# REPORT OF IUCN WORKSHOP
# ON
# MARINE MAMMAL/FISHERY INTERACTIONS
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INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE
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## APPENDICES

# SECTION 1. INTRODUCTION

## 1.1 Background

1.1.1 Interactions between various species of marine mammals and fisheries are geographically widespread and of many different kinds. They give rise to a variety of conflicts of interests which appear to have increased in recent decades - or at least become more widely publicised. They generally involve, on the one hand, fishermen, fishing organisations, governmental agencies and international bodies whose prime concern is to sustain or enhance the productivity of commercial fisheries; and on the other hand, individuals and organisations - national and international - concerned with the well-being and preservation of marine mammals.

1.1.2 It is hardly surprising that most instances of interaction between marine mammals and fisheries are perceived by the fishing community as deleterious to their interests. It is well-known that many (though not all) species of marine mammals are fish-eaters, and fishermen often see dolphins and seals chasing and breaking up schools of fish. Not infrequently, the mammal may forage in the vicinity of fishing gear, take fish which have already been caught in it, and damage the gear, as well as interfere with fishing operations. Thus the fishermen are faced with the direct cost of repairing or replacing gear as well as with the loss of fishing time.

1.1.3 These essentially operational interactions involving damage to gear and the accidental catch of mammals are in principle relatively straightforward to assess, although there may be difficulties in obtaining reliable data. In some of these cases the interaction can be much reduced, and conflict minimised, by technical or operational means; these include modifications to gear, the use of scaring or warning devices and the introduction of zoned fishing regulations. There are, however, some important instances, referred to in Section 2, which are not amenable to such an approach. If then the attempt is made to reduce the numbers of the marine mammal, either by harvesting as a resource or by controlled culling, there is an increasing likelihood that opposition will be aroused.

1.1.4 The conflict can become at once more intense and more difficult to resolve when the case for controlling the numbers of the marine mammal is based, additionally or exclusively, on alleged biological interaction between it and its commercially valuable prey species. It is one thing for fishermen or scientists to observe that the marine mammal in question can and does eat commercially important species; it is another to establish whether the marine mammal population is having an appreciable effect on the abundance of its prey species, and yet another to convince commercial fishing interests that the marine mammal is not reducing the commercial productivity of the fish stock. It is even more difficult reliably to predict the long-term benefit that would accrue to the fishery if the marine mammal population were to be reduced as a control measure, and to convince other interests of the validity of such assessment.

1.1.5 Yet present and future developments are likely to accentuate the demand on the scientists to obtain at least working answers to this question of predatory interaction. There is little doubt that the protection afforded in recent decades to some of the most seriously depleted marine mammal populations is resulting in their recovery, as was intended. At the same time, the world demand for food coupled with modern technology has led to the development of many commercial fisheries that hitherto have been of local significance or non-existent. It is clearly important to anticipate where interaction is likely to occur and, if it already exists, to seek to clarify its true nature and extent. It is necessary to know whether and to what extent control of marine mammals would benefit the fisheries, and how the effect of whatever control measures are implemented may be tested and monitored.

## 1.2 Origin and Terms of Reference of the Workshop

1.2.1 It was against this background that the Scientific Consultation on Marine Mammals convened in Bergen, Norway in 1976[1)] agreed that interactions of various kinds between marine mammals and fisheries were

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Footnote 1) The scientific consultation on the conservation and management of marine mammals and their environment was organised under a UNEP Project on the conservation of marine mammals under contract with FAO.

significantly affecting some sea fisheries - mostly adversely, apparently - and also posed a growing threat to the well-being, and possibly even to the survival, of some of the mammal populations. This matter was subsequently reviewed by the IUCN Interim Committee on Marine Mammals (ICMM), which agreed that a workshop should be convened to review as far as practicable all scientific aspects of this matter, and then provide technical guidance to IUCN and to other organisations which are concerned.

1.2.2 The problems arising from the interactions between marine mammals and fisheries have also been addressed by other international bodies. They were taken into account, for example, in the draft Plan of Action for Marine Mammals prepared subsequently by UNEP, and by the IWC[2)] which endorsed, in July 1980, the following statement by its Scientific Committee:

> "Concerning the question of ecological competition, as is alleged to exist in Japanese and Norwegian waters, the Committee considers that while cases of perceived competition for common resources between fisheries interests and cetacean populations are reported from many areas, there is as yet no case in which quantitative verification is available. The Committee therefore again recommends that member nations be urged to foster and support expanded research on perceived competitive interactions between marine mammals and fishermen. The Committee strongly urges that such competition be assessed in direct and quantitative terms."

1.2.3 Preparations for the proposed IUCN workshop were undertaken during 1980 by a Steering Committee under the auspices of the new Standing Committee on Marine Mammals (CMM) established by the IUCN Species Survival Commission. Members of the Steering Committee are listed in Appendix 1 together with the participants to the workshop. The preparatory work was organised primarily by Dr. D. Lavigne. Financial assistance was provided by IUCN, the People's Trust for Endangered Species and the International Fund for Animal Welfare. The

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Footnote 2) International Whaling Commission

Southwest Fisheries Center of the US National Marine Fisheries Service very kindly provided conference accommodation and services, and members of the Center staff conducting research on marine mammals/fisheries interactions were admitted to the Workshop. All those attending participated in their personal capacities.

1.2.4 The terms of reference for the Workshop were:

1. To examine the ecological relationships involved in the actual or perceived competition between marine mammals and fisheries, including a review of information on historical changes.

2. To develop an approved methodology to determine the nature and extent of the problem, including economic aspects, of marine mammal consumption of marine resources.

3. To develop a methodology for assessing how commercial fisheries may be conducted, including the setting of quotas, to avoid depletion of marine mammal populations dependent on them.

4. To assess the problems of calculating from fish consumption by marine mammals, potential changes in fishery yields arising from changes in the numbers of marine mammals and other top predators.

5. To catalogue and identify particularly acute problems (apart from incidental catch) involving marine mammals and fisheries.

6. To indicate areas where problems may arise in the near future.

1.2.5 These terms of reference were notified to a number of other interested organisations. Of these, FAO asked that careful attention be given to any inference that might be drawn from item 3 that "the interests of marine mammals should have priority over the interests of commercial fisheries". In fact, the position taken throughout the Workshop was a neutral one in the sense that no general assumptions were made as to the relative economic or other social values to be assigned to fisheries activities and to the conservation of marine mammals. A number of scientists were invited to prepare working papers describing particular cases of interaction and these were made available to participants. These papers are listed in Appendix 2. The discussions were founded on the factual and theoretical basis of these and other situations arising from real, perceived or potential interaction and conflict.

## 1.3 Scope of Workshop and Preparation of Report

1.3.1 The working agenda adopted by the Workshop for the conduct of its three days of meetings is given in Appendix 4. Not all the topics listed in the original terms of reference (para 1.2.4) could have been covered with equal thoroughness owing mainly to limitations of time. The Steering Committee therefore proposed that certain matters should be afforded priority, and it was agreed that the Workshop should concentrate on the problems of biological interaction, i.e. on items 4.1.5, 5 and 6 of the agenda. The treatment in the report reflects that decision.

1.3.2 Other topics had, necessarily, to be given less attention, notably the question of operational interactions (i.e. item 4.1.1 - 4.1.4 of the working agenda). The evidence available to the Workshop on this matter was summarised during the Workshop by four participants[3)], presented to the Workshop, discussed and amended as necessary. The outcome forms the substance of Sections 2 and 3 of the present report.

Footnote 3) B.R. Mate
D.P. deMaster
W.F. Perrin
J. Harwood

1.3.3 The treatment given to interactions involving various groups of marine mammals was necessarily unequal. A notable omission, in the papers and in this report, is reference to the interactions between an experimental (and potentially commercial) fishery for krill in the Southern Ocean and the predators on krill which include many species of marine mammals. This omission was deliberate, because those interactions have been discussed and reported upon in detail in other IUCN-sponsored meetings, by the International Whaling Commission and by other groups concerned with the living resources of the Southern Ocean. This work was well-known to several of the participants and its results taken into account when attempting to reach general conclusions.

1.3.4 Problems involving pinnipeds, cetaceans and sea otters were prominent in the papers and the discussion; those concerning sirenians (manatees and dugongs) were much less so, while polar bears were not mentioned at all. Many of the general and theoretical conclusions will, however, be applicable to all of these groups, provided it is borne in mind that the various species of marine mammal have a range of feeding strategies and limitations of habitat with respect to water depth, proximity to land or ice and other environmental and ecological characteristics.

1.3.5 A first draft of this report, summarising the discussion and conclusions of the Workshop, was prepared immediately after the Workshop by members of the Steering Committee, the Rapporteur (R.J.H. Beverton) and Dr. S. Kaza, from detailed notes kept during the meetings. This draft was subsequently revised and consolidated by the Rapporteur and circulated to participants whose comments were taken into account in preparing the final version. The responsibility for this final report rests with the Steering Committee.

1.3.6 It is hoped that full Proceedings of the Workshop will eventually be published, including both the Report and a selection of revised working papers. In addition a more popular version of the report is being prepared by Dr. Kaza, with technical assistance from the members of the Steering Committee, for wider distribution.

## SECTION 2. OPERATIONAL INTERACTION BETWEEN MARINE MAMMALS AND FISHERIES

Many of the interactions between marine mammals and fisheries occur during fishing operations, resulting in damage to gear or to the catch, while individual marine mammals may be accidentally killed, injured or captured. In many cases the problem can be solved, or at least eased, by relatively simple changes in gear, fishing techniques or location of fishing effort. This operational interaction is not treated in detail here as it was not the primary focus of the Workshop, but for each main type we present a brief summary of known information with comments on the extent of the problem.

### 2.1 Damage to Gear

2.1.1 Marine mammals damage gear to varying degrees in many fisheries. Static gear (gill nets, longlines and fish traps) appears to be more vulnerable than moving gear (trolled hooks, lampara nets, trawls and purse seines). The local severity of the damage appears to be related to the size of the marine mammal, that by whales being the most severe. Damage by whales is generally uncommon and sporadic (such as by gray whales (*Eschrichtius robustus*) in the eastern Pacific) but in eastern Canada serious problems arise through interference by humpback whales (*Megaptera novaeangliae*) with traps for cod (*Gadus morhua*) and herring (*Clupea harengus*). This is probably due in part to the high local concentrations of shoaling fish and the length of time gear is left in the water.

