SECTION II

BYCATCHES AND TRAWL FISHERIES

THE PACIFIC GROUNDFISH TRAWL FISHERY BYCATCH PROBLEMS AND POTENTIAL SOLUTIONS

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ABSTRACT

Bycatch has been a growing problem in trawl fisheries for more than a decade. The problem is a result of the non-selectivity of trawl gear, the attitude of fishermen regarding bycatch, and the regulations employed to manage the fishery. The Pacific groundfish trawl fishery is one of the most regulated fisheries in Canada. In an effort to manage to prescribed species TAC's, restrictions have been implemented which limit the catch per trip and the number of permitted trips. These measures have, unfortunately, lead to increased fishing effort and further bycatch and discarding problems. The following presentation looks briefly at the development of the Pacific groundfish trawl fishery, associated bycatch and discarding problems, and discusses management options for remediation.

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RESEARCH AND DEVELOPMENT EFFORT IN BY-CATCH ELIMINATION IN TRAWL FISHERIES OF BRITISH COLUMBIA

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The Deep Sea Trawlers Association was formed in 1980 as a consequence of problems and changes in the trawling industry. As the industry progressed, our Association had to take different lines and different points of view. The real crunch came in the late 1980s and particularly in 1990 when the Department of Fisheries and Oceans (DFO) introduced new regulations and trip limits which made it really difficult to go fishing rockfish. Until this time, more than 30 species of rockfish were fished and if they were red fish, they were put all together in one bin. But as a result of these regulations, this was no longer possible. The Association was at a loss what to do and in 1990 put a think-tank together which included personnel from the higher echelons of DFO, major BC fish processors and other major players in the industry to try and come up with some solution to deal with the DFO management plan. The result of this think-tank was the recognised need for the Association and it members to participate in the development of management plans for the fishery and to contribute their expertise. In 1991 the Association adopted the position whereby the fishery should have a sustainable yield and operation of trawlers, it should be economically viable and environmentally clean. And that's tough: anybody that's been a fisherman knows that that's tough.

After the think-tank, we organised a Gear Selectivity Workshop. Out of the workshop we put a technical group together, again Processors, DFO, Ministry of Agriculture Fisheries and Food, the Union and the Association were represented. It was recognised that for there to be a viable trawling industry by-catch had to be reduced and as far as possible eliminated. By-catch of halibut was identified as a major problem, the trawl fishery causing major mortality of halibut. We do catch halibut and we do have to

Videophotography revealed that fish in the Paulegro trawl codend appeared agitated and were continuously showered with sediment and debris raised by the bobbin line. In contrast, fish in the semi-pelagic trawl codend were swimming with the net; the plume of sediment and the sound of the ground tackle moving over the substrate was greatly reduced.

The semi-pelagic trawl is considered commercially viable in the trawl fishery in the Arafura Sea, as evidenced by the similar catch rates and sizes of the targeted snappers in both trawls, and comparable production costs. The semi-pelagic trawl also enhances product quality by reducing the unwanted catch of fish, benthos and debris, and environmental disturbance was significantly less than that of the Paulegro net due to much reduced impact on the substrate, damage to the benthos and catch of unwanted components. While our analysis of catch data could not detect the shearing and dislodging of benthic structures by the sweeps, videophotography of the semi-pelagic trawl footrope showed no such damage even at the point closest to the substrate (0.3 m off the bottom). We conclude that this type of semi-pelagic trawl is "environmentally friendly" and commercially viable in the tropical snapper trawl fishery off northern Australia. Further research on by-catch reduction is now underway to improve the selectivity and efficiency of ground trawls (e.g. Mounsey et al, 1994; Ramm and Xiao, submitted).

ACKNOWLEDGMENTS

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SECTION III

BYCATCHES AND PASSIVE GEAR FISHERIES

WORLD BYCATCHES OF SHARKS IN HIGH-SEAS FISHERIES: APPRAISING THE WASTE OF A RESOURCE

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ABSTRACT

Estimates of bycatches of sharks in each of the major high-seas fisheries of the world are presented for the first time. Although necessarily rough due to generally poor baseline information, present estimates indicate that sharks are the leading bycatch in this type of fisheries. The total bycatch of sharks and relatives in these fisheries amounted to about 11.6-12.7 million fish or 260-300 thousand t per annum during the late 80's-early 90's. The most important sources of the problem are first the long-line fisheries for tunas and billfishes and secondly the recently banned high-seas driftnet fisheries for various species. Other less important sources of shark bycatches are purse-seine and pole-and-line fisheries for tunas, and the orange roughy fisheries around New Zealand. Estimates of the levels of discard from all these fisheries are also very high. The impacts of such removal rates on shark populations, as well as other problems of shark-fisheries interactions are discussed.

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INTRODUCTION

Several large-scale fisheries operating in the high seas around the world are known to capture elasmobranchs, particularly sharks, as a substantial by-catch. Although sharks are retained and utilized in some of these fisheries, most frequently they are simply thrown overboard, sometimes after having had their valuable fins chopped off, and discarded to an almost certain death.

The amount of elasmobranchs killed in large-scale high seas fisheries is poorly understood and has not been systematically assessed. Reports on the sharks taken by the countries involved in these fisheries do not reflect the real incidental by-catches but most frequently only the amounts retained. The purpose of this paper is to present for the first time a global assessment of elasmobranch by-catches in the most important high-seas fisheries of the world, the amounts taken and the total discards.

The main fisheries analysed were:

- Drift gillnet fisheries
  - North Pacific Ocean
    - Salmon fishery
    - Flying squid fishery
    - Tuna/billfish Large-mesh driftnet fishery (LMDF)
  - South Pacific Ocean LMDF
  - Indian Ocean LMDF
  - Atlantic Ocean LMDF
- Longline fisheries
  - Atlantic Ocean
  - Indian Ocean
  - Tropical and South Pacific
  - North Pacific
- Purse seine fisheries for Tunas Worldwide
- New Zealand Orange Roughy fishery

All other fisheries which incidentally capture elasmobranchs were considered to either include their elasmobranch catches in their official statistics, or their by-catches to be effectively negligible.

DATA SOURCES

Most of the information presented here came from reports of the International North Pacific Fisheries Commision (INPFC), the International

Commission for the Conservation of Atlantic Tunas (ICCAT), the Inter American Tropical Tuna Commission (IATTC), the Indo Pacific Tuna Development and Management Programme (IPTP), and other international bodies. Incidental catches were estimated where no estimates already existed and were then compared with reported landings for each fishery or country in order to assess the quantities of elasmobranchs wasted each year and not included in the official statistics of world fisheries. Reported catch rates were extrapolated to the total effort/catch of each fishery, although in some cases it was proportion of sharks in the catch that was extrapolated to the total catches.

ESTIMATES OF SHARK BYCATCHES

Before their demise at the end of 1992, following UN resolution 44/225, high-seas driftnet fisheries were a very important source of elasmobranch by-catches. Total elasmobranch by-catch could have been between 3.28 and 4.31 million sharks and rays per year during 1989-1991, or in the order of 20,000-38,000 t/year. Total discards of elasmobranchs at sea from driftnet fisheries could have been between 20,803 and 30,500 t/year.

High-seas longline fisheries for tunas and billfishes are a very large source of by-catches and discards of elasmobranchs worldwide. Despite the uncertainty surrounding the different estimations, it is nonetheless evident that the amount of effort exerted by longlining fleets (worldwide total of about 750 million hooks) is the main reason for the high by-catch estimates. The grand total of elasmobranchs caught incidentally by longlining fleets in all the high-seas of the world is estimated at almost 8.3 million fishes or an astonishing 232,425 mt. This represents almost a third of the total world catch of elasmobranchs reported in commercial fisheries by FAO in 1991.The level of by-catches of blue sharks in longline fisheries is very large. Present estimates suggest a total of 4'075,162 blue sharks caught incidentally in the high-seas longline fisheries of the world.

The estimated total catch of sharks in purse seine fisheries during 1989 is of 6,345 t. This estimate is very uncertain as it was based on a single (and poorly representative) account of shark catch rates in tuna purse seine operations in the Western Indian Ocean. The accuracy and precision of the assessment will only improve when more information on catch rates becomes available and as our understanding of the seasonal and spatial changes in the shark-tuna associations increases.

Pole and line fisheries for tunas take some shark by-catches while fishing tuna schools. However, they are very poorly documented and no assessment was possible. It is likely, due to the global scale of pole and line fisheries for tunas that their by-catch of sharks could sum to a significant total, perhaps in the order of magnitude of that from purse seiners.

The orange roughy (*Hoplostethus atlanticus)* fishery of New Zealand is known to take deep water squaloid sharks and other elasmobranchs in their bottom trawl nets. Based on research surveys for orange roughy, the total by-catch of squaloid sharks could be between 4,400 and 22,000 t/y in this fishery. The current catches exceed by far the MSY estimated by New Zealand researchers. The impact of this level of by-catch on the local stocks of deep-sea sharks is poorly known.but it is highly unlikely to lead to sustainable exploitation. However, this is difficult to verify when there is virtually no information about the actual levels of by-catch, survival of discards and about the popualtion dynamics of these deep water sharks.

The estimated grand total of elasmobranch by-catch from all high-seas fisheries considered here at the end of the 1980's, is believed to be around 260,000 and 300,000 t or 11.6-12.7 million fish per year. Most of these catches were sharks, predominantly blue sharks.

Discards from high-seas fisheries also appear to be very high. The figures suggest that up to 230,000-240,000 t of elasmobranchs are discarded every year in the various high-seas fisheries. The fate of most of the discards is probably death, almost certainly for those caught by the driftnet, purse seine and orange roughy fisheries. For longline fisheries, survival depends on whether fishermen release sharks readily and unharmed. Nevertheless, common finning practices make dubious that survival is high in longline operations.

DISCUSSION

Longline fisheries are the most important source of shark kills in the high-seas, mainly because of the magnitude of their effort. They contribute about 80% of the estimated total elasmobranch by-catch in weight and about 70% in numbers of fish. There is large uncertainty around the estimations performed for this type of fisheries. However, the figures are based on the best available information and they seem to compare well with the few reference points available.

The former high-seas driftnet fisheries ranked second for their contribution to the total elasmobranch by-catches. Since their activities were terminated worldwide at the end of 1992, they are now one less problem to worry about in terms of sea-life conservation.

Available information on purse seine and pole-and-line tuna fisheries and the deep trawl fisheries for orange roughy make it very difficult to assess the importance of their by-catches of sharks and rays. Presently, they seem to share a minor part of the total by-catch of elasmobranchs but there is a big gap in direct information on this subject. More, simple research, is needed in this field.

There is another substantial source of by-catch and waste of sharks and rays around the world. This is the incidental catch of bottom trawling vessels fishing for shrimps and fishes in continental shelves. The assessment of the impact of these fisheries upon elasmobranchs is out of the scope of this work primarily because of the extreme difficulty in gathering information about them and the magnitude of this quest.

In contrast with driftnet fisheries, there is no observer programme for any of the high-seas longline fisheries in the world. This accounts for much of the uncertainty surrounding the estimates of non-target species caught in longline fisheries. It is worth noting that most of the international tuna organizations and the governments of longline fishing nations mandating logbook reports from longliner fleets, still do not require or enforce the reporting of by-catches of sharks or other elasmobranchs. Some of these organizations are taking steps to change this situation. This should help reduce the uncertainty about the real levels of by-catches and discards in the near future. Considering the common underreporting of elasmobranchs in longliner logbooks, observer programmes are undoubtedly the best way to tackle this crucial information problem.

A total estimation of elasmobranchs caught and discarded in high-seas fisheries worldwide is problematic when neither of these processes are adequately documented. Discard rates and concurrent survival rates are virtually unknown. There are large uncertainties about the catch rates that should be applied to each region and sometimes also about the effort levels. Additionally, the estimates presented here are derived from the sum of estimates for each fishery and consequently carries along a good degree of accumulated uncertainty. We should expect qualitative and quantitative variations in the elasmobranch by-catches within each ocean due to areal and seasonal changes in availability of the different species. Unfortunately, these sources of variability could not be taken into account in the present work with the available information. In this sense results presented here should be treated with discretion and used only as a first approximation of the level of elasmobranchs removed by high-seas fisheries worldwide. They do however highlight the problems found when trying to assess the magnitude of the elasmobranch by-catch and the proportions dumped to the sea.

CONSERVATION PROBLEMS

Blue sharks are the most common elasmobranch caught incidentally in high-seas fisheries. Present estimates are that 6.2-6.5 million blue sharks are taken annually worldwide in these fisheries. Although this is apparently the first estimate of total catches for blue sharks in all high-seas fisheries of the world, the assessment of blue shark by-catch presented here seems to be within values found for specific fisheries reported elsewhere.

Our current level of knowledge prevents an assessment of the impact that the removal of 6 million blue sharks annually has on high-seas ecosystems or on the blue shark populations. There is virtually nothing known about the size of the stocks of blue sharks anywhere in the world and the biology of most populations is poorly understood. Research is badly needed both to assess the real by-catch levels in each fishery and their impacts on the different populations.

Silky sharks are probably the second most commonly caught species, specially in longline and purse seine fisheries. As for blue sharks, appropriate information is lacking to assess the impacts of the removal levels. In any case, their characteristics of growth and reproduction compare poorly to those of blue sharks, i.e. silky sharks have slower growth, later sexual maturation and are much less fecund. Hence, they are expected to be less resilient to exploitation than blue sharks. Again, much research is needed before it is possible to draw conclusive statements in this field. Local stocks of *Deania calcea, Etmopterus baxteri* and *Centroscymnus spp.* in New Zealand could be added to the list of elasmobranchs under possible threat by large-scale fisheries.

World catches of elasmobranchs are substantially higher than reflected by the different kinds of official statistics. Statistics reported to FAO amount to just below 700,000 t for 1991. The results presented here suggest that the total catch (as opposed to landings) could be closer to 1 million t. If we add to this the bycatches in bottom trawl fisheries in coastal areas and the recreational catch of elasmobranchs, the real total level of sharks, rays and chimaeras caught around the world is probably closer to 1.35 million t or more per year, twice the official statistics.

The by-catch of elasmobranchs in high-seas fisheries around the world seem to be a major source of concern for conservation due to the very high numbers of sharks killed. Blue sharks in particular might be facing extreme pressure in many parts of the globe because of these fisheries, but more specific studies are needed in order to address the real situation.

The possible threat that high-seas fisheries pose to elasmobranchs is actually only one part of a complex technical interaction. There is substantial gear and catch damage caused by sharks in most of these fisheries and this translates directly into economic loss for the fishing industries.

