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Priorities For Assessing Marine Mammals Incidentally Taken In Commercial Fisheries Of The United States

July 1991

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PRIORITIES FOR ASSESSING MARINE MAMMALS INCIDENTALLY TAKEN IN COMMERCIAL FISHERIES OF THE UNITED STATES

Report of the workshop
held 5-7 March 1990

at the

National Marine Mammal Laboratory
Alaska Fisheries Science Center
Seattle, Washington

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ABSTRACT

A workshop was held to assess the incidental take of marine mammals by commercial fisheries in U.S. waters and to prioritize marine mammal species for future studies to identify essential population data gaps. In addition, alternative management strategies were developed to meet the uncertainties of existing population information as required under the Marine Mammal Protection Act. Besides monitoring the kill of marine mammals taken incidentally in fisheries, the highest priority information needed is estimates of population abundance or trends and information on causes of mortality. Of the approximate 38 populations of marine mammals (or species complexes) in U.S. waters, 14 are identified as being of the highest priority for immediate study based on the lack of information on population numbers or trends and the potential for being taken incidentally in fisheries. The priority species or species populations in U.S. waters are harbor porpoise (Atlantic and Pacific), bottlenose dolphin (Atlantic), harbor seal (Alaska and Atlantic), Dall's porpoise (eastern Pacific), a delphinid complex (Gulf of Mexico, Atlantic, and Pacific), and pilot whale (Atlantic and southern California).

Seven preliminary alternative assessment strategies were developed to deal with short-term management under the Marine Mammal Protection Act. These alternatives are formulated under four management scenarios where the optimum sustainable

population (OSP) is based on 1) estimates of historic abundance, 2) current carrying capacity, 3) current carrying capacity when the incremental rate of change is 10% of the maximum rate of change in net productivity, and 4) no defined range of OSP estimates.

Recognizing that managing marine mammal and fish populations is more complex than the current single-species approach, development of a long-term solution to ecosystem management is suggested. To begin this process, it is recommended that an international symposium and workshop be conducted by 1992 to address how to blend theory and solutions for assessing marine mammal-fishery interactions and plan strategy for managing marine resources in an ecosystem context.

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BACKGROUND

After a 5-year exemption period ending in 1993, the 1988 reauthorization of the Marine Mammal Protection Act (MMPA) authorizes the incidental take of marine mammals in commercial fisheries from marine mammal stocks whose population level is within its optimum sustainable population (OSP) range. Data collection activities necessary for estimating the degree of incidental take in fisheries have been implemented in numerous fisheries where incidental take may be significantly impacting marine mammals. However, it is unlikely that sufficient data for determining the effects of incidental take and OSP levels for all marine mammal species or stocks impacted by fisheries will be available by the end of the 5-year exemption period. In recognition of this likely outcome, the 1988 amendments further require the National Marine Fisheries Service (NMFS) to develop a management regime by 1 February 1993 for the taking of marine mammals in U.S. commercial fisheries.

In support of meeting the NMFS's obligation under the 1988 amendments to the MMPA, a workshop was held on 5-7 March 1990 at the National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, Seattle, Washington. The purpose of the workshop was to identify the research information needed for assessing the impact of incidental take and to discuss possible methods to evaluate the appropriateness of, and alternatives to, using OSP levels in making status-of-stocks assessments and implementing management strategies to deal with the takes. Participants at the workshop represented the fields of marine mammalogy and

fishery biology from the NMFS and fishery management councils (Table 1).

OBJECTIVE AND SCOPE

The objective of the workshop was to provide advice to the NMFS on the short- and long-term information needed for assessing the impact of incidental take of marine mammals in commercial fisheries. To accomplish this, the workshop participants undertook the following tasks:

1) to develop a list of species or populations where critical assessment information is missing;
2) to establish a rating of species regarding priority of research for addressing data gaps on the effects of incidental take;
3) to suggest alternative single-species approaches to managing marine mammals taken in fisheries; and
4) to develop a proposal to convene a symposium on advances for investigating ecosystem-level multispecies management concerns emphasizing evaluation and interpretation of alternatives to the use of OSP.

The scope of the workshop during consideration of tasks 1 and 2 above was confined to fishery-induced mortality, such as incidental take, entanglement, and shooting. Information for establishing priorities was based on known or anticipated takes within existing or proposed fisheries working in U.S. waters.

Other factors that may affect marine mammal populations, such as habitat degradation, were not considered in great detail. It was agreed, however, that if fisheries produce a potentially strong indirect effect, then the effects through the ecosystem need to be considered also. This problem became, in part, the basis for task 4.