2.1.2 In other fisheries, the actual costs of damage to gear are small compared to the loss of fishing time while gear is being replaced or repaired. For example, damage to gear arising from operational interaction with marine mammals in the Newfoundland cod fishery was estimated at $½m. in 1979, but the reduction of catch due to lost fishing time was put at $3m. (Lien and Gray, 1980; Lien and McCleod, 1980). A single trap in the Nova Scotia herring fishery costs $40,000, while the seasonal catch of one trap may be worth $570,000 and a single haul $100,000 (reported by Brodie). At least 50 well-documented incidents of net damage caused by whales were reported in

1980 in the eastern Canadian cod and herring fisheries (reported by Mitchell, Brodie and Lien). Sometimes the same net was damaged more than once, probably because it was set in a particularly vulnerable place.

2.1.3 Net damage by pinnipeds appears to be related to the size of the species. Of the estimated 9,000 to 64,000 sq. ft. of damaged net in the Copper River Delta area, Alaska during a three-week period, 80% was probably due to sea lions (Eumetopias jubatus) (Matkin and Fay, 1980). Since sea lions constituted only 40% of the incidental take in the same area it is likely that the relatively large sea lion can break through the net when it is entangled, while smaller species like the harbor seals (Phoca vitulina) are less able to escape and more likely to die.

2.1.4 Harbor seals, California sea lions (Zalophus californianus), harp seals (Phoca groenlandica) and grey seals (Halichoerus grypus) also cause damage to gill nets. In the Columbia River, Washington/ Oregon, approximately 40% of net damaged was attributed to harbor seals and California sea lions during the winter fishing season of 1981 (Washington Department of Game, reported by DeLong). During 1980 on the Columbia River and adjacent bays, 13% of about 1150 fishermen interviewed reported net damage, but of that damage only 20% was attributed to marine mammals (Everitt et al, 1980). In Norway, net damage by harbor and grey seals along parts of the coast was reported by 62% of the fishermen and was most frequent in areas of high concentration. Damage averaged $600 a year per fisherman (WP 16). With 3,000 to 4,000 nets damaged each year, the annual overall damage to gear by harp seal in the Varanger Fiord area of Norway may cost up to $300,000 (WP 17). Damage to salmon nets by grey seals in UK waters has for long been a source of concern to the salmon netsmen. The most serious damage is the total loss of a net in fisheries of eastern Canada, which is usually attributable to whales; this creates a secondary problem of untethered and unclaimed "ghost" nets which continue to ensnare fish of both commercial and non-commercial kinds.

## 2.2 Damage to the Catch

2.2.1 As well as damaging gear, marine mammals are known to eat or damage fish that have already been caught in nets. Pinnipeds and some cetaceans take fish from hooks and nets, eating entire fish or only portions, and the loss to fishermen may be substantial.

2.2.2 Catch damage has been estimated in two ways: by dock-side interviews of fishermen and by observation at sea. Both of these methods can give misleading results because damage to the catch will vary by location, season, fishery and species. Comparisons have shown that in some cases the two methods produce similar results (see Matkin and Fay, 1980), but in other cases the results can be quite different (Everitt et al, 1980). Miller (1981) found that, in general, interviews gave higher estimates of catch damage than did data from observers at sea. Where damage due to seals was heavy in Norwegian inshore fisheries, the response to questionnaires was better than where damage was slight (WP 16). Everitt et al (1980) reported that damage to gill-netted salmonids in the Columbia River and adjacent bays varied between 1.4% and 30% of the catch. They reportted that losses decreased with distance upriver and that loss rates were highest when few fish were being caught. Mate (1980) summarised data for fisheries where an appreciable amount of fish is lost from the catch (Table 1, pp. 13 - 18).

2.2.3 Interpretation of estimates of damage by marine mammals is difficult and the data are often misleading. Figures may be derived from individual local fisheries or from the total overall fishery. Furthermore, the extent of damage to a catch is not linearly related to the financial loss to the fisherman because damaged fish may or may not have commercial value.

2.2.4 A review of the working papers from this Workshop indicates that most estimates of loss varied between 1% and 8% of the total catch (Table 2, p. 19). Two exceptions to this are from the Norwegian inshore fisheries, where estimates of loss by salmon fishermen in areas of high concentration of grey or common seals averaged 15% with an upper figure of 25% (WP 16), and from the Finnish salmon fishery, where losses are reported to vary between 0% and 30% (Stenman, 1978).

2.2.5 Loss of fish that have been surrounded by the net has been reported from the southern African purse seine fishery (WP 4). In this case, Cape fur seals (Arctocephalus pusillus) were reported to frighten fish out of the net. Similar losses by frightening captured or nearly captured individuals have been reported for the dip-net squid fishery, and from some of the trawl fisheries. Participants agreed that estimates of loss due to this kind of predation by marine mammals were extremely difficult to quantify.

## 2.3 Killing or Injuring of Marine Mammals

2.3.1 Marine mammals are killed or injured accidentally in several kinds of fisheries. Although actual data are scanty, the total worldwide figure for cetaceans killed in this way (exclusive of purse-seine fisheries for tuna, which capture dolphins intentionally) is estimated at upwards of 10,000 annually; they consist mostly of small cetaceans (National Marine Fisheries Service, 1981). Estimates of pinnipeds killed accidentally are not as readily available as those of cetaceans, but they do exist for some fisheries. Over 700 northern fur seals (Callorhinus ursinus) were killed in 1978 in the Japanese pelagic drift-gill net fishery for salmon off the western Aleutian Islands in the North Pacific (National Marine Fisheries Service, 1981). An estimated 9,000 or more harp seals were killed in gill-nets set for cod off Finmark in 1980 (WP 17). Sirenians and sea otters are also killed accidentally in certain fisheries, e.g. dugongs in shark nets (Heinsohn, 1972), but the number so killed is largely undocumented (FAO, 1977 and reported by Estes for sea otter). (See Working Papers 4, 11, 16 and 17 for further information.)

2.3.2 Gill-net fisheries appear to cause the most harm to both cetaceans and pinnipeds. The synthetic monofilament used in some gill-net fisheries is virtually undetectable, both visually and acoustically, by many marine mammals. Large incidental kills of marine mammals in gill-nets began with the introduction of this durable material during the last few decades. The gill-net fishery for salmon off the western Aleutians in Alaska currently takes about 700 pinnipeds annually and large numbers of Dall's porpoises (Phocoenoides dalli) (National

Marine Fisheries Service, 1981). Porpoises, Phocoena spp. and other small cetaceans, as well as pinnipeds, are taken in other gill-net fisheries for salmon, sharks and other commercial fishes (WP 11; Mitchell, 1975; IWC, 1976-1981; Everitt et al, 1980). Gill-nets also entangle large whales (Mitchell, 1980: WP 11; and reported by Yablokov for gray whale). The Canadian literature contains reports of marine mammals becoming entangled in damaged or discarded monofilament gill-net webbing and from lost or discarded "ghost" nets (see also DeLong for the North Pacific; and Shaughnessy, 1980, for the southeast Atlantic).

2.3.3 Other types of fisheries taking marine mammals incidentally are trawl fisheries for hake (WP 4) and salmon (reported by Mate), several trammel-net fisheries (WP 11), and purse seine fisheries for clupeoids (WP 4), mackerel, bluefin tuna, bonito and squid (WP 11 and Smith, 1979). The takes in these fisheries are, however, generally orders of magnitude smaller than in the large gill-net fisheries discussed above. Yablokov, however, reported that Soviet trawlers in the North Pacific may take several hundred sea lions annually.

2.3.4 As well as being killed or injured accidentally during fishing operations, marine mammals are not infrequently killed deliberately by fishermen in endeavouring to safeguard their gear or catch. For example, grey seals are sometimes shot by salmon fishermen in the UK when seen close to nets, and they are permitted to do so provided they use rifles and ammunition complying with the legal specification. The numbers thus killed are too few to have any significant effect on the total seal population, but this may not be true in other cases. For example, considerable numbers of humpback whales (an endangered species) are shot in the Newfoundland cod and herring fisheries.

## 2.4 Future Requirements for Data and Research

2.4.1 The Workshop considered several gaps in knowledge concerning the incidental take of marine mammals, the more important being:

a. The extent of incidental take in the many and various fisheries for which such data are not available. Specific examples are the gill-net fishery off central California (possibly taking sea otters (Enhydra lutris), reported by Estes) and other fisheries off California (WP 11).

b. The extent and consequences of injuries suffered by marine mammals that have been released or have escaped from fishing gear.

c. The effect of losses due to incidental take of small cetaceans and pinnipeds on the populations of the species concerned.

d. The incidence and effects of "ghost" nets in the open sea.

e. The numbers of marine mammals deliberately killed by fishermen during fishing operations.

2.4.2 It was agreed that in addition to remedying these deficiencies, development of techniques for reducing the impact of damage by marine mammals and incidental catches of marine mammals should be given a high priority where this approach is feasible. These techniques include acoustic scaring or attracting devices and redesign of fishing gear. It should be noted that gill-nets are a particularly dangerous gear for marine mammals.

2.4.3 The Workshop noted many instances in which the data on perceived or reported damage both to the marine mammal and to gear and fish catch were manifestly incomplete or biased. Notwithstanding the difficulties, it was agreed that any opportunities to obtain independent checks - e.g. by scientists instead of fishermen, or by specially designed censuses - should be taken.