A possible way to solve this dual problem could be to install shark deterrent devices in passive fishing gears (these account for most of the elasmobranch kill). The Natal Shark Board in South Africa is currently testing a promising electroacoustic device to protect bathers from shark attacks without having to kill the sharks. Another possibility would be to design new selective fishing gear that could substantially reduce shark hooking rates. However, for the time being the only viable alternative is the implementation of suitable by-catch quotas for elasmobranchs in the high-seas fisheries of the world through international agreement, and their reinforcement via observer programmes.

(*Note from the editors*: a full version of this paper can be found in F.A.O. Fisheries Technical Paper 341, F.A.O., Rome, 1994).

MANAGEMENT OF BYCATCH IN HOOK-AND-LINE GROUNDFISH FISHERIES OFF ALASKA

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ABSTRACT

In 1993, hook-and-line gear took 90% of sablefish, 34% of Pacific cod, and 86% of Greenland turbot in the EEZ off Alaska. The principal bycatch species is halibut; negligible numbers of crab, salmon, or herring are taken. In the Bering Sea and Aleutian Islands (BSAI) area 13% of total groundfish-fishery-induced halibut *mortality* was from hook-and-line gear, and in the Gulf, 41%.

Several different approaches to reduce such halibut mortality have been made in the last few years: setting halibut caps, setting seasons for target species and cap apportionments, and requiring careful release of halibut. In 1993 the Gulf Plan Team recommended the following as general methods to control bycatch: incentive programs, timing of groundfish seasons, and seasonal apportionment of halibut PSC limits. The Team also suggested that license limitations would reduce halibut catch.

Other non-regulatory approaches have been taken recently to provide information to fishermen to help lower bycatches. During 1994 the catcher/processor fleet has supported a private effort to monitor and avoid halibut "hot spots". Also in 1994 historical hook-and-line observer data (1979-1992) was developed into a series which maps catch and bycatch by time and area strata.

For future attention: How much will sablefish ITQ program reduce bycatch - and how will we know? How effective has "careful release" regulation been, and can it be improved? Are there other time/area closure approaches that can have some positive effect?

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Hook-and-line fisheries off Alaska target on groundfish species including Pacific cod, sablefish, Greenland turbot and rockfish (Fig. 1). The chief bycatch species is Pacific halibut, which may not be retained in groundfish fisheries. Concern for traditional fisheries for halibut has prompted the North Pacific Fisheries Management Council (NPFMC) to impose halibut mortality "caps" which close a target groundfish fishery if reached. To avoid reaching these caps, or at least to maximize the catch of target groundfish species before closure, both regulatory agencies and industry have implemented several approaches in recent years. Hook-and-line fisheries in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) management areas have had very different histories, so the halibut bycatch management approaches have varied in timing and detail between the two areas.

<u>Gulf of Alaska Halibut Bycatch Reduction Methods</u>

In the GOA, the hook-and-line sablefish fishery (with recent annual quotas of around 20 000 mt) was the first Alaska groundfish fishery to become "Americanized" after enactment of the Magnuson Fishery Management and Conservation Act of 1976. Later, Pacific cod became a target both for catcher/processors and for smaller boats delivering shoreside, with a 1993 catch of about 9 000 mt. In the Southeastern area of the GOA, a small (under 1 000 mt) state-managed fishery for demersal shelf rockfish occurs. The 1993 ex-vessel value of all these fisheries was $52 million.

In 1993, hook-and-line gear caused 1 289 mt of halibut mortality or 41% of the GOA total (Fig. 2). The first GOA halibut cap was imposed in 1990; this cap (740 mt) was later seasonally apportioned into trimesters to allow for a winter fishery for Pacific cod and a spring fishery for sablefish. The only cap specifically imposed for a target fishery is for demersal shelf rockfish, which in 1992 was given its own cap of 10 mt.

In 1991, the sablefish season was delayed to begin May 15 instead of April 15, in order to let halibut migrate out of deeper waters where sablefish are caught. In 1993 the hook-and-line fleet exceeded its cap by 85% due to higher than expected bycatch rates in the sablefish fishery. Much of the high bycatch can be attributed to huge effort during the short (one to two weeks in most areas) season, which results in many vessels being displaced into shallower areas where more halibut are present. One of the expected benefits of the sablefish and halibut Individual Fishing Quota program, to be implemented in 1995, is that the extended season will alleviate such crowding and halibut discards will decrease.

Bering Sea/Aleutian Islands Halibut Reduction Methods.

In the BSAI, hook-and-line activity has increased dramatically with the growth of the catcher/processor fleet. Hook-and-line Pacific cod catch increased from 14 219 mt in 1989 to 101 249 mt in 1992. The trawl fishery for Greenland turbot had been closed in 1992 and 1993 due to its extremely high halibut bycatch rates, and hook-and-line gear took advantage of the niche: its catch increased from 1 130 mt to 7 086 mt. The sablefish target fishery, pursued mostly along the Aleutian Island chain, has remained fairly stable (2 648 mt in 1993); it has been unable to expand in part because of gear-stripping by killer whales. Total ex-vessel value of all BSAI targets in 1993 was $38 million.

In the BSAI area in 1993, 13% of total groundfish-fishery-induced halibut mortality was from hook-and-line gear (Fig. 2). Responding to the rapid growth of BSAI fixed gear fisheries, NPFMC imposed a a halibut cap in 1992 which was then divided between the Pacific cod target (680 mt) and all other fixed gear fisheries (220 mt). In 1994 NPFMC divided the fixed gear Pacific cod quota (45% of total allowable catch) seasonally to provide a winter and fall fishery and to avoid high halibut bycatch rates encountered in late spring and summer.

Other Halibut Bycatch Reduction Measures

Common to both the BSAI and GOA is a regulation implemented in 1993 which requires careful release of halibut from fixed gear. (An industry-sponsored program promoting careful release was carried out in 1992). The International Pacific Halibut Commission (IPHC) analyzes halibut mortality information collected by federal observers and recommends rates that are used in mortality calculations each year. In these calculations, non-observed boats are given a higher assumed mortality rate than observed boats. Following the BSAI Pacific cod spring 1994 season, each observed vessel was informed of its own calculated halibut mortality rate and provided with overall fleet statistics. This has been the first opportunity for fishermen to become aware of the variablity of this key component of halibut bycatch monitoring and to put their own vessel's performance into context. Further analysis is needed to discover why such variability exists and how mortality rates can be improved.

Non-regulatory tools are also being developed to reduce halibut bycatch. During 1994 the catcher/processor Pacific cod fleet has supported a private program to monitor and avoid halibut "hot spots". Set-by-set data collected by federal observers was sent twice-weekly from each participating vessel to FIS, who compiled and mapped the rate information, and returned it to the fleet (Fig. 3). Vessels were able to move from high-rate areas; overall, participants had a spring season bycatch rate about 20% below that of the rest of the fleet. Success of this sort of "micro-management" program is dependent on quick turnaround of data, and its vulnerability was evidenced in the fall season when communication problems interfered with data transfer; this suggests that such programs should not be implemented by regulation unless an absolutely dependable information system is in place.

Also in 1994, the Department of Commerce's Saltonstall-Kennedy program supported FIS with a grant to develop historical federal observer catch and bycatch data into a format usable by fishermen and managers. The resultant five-volume series includes maps showing rates (kilograms per hook) for target species and Pacific halibut bycatch, by time (weekly and/or monthly) and area (1/2 degree latitude by 1 degree longitude) strata (Fig. 4). Volumes include BSAI Pacific cod, Greenland turbot and sablefish, and GOA Pacific cod and sablefish. Each volume is further subdivided into foreign and domestic fisheries data sections, reflecting differences in fishing operations and in time (most foreign data are from 1979-1987 and most domestic data are from 1988 to 1992). Fishermen can use the series to plan where and when to fish in accordance with historical patterns. Fisheries managers can use the series to develop further time/area closures, if appropriate (although this management tool has been mostly used in trawl fisheries to date).

Control of halibut bycatch in hook-and-line fisheries off Alaska is effected by a combination of regulatorily-imposed and independently operated programs. Key to the success of both is the proper collection, analysis and prompt dissemination of information to fishermen and managers alike.

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Fishermen's Guide to Catch and Bycatch Alaskan Hook-and-Line Fisheries. Parts 1-5. 1994. Fisheries Information Services, 20007 Cohen Drive, Juneau, Alaska 99802.

FIG. 1 SPECIES COMPOSITION HOOK-AND-LINE CATCH

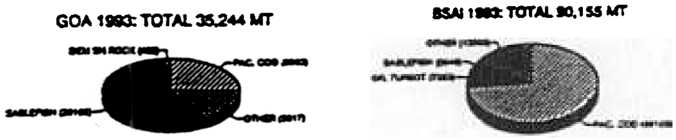
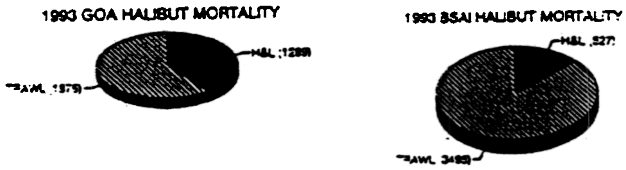


FIG. 2 HOOK-AND-LINE SHARE OF HALIBUT MORTALITY (MT)



1994 SPRING COD SEASON: "HOT SPOT" PROGRAM

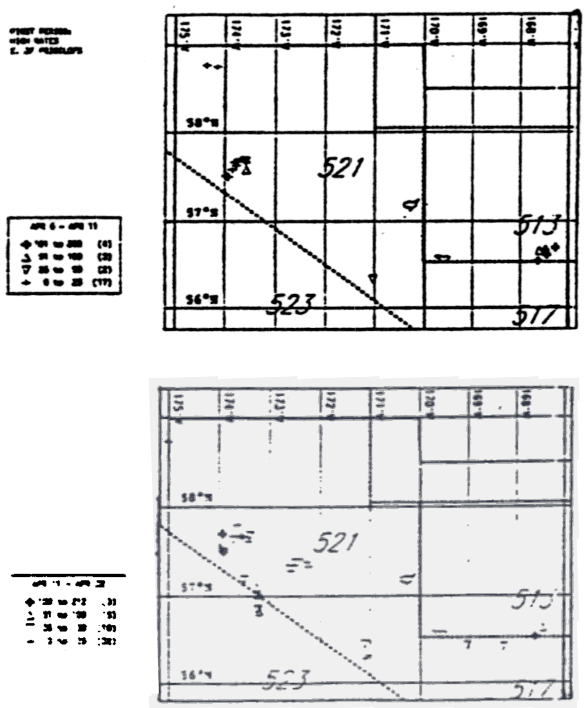
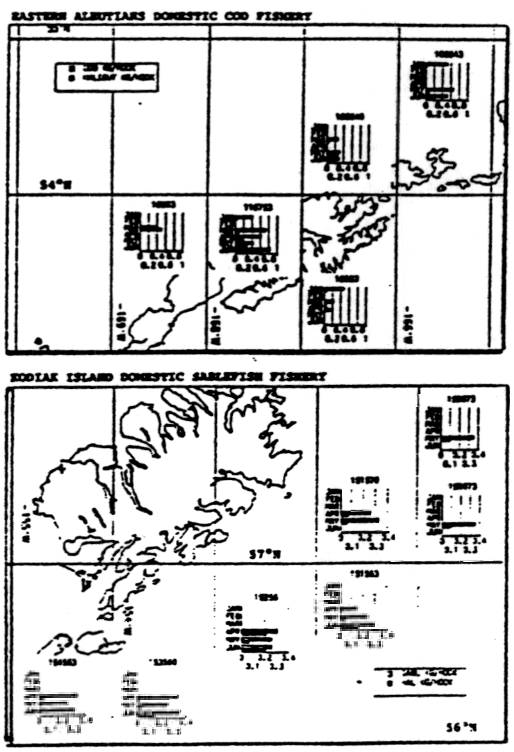


FIG. 4 SAMPLE PAGES FROM FISHERMEN'S GUIDE



BYCATCH OF STEELHEAD AND COHO SALMON IN THE SKEENA RIVER SOCKEYE FISHERY

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ABSTRACT

The Skeena River salmon fishery is the second largest salmon fishery in British Columbia and the third largest sockeye salmon (*Onchorynchus nerka*) fishery in the world. Several user groups harvest the salmon during their migration including: Alaskan gill net fishermen, British Columbia seine boats and gill net boats, the aboriginal food fishery, and sport fishermen. Because of similar migration timings, the sockeye fishery has incidental catches of less productive species, most notably steelhead (*O. mykiss*) and coho salmon (*O. kisutch*). Management's goal is to reduce steelhead interception by 50% in three years. A brief history of the management of the fishery is presented as well as the current management's use of a computer simulation model in conjunction with a test fishery.

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INTRODUCTION

The Skeena river is a large system (watershed area 35,000 km^2) draining into the Pacific Ocean just south of the British Columbia-Alaska border (see figure 1). In British Columbia, the Skeena is second only to the Fraser River for salmon production and is the third largest sockeye producer in the world, behind Bristol Bay, Alaska and the Fraser River. It includes 21 major sockeye stocks and 16 steelhead stocks. The number of coho stocks has not been documented but can be estimated at greater than 20. The biology of Skeena river sockeye have been extensively studied (Brett 1952, Larkin and McDonald 1968, Smith and Jordan 1973, Takagi and Smith 1973, McDonald and Hume 1984, West and Larkin 1987). Current and historical management of the Skeena sockeye fishery has been documented in Sproat and Kadowaki (1987).

The Skeena has 4 major tributaries: Bulkley, Babine, Kispiox, and Sustut and several smaller tributaries including: Lakelse, Bear, Alastair, Kitwanga and Kitsumkalum. The Babine system and its tributaries currently produce 95% of Skeena river sockeye. Steelhead and coho production is more evenly distributed between the various tributaries.

THE FISHERY

Sockeye are the most valuable of the five commercially exploited pacific salmonids and the Skeena sockeye fishery is of considerable economic importance. There has been a directed commercial fishery for sockeye on the Skeena since 1877. Catch data start in 1904 and catch and escapement data go back to 1943 (McDonald et al. 1987). Sockeye has always been the principle target on the Skeena, but by 1920, all species of salmon were fished commercially. Management of the five commercially exploited species is the responsibility of the federal government while management of the sport fished steelhead is the responsibility of the provincial government.