INFORMATION NEEDED FOR ASSESSING IMPACTS

Seven categories of information deemed essential for making a full assessment of marine mammal populations are listed below. Table 2 contains the workshop's conclusions which correspond to these categories and each species or population (stock) reviewed at the workshop. There is great variation in the amount and kinds of information available among species; this degree of certainty and uncertainty was used to evaluate priorities for research (see Table 2 and Discussion and Recommendations). The following descriptions correspond to the seven columns in Table 2.

1. Monitoring the kill. Are the numbers of marine mammals killed directly by fishing gear being monitored?

Yes: Data are expected to be available.

Some: Some data are available but more are needed.

No: Data are not expected to be available.

2. Population estimate. Does a population estimate exist? Are precision and accuracy adequate for management action? Is the management action robust to uncertainties in the estimate?

Yes: An estimate exists, or data have been collected and an estimate can be produced.

Some: It may be possible to produce an estimate using existing data but may not be sufficient for management purposes.

No: Data are not sufficient for an estimate.

3. Population trend. Can a trend in abundance be obtained by 1993?

Yes: Data are available, and a trend has been or can be produced.

Some: A rough estimate may be possible.

No: Data are not sufficient to estimate a trend.

4. Stock definition. What is a stock? Are stock boundaries critical to an assessment? (Stock in this context may or may not be a recognizable subdivision of a population that may need to be managed separately; e.g., harbor porpoise (*Phocoena phocoena*) in California versus Washington.)

Yes: Stock boundaries are known.

Unknown: Stock boundaries are unknown and possibly critical to assessment.

Some: Some data are available but more are needed.

No: Stock boundaries are unknown but not critical.

5. Status with respect to OSP. Is the population level above or below OSP levels? Is the population defined as depleted or endangered?

Yes: Data are available to determine status.

No: Data are not sufficient to determine status.

6. Is incidental take greater than 1% of the estimated population? Is incidental take having a negative effect on the stock? Is the kill level above some fraction of the growth rate or estimated maximum net productivity? An arbitrary level of 1% of the estimated abundance is provisionally selected as a reference point.

Yes: Current take is likely to be greater than 1%.

No: Current take is likely to be less than 1%.

Unknown: Current take is unknown but may be greater than 1%.

7. Possible influences that may contribute to mortality (potential declines in populations or conditions that inhibit population recovery). Several other factors were considered important for fully evaluating the impacts of incidental take.

A: (direct) incidental take

B: "ghost" fishing and entanglement in net debris

C: indirect fishery effects (trophic competition)

D: other human-induced factors

E: physical, environmental, and natural factors

F: directed take (i.e., subsistence harvest or live capture)

G: direct take from shooting

DISCUSSION AND RECOMMENDATIONS

This section of the report addresses which information is most important for assessing impacts, develops species priorities for study, outlines the need for research proposals before any allocation of funds is made, and proposes short-term management strategies and consideration of long-term ecological assessments.

Primary Information Needed

Existence of Incidental Kill Monitoring.

Monitoring the kill will provide the minimum essential information needed to meet the requirements of the 1988

amendments to the MMPA. As noted in the "Kill monitored" column of Table 2, however, the data will be incomplete because for some species or populations the kill is not monitored or is incompletely monitored. In some cases, certain kinds of direct takes, such as shooting, may not be observed even if the fishery is being monitored (item G under "Influences on mortality" in Table 2).

Obtaining incidental-take data alone usually will not provide the information necessary to assess how the species or population(s) are being affected by the take. To do this, other information is needed such as estimates of abundance or population trends and other causes of mortality related to ecosystem interactions (e.g., diseases, fishery interactions, and competition for prey resources).

Population Estimates and Trends.

Estimates of minimum population size are available for many of the populations in Table 2 (about 40%), while estimates of trends are generally not known (about 20%). There was considerable discussion about how accurate and precise estimates of abundance needed to be for assessment purposes. It was noted that where the incidental take was thought to be greater than a small percentage of population size, then more reliable population size estimates were likely required. Also noted was that where both current and historic population size estimates are known and the history of kills is available, then back calculation could provide estimates of OSP status. However, when only point