Table 1. Summary of Marine Mammal/Fisheries Interaction (Data from Mate, 1980)

| Marine Mammal | Location of Interaction | Fish Loss or Damage | Gear Damage | Incidental Mortality of Marine Mammals | Reference |
|---|---|---|---|---|---|
| *Eumetopias jubatus* | Alaska | Japanese have estimated a 50% damage of sablefish caught in Kodiak region & 20-30% damage of catch in Bering Sea south of Pribilofs. | N.R.* | N.R. | Burns |
| | N. Pacific (Cape St. Elias & Gulf of Alaska) | Log books from 58 vessels of Pacific halibut fishery from 1958/1960 indicate 8.1% of fish caught were damaged or destroyed. Extrapolated to the whole fleet, losses were estimated at 500,000. | N.R. | N.R. | International Pacific Halibut Commission Bell (1961) |
| | Hecate Strait, British Columbia | It was estimated that there was a $54 loss per salmon gillnetter in damaged fish. These losses were attributed to *E. jubatus* in May - September, 1962. | An estimated loss of $22 per gillnetter for damaged gear was reported. | N.R. | Pike (unpublished data) cited by Bigg |
| | Oregon | Salmon trollers have reported loss of fish from trolled hooks. | N.R. | N.R. | Mate |

*N.R. - None reported at the Workshop

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| *Eumetopias jubatus* (contd) | Copper River Delta, Alaska* | Based on interviews of 15 salmon gillnet fishermen an estimated 8.3% of the fish were damaged (30,688/ 369,571). This averaged out to a loss of $517/boat in damaged fish for the 445 boats in the fishery. | Gear damage estimated at an average of $162/boat ($72,000 for the fleet). | 40-50 in 1977 | Matkin |
| | Coghill & Eshamy, Alaska | N.R. | N.R. | 10 in 1977 | Matkin |
| *Zalophus californianus* | Monterey Bay, California | In 1969 4% of the fish caught by salmon trollers were damaged. Observations were on only 0.21% of the catch. | N.R. | N.R. | Briggs & Davis, 1972 cited by Odemar |
| | California | Damage to the catch of the salmon troll industry has been estimated as high as $122,000 annually. This represented 2.6% of the ex-vessel landings. | N.R. | N.R. | California Dept. of Fish & Game (unpublished data) cited by Odemar |
| | California | Take anchovy from purse seines and allow fish to escape through holes. | Cause holes in nets | N.R. | Gingerich cited by Mate |
| | Oregon | Movement of sea lions up rivers & subsequent predation on salmonids hooked on sport gear. | N.R. | Low numbers are incidentally taken in the Pacific trawl fisheries. | Mate |

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|---|---|---|---|---|---|
| *Callorhinus ursinus* | North Pacific Ocean & Bering Sea | N.R. | N.R. | U.S. research vessels estimate the Japanese high seas gill net fishery for salmon incidentally catch 3,150-3,750 fur seals. Of the fur seals taken in U.S. research operations, 67% were alive and released. It is not known what proportion of the fur seals taken by the Japanese are taken alive and subsequently released. | French |
| *Phoca vitulina* | Copper River flats, Alaska (see also *E. jubatus*) | Inspection of 10,000 caught fish in the salmon gill net fishery predicted that depredation would not exceed 2% of the total catch. | Cause damage to gill nets | 40-50 killed | Imler & Sarber, 1947<br><br>Matkin |
| | Skeena River, British Columbia | During the 1940s a study of damage to salmon caught in the gill net fishery revealed a loss of 7% for May-July. At times the damage to spring salmon rose to 12%. | Cause damage to gill nets | N.R. | Fisher, 1952 |

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|---|---|---|---|---|---|
| *Phoca vitulina* (contd) | Columbia River | Examination of salmon delivered to the processing plant from 1972-77 revealed that 1-2.3% of those examined were damaged (6,000 fish/year or approx. $60,000). Annually 1.3-25% of the total processed were examined. Higher percentage of spring and summer fish were seal damaged. | Cause damage to gill nets. | N.R. | Hirose |
| | Columbia River | While test fishing* at river mile 28 the incidence of "severely damaged" fish rose from 15% in 1976 to 30% in 1977. Unsaleable fish rose from 5% in 1976 to 12% in 1977. Washington's test fishing at river mile 125 changed from zero damage in 1976 to 11% of caught fish damaged in 1977. | | Using diver nets, 4 harbor seals were incidentally killed during 24 sets in test fishing. | Ore. Dept. of Fish & Wildlife (Hirose) |
| | Coghill & Eshamy, Alaska | N.R. | N.R. | 15-20 incidental to gill netting. | Matkin |
| | Oregon | Reported up river systems where they feed on sport hooked salmonids. | N.R. | N.R. | Mate (Appendix 3) |

*Test fishing operations may encounter greater fish damage because the test fishing boat is the only boat fishing at the time.

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| Globicephala macrorhynchus | California | Anchovy escape through holes made by marine mammals. | On occasions, pilot whales become entrapped in anchovy purse seine nets & tear holes in the net while escaping. | N.R. | Gingerich (pers. comm.) cited by Mate |
| Orcinus orca | British Columbia | Fishermen believe killer whales may frighten salmon and thus reduce the catch. | N.R. | N.R. | Schutz, 1975 |
| Delphinapterus leucas | Bristol Bay, Alaska | N.R. | Damage gill net gear. | N.R. | Pitcher |
| Steno bredanensis | Hawaii | Longline fishery for tuna, marlin & shark have had problems with unverified Steno taking bait off hooks. | N.R. | N.R. | Yuen |
| Tursiops truncatus | Hawaii | Hand-line fishery for snappers, groupers & carangidsfish removed from hooks; 1 porpoise can remove 6 fish. Also line pulled through hands creates risk. | N.R. | N.R. | Yuen |
| Phocoena phocoena | Copper River flats, Alaska | N.R. | Some damage to gill nets during entanglement. | 75 netted, at least 30 killed. | Matkin |

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|---|---|---|---|---|---|
| Phocoena phocoena (contd) | Prince William Sound, Alaska | N.R. | Same as above. | 10 netted (unknown number killed) | Matkin |
| | Central California | N.R. | N.R. | 12% of beach-cast animals examined had probably died as a result of trammel net entanglement. | Morejohn (unpubl. data) |

Table 2. Review of operational interaction from Workshop Papers

| Species | Location | Gear/Fishery | % Loss | Working Paper Ref. |
|---|---|---|---|---|
| grey seal | Scottish coast | bag/stake net | 3.0% | 12 |
| grey seal | N.E. England | drift nets | 2.3% | 12 |
| grey/common | Norway | "net" gear | 15% (5-25) | 16 |
| California sea lion | California | salmon trolling (ocean) | 2.5% | 11 |
| harbor seal | California | gill net (salmon) | ? | 11 |
| California sea lion | California & Baja | party boat | 2.5 - 6.4% | 11 |
| California sea lion/ elephant seal | California & Baja | gill/trammel net | 2.2 - 12.5% | 11 |
| California sea lion/ pilot whale | California | dip net/squid & fish | 8.0% | 11 |
| Cape fur seal | southern Africa | hand lines | ? | 4 |
| Cape fur seal | southern Africa | trawl fishery | ? | 4 |
| Cape fur seal | southern Africa | purse seine | (frequent interference) | 4 |
| *Grampus* | Iki Island | squid/fish | ? | 5 |
| *Lagenorhynchus*, *Pseudorca*, *Tursiops*, *Grampus* | Iki Island | angling/fish | ? | 5 |
| grey/common seal | Finland | salmon/fish | 0 - 30.0% | 1 |

## SECTION 3. TRANSMISSION OF PARASITES

3.1 Marine mammals often carry a heavy burden of parasites which at some stage of their life-cycle may also infest fish. In at least two nematode parasites, the codworm Phoconema (= Perrocaecum = Terranova decipiens), and the herring worm Anisakis sp., the non-mammalian host is a fish of commercial importance, although only the first of these (Phoconema) is well documented. The transmission of parasites therefore constitutes a form of biological interaction between marine mammals and fish which must not be overlooked. This section reviews briefly such information as was available to the Workshop.

3.2 Larvae of the codworm parasite occur in the muscle tissue of many North Atlantic fish, particularly the Atlantic cod (Gadus morhua), where their presence reduces the commercial value of the flesh - substantially if infestation is heavy. Codworm infestation of cod can be an important economic problem in Britain, Canada and Norway. Phoconema has been found in a number of marine mammals, particularly Halichoerus grypus, Phoca vitulina and Phocoena phocoena and Phoca groenlandica - but it is most abundant in grey seals (Mansfield and Beck, 1977; Øritsland and Bjørge (WP 16); Rae, 1972). In Norway and Scotland, levels of infestation in fish appear to be particularly high in the waters around colonies of breeding seals (Young, 1972). Øritsland and Bjørge consider that codworm infestation is the greatest problem associated with Norwegian grey seals.

3.3 No new information was presented to the Workshop about the biological effects of this parasitization on either the fish or the mammal. There is an extensive literature on the theory of host-parasite interaction in other animals, but quantitative data for marine mammals and fish is lacking. Thus, although the population of grey seals in the UK has roughly doubled over the past two decades, no marked change in the occurrence of codworm parasite in marketed catches of cod in Scottish ports has been observed (Parrish, 1979).

It is impossible to interpret these data correctly until more is known not only about the biology of Phoconema, which has a complex life-cycle with a number of alternative hosts, but about the effect of infestation on the condition and viability of the fish. It is unlikely, however, that levels of codworm infestation in fish stocks will be linearly related to the size of the marine mammal population which is the final host.

## SECTION 4. PREDATORY INTERACTION - REVIEW OF CASE STUDIES

4.1 While acknowledging that marine mammals have a profound influence on the general ecology of some areas, it is convenient for the present purposes to focus attention on their direct role as predators. Predatory interaction between marine mammals and commercial fisheries operates in various ways, the two basic mechanisms being:

a. Direct predation by the marine mammal on one or more prey species which are commercially fished, so that the marine mammal is to some degree competing with the fishing vessel for a common resource.

b. Competition between the marine mammal and another commercially fished predator for a common prey species, which may itself be exploited. In such cases the marine mammal is perceived as competing with the prime target of the fishery (the other predator) for food.

4.2 It is also possible that predation by the marine mammal could be confined to an intermediate species which, although of no commercial value, is itself a major predator on a commercially important prey species. Clear cut evidence of such a situation was not presented to the Workshop, but its significance in the present context is that the marine mammal would then probably be perceived as being beneficial to the commercial fishery.

4.3 Many instances of predatory interaction involving one or more of these mechanisms or elaborations of them have been published and others were reported to the Workshop in papers which are listed as Appendix 3. In carrying through its remit the Workshop took all this evidence into account, but concentrated on a smaller number of selected case studies which between them covered the main types of interaction and were relatively well documented. Examples of these are reviewed briefly in this section by way of introduction to the discussion of the theory and practice of assessment of predatory interactions contained in sections 5 and 6. For fuller accounts the reader is referred to the original sources.

## 4.4 Grey seal (*Halichoerus grypus*) in the UK

4.4.1 Conflicts between grey seals and salmon fishing on the east coasts of Scotland and northern England have been recorded over a long period (WP 1, 7, 10 and 12). The grey seal is an opportunistic feeder, many species of fish and squid having been recorded in stomach contents, but salmon is taken where locally abundant.