In 1946 a permanent fish counting fence was completed on the Babine River and in 1955 the test fishery at Tyee was established. Calibrated against the Babine fence count, this test fishery gave a daily estimate of sockeye escapement and formed the basis of a rational in-season management system. Weekly closed times are varied according to fish abundance and escapement targets.

FISHERS

There are five different groups catching Skeena river fish as they migrate to their spawning grounds. The fishery starts in Alaska, of which little is known about the exploitation rates. After the fish reach Canadian waters, they are fished by the Seine fleet. The exploitation rate for the Alaskan fishery and for Canadian Areas 1,3, and 5 is assumed to be 25%. Continuing their migration into Statistical Area 4, the fish are harvested by the gill net fleet 15 km into the river. Upstream of this boundary the fish encounter First Nations and recreational fisheries.

The First Nations fishery occurs mostly with gill nets but also occurs by more traditional methods like harvesting using a gaff. The aboriginal fishery is primarily a food fishery, but excess sockeye (overescapement) are allowed to be caught and sold by the First Nations fisherman.

The other in river pressure comes from the recreational fishery. The sport fishery for salmon is a kill fishery but the fishery for steelhead is non-consumptive.

ENHANCEMENT

Beginning in the mid 1960's, 3 spawning channels were built on two tributaries to Babine Lake under the assumption that the lake could support more sockeye juveniles (McDonald and Hume 1984). An increase in sockeye production of between 500,000 and 1,000,000 sockeye per year has been attributed to these three channels. It is interesting to note that the increased production did not occur until 12 years after these facilities began operation (Hilborn and Winton 1993).

BYCATCH

The bycatch problem (harvest of non-target species) on the Skeena is due to migration timings of the different species, and different stocks within each species, occurring at the same time (see fig 2). For management purposes the run timing of the different species of fish is often represented as a single distribution. This is incorrect since this distribution includes several different stocks.

THE PROBLEM

Since 1980, increased fishing effort has occurred to exploit the increased production of Babine sockeye. This increased fishing effort has caused a decrease in less productive sockeye, coho, and steelhead stocks. In 1991, a goal was established by the federal Department of Fisheries and Oceans to decrease steelhead interceptions by 50% within 3 years. The estimate of steelhead exploitation by the federal fishery managers was 36%, the exploitation estimate by the provincial steelhead biologists was 62%.

EARLIER EFFORTS

Earlier efforts of selective harvest included lowering commercial gill nets 1.2 meters below the weedlines. Initial tests indicated a 60-70% reduction in steelhead catch with a 20-30% reduction in sockeye catch. There have been 2 problems with weedlines; 1) It is not known whether *overall* steelhead mortality would be reduced to 30-40% or whether *each net* contributes 30-40% mortality. The fish encounter dozens of nets on their migration. If each net kills 40% of the vulnerable fish, the cumulative mortality is still too high. 2) fishermen feel that a loss of 20-30% of their fish is unacceptable.

There has been a policy of voluntary live release of steelhead from gillnets. It belived there is low compliance to this policy and up to 70% mortality for those fish which are released (B. Ward, Ministry of Environment, Lands and Parks, pers comm).

The third procedure for selective harvest is seine brailing. This method involves transferring fish from the seine net to the hold using a large dip net rather than bringing the fish on board by the seine drum. It is believed mortality is reduced allowing live release of non-target species. The effect of this practice has yet to be quantified.

CURRENT POLICY

The current practice is to vary fishing effort over time and space. This can occur at different scales. For example, it is known that coho are most vulnerable at dawn and dusk; not fishing at these times is a possible solution to coho bycatch. The dropping of the nets for steelhead was described earlier.

A management model has been developed to account for catch and escapement. The model incorporates the "boxcar" theory; fish pass through a series of fisheries before escapement. Harvest is regulated by varying effort over time and location. The model occurs on a daily time step and calculates catch and escapement past the fishery. It treats statistical Area 4 as four sequential fisheries prior to escapement (see figure 3). We have empirical data about migration rates and timing, catchability in each of the four regions, and the relationship between cpue and number of boats. Some assumptions must be made, it is assumed that 25% exploitation occurs outside area 4, and 6% exploitation occurs in the river due to the first nations and sport fisheries. Other assumptions are for ease of calculation such as uniform distribution of fish within each sub-area and constant speed and direction of fish migration.

The model was calibrated to empirical data; using no weedlines and current openings, sockeye harvest is 40% and steelhead harvest is 36%. Eight management options were examined involving presence or absence of weedlines and varying fishing openings over time and space. Three of these options gave the desired result of 50% steelhead reduction and a 40% sockeye harvest. Common factors were use of weedlines, moving the sockeye harvest earlier in the season and increasing fishing time to account for loss of sockeye due to the weedlines. The model indicates the overall goal is attainable however, each species is treated as a single distribution. The model was not designed to account for different stocks so we do not know the effect of these various management policies on individual sockeye, steelhead, or coho stocks. The model is not used in the daily management of the fishery but as an exploration tool to assess the various management options. The best harvest strategy was established before the season started.

IN-RIVER FISHERY

The First Nations river fishery is being encouraged to use alternative harvest techniques such as live traps, weirs, and fishwheels. These methods allow release of non-target species. Currently, few of these alternate fishing methods are in use and gill nets are still the primary means of harvest.

FUTURE WORK

More work needs to be done on the stock component of the fishery. Stock identification of steelhead by molecular techniques is currently being performed. Both management agencies are optimistic that the goal of a 50% reduction in steelhead bycatch can be obtained.

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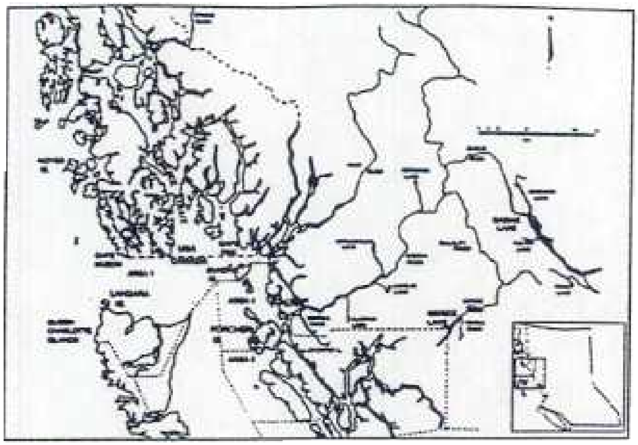

Figure 1. Map of the Skeena river and its major tributaries. Inset shows position in British Columbia.

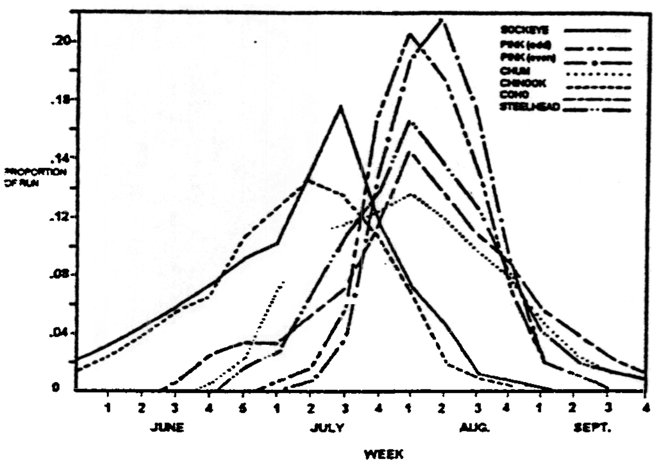

Figure 2. Graph displaying run timings of the various species of salmon and steelhead in the Skeena River.

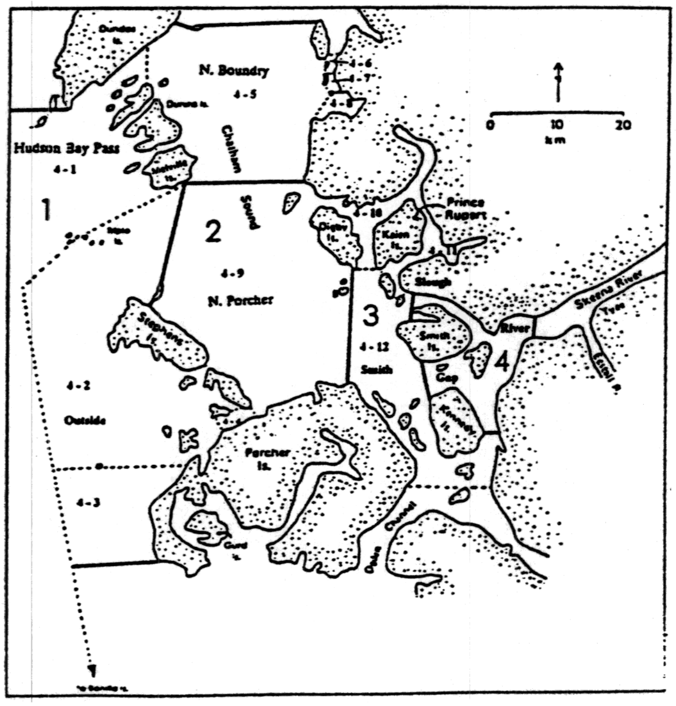

Figure 3. Map of the four sequential fisheries used in the management model.

SECTION IV

BYCATCHES AND PURSE-SEINE FISHERIES

BYCATCHES IN PURSE-SEINE FISHERIES

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ABSTRACT

A brief discussion of the bycatches in purse-seine fisheries is presented, using as a study case the tuna purse-seine fishery from the eastern Pacific.

There are major differences in the utilization of the catch between purse-seine fisheries that produce fish for the reduction industry or for the canning or fresh market. In the former, most of the catch can be used; in the latter, the fishermen retain only some of the mixture of species and sizes that are caught. The bycatch may originate in an ecological association between species, or in a random event. Some examples illustrate these types.

The dolphin bycatch in the tuna purse-seine fishery of the eastern Pacific has been reduced by 97% in the past seven years. A brief description of the changes in technology and training that led to these results is presented, to illustrate the gradual and diverse manner in which progress was achieved. There have also recently been attempts to quantify the bycatches of other species and the ecological costs that occur in alternative fishing methods to setting on dolphins.

Some of the possible ways to increase purse-seine selectivity prior to capture (better information on school composition, on problem areas or techniques) and after capture (types and sizes of mesh, sorting of fish in the net, handling of fish on deck) are briefly discussed.

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INTRODUCTION

In this review, I will not attempt to summarize all that is known about bycatches in purse-seine fisheries, but only to address some of the common traits of most problems with this type of gear. The readers are directed to Alverson *et al.* (1994), for additional information. The scientific names of all species mentioned are listed in Appendix 1.

As opposed to passive gears that are deployed in a habitat that is deemed favorable to catch fish, purse seines are deployed "on fish." When a set is made, the fishermen almost always know that they are encircling a school of fish, and they have a pretty good idea of the species encircled and of the sizes of fish in the school. The accuracy of this information changes from fishery to fishery and from species to species, and may be affected by oceanographic or meteorological factors. In spite of this, there are bycatches of non-target species and/or of unmarketable individuals of the target species.

From the point of view of the bycatch, it is necesary to distinguish the purse-seine fisheries that produce fish for canning or fresh consumption from those that produce fish for the reduction industry.

Because of the characteristics of the product, fishmeal plants can utilize a wide variety of species, even the catch of non-target species can be utilized and becomes a "catch." Practically all sizes caught can be utilized, so there is no discard of unmarketable fish (Guillory and Hutton, 1982). The fact that almost everything can be utilized doesn't mean that there is no ecological impact from some of those captures. It can be argued that to utilize for making fishmeal, species that could be used instead for direct human consumption is a sub-utilization of a resource. Also, the takes of juveniles or small-sized individuals of species of commercial value that may be captured with the target school, are a form of growth-overfishing. Apparently, the larger species incidentally caught in some reduction fisheries are discarded at sea or while unloading (Guillory and Hutton, 1982), so it is not possible to assess this impact.

When the object of the fishery is the canned or fresh-fish market, the fishermen have to be more selective. In some cases, undersized fish of the target species require more labor, and that affects the production costs, to the extent that some canneries cannot afford to process the smaller sizes. Or they may not be acceptable to the consumers. Most non-target species cannot be used in the cans, and their utilization depends on the existence of a market for them. If there exists such a market, and the price per ton is not much lower than the target species, then they can be retained and sold, becoming part of the catch. Unfortunately, in many cases there are no markets for some species, or the price differences are too high to justify the loss of space in the vessel wells, so they are discarded at sea.

From the ecological point of view, the bycatch in purse-seine sets comes from two sources: (a) the "associated" bycatch, composed of individuals that were swimming (or feeding, or resting, or any other behavioral pattern) in association with the target species, and (b) the "chance" bycatch, composed of individuals that happened to be in the area enclosed by the net or wandered into it during its deployment.

Examples of the first type are the sharks and billfishes that are caught with tunas and dolphins in the eastern Pacific Ocean; the types of association include both temporary and long-lasting ones, and the relationships involved in the association include predators that were feeding on the target species, competitors that were feeding on the same prey items, small-sized conspecific individuals that were part of the same school, members of polyspecific aggregations (Au, 1991), prey that were being consumed by the target species, etc. As most fish schools have some degree of size segregation, it is unusual to find a broad range of sizes in the same school, but fish smaller than the smallest size that is accepted by the market may be within the range present in the school, and that will generate discards from the catch. Another situation leading to the capture of a mixture of sizes is the encirclement of two or more schools that may be associated in a temporary way around a food source, as a response to predators or other perceived threats, or to some oceanographic feature.

Examples of the second type of bycatch include sea turtles, the proverbial innocent bystanders, caught in sets on tunas associated with dolphins. For small purse seines, the second type may be low, but for large nets (e.g. 1.5 km long and 200 m deep) the volume enclosed is so large that those chance captures may occur frequently.

The mortality of purse seine-caught animals is caused by asphyxiation due to crowding in the sack of the net, entanglement in the net, and asphyxiation on the deck of the vessel. Air-breathing animals may also become trapped in some portion of the net beneath the surface of the water and asphyxiate. Occasionally animals which are alive, but entangled in the net, may be carried toward the power block and fall from there to the deck, which is likely to injure or kill them.