estimates of kill levels are available, then only simple comparisons of incidental kill and population size would be possible. Simple comparisons would not meet the requirements of the MMPA as currently interpreted. On the other hand, where population trends are available, alternate OSP assessments using, for example, the dynamic response method (see Goodman 1988; Gerrodette 1988) might be possible and appropriate for the MMPA. Such applications become difficult, however, where abrupt changes in population trends are seen, as was the case for some pinnipeds during the El Niño warmwater events in the midlatitudes. Even where such trends do support use of the dynamic response method, this method assumes that the appropriate reference point is the current carrying capacity. This is in contrast to the reference point in the form of the historic carrying capacity as used by the backcalculation approach. Several species were identified where the difference in reference points could be important; for example, toothed whales in the Gulf of Maine and Mid-Atlantic Bight where long-term overfishing may have altered the availability of pelagic prey species (i.e., potential major changes in carrying capacity). It was noted that the recent Marine Mammal Commission (MMC) draft report on this issue did not directly make recommendations as to which reference point to use.

Possible Influences on Mortality.

The workshop concluded that other forms of mortality may be more important for some species than incidental take. All influences of mortality were compiled and are listed by species in Table 2,

column 7. While several other factors are of concern, including human-induced reduction in habitat and entanglement, there was considerable discussion about the role of indirect fishery effects through trophic interactions (indicated by a "C"). The workshop participants noted that these indirect effects went two ways: where the mammals may affect fishery yields of exploitable fishery resources and, conversely, where fisheries may affect marine mammal populations through changing prey abundance or distribution. The former case can occur when marine mammals prey on exploitable species or when they prey on species that are prey to exploitable species. The possible types of interactions become complex and are difficult to distinguish from other changes in the ecosystem such as climate or other environmentally induced changes (indicated by an "E"). It is this complexity of resource interaction that led to the discussion of managing ecological systems and the need for a more detailed discussion of the subject (see Alternative Management Strategies).

Species Priorities

After reviewing the known history and potential for incidental take of marine mammals in fisheries, the workshop generated a list of species or populations of species that require further study (Table 3). These highest-priority species or populations were divided into three groups. Animals whose population size is not sufficiently known and whose incidental take is likely to be greater than 1% comprised Group 1 and

included several populations of harbor porpoise and bottlenose dolphin (Tursiops truncatus, North Atlantic coastal population only). Group 2 contained animals whose population size was also not sufficiently known and whose incidental take could be greater than 1%--this included several populations of harbor seals (Phoca vitulina) and pilot whales (Globicephala spp.), Dall's porpoise (Phocoenoides dalli), bottlenose dolphin (North Atlantic offshore population only), and six population complexes of delphinids. Groups 1 and 2 are considered to be approximately equal in priority. Group 3 accounted for current or recently declining stocks not thought to be directly affected by incidental take (i.e., northern fur seals, Callorhinus ursinus, and Steller's sea lions, Eumetopias jubatus) and is lower in priority than Groups 1 or 2.

Research Experimental Design Considerations

The workshop participants recommended that prior to funding a particular project dealing with the high-priority research needs identified above, an experimental design should be developed and reviewed. In most cases, existing data can be used to determine the level of sampling coverage necessary to result in population indices with an acceptable level of precision. Where such experimental design data are not available, funding to support pilot surveys for their development should first be considered. Within the experimental design, the following information should be specified:

1) Target (geographic) population(s) to be studied;

2) Duration of study within a field season;

3) Summary of available information or data;

4) Methods, design, and sample sizes where possible;

5) Expected level of (statistical) precision;

6) Whether the resulting data will be useful as a minimum population estimate, an absolute population estimate, or an index of relative abundance;

7) Number of replicate surveys needed, if any;

8) Choice of vessel, aircraft, ground surveys, or a combination thereof, and why; and

9) Proposed schedule for both field and laboratory work and completion of reports.

Alternative Management Strategies

To meet the requirements of the MMPA and the Magnuson Fishery Conservation and Management Act (MFCMA), there is a need to determine the magnitude of the effect of incidental take on marine mammal populations. In the absence of full information, management action will have to depend on the perception of vulnerability that a particular species or population may be under. That is, decisions about the level of allowable takes, if any, may largely depend on how much is known about the population dynamics of the species and whether the animal is likely to entangle and die in fisheries gear.

Table 2 shows that the status of most species or populations is not well known. Obtaining the necessary information to determine status is sufficiently difficult that their status will

not be known with respect to their OSP by 1993. Present management practices (e.g., those based on OSP levels) may therefore be inadequate to meet the criteria of assessing impacts and formulating appropriate allowable takes. And, given the direction proposed by the National Oceanic and Atmospheric Administration (NOAA) to manage on the basis of marine ecosystem concepts, there is a definite need to reevaluate our current understanding of management options in light of the growth of knowledge in the fields of theoretical ecology, systems dynamics, and fisheries management.

