Kg/km^2/yr.; slightly lower than valued previously obtained for George's Bank and the North Sea, probably because much of the Canadian area is under ice for part of the year. Energy demands were highest on the southern Labrador Banks (10.2 X 10^6 kj/km^2/yr.) and lowest on the Scotian Shelf (2.9 X 10^6 kj/km^2/yr.). In most areas of the study, year-round energy demand came mainly from non-breeding birds, especially from populations breeding in other geographic regions (northeast Atlantic, southern hemisphere).

The second initiative was necessitated by the large increase in use of gillnets in the inshore fishery in Newfoundland in the last few decades. Gill nets are often set close to seabird colonies and an unacceptably high by-catch of birds, estimated to be tens of thousands of birds per year, has been taken. The Canadian Wildlife Service, in co-operation with the Department of Fisheries and Oceans and a fisherman's union, had planned an experiment in which the catches of both fish and birds in normal and high-visibility white gill nets would be assessed. This approach was advocated by fishermen who fish in an area of particularly high bird bycatch. They maintain that they have caught fewer birds in white monofilament nets. The closure of the fisheries for cod and salmon in Newfoundland has necessitated the postponement of this experiment.

2.4 Marine mammals

IFREMER and Centre National d'Etude des Mammiféres Marins are conducting a study on the by-catch of small cetaceans in the driftnet fishery for albacore tuna in the northeast Atlantic in collaboration with the Sea Mammal Research Unit and the University of Barcelona.

BFAF has collected data from the set net fishery for sole in the German Bight. The by-catch consisted mainly of cod, plaice, dab and edible crab (*Cancer pagurus*). No sea mammals were caught. It has been reported that the German gillnet fleet occasionally catches harbour porpoises in the area west of Sylt and investigations of the by-catch in this area are planned.

DIFMAR is involved in a study of the by-catch of small cetaceans in the danish North Sea gillnet fisheries for cod and turbot. The aim of the study is to provide an estimate of the total annual by-catch in these fisheries. The incidental by-catch will be recorded by observers on board the commercial vessels. By taking recent studies of the spatial distribution and abundance of harbour porpoise into account the relative importance of different seasons and areas will be evaluated.

In Canada the Scotia-Fundy Region of DFO has been examining the bycatch impacts on north Atlantic harbour porpoise (*Phocaena phocaena*) of Canadian and U.S. sink-line gillnet fisheries in the Bay of Fundy/Gulf of Maine.