SOME EXAMPLES OF BYCATCHES IN PURSE-SEINE FISHERIES

There has been a problem with dolphin bycatches in the tuna purse-seine fishery of the eastern Pacific Ocean since the late 1950s. For reasons still unknown, yellowfin tuna swim with some dolphin species. The most common way of fishing in that area is to encircle a group of dolphins to capture the tuna school that is associated with it. In the early years of the fishery, the levels of incidental mortality of dolphins were high (average of about 350,000/year during the 60s),which caused declines in most of the dolphin populations involved. The fishermen soon found ways to reduce the incidental mortalities, and the levels of mortality dropped to 20,000 to 40,000 in the early 80s. More recently, more effort on dolphins, and the incorporation of many skippers and crews that had no experience in this way of fishing caused the mortality to increase again, peaking in the mid 80s. The last few years have seen a decline of about 97 % in mortality, from 133,000 in 1986 to 3,600 in 1993 (Lennert and Hall, In Press). Most of these improvements came from the development of a series of modifications of the purse-seine, and the application of sound techniques to release the dolphins encircled (National Research Council, 1992; Joseph, 1994).

The changes include technology and procedures:

1) different mesh sizes in some portions of the net,

2) an additional maneuver after encirclement, the "backdown",
3) the use of towing speedboats and a skiff,
4) the use of a dolphin rescue raft,
5) a different tying up of the corkline,
6) the addition of a floodlight on the vessels,
7) the use of a jet engine auxiliary boat,
8) .. new concepts are being tested at this time

And also education and training to improve the decision-making of the skippers and the special skills of the crews:

1) training of speedboat and skiff drivers,
2) training of raftperson,
3) training of deck boss and crew in the handling and maintenance of the equipment,
4) training of skipper and crew on the backdown maneuver,
5) training of skippers to identify the risk factors that lead to high dolphin mortality, and the counteractions required.

The reasons to include a long list of rather specific information are: I) illustrating the variety of changes that can be tried; II) showing that even though some developments were more influential than others, there was no magic solution, but an accumulation of small and large changes over decades; III) that technology alone did not solve the problem; IV) that the process is still moving forward. From the beginning of the fishery, when annual mortality was, on average, close to 350,000 to the level of 3,600 in 1993, the reduction in bycatch was 100-fold. But it wasn't fast, it wasn't easy, it wasn't cheap.

In recent years the dolphin populations have remained stable (Anganuzzi and Buckland, 1994).

Another common way to purse-seine for tunas is to use the association of tunas with floating objects of different types. Again, for reasons unknown to scientists, tunas of some species (e.g. yellowfin, skipjack, and bigeye) associate during the night with drifting objects. Besides the tunas, other species of fishes, invertebrates, reptiles, etc., associate with these objects, forming characteristic communities. This way of fishing is common in all oceans of the world (Fonteneau and Hallier, 1992), and different studies (*e.g.* Habib *et al.*, 1982; Hampton and Bailey, 1993; Scott and Anganuzzi, 1992) show that the communities involved are quite similar in composition. Typically they include mahi-mahi, wahoo, several shark species (silky, whitetip, hammerheads), several ray species (manta, stingray), yellowtail, rainbow runners, several billfishes (black, blue, and striped marlin, swordfish), several small tuna species (frigate and bullet tuna, black skipjack, triggerfishes, sea turtles, etc. When a set on a log is made, many of the species listed above are caught incidentally. Table 1 (see paper on Classification of bycatches ... in this report) shows the ecological costs, in terms of bycatches, of producing 1000 tons of yellowfin tuna in different types of sets (associated with dolphins, with logs, or not associated). It illustrates the dangers of making decisions without complete information, and focusing on a single problem. The reductions in dolphin mortality that can be achieved by switching the mode of fishing, have a counterpart in the increase of the bycatches of many other species. To assess whether the alternatives are "better" from the ecological point of view requires a large amount of information which is not currently available (abundances and conservation status of different species, mortality rates from different sources, recruitment rates, etc.)

HOW TO IMPROVE THE SELECTIVITY OF A SEINE

The first step toward improving selectivity in purse seines is to increase the amount and quality of the information available to the fishermen before deploying the net. Better information on the species and size composition of the schools to be encircled should lead to better decisions concerning whether to deploy the net, or in the deployment itself. This information may be acquired by visual means (e.g. helicopter overflights) but more likely by acoustic techniques. Better sonars, that are affordable to the fishermen, should result in significant improvements.

One way to contribute to this goal is to identify areas that are consistently problematic and to avoid them. Areas with large numbers of juveniles of the target species, or of some other species could be closed to fishing, or could be avoided voluntarily. Another way is to identify modes of fishing that have higher incidences of bycatches than others, and reduce their frequency.

HOW TO IMPROVE RELEASE FROM A SEINE

After encirclement, the characteristics of the net play a major role in reducing bycatches. Several experiments showing the impacts of different mesh sizes and of different types of mesh (square, hexagonal, diamond-shaped) on the escapement of fish which are encircled by seine have been conducted. A recent review can be found in Ben Yami (1994). The regulation of mesh sizes of trawls and other nets has been used for many years to limit the captures to some desirable sizes. However, the fact that some fish escape the net doesn't necessarily ensure that they will survive. Some species, such as mackerel, have little resistance to the physical stresses involved in the capture process, and die soon after release (Pawson and Lockwood, 1980), while others are much more hardy. These differences highlight the need to back up the management decisions with experiments to determine if the effects sought can actually be achieved.

Perhaps different species, or different size-groups could be manipulated inside the net, to allow their release when it is desired. This type of solution would require a solid knowledge of the behavior of the different species in the net, especially of their horizontal and vertical stratification, and their responses to different stimuli that could be used to herd them or separate them (*e.g.* air curtains (Smith, 1963, Kim and Choo, 1993), sounds, scents, lights, etc) and also the development of modifications in the net such as zippers (Coe *et al.*, 1984) or the use of rigid grids inside the net to facilitate the escapement of the smaller fish (Beltestad and Misund, 1993). The development of some system that would allow the tranfer of the catch to some kind of floating cage, through a chute where the fishers could sort the catch, would be a major step towards solving many of the bycatch problems in different fisheries. If this transfer could be performed before crowding the fish in the net, those fish released should have high survival rates.

In the case of small cetacean bycatches, some of the techniques and equipment developped in the eastern Pacific fishery to release them from the net could be used in other purse-seine fisheries, some of which have, or are believed to have, incidental takes of dolphins (Northridge, 1984,1991).

The possibility of changing the methods of handling of the unwanted fish after they have been brought on board cannot be discounted. This may work only in the case of the most resistant species, such as sharks, because they must survive not only crowding in the net, but also the crushing in the brailing system and lack of water on their gills on the deck of the vessel.

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APPENDIX 1

Tunas

yellowfin tuna	*Thunnus albacares*
skipjack tuna	*Katsuwonus pelamis*
bigeye tuna	*Thunnus obesus*
black skipjack	*Euthynnus lineatus*
frigate tuna	*Auxis thazard*
bullet tuna	*Auxis rochei*

Dolphins

spotted dolphin	*Stenella attenuata*
spinner dolphin	*Stenella longirostris*
common dolphin	*Delphinus delphis*

Billfishes

black marlin	*Makaira indica*
blue marlin	*Makaira mazara*
striped marlin	*Tetrapturus audax*
swordfish	*Xiphias gladius*
sailfish	*Istiophorus platypterus*

Sharks and rays

silky shark	*Carcharhinus falciformis*
blacktip shark	*Carcharhinus limbatus*
whitetip shark	*Carcharhinus longimanus*
hammerhead shark	*Sphyrna spp.*
manta ray	*Manta spp., Mobula spp.*
sting ray	*fam. Dasyatidae*

Other large pelagic fish species

mahi-mahi	*Coryphaena spp.*
wahoo	*Acanthocybium solandri*
yellowtail	*Seriola spp.*
rainbow runners	*Elagatis bipinulatus*
triggerfishes	*fam. Balistidae*

Sea turtles

olive ridley	*Lepidochelys olivacea (the vast majority)*
leatherback	*Dermochelys coriacea*
loggerhead	*Caretta caretta*
hawksbill	*Eretmochelys imbricata*

BY-CATCH IN B.C. PURSE SEINE FISHERIES: RECENT EXPERIENCES IN SOUTH COAST CHUM SALMON FISHERIES

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ABSTRACT

Southern B.C. chum salmon fisheries take place in the fall; with the most seaward fisheries taking place in Johnstone and Queen Charlotte Straits. This fishery operates under a framework known as "Clockwork". The name is derived from the stepped harvest rates that occur with changing run size. Basically, the rules are for chum salmon run sizes between 0 and 3.0 million the harvest rate is 10%, 3.0 to 3.9 million 20%, 3.9 to 5.2 million 30% and over 5.2 million 40%. The objectives of the "Clockwork" plan are:

Achieve the maximum potential of the resource and long term benefits to the fishing industry.

2. To rebuild wild chum salmon and sustain a spawning stock of wild fish at 2.5 million for the study area.

3. Reach this escapement goal within three cycles (12-15 years). Program was initiated in 1983.

4. Learn as much as possible about the productivity of the stocks.

5 Allow limited fishing at low stock sizes.

In the last number of years the possibility of adding a sixth objective, minimize by-catch of chinook, coho and steelhead has been raised. In the last three years (1991-93) the average catches of chinook, coho and chum salmon in this fishery were 1,700, 17,700 and 909,200 respectively. The majority of this incidental catch occurs in late September. It has been these late September fisheries that has been the focus point for other resource users. While recognizing the concerns over incidental catch Canada Dept. of Fisheries and Oceans has also found this fishery to be very important in providing accurate stock assessment information. A number of meetings were held with resource user representatives attempting to find a resolution that would meet a number of objectives. Namely, allow for a late September fishery for stock assessment purposes and reduce the by-catch of chinook, coho and steelhead. The options proposed to the interested parties ranged from maintain the existing commercial fishery with voluntary release of chinook, coho and steelhead to not conducting the fishery. The action put into place for 1994 was to hold the fishery at a later date, when abundance of the by-catch species had declined, and with mandatory release of chinook, coho and steelhead by purse vessels and voluntary release by gill net vessels.

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REDUCING BY-CATCH THROUGH GEAR MODIFICATIONS: THE EXPERIENCE OF THE TUNA-DOLPHIN FISHERY

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By 1963 most of the tuna fleet fishing for yellowfin and skipjack tuna in the eastern Pacific from ports in southern California had switched from use of the pole and line method to the purse seine. Although all the boats were familiar with the fishing grounds, those who had changed method recently were unfamiliar with the techniques associated with the new gear. Yellowfin tuna in the eastern Pacific are commonly associated with schools of dolphins and the fishermen had learned to find and catch tuna shoals by setting the net around a school of dolphins with a consequent high mortality of the latter. Operational techniques for releasing the dolphins unharmed from the net were developed and the gear itself was gradually modified in the light of experience to further reduce dolphin mortality.

The operational technique that was developed is known as "back down" and relies on the dolphins remaining near the surface and separated from the tuna shoal once surrounded by the net. When about two thirds of the net has been hauled back on board, the ship is put in reverse, causing the net to elongate into an elliptical shape towards the bow of the ship and the corkline (a row of floats which support the net at the surface) to be dragged below the surface, thereby creating an area through which the dolphin can escape.

One of the earlier modifications to the fishing gear was to reduce the mesh size from 4.5 inches (112mm) to 2 inches (50mm) at the end of the net where the escape was intended; this resulted in fewer dolphins tangling their snouts in the netting and drowning. It also acted to increase the drag on that area of the net, forcing it underwater and creating a slide for the porpoises to escape over. Nowadays federal regulations require a mesh panel of 1.25 inches (30mm) to be used in this part of the net.

Another improvements were: (1) the use of a raft with a crewman inside the net, releasing dolphins entangled and helping with the release procedures, (2) the use of the speedboats with towing briddles to keep the net open, (3) the use of floddlights to help the rescue in sets in darkness, and (4) the use of a double corkline, that allows the dolphins to leave the net simply by pushing on any of the floats.

A further modification that is currently being tested is to sew a canvas panel (approximately 3m deep by 30m long) below the corkline in the escape area to further increase the drag effect and to ensure that this area of the net retains sinks faster and deeper, and retains its shape without collapsing, thereby allowing even the smallest dolphins to avoid entanglement and to escape over the top of the net. Water welling over the top of the corkline assists the dolphins out of the net.

Speedboats and rubber rafts are also used to assist in herding the dolphins to the right area, and any that do get entangled are often released by crew members with snorkel gear. There is some evidence of learned behavior in dolphins that have been captured before; they appear to know when and where an escape gap will be formed and will wait until the right moment before attempting to escape.

The use of all these methods allow the escape of some 99.5% of encircled dolphins and the only time that any mortality is encountered is when an operational problem, such as the net rolling up, traps some animals under water. Currently about 84% of the sets made "on dolphins" do not cause any mortality; this number was about 40% in 1986.

Finally, perhaps the most important factor in achieving the results obtained has been the awareness and motivation of skippers and crews.

(Tape transcribed by Martin Esseen, Fisheries Centre, UBC.)

SECTION V

TOWARDS SOLVING THE BYCATCH PROBLEM

BYCATCH STRATEGIES: SUCCESS STORIES, PROMISING APPROACHES, AND ROLE OF THE THIRD SECTOR

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ABSTRACT

Among common strategies for addressing bycatch problems, the sharpest debate has focused on access-based reforms: quota and reward regimes that use permission to go fishing as either carrot or stick to reduce bycatch or associated mortalities. Such reforms amount to writing a new constitution for fisheries. They redefine the "citizenry" of a fishery and profoundly alter relations between the individual and the state. But such deep change isn't easy. Political and institutional obstacles, which impede most bycatch solutions, may render access-based reforms impossible in many fisheries.

This article suggests that non-government science and advocacy organizations are changing what is possible. Hard-hitting environmental groups have (largely unwittingly) created the preconditions for at least one fishery to make access-based reforms and other difficult solutions politically feasible. More moderate science and conservation groups have begun to facilitate bycatch experiments and measures that the fishing industry and government, if left to their own devices, could not undertake. Such interventions, however, must be delicately managed to support real problem-solving. Otherwise they risk spinning into simplistic campaigns that serve neither the resource nor those who harvest it.

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BACKGROUND ON THE NFCC

With the help of National Fisherman magazine, in early 1994 the National Fisheries Conservation Center (NFCC) was created to promote cooperative problem-solving in the areas of fisheries bycatch and conservation. Operating as a project of the Fisheries Management Foundation, we are preparing a handbook and organizing a forum at FISH EXPO Seattle on "Win-Win Bycatch Solutions." The handbook addresses strategies for collaborative problem-solving in bycatch and provides a directory of resources and expertise in the area.[1]

We've addressed not only the fisheries community (fishermen, scientists, managers), but also to the newcomers in this arena, conservation community and grantmaking foundations: They represent the non-profit "third sector" of America's economy, which plays a major role in social and environmental problem-solving in many areas of modern life. Most of them are still just learning the ropes in fisheries. One of our aims is to help them find ways to contribute genuinely to solutions, linking their skills and resources to those already engaged in fisheries problems.