Two solutions are proposed for meeting the short- and possibly the long-term management of marine mammal populations relative to the impacts of incidental take in commercial fisheries. The short-term recommendations deal with alternative proposals based on existing information about populations and some presumptions about carrying capacity. The long-term needs address the broader ecological conditions; a symposium is proposed to evaluate our knowledge about how and why species and environmental interactions affect the assessment process and thus potential management strategies.

Short-term Proposals (see Appendix I).

A subgroup was convened (chaired by DeMaster) to develop suggested draft short-term, transitional management strategies consistent with current single-species management concepts, and to meet the immediate requirements of the reauthorized MMPA (1988

amendments). Appendix I contains the proposed short-term alternatives to address decisions needed by 1993.

The alternatives were developed based on consideration of productivity levels, minimum population estimates, levels of incidental take, and trends in population abundance, as well as traditional methods of population assessment (see Gerrodette and DeMaster 1990). Recognizing the interim nature of these alternatives, it is recommended that a special meeting be held with the NMFS Task Force on Implementing the 1988 Amendments to the MMPA to fully explain and evaluate the proposed options in Appendix I. A complete review of the performance of the various proposals needs to be done to ensure that the selected approaches perform well under situations with different amounts of information (i.e., scientific data).

Long-term Proposals (see Appendix II).

In the future (completion by Fiscal Year 1993 for possible application thereafter), new management strategies must be considered. The interim alternatives in Appendix I are a continuation of the application of single-species approaches, whereas the longer-term approach is based on multispecies interactions and ecosystem dynamics.

To stimulate the development of such an approach, a second subgroup (chaired by Fowler) was convened to produce a proposal for a large-scale symposium and workshop on ecosystems management of marine mammals and fisheries (Appendix II). The rationale for such a symposium was developed within the context of mandated

management requirements for ecosystem considerations. The principal question that needs to be addressed relates to whether or not there has been sufficient development in our understanding of fishery-marine mammal ecosystems to provide useful advice. Furthermore, it is necessary to evaluate our ability to study such ecosystems. The present definition of OSP was promulgated in the late 1970s. Since then, some marine mammal and fishery populations have changed greatly. Is the concept of an OSP still appropriate even if the carrying capacity of the ecosystem has changed substantially? It may be that sufficient progress has been made in understanding population dynamics and ecological theory to allow a better evaluation of the concept and utility of an OSP. If so, then a sufficiently focused symposium and workshop might result in new and more effective research and management recommendations. The utility of better understanding ecosystems, however, is not solely dependent on whether a resolution can be made about the appropriateness of the use of an OSP.

Table 1.--Participants at the 5-7 March 1990 workshop on priorities for assessing the impact of incidental take on marine mammals in commercial fisheries.

Participant	Affiliation
James Balsiger	Alaska Fisheries Science Center
Howard Braham (Convener)	Alaska Fisheries Science Center
Douglas DeMaster	Southwest Fisheries Science Center
Charles Fowler	Alaska Fisheries Science Center
Thomas Hoff	Mid-Atlantic Fishery Management Council
Alec MacCall (Chairman)	Southwest Fisheries Science Center
Richard Methot	Alaska Fisheries Science Center
Sally Mizroch (Rapporteur)	Alaska Fisheries Science Center
Gerald Scott	Southeast Fisheries Science Center
Tim Smith	Northeast Fisheries Science Center
Harold Weeks	North Pacific Fishery Management Council

Table 2.–Species-population list and information needed for assessing the impact of incidental take in U.S. commercial fisheries. See legend definitions and explanations at end of the table.