4.4.2 The British grey seal breeds on remote islands in autumn, at which season a licence is required to take or kill a pup or adult. Pups and adults were heavily cropped for their pelts in the past, but hunting has declined in recent years. Whether for this reason or not, it is well established that grey seals in Scotland (which account for about 50,000 of the total UK population of 70,000) have been increasing for some years at about 5% per annum, and still are. Although in principle "space-limited" (see section 5.19), there appear to be plenty of suitable breeding sites for grey seals on the Scottish coast which are not at present used.

4.4.3 Owing to the difficulty of obtaining good data on stomach contents, and the uncertainty of calculations made from food requirements in captivity, rough estimates only have so far been made of the total amount of fish consumed annually by the UK grey seals (Parrish and Shearer, 1977; Parrish, 1979; ICES CM, 1978; ICES, 1979). The figures are in the region of 100,000 tons annually; this is a small percentage of the total commercial catch of the species concerned (gadoids and several others), but in the particular case of salmon the percentage may be substantially higher. Most of the species in the food are from heavily-fished stocks whose dynamics are well documented for purposes of fishery management. There is no evidence to show whether grey seals in the UK have been affected by the abundance of their prey species.

4.4.4 Following the attempted Orkney Cull of 1978, control measures have been largely in abeyance while the "disturbance" effect of the culling operation is assessed (see section 5.23) and better information obtained about the feeding habits and distribution of adult seals out of the breeding season.

## 4.5 Harp seals (Phoca groenlandica) in the Northwest Atlantic

4.5.1 Harp seals in the coastal regions of the Northwest Atlantic have been exploited for more than 250 years. Between 1950 and 1970 the population declined substantially through excessive hunting. After the introduction in 1971 of management by quota, the harp seal population may now be stablising. The current management objective of the Canadian Government is to permit the harp seal to increase in abundance while allowing hunting to continue.

4.5.2 As with grey seals in the UK, harp seals appear to be opportunistic predators, feeding on a variety of commercial and non-commercial species of fish and invertebrates ranging from the Gulf of St. Lawrence to the Arctic (WP 10; Sergeant, 1976). An important prey species is the capelin (Mallotus villosus), the fishery for which off Newfoundland increased and then declined in recent years, but the effect of this on the harp seal has not yet been established (see also section 5.22).

4.5.3 Although there is considerable information on the dynamics of the Northwest Atlantic harp seal, the predator-prey system of which it is part appears to be more complex and less stable than in the case of the UK grey seal. For example, in addition to harp seals, baleen whales and cod are also predatory on capelin and, as with harp seals, are being managed with the intention of allowing the stocks to recover. These complications have made it difficult, so far at least, to identify clear-cut effects of the interaction between harp seals and fisheries, in either direction.

## 4.6 Fur seal (*Callorhinus ursinus*) in the North Pacific

4.6.1 The fur seal is one of a number of marine mammals inhabiting the Bering Sea, where there are also important commercial fisheries. The fur seal (and other marine mammals) and the fisheries of the North Pacific are subject to management under different legislation by different organisations. Partly in order to provide scientific advice to these bodies, a considerable amount of information exists on the populations of marine mammals and fisheries of the region, but much of it has not yet been analysed.

4.6.2 The present concern centres on the observation that after a period of fairly intensive hunting in the period 1956 to 1968, the Pribilof seal population appears to be some 50% below the estimated equilibrium level prior to 1956 and is declining (National Maritime Fisheries Service, reported by DeLong). It happens also that in recent years the fishery for Alaska pollock and other fish in the eastern Bering Sea has greatly intensified. Since pollock is a major component of the diet of the fur seal, the question arises whether there is a shortage of pollock as food for the fur seals which could be causing their decline (Kozloff, 1981).

4.6.3 Despite recent intensive research and analysis of existing data, it has not so far been possible to answer what would seem to be a relatively simple question. A critical comparison between the dynamics of the Pribilof fur seal populations prior to 1956 and at the present time is difficult, and the reason for the apparently lower present abundance is not clear. The feeding data are also inconclusive, since the occurrence of pollock in seal stomachs did not decline in the 1970s as might have been expected. However, the size range of pollock eaten by fur seals is below that in the commercial catch. Therefore, the only way in which increased fishing intensity could affect the supply of these pre-recruit fish as food for the fur seal is by causing a decline in recruitment resulting from decreased reproduction.

4.6.4 The predatory interaction between fur seals (and other species of marine mammal) and fishes in the Bering Sea illustrate some of the complexities that arise when attempting to formulate such interactions quantitatively. However, it seems that the habitats of many of the species concerned are spatially distinct, at least for critical periods of the year and stages in the life-histories, and there are good reasons from an evolutionary standpoint why this should be so. This shows the importance of obtaining data for individual species related as precisely as possible to seasons and localities in the context of a proper understanding of the life-history before turning to the more complex multi-species approach. Such investigations are now in progress.

## 4.7 Fur seal (<u>Arctocephalus pusillus</u>) in southern African waters

4.7.1 The cape fur seal is the only species of seal resident in the waters of southern Africa (WP 4). The population is large, numbering about one million individuals. After severe depletion prior to the beginning of this century it has subsequently recovered. The number of pups born during the 1970s increased at about 3% per year. The present policy is to manage the population as a resource, with quotas designed to enable the maximum sustainable yield to be obtained.

4.7.2 The Cape fur seal seems to be an opportunistic feeder on fish and squid in proportions which broadly reflect the occurrence of the species in that part of the sea where the seals are foraging. The amount of fish consumed annually for food by the seal population may be in the region of one-third to one-half of the total annual catch by the commercial fisheries in the Southeast Atlantic, i.e. about 3m. tonnes. The lack of detailed quantitative data concerning the food consumed by the Cape fur seal population makes it impossible to assess its effect on the commercial fisheries, or vice-versa, but their relative sizes are such that interaction may well be substantial.

## 4.8 Pacific Walrus (*Odobenus rosmarus divergens*)

4.8.1 The pattern of change in the walrus population of the North Pacific is similar to that of several other marine mammals considered by the Workshop (WP 2). After severe depletion late in the 19th century and the early years of the 20th, the walrus has been increasing in numbers and extending its range, especially during the last three decades since hunting has been prohibited. Its feeding habits differ markedly from those of the other pinnipeds considered, since it is a specialised feeder on bivalve molluscs (WP 14). There is at present no commercial fishery for these molluscs, though exploratory surveys to that end have been undertaken, and it has been conjectured that if a commercial mollusc fishery were to be developed it might be in strong competition with the walrus, and possibly reduce the carrying capacity of the walrus habitat.

4.8.2 Although the type of predator-prey system exemplified by walrus feeding on clam would seem likely to demonstrate marked interaction, attempts to establish this convincingly have so far proved unsuccessful. It is not clear, for example, whether space or food is the main factor limiting its natural abundance, yet such knowledge would be of considerable help in setting the boundary conditions for assessment. One problem has been the lack of a reliable estimate of the size of the walrus population, either in total or regionally, owing to the nomadic characteristics of the animal and its tendency, at certain times of the year, to be difficult to detect by aerial survey. This deficiency is now being remedied by Soviet and American surveys, but reliable information on the distribution, density and productivity of clams is still lacking.

## 4.9 Sea otter (*Enhydra lutris, L.*) on the west coast of North America

4.9.1 The sea otter is widespread on the Pacific seaboard of North America from central California to Alaska, and extends to the Pacific coast of the USSR. It was seriously depleted by hunting in recent historical times throughout its range. After the introduction of protective measures it is now re-establishing itself and extending its range, although the population in the California region is still in a more precarious state than those further north.

4.9.2 The sea otter, like the walrus, feeds exclusively on benthic invertebrates. It is essentially an opportunistic feeder consuming a variety of species according to their availability, but Pismo clams (Tivela stultorum), abalone (Haliotis spp.) and sea-urchins (Strongylocentrotus spp.) are the most commercially important of their food species. These and other prey species are sessile or weakly motile, living on beaches or in shallow water, and are highly vulnerable to predation by the actively foraging otter. They are typically long-lived, slow-growing organisms with a relatively long immature phase (several years in the case of abalone). Consequently, they are not resilient as populations to natural predation or to exploitation by man. Many of the species comprising the food of the sea otters are, in fact, also exploited commercially or for recreation, some (e.g. abalone) being highly prized.

4.9.3 Because the system is accessible, observable and amenable to experimental study, the over-exploitation and subsequent recovery of the sea otter provides exceptionally favourable opportunities to measure its effect on its food populations, and to distinguish this from the natural fluctuations and exploitation by man. For example, studies carried out by the California Fish and Game Department in the Point Estero region showed that the density of red abalone decreased by seven-fold in a very few years as otters recolonised the area (Wild, P.W. and Ames, J.A., 1974). The interaction between otters and Pismo clam is equally sharp, and the Workshop noted with interest the socio-economic analysis which has been undertaken of the conflict between the otter and the recreational clam fishery in the Pismo Beach area (WP 6). Interaction, however, may not always be a direct predatory-prey mechanism of these kinds. Thus, sea-urchins graze kelp, which is itself a resource and a habitat for fish, so that sea otters may indirectly benefit the productivity of kelp by depleting sea-urchins. Secondary implications of this kind would need to be taken into account when evaluating the overall significance of sea otter predation.

## 4.10 Killer Whale (Orcinus orca) in the North Atlantic

4.10.1 This is a case of an oceanic mammal which is predatory on a major commercial fish species, Norwegian spring herring (Clupea harengus), the fishery for which has declined in recent years and is now managed for recovery. Herring fishermen are concerned that the killer whales might significantly impede this recovery, and the present annual take of this mammal is intended to help prevent this interaction as well as to yield commercially useful products (oil and animal foodstuffs).

4.10.2 Not enough is known about the dynamics and distribution of either the killer whale or herring populations for accurate assessments to be made, but theoretical calculations were reported to the Workshop (WP 3) which illustrate some possibilities. The indications were that a take of as many as 500 killer whales annually would have little effect on the rate of recovery of the herring stock as a whole, provided it can be assumed that that stock is increasing from its recently depleted state. In fact, the authors were unable to find any combination of initial size, growth rate and predation rate of the local killer whale population which could allow a take of a few hundred whales per year to be justified as expediting the recovery of the herring.

4.10.3 It is, however, necessary to make clear that these calculations used a theoretical model based on the North Sea herring, not on the Norwegian spring herring, with which killer whales interact. The Norwegian herring stocks are not in the same state as the North Sea, and may have different dynamics.