As part of our research this year we talked to people in fisheries all around the United States to find out what kinds of bycatch approaches have proved successful or promising. The results suggest some important characteristics of the political institutions that shape what kind of solutions are attainable.

"MY LAWYER IS BIGGER THAN YOURS"

The most powerful, and controversial, methods for controlling bycatch are access-based: they put caps on what individual vessels can take. This amounts to changing the rules for access: fish clean or quit. In principle, everybody loves these systems because they provide individual accountability. Under most of the individual quota schemes and "harvest priority" ideas that are being debated in Alaska, for instance, a fisherman could not externalize the cost of sloppy fishing as he can under an open-access regime.

But in practice, the United States is a tough place to tell somebody he or she can't go fishing while the rest of the fleet is still grinding away on the grounds. Try instituting one of these regimes and you quickly run into a big obstacle: the "my-lawyer-is-bigger-than-yours" syndrome.

"Win-Win Bycatch Solutions", pubished December 1994, is available from NFCC.

This is a built-in flaw in our democracy. In a system designed to give everbody a fair crack, the founding fathers made sure anybody can haul you into court if they think you unfairly cut off their access to the public bounty. And in this country we are quick to reach for our lawyers. This has a profound effect on what can be accomplished in the way of fisheries policy. In fact, some people have speculated that the United States may never be able to follow British Columbia's lead in instituting an effecitive program of individual fishing quotas for longline fisheries, because the lawsuits will drown out the benefits.

Looking at fisheries in light of these issues has led me to a hypothesis. I'd like to ask you to help evaluate it. It seems that there may be two preconditions, one or both of which are necessary to make access-based bycatch controls politically feasible:

• First, you need a fishery where nobody has recourse to the U.S. courts to challenge the new system. This means the fishery is either outside U.S. jurisdiction, or the people whose access is being tinkered with are foreigners, operating more or less as "guests" in U.S. waters.

• Second, the fishery has to face a mortal threat to its future. If you look at the success of the individual mortality quota on dolphins in the Eastern Tropical Pacific, you see a fishery that had become an international pariah. Some of the toughest environmental advocates in the business had made their careers villifying the purse-seine tuna fishery in that region, and they had succeeded in virtually wiping out the U.S. fleet that once dominated the fishery. They had already helped drive the Asian high-seas driftnetters off the Pacific by U.N. decree. There was no reason to hope for any leniency toward Latin American purse seiners. What's more, they had already persuaded the U.S. government to embargo the Latin Americans who took over had the ETP fishery. I would say they had good reason to be anxious about their future. It wasn't a question about which boat would get the fish; it was a question of whether any of them would if they couldn't prove conclusively that they could fish tuna without killing significiant numbers of dolphins.

The mortality quota in the Eastern Tropical Pacific tuna fleet is a successful access-based control. The fleet catches tuna by wrapping seine nets around the easily spotted schools of dolphins that apparently attract the most desirable tuna. By 1992 a long process or refining gear and fishing practices had gradually reduced dolphin mortalities from somewhere in the hundreds of thousands to about 15,000 animals per year. Then in 1993, the quota took effect. It spurred a dramatic drop in mortalities. That year the fleet cut dolphin deaths to 3,605 animals — a better-than-fourfold drop. The fleet actually outperformed its goals and finished the year far ahead of the newly lowered cap on mortalities. And little wonder Skippers who failed to avoid killing dolphins saw their jobs jeopardized. Owners saw their investments imperiled. They got very serious about using the techniques for reducing mortalities.

Two points are worth noting about the context within which all this happened.

1. Reliability of data. The data underlying the quota was extraordinarily trustworthy. By 1993, dolphin mortalities in the Eastern Tropical Pacific tuna fishery were few enough, and well-enough monitored, to be outright counted, not just estimated. On-board observers recorded and described every dead dolphin in detail. So if anybody wanted to challenge the decision to terminate a boat's season for killing too many dolphins, they would have a rough job. I haven't included this in my list of hypothetical preconditions, but if you want to apply access-based controls, especially in the United States, this kind of hard data may be essential. In the North Pacific, the statistical uncertainty of bycatch estimates has scuttled a number of promising bycatch initiatives, because policy-makers reckoned the lawyers would make hay out of that uncertainty. Just imagine the courtroom scene:. ***Plaintiff's Attorney: Mr. Codwatcher, are you telling me you don't actually know how many juvenile pollock my client caught, but you still shut him down for catching too many? (To Judge) Your honor, i rest my case.***

2. Jurisdiction. The fishery occured outside of U.S. jurisdiction in Latin American or international waters. The international authority that established the quota system was not a U.S. agency.And the Latin Americans who inherited this fishery from the vanquished U.S. fishermen were not subject to American law. This meant that they could work out a solution to the dolphin-mortality problem in their own way.

TO KILL OR TO CURE?

This leads to a delicate political matter. In the U.S., the movement that led to our "dolphin-safe" policies — a virtual ban on encirclement of dolphins — was driven by outrage and a desire for harsh justice. The San Diego tuna fleet was widely seen as a group of evil-doers, slaughterers of dolphins.

The fishermen had actually sought government help to reduce dolphin mortalities in the late 1960s, but the resulting disclosure of shockingly high mortalities did not foster a great public impulse to help them solve the problem and stay in business. The dolphin kill became a galvanizing theme in the early years of the environmental movement. Like most of the political leaders of the age, the new environmental leaders cut their teeth in a time when political leadership was based mainly on military models. The way to promote justice was to defeat wrong-doers: Destroy Hitler, beat the Communists, overthrow the dictator. Winning was about vanquishing enemies.

That approach has since mellowed in many areas of environmental discourse, but with regard to fisheries conservation problems it remains a powerful theme in our politics and our policy-making. Especially where bycatch and waste are involved, and even more so where marine mammals are being killed, the impulse for vengeance runs hot. A strong element within the environmental community, and in government, still gathers great energy from a "crusade" approach to fisheries problems.

The prevalence of this view in the United States may have made it impossible to develop any viable solution for the U.S. tuna fleet. Neither the schoolchildren who wrote to Congress, nor the environmental groups who led the campaign for "dolphin-safe" policies, were very interested in allowing the U.S. tuna fleet in the ETP to stay in business while reducing dolphin mortalities. To cure the disease we killed the patient.

But inadvertantly, the enormous pressure generated by the dolphin-protection movement did make it a lot more feasible for the Latin Americans who took over the fishery to bite some hard bullets on access-based controls. Those controls, not the "dolphin-safe" policy, have essentially solved the dolphin problem in the region. But it's an important question whether we in the United States have the political fortitude to help fleets solve their bycatch problems. Canada so far has done a little better. There are reasons for hope in New England as well.

AN ALTERNATIVE APPROACH

One Newfoundland gillnetter had better luck than the San Diego purse seiners when he asked for help. It was 1978 and he had spent three months — really, this is not a joke — trying to disentangle a whale that was snarled up in his webbing. The beast was looking hungry, and the fisherman was too, when Jon Lien, a professor of animal behavior at Memorial University of Newfoundland's Whale Research Group, arrived with a group of students to disentangle the whale. To put this in perspective, this is not a lucrative fishery where vessel owners can afford to support expensive research to solve their problems. Average income in the gillnet fleet in that region has been about $10,000 a year.

Since then, Lien's group at Memorial University has set up a program that regularly helps fishermen separate their gear from whales. Lien estimates that each "whale rescue" saves an average of $1,300 for fishermen — in lost gear and fishing time. Each rescue also trims whale mortalities from about 50% to 10%.

Lien has also played an important role in efforts by New England sink gillnetters to reduce entanglement of harbor porpoises. The numbers are disputed, but federal estimates peg the porpoise kill at about 2,900 animals in 1990; they reduced the kill to about 900 animals in 1992, and maybe slightly more than that in 1993. Whether the harbor porpoise stocks can sustain this pressure is unclear. Neither their abundance nor their fecundity is well understood. The National Marine Fisheries Service (NMFS has been petitioned to list them as a threatened species. Conservation groups in 1993 began focusing national attention upon this fishery. Fishermen reckoned they had to solve the problem or be forced out of business.

They initially sought Lien's help in hopes of avoiding a swath of closures that the fisheries service was preparing to impose to keep them off the water during times of high porpoise entanglement.

Lien had invented a "pinger" to warn whales away from cod traps, and a series of shoestring experiments in the Gulf of Maine convinced the gillnetters that it could keep harbor porpoises out of their gear. They also liked the fact that the devices are cheap -- about $20 -- and relatively easy to build.

But NMFS wasn't sold on the pingers. Without the agency's approval, the devices would not help fishermen even if they worked brilliantly; NMFS would still rely on other methods to control their porpoise kill.

The trouble was, noisemakers in general had a spotty record in scaring away mammals. Some early experiments seemed to show they acted like a dinner bell when salmon fishermen in the Pacific Northwest sought to scare away seals. The idea of conducting a large-scale test of to determine the efficacy of the pingers made sense in principle, but how to do it was a matter of sharp dispute between NMFS and the fishermen. Their disagreements were many and intense, and several observers have suggested that they could not have come to terms on a research protocol without intervention by some interested third parties.

The "intervenors" turned out to be the National Fish and Wildlife Foundation, the New England Aquarium, and the Manomet Observatory. They had the scientific credibility that it took to satisfy NMFS and willingness to listen that they needed to work with fishermen.

An experiment began in autumn, 1994, deploying pingers in a standardized array on 15 cod gillnetters in New England. Funded partly by the Fish and Wildlife Foundation (with money from the federal disaster assistance program for New England groundfish fleets), the study is expected to provide a basis for determining whether pingers offer a viable policy alternative to more costly closures to protect the porpoises.

THE NEED TO BUILD PROBLEM-SOLVING CAPACITY

It's tough to imagine a stronger way to promote bycatch reduction than to make fishing rights contingent upon bycatch performance. But the political prospects for such access-based reforms look poor for now, at least in the United States.

These regimes raise difficult questions about the just distribution of public resources. They require uprooting established patterns of commerce, enriching some fishermen and processors at the expense of others. Those who lose —or think they might — are prone to hire lawyers.

The entry of non-government organizations (NGOs) into the fisheries management arena is reframing this picture in two ways. First, those groups that crusade against "destructive" fleets have (perhaps unwittingly) taken on the role of creating the mortal threat required to induce access reforms -- or at least to spur effective bycatch-reduction programs. Second, other groups have embraced a more collaborative role: acting to support innovations in fishing technique and management that might enable fishermen to "clean up" their fisheries enough to survive the heat.

There is a valid and useful role for environmental "pressure" groups in fisheries, but it seems to me that the problem-solving end of the spectrum is where we most need to build capacity. Otherwise, the pressure will merely vanquish fisheries, rather than solving their problems, and many people who are hurt by that Draconian approach will continue to drift into reactive, cynical postures: joining the so-called "Wise Use" movement, digging in their heels against the whole effort to conserve resources, and so on. Then we'll have a discourse dominated by the extremes, hard-line preservation vs. rampant exploitation, and we will risk losing sight of the real aim: sustainability.

A CLASSIFICATION OF BYCATCH PROBLEMS AND SOME APPROACHES TO THEIR SOLUTIONS

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ABSTRACT

An attempt is made to seek some common traits and some basic differences among bycatch problems in fisheries. Even though the existence, level and nature of the bycatch problem vary widely, we can identify some basic types of bycatch using: (a) spatial and temporal patterns in its occurrence, (b) degree of control by the fishermen, (c) rarity, (d) predictability, and (e) origin of the bycatch. A classification of bycatch problems helps to pinpoint the strategies that can be used to mitigate them.

The bycatch problem, when it exits, can be attacked in two fronts: reducing effort or reducing the bycatch per unit of effort. Different ways to achieve these goals are discussed, including technological changes, regulations, and training of fishers.

From the technological point of view, we can increase selectivity prior to capture by improving the release of unwanted individuals after capture, either in the net or on deck. Another technique to reduce bycatches is the opening of markets for new species, which converts bycatches to catches.

Up to now, none of the sectors involved in the global bycatch problem has been very successful in implementing coherent, continued and well-oriented efforts towards achieving some long-term goals that need to be defined. There are challenges for scientists, for managers, for fishermen and for environmentalists that need to be faced in the near future. The major challenge, however, is to bring all the sectors together, even those that appear to be in conflict now, to work in concert towards these long-term goals.

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INTRODUCTION

"Bycatches" are defined by Alverson *et al.* (1994) as animals other than the target species plus individuals of the target species which are unmarketable because they are too small or for some other reason. Bycatch problems have probably existed since the beginning of world fisheries. Harpoons, arrows, spears, can be aimed at an individual of known species and size; handlines with hooks can be used in such a way that they are quite selective, but almost invariably there will be catches of unwanted species or individuals; however, some of these can be returned to the water alive. But other early forms of fishing, such as the use of poisonous substances (*e.g.* plant toxins from ***Euphorbia*** spp., *Verbascum* spp., *Derris* spp. (Merino, 1991), traps, longlines, or gillnets, were not very selective, and in many cases, the bycatches could not be released alive.

However, increases in human population, industrialization of many fisheries, full utilization or overexploitation of most marine living resources, and a growing awareness of the potential ecological impacts of the problem have brought the issue to the forefront of fisheries science. A recent review (Alverson *et al.*, 1994) gives an idea of the magnitude of the problem for different types of gear and regions. That study also shows that reliable data are scarce or non-existent for most fisheries, and that problems are apparent for those that are closely monitored.

Increased data collection is needed to identify the problems, diagnose the causes, and search for solutions. But not all bycatch problems are equal, and at this stage, we could benefit by some generalizations with regard to the different types of problems. To illustrate many of the points, I will use the information on bycatches of different species in the purse-seine fishery for tunas in the eastern Pacific Ocean. This is a large data set, containing more than 5,500 records of bycatches in purse-seine sets.

TYPES OF BYCATCH PROBLEMS

I) Concentrated versus diffuse

Some bycatches occur in well-defined spatial and/or temporal strata. Examples of this include most migratory species, species with small ranges, *etc.* Sea turtles that aggregate near a nesting beach in large numbers and for a short period of time show an extreme degree of concentration; sometimes they also aggregate in oceanic feeding grounds. Bycatches of sea turtles in these areas are much greater than the average over the whole fishing ground (Fig. 1).