Text reference number	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Species/species complex	Kill monitored	Population estimates	Stock trends	Status Definition	Status WRT OSP	Incidental take >1%	Influences on mortality
Right whale	S	Y	S	Y	Y(E)	Y	A,B,D,E
Humpback whale							
North Pacific	Y	S	N	S	Y(E)	N	D
North Atlantic	S	Y	S	Y	Y? (E,R?)	U	A,D,E
Minke whale							
North Pacific	Y	N	N	N	N	U	A
Other baleen whales							
North Atlantic	S	N	N	N	U (E)	U	C
Sperm whale	S	N	N	N	N	Y	C,D
Gray whale	Y	Y	Y (15)	Y	Y (E,R?)	N	D,E,F
Harbor porpoise							
Alaska	S	N	N	U	N	Y	A
Washington/Oregon	S	S	N	U	N	Y	A
California	Y	Y	Y (5)	U?	Y	Y (5%)	A,D
North Atlantic coast	S	S	N	U	N	Y (6%)	A,C
Beluga	Y?	Y	N	Y	N	N	A,F
Killer whale	S?	S?	S?	N	N	N	D,G
Dall's propoise	Y	N	N	N	N	Y	A
Pilot whales spp.							
North Atlantic	Y	S	N	S	N	U	A,C
Southern California	Y	N	N	U	N	U	A,E
Beaked whales spp.							
North Atlantic	Y	N	N	N	N	U	A
North Pacific	Y	N	N	N	N	U	A

Table 2.–Continued.

Text reference number	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Species/population complex	Kill monitored	Population estimates	Stock trends	Status definition	Status WRT OSP	Incidental take >1%	Influences on mortality
Delphinids, including spotted, white-sided, grampus, others							
Alaska	S	N	N	U	N	U	A,B
California/Washington/Oregon		Y	N	N	U	N	U A
Southern California bight	Y	N	N	U	N	U	A,E
North Atlantic	Y	Y?	N	U	N	U	A
South Atlantic bight	N	N	N	U	N	U	A,D,E
Gulf of Mexico	N	N	N	U	N	U	A,D,E
Bottlenose dolphin							
North Pacific	Y	Y	N	N	N	U	D
Atlantic offshore	N	S	N	N	N	U	A,D,E
Atlantic coastal		N	S	S	S	Y (D)	A,D,E,G
Gulf of Mexico	N	Y	S	N	N	Y	A,C,D,E,F,G
Northern fur seal	Y	Y	Y (80) (S or D)	Y	N	N	B,C,D,E,F
Northern sea lion	Y	Y	Y (25) (D)	Y	Y (T)	N	C,D,E,F,G
California sea lion	Y	Y	Y (15) (I)	Y (? Mex.)	Y	Y (3%)	A
Harbor seal							
Alaska	S	N	N (D)	U	N	U	A,F
Washington/Oregon	Y	Y	Y (8)	U	N	U	A,D
California	Y	Y	Y (8)	U	Y?	Y (10%)	A
North Atlantic coast	Y	S	S	Y	N	U	A,B
Gray seal							
North Atlantic	Y	Y	S	Y	N	N	A,B,D
Hawaiian monk seal	N	Y	Y (7)	Y	Y (E)	N	A,B,D,E

* See text for complete definition of each information category using the indicated text reference number.

Legend for columns (1) to (7):

General (1-2,4,6)	Stock Trends (3)	Status (5)	Influences of Mortality (7)	
Y: Yes	(Years of data)	D: Depleted under MMPA	A: Indirect take	E: Natural/environmental
N: No	D: Declining	T: Threatened under ESA	B: Ghost fishing	F: Subsistence/live capture
U: Unknown	S: Stable	E: Endangered under ESA	C: Indirect effects	G: Shooting
S: Some	I: Increasing	R?: Possibly recovered	D: Other human causes	

Table 3.--List of priority marine mammal species or population(s) for research to assess the impact of incidental take in commercial fisheries.

Group 1 Where population size is not sufficiently known and incidental take is likely to be >1%.

Harbor porpoise (*Phocoena phocoena*)
- Alaska
- Washington and Oregon
- North Atlantic

Bottlenose dolphin (*Tursiops truncatus*)
- North Atlantic Coastal

Group 2 Where population size is not sufficiently known and incidental take could be >1%.

Harbor seal (*Phoca vitulina*)
- Alaska
- North Atlantic

Dall's porpoise (*Phocoenoides dalli*)

Delphinid complex
- Alaska
- Washington, Oregon and California
- Southern California Bight
- North Atlantic
- South Atlantic Bight
- Gulf of Mexico

Bottlenose dolphin (*T. truncatus*)
- North Atlantic Offshore

Pilot whale (*Globicephala* spp.)
- Southern California Bight
- North Atlantic

Group 3 Depleted or declining populations with a small incidental take.