## 4.11 Dolphins and Yellowtail in the Iki Island area

4.11.1 Several species of small cetaceans interact with fisheries for yellowtail (Seriola quinqeradiata) and squid (Loligo spp.) off the coast of Japan in the area of northern Kyushu, particularly in the vicinity of the Iki, Goto and Tsushima Islands (WP 5). Yellowtail are caught by hook and line, the fish having been attracted to the locality by baiting with sardine or other fish. The dolphins (mainly Grampus griseus and Tursiops truncatus) damage the fishing gear, take fish that have been hooked, and are reported to disperse shoals and to stop the fish from feeding.

4.11.2 This interaction is not a new phenomenon, having been recorded from the early years of the century. Whether it is purely operational or whether the dolphins significantly affect the yellowtail population has not been established.

4.11.3 Various attempts have been made over the years to reduce the intensity of the conflict. At present, when large schools of dolphins are located on the fishing grounds, they are driven ashore by the fleet and most are killed. A bounty is paid for dolphins killed, which could lead to excessive depletion of the dolphin population. Attempts to scare dolphins away from the vicinity of fishing gear have not so far been successful.

4.11.4 The catch per unit effort in the yellowtail fishery in the Iki Island area has been declining while the number of dolphins in the fishing area appears to have been increasing. These circumstances are, understandably, causing concern to the fishermen and the authorities, but it is not clear whether the decline in the yellowtail fishery is attributable to the increased numbers of dolphin, or to some other cause, such as fishing.

## 4.12 Dolphins and yellowfin tuna in the Eastern Pacific Ocean

4.12.1 In the eastern Pacific yellowfin tuna (Thunnus albacares) often associate with some species of dolphins (principally Stenella and Delphinus spp.), as well as with large floating objects. The reason for this association is unclear, but the fishermen have for long taken advantage of it by using the presence of dolphins as a clue for locating tuna schools (WP 9). The change in fishing method in the late 1950s from pole and line to purse seine resulted in the incidental killing of large numbers of dolphin which became entangled in the nets and drowned. It seems that the dolphins are relatively quiescent in the net until it is too late to escape. In earlier years up to 500,000 dolphins were killed each year, and it is estimated that some dolphin populations have been reduced to between 20% and 60% of their original size. The numbers killed have greatly decreased in recent years, mainly because legal limitation to the kill has led to the invention of techniques for releasing trapped dolphins. There is also some evidence that the behaviour of the dolphins has changed.

4.10.2 This example of interaction is unique because the presence of the marine mammal is in one sense advantageous to the fishermen, actually helping to make tuna fishing in some areas economically viable. About half the tuna catch is, in fact, taken from schools in association with dolphins.

4.10.3 This marine mammal/fishery interaction has been investigated more intensively than most, but its biological basis is still not properly understood. Thus, while it is known that dolphins do not eat the tuna, both are predators on much the same kinds of food. On the other hand, food generally seems not to be a limiting factor for either predator, while differential size selection of prey species tends to minimise any local competition between them that might otherwise arise.

4.10.4 Present management goals of the IATTC[4)] are to maintain dolphin populations at or above the levels which allow maximum net reproduction and for the yellowfin population to be fished so as to allow it to increase only slightly from its present size at around the estimated MSY level. However, the yellowfin tuna is fished by a number of countries, not all of which are members of the IATTC, so it is not clear whether the actual catches of either fish or dolphins are within the prescribed limits. On present knowledge there is no practicable alternative but to treat the dolphin and tuna as if they were independent, and to have separate management plans for them.

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Footnote 4) Inter-American Tropical Tuna Commission

## SECTION 5. ASSESSMENT OF PREDATORY INTERACTION - CONCEPTS AND THEORY

5.1 Where a marine mammal is perceived to be interacting with a commercially fished resource - usually by feeding on it as illustrated by the examples reviewed in section 4 - the following questions arise:

a. What effect is the marine mammal having on the abundance of the resource and hence on the fishery for it?

b. In what circumstances, and by what amount, would the yield of the resource be enhanced if the marine mammal abundance were to be reduced or otherwise controlled?

c. How can a given level of marine mammal abundance be achieved by a management programme, assuming such to be desired as a matter of policy?

These three questions concern the effect of the marine mammal on the commercial resource, but the converse must also be considered, leading to the further question:

d. In what circumstances is a change in the abundance of the prey species (the resource) likely to affect the abundance and viability of the predatory marine mammal population?

Underlying all these questions is the general problem of how this predatory-prey interaction may be detected and measured.

Two-species interaction

5.2 To develop the theory needed to answer these and related questions it is convenient to start by postulating a simplified system of one species of marine mammal feeding on one species of fish which is also exploited commercially, although acknowledging that in reality the interaction will almost always be more complex. The mortality in the fish population caused by marine mammal predation can be regarded as a component of what is normally referred to as the "natural mortality rate", i.e. that due to all causes other than fishing. In terms of instantaneous coefficients, with the usual notation, the total mortality in the fish population can then be written as:

$$Z = F + M^* + M \quad \ldots\ldots\ldots \quad (1)$$

where $M^*$ is the mortality coefficient due to marine mammal predation.

5.3 This formulation does, of course, carry certain implications, notably that the various instantaneous coefficients are independent, and this will be examined further below. For the moment, however, this approach enables the marine mammal population to be envisaged as if it were a separate group of fishing vessels operating independently of the main fleet but exploiting the same fish population and hence competing with the main fleet. To obtain even a crude estimate of the predatory mortality $M^*$ due to the marine mammal, and hence its influence on the commercial fishery, it is necessary to obtain some estimate of:

a. the total amount of the fish species eaten annually by the marine mammal;

b. the size composition of the fish species eaten compared with that of the commercial catch.

5.4 In the simplest case, if the two size compositions are the same, then the ratio of the annual commercial catch to the total annual consumption by the marine mammal can be used as a close approximation to the ratio $F/M^*$. Thereafter, the conventional fishery assessment techniques can be used to calculate the potential loss to the fishery corresponding to various levels of marine mammal abundance, provided it is assumed throughout that the predatory activity of the marine mammal continues to correspond formally to that of the hypothetical fishing fleet. Such calculations would show, for example, that the potential loss to the fishery will be greater the higher the exploitation rate ($F/Z$) and the higher the predation rate $M^*$ compared with the residual mortality rate M.

5.5 It is now necessary to consider some of the ways in which the real situation may depart from this simple model, and the implications in terms of assessments made with it. The most obvious is that the size composition of the fish species eaten by the marine mammal will probably differ from that of the commercial catch. Generally speaking, if the marine mammal eats fish which are, on the average, larger than those in the commercial catch, the potential loss to the fishery will be less. The extreme case is exemplified by California sea lions in the Rogue River feeding on post-spawning steelhead trout (Salmo gairdnerii), most of which would shortly die anyway, so that there is little loss to the fishery. Conversely, if the marine mammal eats fish on the average smaller than those comprising the commercial catch, but still beyond the juvenile phase where natural mortality is high, it means that the marine mammal has, in effect, "free" access to each cohort of fish before they enter the fishery. The impact on the fishery of a given predatory activity will therefore tend to be rather greater than if the size range of fish eaten coincides with that of the commercial catch, and especially so if it is assumed that the same total weight of fish is consumed by the marine mammal in each case.

5.6 The predatory activity of the marine mammal may also depart from the fishing analogy if it preferentially eats fish which are moribund or otherwise incapicitated. To the extent that this happens it would introduce an error in the estimation of M* and in subsequent assessments, in the direction of over-estimating the potential loss to the fishery.

5.7 The impact on a fishery would also tend to be over-estimated by the use of equation (1) in conventional fishery assessment models if the marine mammal confines its predation to relatively lightly fished local concentrations of prey, between which and the main fishery the interchange is incomplete. This possibility needs to be borne in mind in cases where the marine mammal frequents coastal or inshore areas for feeding.

5.8 Difficulties of another kind arise when extending assessments of the kind described above to predict the long-term consequence of a change in the numbers of the marine mammal relative to that of its prey. In such circumstances the predatory activity of the marine mammal may not necessarily follow the same strategy as that of the commercial fleet. For example, a shift in the relative abundance of the marine mammal and its food species may cause the former to shift the size range of its food. In the extreme case, if an alternative food species became abundant, the marine mammal might choose to concentrate on it and neglect its original prey, thus rendering invalid the whole basis of assessment. Departures of this kind from the initial observed situation would, in principle, be detectable from a monitoring scheme, as is discussed in the next section. Existing assessment theory could then be used to re-calculate the modified effect of marine mammal predation on the commercial fishery.

5.9 Another possible complication in long-term assessments arises from the increase in the density of the prey due to a lessening of the predatory activity of the marine mammal. If this greater density were to result in an increase in the residual natural mortality coefficient M in the prey species, the two coefficients M and M* of equation (1) would not be independent. To the extent that compensation of this kind occurred it would, of course, reduce the actual long-term gain in yield from the fishery for the prey compared with that predicted on the assumption that M and M* are independent.

5.10 For density dependence of this kind to operate, the increased prey density would have to be directly responsible for causing a higher incident of one or more factors generating its residual natural mortality rate. This might happen if, for example, other predators aggregated on the denser prey or their population size increased because of their more abundant food supply. Specific evidence that such consequential changes were happening would be needed in order to make the appropriate allowance for compensatory changes in the residual natural mortality coefficient M, and a multi-species theoretical treatment would then be required for assessments along the lines outlined below.

<u>Multi-species interaction</u>

5.11 An obvious limitation of the simple one predator-one prey interaction that has been postulated so far is that, in practice, most marine mammals feed on several prey species and are typically opportunistic feeders. In theory, if the amounts of each species in the diet are known, they can be regarded to a first approximation as independent and so can be combined for purposes of assessment, with a weighting, if desired, that reflects their differing commercial values. The limitation of this approach is that differential changes in the relative abundance of the prey species in the food of the marine mammal are quite likely to occur, and if there are marked differences in their market value weighting, the combined assessment would then be in error. Such changes could be detected by a monitoring programme and the appropriate adjustments made, but could not be predicted in advance.