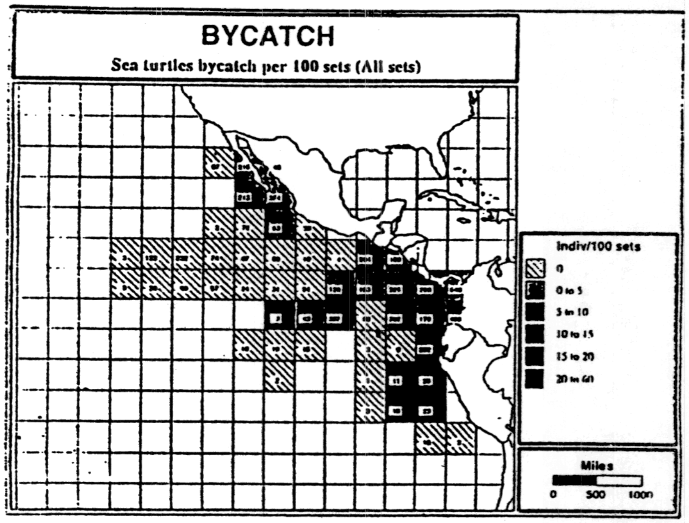

Figure 1: Bycatch rates of sea turtles (per 100 sets) for all types of sets. Based on 1992-1993 data.

An intermediate degree of concentration is shown in the case of the wahoo (*Acanthocybium solandri*, Fig.2) and the mahi-mahi (*Coryphaena* spp., Fig.3) in the tuna purse-seine fishery. Bycatches of these species are quite high in a much larger area of the fishery than in the case of the sea turtles. However, there is a high degree of spatial heterogeneity, and there are areas where the bycatches are very low.

A more diffuse case is exemplified by some species of billfishes (Fig. 4) such as the black and striped marlins in purse-seine sets made on dolphins. Here the bycatches are more uniform over the whole range of the fishery; there are no "hot spots."

These differences are important because they determine, or at least constrain, the possible strategies to mitigate the problems. If these distributions are stable over time and/or space, they introduce an element of predictability in our management scheme. We can produce plots such

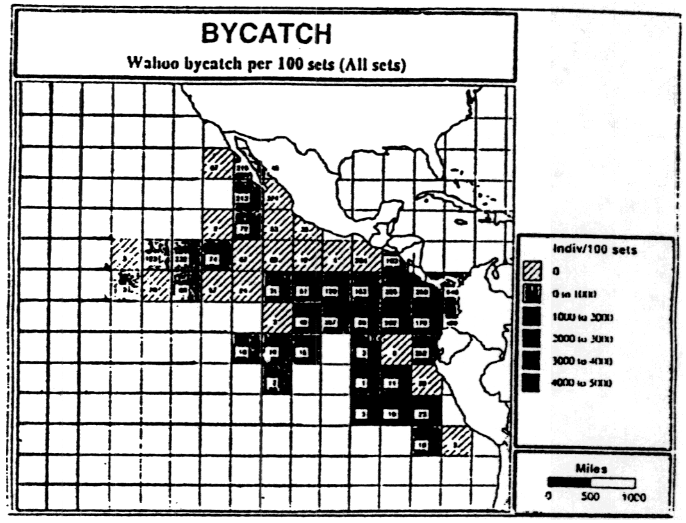

Figure 2: Bycatch rates of wahoo, *Acanthocybium solandri*, (per 100 sets) for all types of sets. Based on 1992-1993 data.

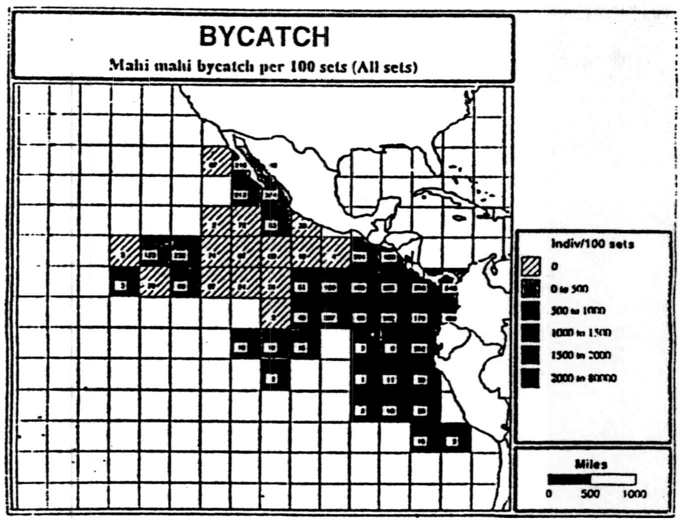

Figure 3: Bycatch rates of mahi-mahi, *Coryphaena spp.*, (per 100 sets) for all types of sets. Based on 1992-1993 data.

as those shown in Fig. 5, giving us a clear idea of the trade-offs involved in any attempt to reduce the bycatches. The plot of loss in catch *versus* reduction in bycatch may show: 1) steep slopes and convex shapes (Fig. 5a) when the bycatches are highly concentrated, indicating that management options (in this case areal or temporal closures) are available, their potential effectiveness and their costs or, 2) more linear functions (Fig. 5b) when the bycatch rate is quite constant, indicating that the reduction of the bycatch would be made at the expense of catches

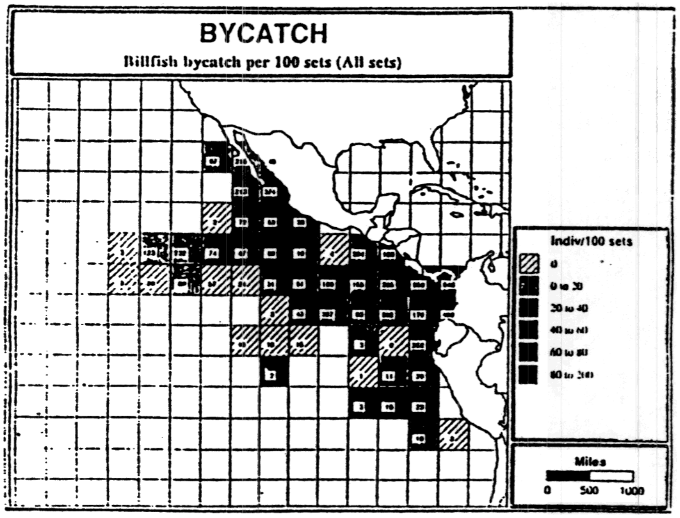

Figure 4: Bycatch rates of billfishes (per 100 sets) for all types of sets. Based on 1992-1993 data.

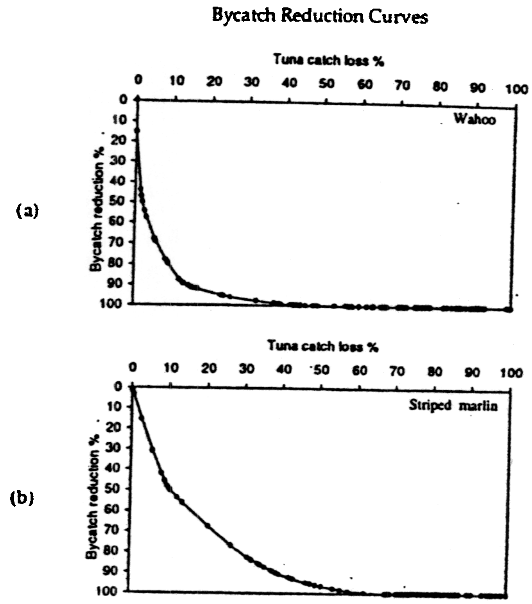

Figure 5: Bycatch reduction curves. Losses in catch of tunas (on the x-axis) corresponding to different levels of bycatch reduction for a given bycatch species (on the y-axis). Examples for a species with a highly aggregated distribution of its bycatches, the wahoo, in curve (a) and a less aggregated case, the striped marlin in curve (b). The curves are generated by successive elimination of time-area squares (time in monthly periods and areas of 5 degrees x 5 degrees), with decreasing bycatch/catch ratios. Note that horizontal and vertical scales are not equal.

of the target species, unless technological solutions are found. For these linear functions, we can compare the bycatch/total catch ratios, and decide which ways of fishing or which gears are better, or which ratios are "acceptable" based on whichever criteria are chosen to make this decision. The problem with this type of approach is that it is based on the bycatch of a single species; the function we really need to compute is the "aggregated ecological cost" of the fishing operations, including the bycatches of all species, mechanical damage to the habitat, pollution, etc. Reductions of this cost should be plotted against the losses in catch.

II) Controllable versus un-controllable

In the case of the incidental mortality of dolphin in the tuna purse-seine fishery, in a particular location at a particular time the performance of the fishermen plays a major role in determining the bycatch level; this bycatch is more controllable than others. But there are many different levels of control; the bycatch level in more passive gear, such as gillnets or longlines can be controlled, at least in part, by the location of deployment, form of deployment, *etc.* Trawl hauls can be aborted under certain circumstances, thus reducing the bycatch. But there is a continuum of control levels, and the degree of control of the bycatch in a fishery will indicate whether training programs for fishermen can be effective. The training can be directed toward avoiding the problem or, if that is not possible, toward dealing with it. For instance, a procedure called "resuscitation" can be used with sea turtles that have been entangled in fishing gear, and many respond positively to it.

But for many fisheries it will be difficult to ascertain which is the level of control by the fishermen, and we should not assume quickly that the level of control of a fishery is low, simply assuming that random events are the causes of the problems.

III) Rare versus common

Some species are seldom involved as bycatch in a fishery. This can happen for two basic reasons: a) the species is rare, or b) because of its behavior, ecology, morphology, *etc.*, it is not vulnerable to the gear, and some exceptional circumstance generated the problem. The second case is not very significant, but the first one may be. The ecological significance of rare species is difficult to assess, and frequently our knowledge of them is so scarce that it is impossible to estimate the impact of the takes, or to diagnose the factors that cause it in order to mitigate them. In fact, species which are believed to be rare may not really be so rare, but may appear to be rare because they are nearly invulnerable to capture in all types of fishing gear used in the areas where they occur.

IV) Predictable versus unpredictable

We have already mentioned the issue of predictability when discussing how to deal with some concentrated bycatches. Unpredictability can originate in different ways: a) rare species bycatches will tend to be unpredictable because our databases will be insufficient to describe their distribution in a quantitative way; or b) species with highly-variable recruitment may show up in the bycatches at very different levels in different years; or c) the behavior or ecology of a species may be modified by some external factors (*e.g.* "El Niño," flood, *etc.*).

V) Associated versus "random"

The species that constitute the bycatch of a fishery may be caught because they are associated in some way to the target species. Or it may be a "chance" bycatch, composed of individuals that happened to be in the area enclosed by the net or wandered into it during its deployment.

Examples of the first type are the sharks and billfishes that are caught with tunas and dolphins in the eastern Pacific Ocean; the types of association include both temporary and long-lasting ones, and the relationships involved in the association include predators and prey of the target species, competitors that were feeding on the same prey items, small-sized conspecific individuals that were part of the same school, members of polyspecific aggregations (Au, 1991), etc. As most fish schools have some degree of size segregation, it is unusual to find a broad range of sizes in the same school, but fish smaller that the smallest size that is accepted by the market may be within the range present in the school, and that will generate discards from the catch. Another situation leading to the capture of a mixture of sizes is the encirclement of two or more schools that may be associated in a temporary way around a food source, as a response to predators or other perceived threats, or to some oceanographic feature.

Examples of the second type of bycatch in tuna purse-seine fisheries include sea turtles, the proverbial innocent bystanders, or, in some cases, cetaceans and seabirds in such gears as trawls or gillnets.

BASIC STRATEGIES TO MITIGATE BYCATCH PROBLEMS

The basic formula to estimate the total bycatch of a given species, caused by a given gear is a good starting point to visualize the strategies that can be used to reduce it (Hall, In Press):

Total bycatch = Total effort x Bycatch per unit of effort

To reduce the total bycatch there are two options: 1) trying to reduce the total effort, or 2) trying to reduce the bycatch per unit of effort (BPUE). Of course, both options can be pursued simultaneously.

Reducing total effort

Banning effort or limiting the level of effort: this can be done directly, as a regulation promulgated by one or more governments (*e.g.* the recent ban on the use of drift gillnets on the high seas) or, indirectly, through the use of economic forces (demand, prices, *etc.*). Embargoes, consumer campaigns, boycotts, and tariffs, can be applied toward achieving this goal (*e.g.* recent US embargoes on tunas and shrimp related to bycatch problems, and the "dolphin-safe" campaign (Joseph, 1994)). These options are open to governments, but also to industries, advocate groups, *etc.* As a result of these actions, demand for a product may drop, markets may close, prices may decrease, *etc.*, and fishing effort should be affected by those forces. The effectiveness of these measures will depend on the viability of the enforcement and control mechanisms, public response, *etc.* If they are effective, the effort will be stopped or reduced, or in some cases it may be re-directed toward another target species or toward the same species, but with different gears. Unless a feasible alternative is developed, it may lead to the loss or limitation of the use of the resource. Only a prosperous society can afford to give up use of a resource; it seems unlikely that third-world countries with social and economic priorities different from those of the developed world could be in a position to make this kind of sacrifice. Another factor to take into account is which are the alternatives available. Other ways of fishing may be more detrimental to the ecosystem that the current one, for example, attempting to reduce the bycatch of dolphins by redirecting effort toward tunas not associated with dolphins would result in lesser catches of yellowfin tuna (Punsly *et al.*, 1994) and high bycatches of many other species (Joseph, 1994, Hall, Unpub.ms.).

Setting limits on the bycatch levels allowed: If the fishermen cannot find ways to reduce the BPUE, they will be forced to cut effort to stay within the limits.

A more desirable solution is the development of alternative ways of fishing that will allow the fishermen the continued use of the resource, while at the same time reducing the negative impacts of the fishery. A thorough assessment of the impacts of the proposed alternatives must be carried out before promoting them.

Reducing the bycatch per unit of effort

Depending on the characteristics of the fishery, different options will be available to achieve this goal.

Technological change: In many cases, bycatch problems can be eliminated, or at least reduced, by technological improvements in the fishing gear, mode of operation, materials, *etc.* The use of turtle-excluder-devices (TEDs) in the shrimp trawls, the backdown maneuver and the Medina Panel while purse-seining for tunas associated with dolphins, pingers in gillnets, square mesh in some areas of the net, grids, *etc.*, are examples of this. One of the major points of any program to reduce bycatches is promotion and acceleration of the development of new technologies. Given the magnitude and diversity of the bycatch problems in world fisheries, it is surprising that so few engineers and fishermen are working on the development of technological innovations. As many of the developments are costly, and require complicated experiments and tests, the flow of new ideas is not as fluid as it should be.