Steller's or northern sea lion (*Eumetopias jubatus*)

Northern fur seal (*Callorhinus ursinus*)

APPENDIX I

ALTERNATIVE APPROACHES TO MANAGING THE INCIDENTAL TAKE OF MARINE MAMMALS IN U.S. COMMERCIAL FISHERIES

(Subgroup report by Douglas DeMaster)

By legislative mandate, the National Marine Fisheries Service (hereafter referred to as NMFS) is to provide Congress with a proposal to govern the incidental take of marine mammals in commercial fisheries on or before February 1992. This proposal is to be developed in cooperation with the Marine Mammal Commission (hereafter referred to as MMC) and the U.S. Fish and Wildlife Service and may involve development of management approaches other than those described in the Marine Mammal Protection Act (MMPA) of 1972. This process benefited from a proposal the MMC made available to the NMFS in the spring of 1990. In February 1990, the MMC circulated a draft proposal for comments. After evaluating the merits of the proposal, scientists from the NMFS identified the following problems:

1) the use of terms that are not well-defined or that can not be estimated with current techniques available to wildlife or fishery scientists (e.g., use of the term "carrying capacity" without clarifying whether the historical or current carrying capacity is intended, and to what extent estimates of the carrying capacity should account for the ecosystem rather than (as currently done) taking single-species approaches);

2) the use of seemingly arbitrary values in setting levels of allowable take; and

3) the lack of a comprehensive analysis concerning how the application of the proposed guidelines would apply to the management of fishery-marine mammal interactions.

The purpose of Appendix I is to introduce possible alternatives to the MMC's proposal. It should be noted that the MMC's proposal, as well as all of the alternative proposals discussed in this document, satisfy the management requirements described in Holt and Talbot (1978). Holt and Talbot believe that marine resources can be exploited in ways that do not compromise the health of an ecosystem, and suggest that irreversible changes in the ecosystem should be avoided, that a safety margin should be incorporated into the guidelines used to manage marine resources because of uncertainty and errors in parameter estimation, and that population monitoring and assessment should precede and accompany actual use of a marine resource. To this end, we assume that information is available on population size, trends in abundance, and the combined level of incidental take by fisheries. We further assume that the incidental take of marine mammals will not be random with respect to the sex of animals taken incidentally by fishermen and, therefore, are proposing to set levels of allowable take on the female segment of the population, as well as for the entire population. This will require information on the sex of animals taken in commercial fisheries. We consider this a necessary

piece of information to meet the intent of the MMPA in managing marine mammal populations that interact with U.S. fisheries. Finally, because the status of a population under the Endangered Species Act (ESA) is based on both population size (relative to the carrying capacity of the environment) and habitat considerations, and status determination under the MMPA is based solely on population size, we recommend that the automatic classification of a population as depleted under the MMPA be dropped when a population is listed as threatened or endangered under the ESA. In developing the following suggestions, we have assumed that this recommendation has been followed.

Description of Suggested Alternative Approaches

The workshop considered four management scenarios based on the use of historic versus current carrying capacities, and on the definition of the lower bounds of the optimal sustainable population (OSP). Within these four scenarios, a total of seven alternative management strategies were formulated and are described below. This list is intended as a set of suggestions to be reviewed and more fully developed in the context of a meeting environment (or by correspondence) with significant involvement by managers. It is especially important that the implementation of the final product of such considerations be clearly formulated and that implementation be clear and explicit.

The seven alternative strategies differ primarily in whether an OSP determination is required, and the way in which allowable

takes are calculated. For six of the seven alternatives, an OSP determination (i.e., the possible outcomes of "at OSP", "below OSP", and "status uncertain") is required to set levels of allowable take. For only one of the alternatives is an OSP determination not required. In this case, the level of allowable take is determined by trends in relative abundance of the population. The seven suggested alternative approaches are as follows.

Scenario I: OSP based on estimates of historic abundance (i.e., preexploitation).

Alternative 1--If the population level is thought to be less than the estimate of historic abundance and greater than the level where net production is maximized (hereafter referred to as the maximum net productivity level--MNPL), then maximum allowable take levels (per year) for all animals and for females are set equal to 90% of average net productivity at the MNPL. If estimates of net production at the MNPL are not available, maximum allowable take levels (MATL) are estimated as follows:

$$MATL = 0.9 \cdot 0.25 \cdot Rmax \cdot HAL, \qquad (1)$$

where,

Rmax = maximum rate of population growth, and

HAL = historic abundance level, and MATLs are expressed in numbers of animals per year.

See Annex IA for the derivation of Equation 1. To estimate the MATL for females, the number of females in the preexploited population is estimated, and this number is used in Equation 1. In the absence of data on the sex ratio of the preexploited population, the sex ratio is assumed to be 1:1.