5.12 The possible compensatory changes in mortality discussed above become correspondingly more complex with a multi-species predator-prey system. The Northwest Atlantic harp seal described in section 4 is one example. This is an opportunistic predator, with capelin (Mallotus villosus) thought to be an important food species. However, capelin is also eaten by cod (Gadus morhua) which is itself fished commercially, and by baleen whales, which are protected. If the abundance of capelin were to be increased by control of harp seal numbers, it is therefore possible that the cod stocks, and thus the cod fishery, would also benefit, but predation by cod on capelin would also increase. It is possible also that the number of baleen whales would increase if capelin were to become more plentiful, and to the extent that this were to happen it would tend to offset the purpose of reducing the number of harp seals. Interspecific links such as this, through food supply, growth and reproduction, are poorly documented in quantitative terms; but at least the direction of the effect of reducing harp seal numbers on the combined cod and capelin fisheries is unlikely to be wrongly predicted if secondary effects of this kind are not taken into account.

5.13 Such a presumption cannot, however, be made in the case of the somewhat different system reported by Mate. This consists of sea lion feeding both on salmon and on sea-lamprey, but with the complication that the sea-lamprey is itself a significant predator on the salmon but of no commercial value. In this case, attempting to reduce the predation of salmon by reducing sea lion numbers would also benefit directly the lamprey and hence increase its predation on salmon. The net result depends critically not only on the response of the lamprey population to reduced sea lion predation, but on the dynamics of the lamprey-salmon interaction. In the absence of information on this latter question there would be no guarantee that the net effect of reducing the number of predatory sea lions would be to increase the salmon stocks.

Population dynamics of the marine mammal

5.14 The foregoing analysis has been concerned with assessment of the effect of the marine mammal as predator on the commercially-exploited prey species, with the implication that the abundance of the marine mammal can be maintained at any desired level by an appropriate management policy. It is now necessary to consider specifically the dynamics of the marine mammal, including the effect on them of changes in prey abundance, and the theoretical questions raised thereby.

5.15 For control of the population size of the marine mammal, whether by regulating its exploitation as a resource or by means of a special culling programme, sufficient knowledge of its parameters of reproduction, growth and mortality are obviously needed. The Working Party did not devote much time to this question, mainly because research on the biology and dynamics of a variety of species of marine mammals is in progress in a number of countries. Certain requirements were, however, identified which are of particular signifiance where interaction with fisheries is involved.

5.16 One requirement is to establish the status of the marine mammal population and, in particular, whether or not it can be regarded as in a steady state. Several instances came to the attention of the Working Party in which the marine mammal is known or suspected to be increasing. Grey seal in the UK is one example. The rate of increase may be highest where the marine mammal has been heavily depleted in earlier times and has since been protected, or where hunting has declined for economic reasons. This is the case for walrus in the Bering Sea (WP 13 and 14) and for South African fur seal (WP 4). The management objective for the harp seal in the Northwest Atlantic is to permit the stock abundance to increase, and it may already be doing so.

5.17 In these circumstances, if the marine mammal is allowed to continue to increase in abundance, it is reasonable to suppose that it would increase the predation mortality in the prey and hence decrease the fishery yield from it, for a given fishing effort. A sustained culling or harvesting regime to hold the marine mammal population steady by removing the surplus growth increment would be expected to prevent the predation mortality in the prey from increasing and hence benefit the fishery yield.

5.18 The theory required for assessing the potential gain to the fishery from such a stabilisation policy - strictly speaking, the avoidance of what would otherwise have been an increasing loss - is in principle the same as that discussed above. Apart from the transitional stage while the structure of both the prey and predator population are adjusting to stabilisation of the marine mammal population, both the immediate and long-term assessments are likely to be more reliable than when predicting the effect of changing the marine mammal abundance from a present equilibrium to a new one outside the range of historical experience.

5.19 Where it can be established that the marine mammal population is increasing, those responsible for management would be helped if they had some idea of how much more the population could be expected to increase if nothing was done to control it. Two main groups of marine mammals can be distinguished in this connection. There are those that depend at one or more stages of their life-history on a spatially-limited habitat; the need for grey seals to haul out on suitable beaches for breeding is a case in point. Then there are those exemplified by the oceanic cetaceans, which spend the whole of their life in the open ocean without, so far as is known, encountering any spatial limits. Availability of food must place an ultimate limit on the abundance of both groups, but space limitations may well come into play in the former group before there is any shortage of food.

5.20 Both these boundary conditions need to be represented in a comprehensive theoretical treatment of marine mammal/fishery interaction, but the Working Party was unable to do more at this stage than outline some of the problems involved. Subtle behavioural factors must be expected to enter into the question of what determines a suitable habitat, and there is unlikely to be a simple linear relationship between population size and the availability of what, to the human eye, would seem to be suitable space.

5.21 Shortage of food for the marine mammal would be expected to show first as a fall in the growth rate of immatures, followed by a decline in the general "condition" of the marine mammal, particularly in its stored energy resources. If the food shortage were prolonged, it would be expected that reproductive and infant survival rates in the marine mammal would fall leading, in due course, to a decline in population size. In conditions of severe shortage it would not be surprising if the distribution of the marine mammal changed as it sought alternative sources of food.

5.22 The Working Party was unable to find convincing evidence of shortage of food affecting a marine mammal, with the exception of the sea-otter/mollusc system, in which if the mollusc becomes scarce the sea-otter disappears from the locality. The dramatic collapse of the Northwest Atlantic capelin fishery in recent years might be thought to provide another example, and a contemporaneous deterioration in the stored-energy reserves of the harp seal has indeed been reported. A decline in reproductive success or pup growth rate has not, however, so far been observed. Thus, a cause and effect relationship cannot safely be deduced, especially as the decline in capelin has occurred off Newfoundland whereas the harp seals sampled for determination of stored energy reserves were thought to have been feeding mainly in the Gulf of St. Lawrence.

5.23 Finally, there is the question of translating a desired policy of marine mammal control into a practical programme of management. The theoretical aspects involved concern mainly those of the population dynamics of the marine mammal, and must take into account the effect of a culling programme on its age-structure and sex-ratio as well as its migratory and reproductive behaviour. The Workshop also noted the experience of a small cull of adult Scottish grey seals in 1977, which appeared to cause an unexpectedly large drop in pup production in colonies which were culled for two further years. In addition, the presence of anti-cull protesters on one Orkney island in 1979 was followed by a drop in pup production on that island, even although no seals had been culled. The full extent and duration of this phenomenon has still to be determined, but it is clear that the "disturbance factor", whether accidental or deliberate, should be allowed for in the theoretical formulation of a controlled marine mammal/fishery system.

Economic Considerations

5.24 The above analysis of the interaction between marine mammals as predator and commercial fish or molluscs as prey has been concerned with assessing the effect on the weight of yield from the commercial fishery. This may sometimes be sufficient as a basis for action, but more usually the evaluation of losses or gains to the fishery will also need to be expressed in monetary value or other economic terms.

5.25 The Working Party was unable to discuss this question in any detail, but agreed that the following are among the more important points to be borne in mind in this connection:

a. In so far as the yield from the fishery is that much greater with control of the marine mammal than would otherwise have been the case, and control does not involve any direct increase in costs to the fishermen, then the catch in weight per unit cost will be higher.

b. On the other hand, the effect of an increase in catch on its monetary value will depend on the relationship between supply and demand for the fish on the markets in question.

c. In assessing the overall costs and benefits, regard should be paid to their distribution among different groups of fishermen and, indeed, to whom benefits might accrue other than to the fishing industry. Such considerations would involve calculation of consumer surplus and might include quantification of other economic values of the marine mammal population.

d. In the overall assessment the costs of research and monitoring required specifically for the purpose of pursuing a policy of marine mammal control must also be taken into account, with quantification of risks using discounting techniques, as appropriate.

## SECTION 6. PREDATORY INTERACTION: REQUIREMENTS FOR RESEARCH AND MONITORING

### The Initial Assessment

6.1 The analysis of the previous section indicates the information needed to make at least an initial assessment of the degree of predatory interaction between a marine mammal and its commercially-fished food species. There must be enough data to establish quantitatively the main species composition of the catch and to provide a sufficient understanding of the ecology of the fish stocks. Correspondingly, enough must be known of the life-history, distribution and feeding habits of the marine mammal to establish how far the commercially important fish species are a consistent feature of its diet.

6.2 The Working Party discussed whether at least a crude estimate of the present population size of the marine mammal is also essential before control of it should be considered. One view was that, provided the decrement (in numbers) of the marine mammal to be caused by a proposed culling regime can be achieved accurately, in practice, the necessary conditions would be satisfied. The general conclusion was that, even if this were so in theory, to attempt management on such a limited basis of knowledge would, in practice, be undesirable.

6.3 The information specified in 6.1 must be regarded as the absolute minimum. In practice, rather better information would almost certainly be required, including:

a. Approximate size composition of the prey species eaten by the marine mammal compared with that of the commercial catch.

b. Rates at which the prey species are consumed by the marine mammal, so that an estimate can be made of the relative amounts consumed by the marine mammal compared with the commercial catch.

c. Exploitation and growth rates of the prey species, so that the appropriate fishery assessment techniques can be applied to estimate the predatory mortality in the prey populations and the effect on them of reducing the marine mammal by given amount.

d. Sufficient knowledge of the biology and population dynamics of the marine mammal for its present status to be ascertained if a management programme is to be set up which has the desired effect on its population size.

<u>Monitoring a Programme of Marine Mammal Control</u>

6.4 If it is decided on the basis of an initial assessment to introduce control of the marine mammal population, this should be accompanied by a programme of monitoring to:

a. identify changes which might modify or invalidate the initial assessments on which the decision to begin control of the marine mammal was taken;

b. indicate whether further control measures would be justified on scientific grounds.

6.5 A probable scenario is that control takes the form in the first instance either of holding constant the marine mammal population (if it would otherwise have been increasing), or of reducing it to a somewhat lower level of abundance and maintaining it there. The Workshop acknowledged that unless the marine mammal was the dominant influence on the abundance of the prey species, the natural variability of the latter would make it virtually impossible to test the efficacy of the control measures by simple observation of the "before and after" characteristics of the fishery yield. More sensitive indicators of the mechanism of interaction, covering both the prey species and the marine mammal, are therefore needed.

6.6 The most important of these are the species and size compositions of the food consumed by the marine mammal compared with those of the catches by the commercial fishery (see section 5). Any appreciable changes in these would imply that the initial assessment of interaction would need revision. It is likely that such changes would be triggered or followed by changes in the distribution of the prey species relative to the fishery, and this information would be an important adjunct to the species and size composition data.