Regulations: Some regulations may be aimed at reducing the BPUE.

a) Gear or operational restrictions: Examples of this could be restrictions in mesh size, duration of trawl hauls, *etc.* They may force changes in the gear or operations leading to lower BPUEs, either by reducing the probability of encounter with a bycatch species, or by improving the chances of that species surviving the encounter.

b) Individual limits or "acceptable" ratios: Another type of regulation that can have an impact is the setting of individual bycatch limits, or "acceptable" ratios of bycatch to total catch. In either case, if the fishermen have any control on the bycatch level, they will change their behavior, area of deployment, or other variables to stay within the established parameters. In the eastern Pacific, tuna purse seiners have an annual limit to the number of dolphin that can be taken, and if reached, they have to stop fishing for tunas associated with dolphins.

c) Partial closures: if some areal or temporal strata have much higher bycatch rates than others, closures of those strata should result in lower average BPUEs. If effort can be re-distributed to other strata, the gains made may not be accompanied by losses in effort or in catches.

d) Incentives: not all fishermen are equally skilled at handling their gear and boats, or at making decisions, and not all are equally motivated. Individual limits or "acceptable" ratios can be considered as incentives, but there are other possibilities. A system of positive and negative incentives, that would reward the fishermen who contribute less to the problem and penalize those that are less apt or motivated is a good option to promote the reduction in BPUEs, by allowing the best fishermen (from the point of view of the bycatch) to fish more than those who are less skilled or less motivated. In the extreme case, weeding out the fishermen who cause a disproportionate part of the problem should result in lowered BPUE averages. The incentive system should also promote the development of new techniques, by conferring an economic advantage to those that can find better ways of fishing. The individual vessel mortality limit is an example of a "selective" mechanism that rewards the better operators, but there are many other possibilities, including extended seasons, higher catch limits, access to desirable areas, etc.

Training: when there are maneuvers or procedures, or some devices that can reduce bycatches, it is possible to train captains and crews of fishing boats to use them effectively. One of the main tasks of the scientists working on bycatch problems is the identification of causes and conditions that lead to bycatches. When a significant database is available for analysis, the main factors causing the problems can be defined, solutions can be selected by scientists, engineers, and fishermen working together, and the information can then be transferred to the fishermen to serve as a basis for improving their decision-making regarding the deployment of the gear and the form it is used. At the risk of being too obvious, it should be stated that it is crucial to find out what causes bycatches, and which are the conditions that produce or intensify the problem, and which conditions reduce or eliminate it.

Observer programs

Observer programs are usually considered as a way to monitor bycatches, or to verify compliance with regulations, but the role of observer programs in helping identify the problems is frequently ignored. Bycatches result from a combination of environmental, biological, ecological and gear factors. To identify them, and to assess their relative importance is vital to undertake the measures needed to mitigate the problems. Research programs and management actions should be based on solid scientific facts. Observer programs that are designed to be a tool in the search for solutions can provide the data required. Given the large number and complexity of the factors that can be involved, extensive databases are required. To illustrate this complexity, in the eastern Pacific tuna fishery the following factors have some effect on incidental mortality rates: species of dolphin, area, size of dolphin herd, size of tuna school caught, time of day, presence of strong currents, malfunctions on the equipment, use of a rescue raft, condition of equipment (repair, alignment, *etc.*), and of course the skill and motivation of the skipper and crew.

THE LINES OF DEFENSE AGAINST BYCATCH PROBLEMS

1) Selectivity: "catch only what you want.

It is necessary to devote more effort to the design and testing of new or improved gear. Studies of the target and bycatch species, may suggest gear improvements or alternative ways of fishing. In the case of active gear, better information on the species and size composition of the targets prior to capture may help reduce the waste by identifying schools that have high bycatches. More information on the spatial and temporal distribution of bycatches may lead to better deployment of the gear, avoiding areas with high levels of the bycatch/total catch ratio or other problem areas. Scientists must work to identify the factors that cause high bycatches, such as environmental conditions (currents, turbidity, *etc.*), gear characteristics and "behavior", and behavior and ecology of the species involved. This knowledge must be transfered to the fishermen to improve their decision-making processes. Fishing logbooks may be used for some of the needed studies, but the experience from the eastern Pacific tuna fleet suggests that there is no substitute for an extensive observer program.

2) Release: "if you caught it and don't want it, release it alive."

Because of the characteristics of many types of fishing gear, the incidental capture of unwanted species or individuals may be unavoidable, so the second line of defense against the bycatch problems is to develop ways to ensure that as much as possible of the bycatch is released unharmed. This may require modifications of the gear itself, of the way it is used, of the way the catch is brought aboard or discarded, of the way the bycatch is handled on deck, *etc.* Procedures or devices that allow the pre-sorting of the catch, while they are still alive and unharmed, would result in a selective fishery even if the gear itself is not.

3) Utilization: "if you caught it and killed it, use

it."

Some of the species that are considered targets today, were bycatch a few years ago. The development of markets for bycatch species may help reduce the impacts on the marine ecosystem. Although an individual discarded at sea will be recycled faster than one utilized, if the utilization of these discarded individuals replaces others that will not be fished, then it may be better to take advantage of the ecological costs already incurred by the fishing operations (e.g. physical impacts on the habitat, pollution, *etc.*) The opening of markets for new species may release the pressure on the stocks that are the favorite targets today, and the effect of this may be beneficial from the ecosystem point of view. However, if the human population continues to grow at the current rates, all new target species will progressively become more fully exploited or, in some cases overexploited, so this solution depends on reaching some controls on that growth.

The same can be said of most other proposed solutions; continued increases in the levels of effort will eventually nullify any gains achieved through technology, training, *etc.* A more detailed treatment of these "lines of defense" can be found in Hall (In Press).

CHALLENGES FOR SCIENTISTS

Many of the scientific questions that the bycatch problem generates should be answered if and when we obtain a thorough understanding of the way the ecosystem functions. Unfortunately, we are lacking that understanding, and we are often left with only intuitions, which are frequently wrong. If we try to analyze the processes that follow the development of a fishery in an undisturbed ecosystem, simply viewing the fishermen as a new predator entering that system, we can ask ourselves some questions about its impact and influence on it, given the similarities and differences between a fishery and a natural predator. The coexistence of natural predators and prey has been fine-tuned by evolution; both form part of a system with feed-back mechanisms, and different types of controls. However, even natural systems have "catastrophic" events, such as an invasion by an exotic species, an epidemic of some disease, *etc.*, that may move the system toward new equilibrium points, or from one instability to another. In what follows, I include some questions that may be pertinent to understanding the ecological impacts of the fisheries.

1) A new fishery develops in an area, which is equivalent to a new predator entering the system. Regardless of the trophic level it is exploiting, the new predator "population size" (effort, not fleet size) is not controlled by its own predators. The predator may take its prey high in the food web (*e.g.* some sharks and tunas) or at much lower levels (*e.g.* clupeoids, krill). With time, several fisheries may develop, in which several levels may be harvested simultaneously. What are the differences in the ecosystem response to fisheries which harvest species at different trophic levels? Is an ecosystem more stable when many levels are exploited at the same time?

2) Fisheries usually take a narrow range of prey items; some species and sizes are selected, but the selectivity is variable depending on the gear, the fish community, the habitat, *etc.* In general, fisheries have different selectivity than "normal" predators. How does the selectivity of the predator influence its impact on the system? Is a selective fishery better, from the point of view of ecosystem stability, than a non-selective one? Shouldn't our management systems tend toward "proportional" utilization of the different levels of a food chain rather than putting all the pressure in a narrow size range of one or a few species?

3) The biomass taken by the fisheries is removed from the system (of course changing the boundaries and the definition of the system); occasionally it may end up in a different ocean basin (*i.e.* some tuna from the eastern Pacific is canned in Thailand, Puerto Rico, or Italy). The wastes from fish processing operations frequently end up in garbage dumps on land, and the fish products themselves may be consumed in distant locations. Natural predators, on the other hand, excrete, secrete, defecate, reproduce, and die in the same ecosystem where they feed; the recycling of the prey is "local." Which are the consequences of these differences?

4) The species and size composition of the

community are altered. Biomass is redistributed among species. If the fishery is directed toward a "small" or a "large" species, or toward small or large individuals of the target species, it may affect the average size of the individuals in the community. What happens in a community where we reduce (or increase) the average size of its individuals?

5) The fishing boats "forage" in groups, in a contagious pattern, so the prey removals are not uniformly distributed in space. There are also natural predators that do that, but the fishermen may share information on prey abundance over much longer distances than other predators. If the information is accurate, they concentrate the effort in the areas of high prey abundance. The spatial distribution of prey densities is altered, driving the distribution toward uniformity. What happens when not only the abundance of a prey is reduced but also its spatial distribution is modified?

6) Even though the prey species can renew its numbers, there are time delays caused by "generation time" and by seasonalities in reproduction. During these periods there are "biomass gaps," unless other species fill them. Which are the short-term responses of different species to the removal of biomass caused by an intense fishing season?

7) Some fisheries are quite wasteful, and the discards generate opportunities for scavengers. Variable biomasses are added to the water column or to the benthos as leftovers from fishing. The spatial distribution of these leftovers is also of interest (concentrated in a single point, scattered over a line, diffuse, *etc.*). What happens to the stability and productivity of the system, and to the cycling of different components?

8) Some species benefit from the activities of the fishery (stealing prey from nets or hooks, picking up drops from longlines, *etc.*). Those species receive a subsidy from the fishery. This advantage may result in the competitive exclusion of other species, or at least in a shift of the species proportions. Are these subsidies a threat to ecosystem stability? Should action be taken to reduce or eliminate the subsidies?

9) Bycatches affect some species of the community more than others, so shifts in the species composition and proportions should be expected from this source. What are the characteristics of a species that make it more vulnerable (or less vulnerable) to the fishing operations?

10) Some fishing activities disturb the habitat: *e.g.* noise, turbidity affected by bottom trawling, pollution, *etc.*, that may limit the use of the habitat by other species, or affect them in other ways. Are the consequences of these impacts long-lasting? Do we have "chronic-trawling" communities, *etc.*?

11) Considering that all ways of fishing have some ecological impacts, how do we compare the impacts of different techniques or gears? Here we should consider at the same time the effects of bycatches, subsidies to certain species, damages to the habitat, energy use, *etc.*, and the productivity of the fishery. Table 1 shows, in very crude terms (aggregations of species, no considerations of size, sex, reproductive condition, *etc.*), the costs, in terms of bycatches, of producing 1000 tons of yellowfin tuna by purse-seining in three different ways. How do we decide which is the best (or least worse) way to fish? If the bycatch is composed of individuals of the same species, we can compare the impacts of different gears or techniques on the basis of the age, sex, size, reproductive value, social position, genetic characteristics of the bycatch. For instance, a technique that produces some bycatches of pregnant females may be compared to another that causes higher mortalities of immature males. A good understanding of the population dynamics of the species would suggest an answer based on whatever impact is easier to reverse, if that should prove to be necessary. But if we need to compare individuals of different species, we must add other factors such as population abundance, conservation status, trophic level, "vulnerability," *etc.* The answers are not trivial, and our lack of knowledge of many of these parameters, and of the functioning of the ecosystems, makes them even more difficult and uncertain.

For simplicity, I have carefully avoided the introduction of genetic/evolutionary consequences of fisheries. But in reality, the fisheries

Table 1: Bycatches in numbers of individuals and discards of yellowfin (in tons) per 1000 tons of yellowfin loaded for the different types of sets. The numbers in parenthesis are sample sizes.

	School Sets (n = 2,317)	Log Sets (n = 702)	Dolphins Sets (n = 2,447)
Dolphins	<0.1	0.5	38.9
Small tunas	50,201.5	1,304,061.6	9,023.0
Mahi mahi	45.2	10,429.0	2.4
Sharks	560.2	2,042.0	63.9
Wahoo	3.1	4,252.3	0.6
Rainbow runners	1.4	599.6	-
Other small fish	80.1	3,858.5	21.1
Billfish	23.7	113.7	4.1
Yellowtail	179.3	234.1	0.7
Sea turtles	3.6	6.6	0.6
Other large fish	9.2	305.6	-
Trigger fish	12.1	4,911.8	-
Discards of Yellowfin (tons)	25.8	309.1	7.8

are powerful selective forces that have been operating for many decades, so these consequences should not be ignored. Perhaps many of these questions, and some new ones, should be examined with this in mind.

Some research priorities concerning bycatches for the coming years (in no particular order):

i) Estimation of the quantity and composition of the bycatches. Development of programs to monitor bycatches, and of instruments to assess collateral mortality.

ii) Inclusion of bycatch and discard information in management models and decisions.

iii) Behavior and ecology of target and bycatch species that may influence capture or release.

iv) Fate of bycatches: ecological impacts and cycling of the material discarded by the fishery.

v) Utilization of bycatches: new products or new uses.

vi) Species subsidized by the fishery's operations (facilitated predation, scavenging on wastes, etc.) as an additional source of ecosystem instability.

vii) Physico-chemical characteristics of fishing gear and their properties to attract or repel different species; detection and perception of the gear.

viii) Studies to assess the "relative value" of individuals of different sizes or species to compare the impacts of different ways of fishing.

ix) Assessment of the overall ecological impacts of different ways of fishing, encompassing the effects of bycatches, subsidies to species, damage to the habitat, energy use, pollution, etc.

CHALLENGES FOR MANAGERS

Putting together teams of fishermen, gear engineers and behaviorists to find the technical, regulatory or educational solutions to the problem (Hall, In Press). Developing international programs to pool technical expertise and resources.

Developing multidisciplinary teams to assess the ecological impacts of different fisheries to have a clear idea of the relative costs of available or proposed alternatives, and implement mangement plans based on those assessments.

To find ways to continue using the resources, while at the same time beginning or intensifying the effort to reduce the "side effects", the ecological impacts of the fisheries. Of special importance is the development of programs containing positive and negative incentives, and emphasizing individual responsibility. These programs should be fair and equitable and based on the best science available.

CHALLENGES FOR FISHERMEN

Fishermen will have to lead the way in the development of improved or alternative ways of fishing. When society sets limits on their activities, they will have to develop the innovations needed to survive under those limits. This will require both creativity and financial commitments (investments). The industry will have to change in the direction of organizing continuous programs to tackle the different problems facing it. In the same way other industries set aside Research and Development funds to produce or keep up with technological advances, fishermen will have to set up a system to finance the needed research.