6.7 Events within both the predator and prey populations, as distinct from their interaction, should also be monitored sufficiently well to bring to light any major changes. It needs to be checked, for example, that the culling regime set up to achieve control over the population size of the marine mammal is indeed having the desired effect. In addition to population surveys, this means monitoring the changes in pregnancy rates, juvenile mortality and the growth and condition of both pups and adults. In view of the "disturbance" that may be caused by applying control measures (see section 5.23) it is important that the monitoring programme should be able to detect any marked changes in the behaviour or social structure of the marine mammal population that might indicate a significant departure of its dynamics from those predicted.

6.8 Events in the commercially-fished prey species would normally be followed in the context of a fisheries management programme. Although the chance of detecting in those circumstances the direct effect of a relatively small change in marine mammal predation is small, clues of other kinds may be observed. Of particular significance in this connection would be any marked changes in the abundance of other predators on the fish, notably sea birds. Where the predatory influence of the marine mammal is a major factor in determining the prey abundance, direct observation of changes in the abundance and possibly the structure of the prey populations would form a central part of the monitoring programme. Similarly, if a particular form of secondary interaction is known or suspected which could materially influence the reliability of the assessments, the monitoring programme should include the relevant observations. For example, if control of seal numbers in the case described in paragraph 5.13 were attempted on a trial basis, it would be important to follow the consequential changes in the abundance of the lamprey population and its predation on salmon.

6.9 The management of any natural resource is to some degree experimental, in that the future dynamics of the resource populations are bound to be influenced to a greater or lesser extent by unpredictable events. It is, however, the way in which the natural system responds in those circumstances that often provides vital information to enable the management strategy to be improved. It is a no less important purpose of a monitoring programme to bring to light such changes as it is to check whether or not the initial prognoses are being borne out in practice.

## Priorities for Future Research

6.10 Much of the research needed to improve our understanding of the biological interaction between marine mammals and their food species will be evident from the theoretical analysis in section 5 and the monitoring requirements outlined above. There were, however, certain particular questions to which the Working Party agreed it would be worth drawing attention.

6.11 Distribution of marine mammals and prey species

A number of instances have been mentioned where assessment of interaction depends critically on knowing the relative distribution of the marine mammal and its prey species in time and space. This information is frequently lacking and is admittedly difficult to obtain. A thorough knowledge of the "fine structure" of a predator-prey system may, however, be essential if possibly serious misconceptions are to be avoided.

6.12 Metabolic studies

The tendency for adults of some species of marine mammal to vomit while being caught is a serious difficulty when attempting to estimate food consumption rates. Calculation of the energy requirements of marine mammals from metabolic studies could therefore be a potentially valuable, if indirect, way of estimating food consumption. The Workshop was, however, divided on the reliability of feeding experiments on marine mammals in captivity as a means of predicting food requirements under natural conditions. While acknowledging the limitations of this approach it was nevertheless agreed that the aim should be to improve the technique of experimentation so that it can provide data more representative of conditions in the wild.

6.13 Condition of fish eaten by marine mammals (see section 5.6)

Two suggestions were put forward by the Working Party that might throw some light on this intractable problem, namely:

a. Use of otoliths from marine mammal stomachs to test whether the size-at-age of the prey differs from that in the commercial catch. If, for example, it were smaller it might be inferred that the marine mammal was taking weaker individuals than the fishery.

b. Observing the feeding behaviour of the marine mammal to detect whether it will seek to capture more or less readily the weaker individuals of the prey population, perhaps by deliberately introducing moribund specimens among wild fish in the vicinity of the foraging marine mammal.

6.14 Factors limiting the population size of the marine mammal

The significance of knowing whether space or food are likely to be the dominant factor in setting an upper limit to the size of the marine mammal population is discussed in paragraphs 5.19 and 5.20. Known space limitations take the form of restricted habitats at breeding times or, with the more territorial species, for much of their life-history. Field studies on how space-limited marine mammal populations utilise the habitats available to them might therefore provide valuable clues about the upper limit of population size that can be expected. The colonisation in recent years of the Isle of May (in the Firth of Forth) by grey seals, mainly from the Farne Islands, is an example. The question of food limitation might be investigated by taking the opportunity to observe the effect of locally severe food shortages on the population parameters of the marine mammal (see paragraph 5.21). It might thus be possible to establish relationships between food density and the onset of symptoms of food shortage which would be of general significance.

6.15 Methods of controlling population size of marine mammals other than by selective killing

In view of the adverse public reaction to killing marine mammals, it would clearly be advantageous if other ways of controlling their numbers could be developed. Two possibilities were considered by the Workshop, namely:

a. Reduction of the effective reproductive rate of animals with limited and accessible breeding sites, by deliberate disturbance on breeding sites or restriction of access to them. It is known that this can be done, but the extent and significance of any side-effects on the social structure and general well-being of the breeding communities have yet to be assessed.

b. Use of substances to cause infertility or otherwise to reduce the effective reproductive rate, without causing undesirable side-effects.

6.16 Theoretical studies

A satisfactory theory of marine mammal/fishery interaction would be of great value as a basis both for assessment and for identifying the most important areas where further observations are most needed. The analysis in section 4.5 is no more than an initial exploration of concepts and relationships, treating predation by the marine mammal population as if it were equivalent to a subset of the fishing activity. The need is now to develop a more general theory, drawing upon the experience of predator-prey system analysis elsewhere in the biological sphere.

## SECTION 7. AREAS OF POSSIBLE FUTURE CONFLICT

7.1 The last of the terms of reference for the Workshop (paragraph 1.2.4) was to identify where and in what circumstances interaction between marine mammals and fisheries, whether perceived or real, may in the future become more intense and liable to generate serious conflict of interest. The Workshop's conclusions on this question are reported in this section.

### 7.2 Operational interaction

7.2.1 One approach to this task is to review the well-documented cases of conflict and relate them to the circumstances - biological, operational or social - which gave rise to them. An important factor generating operational interaction is the natural inquisitiveness of marine mammals and their propensity, as hunters, to forage in the vicinity of fish shoals and to be attracted by fish already herded together or trapped in fishing gear. Indeed, in some fisheries, fishermen search for concentrations of marine mammals and birds as indicators of the whereabouts of fish shoals, which tends to enhance the operational interaction.

7.2.2 Another factor has been the replacement of traditional fishing methods such as lining, which are relatively harmless to marine mammals, by gill-netting, purse seining and related gear which have been proved to be much more likely to ensnare the foraging mammal. The introduction of synthetic net materials has made the gear more robust but at the same time has given rise to the "ghost net", which has become lost from its moorings but continues to ensnare and kill both fish and marine mammals (see section 2.3.2).

7.2.3 The growing body of practical experience combined with improved understanding of the habits and behaviour of the various species of marine mammal should make it possible to anticipate the probable consequences of proposed developments in fishing operations and gear. The instances brought to the attention of the Workshop of possible future problems were:

a. Change to gill-netting for certain species in the Gulf of Maine, which would constitute a hazard to humpback whales.

b. Increased use of gill-nets on the West Coast of North America for species such as swordfish, which would affect resident and migratory populations of marine mammals.

c. Development of trawling for squid in New Zealand waters and off the Kamchatka Peninsula, which would increase the incidental capture of Hooker's and Steller sea lions, respectively.

7.3 <u>Predatory interaction</u>

7.3.1 The evidence on predatory interaction between marine mammals and fish stocks is less clear as a guide to anticipating future conflict areas, but provides clues. Indeed, of the many cases considered by the Workshop and documented in the literature, there is hardly any incontrovertible evidence of this form of interaction being the dominant factor in determining the long-term abundance, and possibly even the distribution, of either components. Sea-otters and certain benthic invertebrates in the shallow coastal waters of the temperate and boreal north Pacific region are one of the very few exceptions to this generalisation (WP 6). It is noteworthy that the otter's prey are sessile or weakly motile species with poor resilience as populations to predation or to exploitation by man. Unrestricted sea-otter populations and clam fisheries are, it seems, incompatible in one and the same locality (see also paragraph 4.9).

7.3.2 Great care has to be taken in drawing conclusions about the significance of predatory interaction in other cases where evidence as clear as that for the otter and clam does not exist. In most cases the available data are insufficient to give a conclusive answer, and the picture is obscured by the high variability typical of fish stocks and associated fisheries. Even so, it seems from general ecological inference that there are likely to be few, if any, other examples where the components of interaction are so precisely drawn and antagonistic as in the otter-clam system. The walrus of the Bering Sea may conceivably approach it, because it also feeds on molluscs, but recent evidence suggests that it ranges over a considerable territory without causing obvious local depletion of its food supply.

7.3.3 Generally speaking, fish-eating marine mammals are unlikely to create sharply defined instances of biological interaction, simply because they usually have a varied diet and their prey is also mobile. Nevertheless, if the seasonal habits of the mammal and its prey are such as to bring the two into close proximity at certain times, especially in a confined locality such as a river mouth, the situation must be regarded as potentially liable to create significant interaction - or at least the perception of it and a resulting conflict of interest. If the population of the marine mammal is very large, as for example the Cape fur seal, then its potential for biological interaction must be regarded as considerable. In contrast, the British grey seal, although it may have a considerable adverse effect on local salmon fisheries, can generate a small component only of the mortality of the major fish stocks of the North Sea.

## 7.4 Possible future conflicts due to the marine mammal

In trying to anticipate where future conflicts are likely to arise from predatory interaction it is convenient to consider possible changes from the present situation, treating separately the marine mammal and its prey.

7.4.1 An important case is that in which the marine mammal has been depleted by exploitation and is now increasing, hunting having declined or ceased because it has become unprofitable or because of protective legislation, or both. Several instances of this have been described earlier in the report and more are likely to arise in the future. If commercial fisheries have developed or are proposed on prey species which increased when their predator was depleted, the future conflict of interest is likely to be heightened. Among examples are several species of marine mammal and fish stocks in the Bering Sea, the British grey seal in the North Sea, the sea otter in California, the fur seal in New Zealand and S. Georgia and harp seals and humpback whales in the Northwest Atlantic.

7.4.2 The converse possibility is that the marine mammal is decreasing, and in an endeavour to arrest the decline a fishery for its food species may be restricted. No direct evidence was available to the Workshop of a marine mammal declining through shortage of food, though physiological changes in the condition of the mammal (e.g. in its stored energy) have been reported in seals, which are thought to reflect changes in food consumption (e.g. WP 8 and 10). If a proposed solution is to set up conservation areas for the marine mammal in which its prey species are also protected, new conflicts may be generated, especially at the boundaries of such areas.

7.4.3 A third possibility is that the marine mammal changes its feeding habits from a less to a more commercially important species. The yellowtail/dolphin interaction at Iki Island may be a case in point, but long-term evidence on feeding is usually lacking. If such a change occurs it is likely to be caused or accompanied by a shift in the distribution of the marine mammal relative to its prey.

## 7.5 Possible future conflicts due to the fishery

7.5.1 Where fisheries are newly developed and expanding, the increased fishing activity may come more into conflict with a predatory marine mammal, whose existence had hitherto gone largely unnoticed. A number of examples of potential conflict can be anticipated from actual or proposed expansion of fisheries, among them being:

a. Shellfish fisheries in Alaska and British Columbia, involving sea otters.

b. Squid fisheries in the eastern tropical Pacific, involving open ocean cetaceans.

c. Krill fisheries in the Antarctic, involving baleen whales and crab-eater and fur seals.

d. Coastal fisheries in Alaska for herring and capelin, involving sea lions and a number of species of seal.

7.5.2 Similar, but probably more serious, situations are likely to arise if the stocks of the prey species become depleted by fishing. The competitive influence of the predatory marine mammal may then actually increase, if it is able to search out the remaining concentrations of fish better than can the fishermen. The fishermen are likely in those circumstances to perceive the marine mammal as a serious threat to their livelihood and demand remedial action. Again, if, faced with falling catches offshore and rising costs, fishermen were to work more in coastal areas nearer to port, they may be brought for the first time into close contact with marine mammals, possibly during their breeding season. Control of a marine mammal to assist fisheries which are in difficulties has been called for in several instances, such as grey seals in Britain (WP 7). The present concern in Norway about the possibility that killer whales may be a factor inhibiting the recovery of the Atlantic-Scandian herring is an example of the anxieties that are expressed when a fishery has become seriously depleted (WP 3).

7.5.3 There are two other possibilities that should be mentioned here. One is that a commercial fishery may shift to new target species which comprise a significant proportion of the diet of a marine mammal. An example is the probable shift of the prime target species in the Southwest Africa/Namibia fishery to the bearded goby, which is an important food for Cape fur seals (WP 4). The other possibility is that the fishery, while continuing to exploit the same species, may alter the size range of fish it exploits, which may in turn alter the intensity of interaction with the marine mammal. Potentially the most serious case of this kind is that in which the exploited size is increased, for example by a mesh regulation, leaving the marine mammal predatory on smaller fish (see section 5.5). The Workshop was unaware of documented evidence of either of the above situations, but both could occur in the future.

## SECTION 8. CONCLUDING REMARKS

8.1 The various questions posed by IUCN in the Terms of Reference (section 1.2.4) are answered to the best ability of the participants in the preceding sections of this report, and a further summary would be superfluous. It is appropriate, however, to conclude with certain general considerations which arose during the discussions.

8.2 The first is whether the concern of IUCN and other bodies about the seriousness of the conflict, actual and potential, between marine mammals and fisheries is justified. By and large the answer is yes, despite the frequent lack of conclusive evidence. Some of the instances which have generated the most public controversy so far may prove eventually to be of less significance than has been thought. This is true both as regards the adverse effect of the marine mammal on the fishery and of the threat to the marine mammal of action taken to stablise or reduce its numbers. But there are instances about which it is necessary at least to reserve judgement; and yet others where the probability is that the interaction between the marine mammal and the fishery is already substantial, or is likely soon to become so.

8.3 The reader may well wonder why so many of the conclusions reached by the Workshop are tentative and qualified by the lack of scientific evidence. The fact is that it is difficult enough to reach sound conclusions about the ecology and dynamics of natural populations of fish or marine mammals taken individually. When the requirement is to assess the interaction between them, sometimes involving several components, the task is a great deal more difficult. For many fish stocks, and for some marine mammal populations, it is only in the last few years that the accumulated evidence of decades of observation is now making it possible to disentangle the influence of man and natural events in determining their abundance and stability. No such long series of reliable data exist for any marine mammal/fishery system.

8.4 Although it is encouraging to see the increased importance being given to research on the interaction between marine mammals and fisheries in many countries, it must not be assumed that quick answers will be forthcoming. Many mammals and the fish they eat typically live for a number of years, and so the long-term effect of one on the other cannot be fully worked out and tested in a short time. In the meanwhile, the natural fluctuations in the system due to quite different factors may well obscure, though not necessarily remove, the interaction being investigated. In many fisheries, for example, a sustained decline of, say, 25% or even more in the productivity might be impossible to detect from fisheries statistics alone against the background of much larger fluctuations due, for example, to environmental causes. Yet if it could be established that such a decline had indeed happened, and was due to a marine mammal, the implications could not be lightly set aside. The assessment of such interaction, even of a substantial nature, will usually come from careful analysis and a proper understanding of the system. Impartial scientific judgement of limited and often circumstantial evidence will be of vital importance. This needs to be understood and appreciated by those who tend, for whatever reasons, to be committed to a particular view of what should or should not be done.

8.5 This brings us to the final point, namely the contrast between the real nature and extent of interaction and how it appears to the interested parties. The participants confined themselves strictly to scientific considerations in accordance with the remit of the Workshop, but they were fully aware that social factors, economic or cultural, may predominate in determining what is to be done.

8.6 The juxtaposition between a perceived threat, on the one hand to a food resource and dependent livelihoods, and on the other to the protection of a highly-prized wildlife population and perhaps other dependent livelihoods, is a conflict of interest which science cannot resolve. Some form of compromise will be needed, based on a mutual recognition and understanding of respective positions. It is for the scientists to attempt to establish the true substance of the perceived threat to each side, distinguishing fact from guesswork, and so to offer the best impartial guidance that is possible on existing knowledge to those with whom the ultimate decision will lie.

# APPENDIX 1

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## APPENDIX 2

## WORKING PAPERS

1. Harwood, J. and A.R. Hiby. Competition between British grey seals and fisheries.

2. Harwood, J. Fisheries conflicts and the Pacific walrus population.

3. Hiby. A.R. and J. Harwood. Killer whales and herring in the North Atlantic.

4. Shaughnessy, P.D. Interactions between fisheries and Cape fur seals in southern Africa.

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7. Beverton, R.J.H. The grey seal/fishery problem in the UK: science in the cross-fire.

8. Yablokov, A. Seal/fisheries interactions in the Baikal and Ladoga Lakes and in the Caspian and White Seas: historical lessons.

9. Allen, R. Dolphins and the purse seine fishery for yellowfin tuna.

10. Bowen, W.D. Harp seals and their foods: how do they interact?

11. DeMaster, D.P., J.R. Henderson and J.C. Coe. Conflicts between marine mammals and fisheries off the coast of California.

12. Greenwood, J.J.D. Grey seals in Scotland: the management controversy.

13. Frost, K.J. and L.F. Lowry. Foods and trophic relationships of cetaceans in the Bering Sea. In The eastern Bering Sea shelf: oceanography and resources. Edited by D.W. Hood. In press.

14. Lowry, L.F. and K.J. Frost. Feeding and trophic relationships of phocid seals and walruses in the eastern Bering Sea. In The eastern Bering Sea shelf: oceanography and resources. Edited by D.W. Hood. In press.

15. Brodie, P. and B. Beck. Predation by sharks as a factor in grey seal (Halichoerus grypus) mortality in eastern Canada.

16. Øritsland, T. and A. Bjørge. Seals on the Norwegian coast from Stadt to Lofoten and their interactions with inshore fisheries.

17. Ultang, Ø. Harp seals in the Barents Sea (White Sea harp seals) and the fishery for cod.

18. McAlister, B.W. Estimates of fish consumption by marine mammals in the eastern Bering Sea and Aleutian Island area.

19. Perez, M.A. and M.A. Bigg. An assessment of the feeding habits of the northern fur seal in the eastern North Pacific Ocean and Bering Sea.

20. Perez, M.A. and M.A. Bigg. Modified volume: A two-step frequency-volume method for ranking food types found in stomachs of northern fur seals.

21. Estes, J.A. and E.E. Ebert. Sea otters and invertebrate fishery resources: existing and potential conflicts from Canada to Mexico.

22. Swartzman, G. and R. Hoar. Exploring interactions between fur seal populations and fisheries in the Bering Sea.

## APPENDIX 3

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# APPENDIX 4

## WORKSHOP AGENDA

1. Opening of Workshop
   Introduction of participants and rapporteurs

2. IUCN/Committee on Marine Mammals, background and workshop objectives.

3. Adoption of Agenda

4. Tabling of Working Papers

   4.1 Case studies

      4.1.1 Damage to gear
      4.1.2 Damage to catches
      4.1.3 Incidental catch
      4.1.4 Transmission of parasites
      4.1.5 Biotic interactions between marine mammals and fisheries
      4.1.6 Other

   4.2 Theoretical papers

5. Biotic interactions between marine mammals and commercial fisheries

   5.1 Problem identification and assessment

   5.2 Under what (if any) conditions are marine mammal predators likely to affect the abundance of their prey species to the extent that they compete with fishermen for commercially important species? Are these problems best viewed in the context of "niche overlap" between marine mammals and fishermen?

   5.3 What are the best ways of calculating the effects on fishery yields of changes in marine mammal populations?

   5.4 May fishing (and possibly depletion) of prey species affect marine mammal populations, and if so under what conditions is this most likely to occur?

5.5 What are the possible effects of quotas based on surplus yield calculations on subsequent interactions between predator (including marine mammal) populations and prey populations?

5.6 Adequacy of existing data and current theory for assessing the ecological aspects of marine mammal/fishery interactions.

6. Future considerations

6.1 How may commercial fisheries be conducted in the future, including the setting of quotas, in such a way as to ensure that marine mammal populations are held at some predetermined (and stable) level?

6.2 Under what conditions should harvesting of a marine mammal population be considered the appropriate management action to reduce marine mammal/fishery interactions?

6.3 What monitoring will be required to assess the extent of marine mammal/fishery interactions in order to provide scientific advice to management authorities? What monitoring will be required to check the validity of the scientific theory on which management is based?

6.4 Where may marine mammal/fishery conflicts arise in the foreseeable future?

7. Economic and management considerations in marine mammal/fishery interactions

8. Legal considerations

9. Other considerations

10. Priorities for future research

11. Other business