Fishermen will have to find ways to market some of the species that are incidentally caught.

or change the way they operate to utilize them better.

Fishermen will have to learn to deal with the ecological problems generated by the fisheries before they get to the critical level that requires painful actions to mitigate them. They have to understand and accept, that the sustained use of marine resources requires the maintenance of a healthy ecosystem, and that management actions with that objective are in their best interest, even if the short term effects may be negative to their businesses.

CHALLENGES FOR ENVIRONMENTALISTS

Most of the campaigns related to bycatch problems have been centered on the "charismatic megafauna" involved. The public reaction to dolphins is very different from their reaction to sharks or mahi-mahis. However, the ecological significance of a bycatch problem is not correlated to the emotional appeal of the species in question. It is necesary to educate the public so that it outgrows the purely emotional approach based on "cuteness," fears, prejudices, and anthropomorphic concepts and replace it with one which is more rational and science-based. It is impossible to conserve an ecosystem if your management actions are focused only in providing full protection to a single species. Environmentalists should lead this change.

Environmental groups have played a very significant role in bringing issues to the attention of the public, which has proved decisive to generate laws and regulations that have been valuable in some cases to solve or mitigate ecological problems. However, the proliferation of problems coupled with reduced government budgets has resulted in a growing number of unresolved crises. Environmental groups should become part of the solution of the problems rather than just denouncing them. This role could be fulfilled in many different ways, from funding research projects to volunteer work. However, one of the more critical needs to solve bycatch problems is to bring to the attention of a much broader sector of society that includes engineers, scientists, inventors, gadgeteers, *etc.*, the technical issues that need to be addressed and solicit ideas and proposals for solutions. The role of involving the public in the challenge of finding solutions that can allow the continuous use of the resources while at the same time mitigating or eliminating the bycatch problems, is one where environmental groups can be more effective than any other sector involved.

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SECTION VI

SUMMARY OF WORKING GROUPS

SUMMARY FROM THE TECHNOLOGY WORKING GROUP

Steven J. Kennelly (Chairperson)

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INTRODUCTION

Towards the end of the first day of the workshop (during which invited speakers presented their papers), several groups of issues were identified as being central to the overall field of by-catch in fisheries. These were policy-related issues, ecosystem considerations and technological issues. We decided to separate into working groups to discuss each of these during the second day. The following is a summary of the things discussed in the technology working group. The key issues that were identified as being important for this particular working group were: (i) incentives and support for change in tackling by-catch problems; (ii) escape methodologies; (iii) survival of discards; and (iv) ways to accelerate technological developments.

INCENTIVES AND SUPPORT FOR CHANGE IN TACKLING BY-CATCH PROBLEMS

Discussion concerning these issues naturally dealt with attitudinal perspectives of the by-catch problem in commercial fisheries. We felt that an absolute pre-requisite to solving by-catch problems is to have commercial fishers WANT to solve these problems. This is particularly important within the overall objective of solving by-catch problems through technological change using a combination of scientific rigor and fishers' unique practical knowledge of their particular gear and fishery. We felt that such a combination of expertises would be the most expeditious and efficient way to tackle the problems.

We decided that this goal requires the appropriate attitude to be held by all scientists who are dealing with the problem and at least a few fishers (not necessarily all or even a majority of fishers in the first instance because once successful, other fishers will soon "follow the leader"). For fishers to improve attitudes we discussed how they need to be aware of any monetary benefits to be gained from solving by-catch problems in addition to the often very real advantage that, in the absence of change, the longevity of the entire fishery could be at stake. Scientists who work in the by-catch field need to improve and maintain a strong working relationship with fishers by (in the first instance) earning fishers' respect at sea. Once this sort of liaison is developed, more formal meetings and small workshop fora can be used to discuss/disseminate solutions. We felt that large meetings with lots of scientific information and other extraneous inputs would not be very productive in terms of aquiring fishers' knowledge of how to deal with by-catch problems through technology.

ESCAPE METHODOLOGIES

A common theme throughout our working group was that technological solutions to by-catch problems require fishery-specific answers. We therefore concentrated on a few disparate examples and tried to avoid the solutions discussed on the first day of the workshop for trawl (separator grids, square-mesh panels, etc.) and purse-seine fisheries (operational procedures combined with modified purse-seines).

The key by-catch problems with the rock sole fishery involves another flatfish (halibut) and king crabs. We discussed several ways that the crabs may be excluded from rock sole gears using panels, chutes etc. but could not think of any way to fish selectively for one species of flatfish whilst excluding another. Possible alternative solutions to this difficult by-catch problem included having by-catch limits placed on individual vessels rather than the whole fleet; operational changes in terms of the places and times of fishing; and if by-catches of halibut could not be reduced, then their on-deck mortality may be reduced by getting the fish back into the water as soon as possible. The latter approach is complicated by the requirement that detailed measurements of by-caught fish have to be taken (see below).

Longline fisheries have by-catch problems that involve sharks, sea-birds and turtles. We discussed several ideas that have been (or could be) tried to reduce such by-catches. These included pingers (sonic devices) to scare off sharks and turtles, streamers (acting like scare-crows) to scare off birds, setting lines in deeper water, using hook sizes and baits that are more selective for the target species.

Gill netting was discussed as having several attributes that can be modified to reduce by-catches. These included mesh size, hanging ratios, twine strength, the materials used and the depth of setting. Gill netting for salmon was an interesting example: An innovation in the gear and method of setting has been developed and is known to be successful in reducing the unwanted by-catch of another salmon species but has not been accepted by industry because the correct attitude is lacking. It was discussed that there is a clear need for the correct incentive to be provided to the fishers in this fishery which may be a fishery-longevity issue: i.e. no innovation = no fishery.

Ghost fishing (when fishing gear is lost but continues to fish) was discussed as a major problem in many fisheries and we discussed the various materials that could be used and/or avoided. The chief problem, however, was that using nets etc. that corrode quickly once lost also means increasing the costs to fishers in terms of replacement and maintenance. A regulatory solution to ghost fishing was mentioned where all nets used in a fishery had to be labelled and fines were imposed on fishers if their gear was found but its loss was unreported.

SURVIVAL OF DISCARDS

Two issues were discussed here: (i) survival of discards on deck after "by-capture"; and (ii) the survival of by-catch that has been excluded through various gear modifications (e.g. grids, square-mesh panels etc.).

It was noted that the survival of finfish by-catch on deck may be enhanced through the use of recovery tanks (i.e. sorting the catch in water) and this has been quite successful in some Australian prawn trawl fisheries. Other operational possibilities may involve returning the by-catch to the water as soon as possible although this is not the case for some species like turtles who may drown if returned to the water immediately after capture. Some types of specialized resuscitation may be required for such species. It was also noted that for the by-catch of halibut in the rock sole fishery, certain data collection methods may lead to increased on-deck mortality by prolonging the time spent out of water. Some abbreviated form of data collection may be needed in such circumstances.

We discussed the possibility that the exclusion of by-catch through modified gears during their actual fishing operation (e.g. grids, square-mesh panels, etc. in trawl nets) may cause damage and consequent mortality of by-catch that goes undetected. That is, whilst such excluders remove the by-catch from the net and therefore the deck, they may not be doing much in terms of saving fish if the fish die as a result of passing through, between or over some structure in the net. This is a common argument concerning these sorts of gear modifications and what research that has been done has usually shown quite small mortalities due to gear modifications. These results are, however, usually species-specific - some species show quite high mortalities. It was noted that the materials used to make modifications in fishing gear is critical to minimizing such mortality.

It was also discussed that, apart from physical damage caused by gear modifications, excluded by-catches may be subjected to enhanced predation by certain species. The example discussed was that predatory sharks may follow trawl nets and position themselves directly over escape panels and grids so that they can easily feed on the excluded by-catch. Methods for quantifying this problem were discussed which basically involved video cameras determining if this is a major or minor problem.

WAYS TO ACCELERATE TECHNOLOGICAL DEVELOPMENTS

It was noted that funding for research into the technological aspects of the by-catch issue was very small. There is a very real need for more money to be made available for equipment like flume tanks, underwater video gear, netsons, etc. to facilitate the development of by-catch reducing technology. In addition to direct government funding, other possible sources for such funding were noted to be: levies on individual fisheries (not just the "by-catching" fishery but any fisheries that may benefit from reducing by-catches - e.g. recreational fisheries); taxes on seafood; and extra quota being given to fishers who develop or use by-catch reducing technology.

In keeping with our conclusions from the first issue we discussed - that industry should be actively involved in all technological developments from the earliest possible stages (see above) - we noted that it was important that any additional funding for by-catch research should be made available to industry and scientists in the appropriate manner. Chartering industry vessels to do the field work instead of maintaining expensive government research ships was noted to be an excellent way to facilitate such research. It was felt that such moneys (if generated specifically for technological research into by-catch reduction) should be administered by the relevant scientists and fishers - keeping it separate from general government revenues.

GENERAL COMMENTS / CONCLUSIONS

Several general points were made during the session:

- Each fishery that was discussed was said to be "a different type of fishery", highlighting the fishery- and species-specific nature of by-catch problems, particularly with respect to technological issues.

- There is a need to overcome any suggestion of "scientific arrogance" in dealing with fishers on these issues so that we can adhere to:

- The best course for solving by-catch problems is to involve industry in all technological developments from the earliest possible stages.

- Funding for research into technological developments to reduce by-catches is small and more needs to provided and/or raised. Such moneys need to be distributed to the approriate scientists and fishers so that joint research can be facilitated.

SUMMARY FROM POLICY AND ATTITUDES WORKING GROUP

A.W. Trites (Chairperson)

Bycatch is of concern to many different people for many different reasons. For some, the central issue is one of waste. Others are primarily concerned with the health of the ecosystem and the negative effects on the productivity of both targeted and non-targeted fish stocks. Economic losses are another concern, whether they be from handling costs or loss in numbers of fish available to other vessels. Finally, many people are only concerned with the ethics of catching and killing non-targeted species, particularly when the bycatch consists of sea turtles, sea birds, and marine mammals.

Differences in attitudes and perceptions about bycatch are likely rooted in social and cultural values. The developed world tends to take a protectionist position, desiring to either protect the health of the ecosystem, or protect traditional commercial and recreational fisheries, or protect the birds, turtles and marine mammals of the oceans. Such a view of bycatch is in sharp contrast to that of the developing world who tend to strive towards full usage and reduced waste.

Bycatch consists of species that are discarded and those that were mistakenly caught but kept anyway. Often it occurs because fishermen are involved in race-fisheries. They do not have the time to fish more carefully or to develop new methods. The bottom line for the commercial fishermen is the profit margin. They are economically driven to fish for dollars.

Policies that will reduce excessive bycatch levels tend to evolve outside the scientific arena. To date, policies have been evoked to protect certain valuable fisheries (such as for halibut and salmon) and certain top level predators (e.g., the U.S. Marine Mammal Protection Act). More policies will likely be proposed as the slowly evolving attitudes of the public begin to harden.

No single policy is likely to apply to all fisheries. Nevertheless, there are two basic approaches that can be considered to reduce bycatch. One is to impose legislative regulations and restrictions on gear, effort and time and areas fished. The second is to place the onus on the fishermen to reduce bycatch through economic incentives and penalties. For example, rewarding fishermen with additional quotas if they catch clean will encourage fishermen to develop better fishing methods. Individual Fishing Quotas is one means that may allow fishermen the time to develop new and better techniques. Similarly, requiring all vessels to land all bycatch at no cost will also be incentive for fishermen to actively seek means to reduce their bycatch levels.

In some cases, successful solutions will require technological changes. In others it may mean the development of new markets to distribute the bycatch. Some fishermen may need training. All will require information feedback. The bottom line to successful solutions will be fishery-specific research, monitoring and documentation.

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FISHERIES CENTRE WORKSHOP SERIES

The Fisheries Centre organizes workshops concerning fisheries-related topics and issues of current interest. We aim at developing the knowledge and tools required to study particular problems arising in fisheries. Also, we focus on enhancing understanding of natural ecosystem.

Our workshops are designed to be as practical as possible. Thus they usually include some practical work and/or model development, as well as presentation of papers and/or talks by experts in the field. The workshops have an informal format and are held in small groups to generate discussion and to provide a comfortable working environment.

The report from each workshop is edited and published in the Fisheries Centre Research Report series which is distributed among various institutions and organizations and available on request. Outputs from the workshops are formulated into plans for future research in each area.

We welcome participants from around the world, and from all fisheries institutions/organizations, including the private sector. Graduate students are particularly encouraged to attend and participate in our workshops.

In general, all the workshops in this series are held at the Fisheries Centre on the UBC campus. However, FC resources and personnel have experience in tailoring workshops to suit particular interests and can be held elsewhere.

FC Workshops 1993

Commercial Whaling - The Issue Reconsidered *(Fisheries Centre Research Reports 1993, Volume 1, Number 1)*

Decision Making by Commercial Fishermen: a missing component in fisheries management? *(Fisheries Centre Research Reports 1993, Volume 1,Number 2)*

FC Workshops 1994

Bycatches in Fisheries and Their Impact on the Ecosystem *(Fisheries Centre Research Reports 1994, Volume 2, Number 1)*

FC Workshops 1995

Impact of Changes in North Pacific Oceanographic Regimes on Coastal Fisheries *(Fisheries Centre Research Reports 1995, Volume 3, Number 1)*

Graduate Student Symposium on Fish Population Dynamics and Management *(Fisheries Centre Research Reports 1995, Volume 3, Number 2)*

Upcoming FC Workshop 1995-1996

Workshop # 1:

A Mass-Balance Model of Trophic Fluxes in the North Pacific

A one-week workshop is proposed during which 12-15 invited participants would assemble the elements required for mass-balance models of trophic fluxes in the North Pacific Ocean, with emphasis on the waters off British Columbia and Alaska.

Date: November 6-10, 1995.

Workshop # 2:

Harvesting Krill: Issues and Potential

A three-day practical workshop focusing on the issues raised by harvesting of krill, including how to assess sustainable krill harvests, ecological implications, harvest methods, markets and utilization. The intended output of this workshop will be a volume in Chapman & Hall Fish and Fisheries Series.

Date: November 14-16, 1995.

Fisheries Centre Symposium

This three-day symposium will focus on various issues of fisheries on a national and international level. The symposium will be led by members of the Fisheries International Advisory Council.

Date: February 21-23, 1996.

If you would like to know more about our activities, or to receive copies of Fisheries Centre Research Reports, please write to:

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