If the status of the population is uncertain and the population is not listed as depleted under the MMPA or as threatened or endangered under the ESA, then the MATL is calculated as given in Equation 1, except that HAL is replaced by a minimum population estimate. If Rmax is unknown, a default value of 8% is used (See Annex IB for justification of 8%). The MATL for females is calculated by using Equation 1 where HAL is replaced by the minimum number of females in the population. If the status of the population is uncertain and thought to be below the MNPL, or if a minimum population estimate does not exist, the maximum allowable take is restricted to no more than 50 animals per year or 25 females per year (see Annex IC for justification). Where the estimated MATL using Equation 1 is less than 50, this lower estimate is used as it is more conservative.

<u>Alternative 2</u>--If the size of a population is greater than 20% of its HAL, then the MATL is estimated as follows:

$$MATL = 1.8 \cdot netprod \cdot ((POP/K) - 0.2), \qquad (2)$$

where,

netprod = net production of the population at the MNPL in units of numbers of animals per year,

POP = the current population size, and

K = equilibrium population prior to exploitation.

If net production at the MNPL is unknown, it is estimated using Equation 1 except that the 0.9 is dropped from the equation. The MATL for females is calculated using Equation 2, except that the number of females in the population is set equal to POP.

If the status of the population is uncertain, net production is calculated as given in Equation 1 (except that the 0.9 term is dropped), where HAL is replaced by a minimum population estimate and the population is assumed to be at 25% of K. If Rmax is unknown, then a default value of 8% is used. The MATL for females is calculated by using Equation 1, where HAL is replaced by the minimum number of females in the population. If the population level is below 20% of its HAL and the population is not listed, the maximum allowable take level is restricted to no more than 50 animals or 25 females per year.

Scenario II: OSP based on estimates of current carrying capacity (i.e., equilibrium population in the absence of direct exploitation, incidental mortality, or commercial fisheries).

Alternative 3--Same as Alternative 1, except that the status

determination is relative to current carrying capacity. In this case, backcalculated estimates of carrying capacity can only be used if there are no data to suggest that the carrying capacity has changed. Status determinations based on dynamic response analyses are appropriate for this alternative (e.g., see Goodman 1988; Gerrodette 1988).

Alternative 4--Same as Alternative 2, except that the status determination is based on estimates of current carrying capacity.

Scenario III: OSP based on current carrying capacity, but the lower end of the OSP range is defined as a population level, where the rate of change of net production per increment in abundance is 10% of the maximum rate of change in net production (see Annex ID for justification). This population level is analogous to the common F(0.1) standard in the fishery literature and will be referred to here as N(0.1). The maximum rate of change in net production is assumed to occur at population levels near zero and is approximated by the maximum rate of change in the population. Therefore, relative to Alternatives 3 and 4, the OSP range using this definition of OSP is necessarily larger because the population level where N(0.1) is realized is always less than the MNPL.

Alternative 5--Same as Alternative 3, except that the lower end of the OSP range is defined as the N(0.1) level.

Alternative 6--Same as Alternative 4, except that the lower end of the OSP range is defined as the N(0.1) level.

Scenario IV: OSP range is not defined. The maximum allowable take is set depending on trends in population size.

Alternative 7--For populations that are either increasing or stable, or for populations where trends in abundance are uncertain, MATL is estimated as follows:

$$MATL = 0.9 \cdot 0.25 \cdot Rmax \cdot POP. \quad (3)$$

In the absence of data on the sex ratio of the population, the sex ratio is assumed to be 1:1. If Rmax is unknown, a default value of 8% is used. To estimate the MATL for females, the number of females in the population is estimated and this number is used in Equation 3. For populations that are declining, the MATL is 50 animals per year and the MATL for females is 25 animals per year.

Annex IA: Derivation of Maximum Allowable Take Levels.

The MATL for a population is the number of animals that can be removed from the population on an annual basis where the population will equilibrate at some nonzero number. If all age classes and both sexes are taken in proportion to their relative abundance in the population, the MATL will be equal to the MNPL of the population. Because net production is the product of both an increasing function (population size) and a decreasing function (per capita growth rate), maximum net production occurs

at a population level that is approximately midway between zero and the maximum number of animals the environment will support (K). If the density-dependent mechanisms that determine the functional relationship between the per capita growth rate and population size are such that the resulting function is linear, then the resulting population's growth over time will have the familiar logistic trajectory. In that case, the MNPL will occur at a population size equal to 0.5 K with a per capita rate of increase at that population level equal to one-half the Rmax. Therefore, the equation for the MATL is derived as follows:

$$MNPL = POP(MNPL) \cdot NETPROD(MNPL) \tag{1}$$

$$POP(MNPL) = 0.5 \cdot K \tag{2}$$

$$NETPROD(MNPL) = 0.5 \cdot Rmax \tag{3}$$

;therefore,

$$MNPL = 0.5 \cdot K \cdot 0.5 \cdot Rmax = 0.25 \cdot Rmax \cdot K \tag{4}$$

and,

$$MATL = 0.25 \cdot Rmax \cdot K, \tag{5}$$

where POP(MNPL) is the population size at the MNPL, and NETPROD(MNPL) is the net production of the population at the MNPL.

For most long-lived vertebrates, the function that relates the per capita growth rate to density is thought to be nonlinear (Fowler 1981), such that the MNPL occurs at a higher fraction of K than 0.5. Additionally, the rate of increase at the MNPL for

these nonlinear models is generally greater than 0.5 · Rmax (Smith 1983). Therefore, Equation 5 will be a conservative estimate of the MATL for most marine mammal populations.

Annex IB: Use of 8% as Default Value for Rmax

The Rmax for most marine mammal populations has never been measured. There are a few exceptions: northern elephant seal (Mirounga angustirostris) 13-17% (Cooper and Stewart 1983); Antarctic fur seal (Arctocephalus gazella) 14-17% (Payne 1977); sea otter (Enhydra lutris) 17% (Estes 1990); southern right whale (Balaena glacialis) 7% (Best 1990); North Atlantic blue whale (Balaenoptera musculus) 5% (Sigurjonsson and Gunnlaugsson 1989); and North Atlantic humpback whale (Megaptera novaeangliae) 12-15% (Sigurjonsson and Gunnlaugsson 1989). There are no data for any of the delphinids. Reilly and Barlow (1986) reported that for a reasonable set of population parameters, most marine mammal populations that have reproductive intervals of greater than 1 year can not have an Rmax of greater than 6-8% per year. However, in light of recent studies on the survival of juvenile and adult animals from a variety of studies (Gilmartin, Johanos, and Gerrodette 1987; Bigg 1982; Wells and Scott 1990), adult survival rates in excess of 0.97 and recruitment rates as high as 80% may not be that unusual. In addition, Reilly and Barlow assumed that adult survival rates were constant and that the reproductive interval was fixed. Both of these assumptions may underestimate Rmax. If adult survival is not constant, but

varies with age as proposed by Eberhardt (1985) and Barlow and Boveng (1991), the Rmax reported in Reilly and Barlow (1986) would be an underestimate. Similarly, if calf mortality (or interutero-mortality) caused a mature female to come into estrous earlier than the modal period for the reproductive interval, then the Rmax reported in Reilly and Barlow (1986) would also be an underestimate.

Many estimates of the rate at which marine mammal populations have increased are not valid estimates of the Rmax because either the observed rate of increase was measured over a density range where density-dependent mechanisms were operative or fishery-caused mortality was occurring. This would be the case for estimates of Rmax for gray whales (Eschrichtius robustus), California sea lions (Zalophus californianus), California sea otters (E. lutris), Pacific walrus (Odobenus rosmarus), California harbor seals (Phoca vitulina), and polar bears (Ursus maritimus).

Estimates of Rmax for marine mammal populations are therefore not easily derived either from field data or by analogy from the literature. Of the five or six species where data exist, the range of Rmax was 5-17% per year. Of course, to generalize to all species of marine mammals from these few cases is speculative. Still, based on the results reported in Reilly and Barlow (1986), and given the arguments that these estimates may be negatively biased, it seems that using 8% is conservative as a default value for the Rmax in the absence of data. This

default value seems especially appropriate for marine mammal species with an average reproductive interval of less than 2 years.

Of greatest concern is the application of this rule to delphinids, where reproductive intervals of 3-5 years are not uncommon. Without better information on vital rates or time series of population estimates from delphinid populations at low densities relative to carrying capacity, this question is not resolvable.

Annex IC: Maximum Allowable Take Levels for Populations Below Their Maximum Net Productivity Level.

Prior to the 1988 amendments, the MMPA did not allow for the authorization of an incidental take by a commercial fishery from populations classified as anything other than optimal. Animals from a population classified as depleted (and this would include populations listed as threatened or endangered under the ESA) or from a population with a status that was unknown could not be legally taken in a commercial fishery. The MMPA does allow for the authorization of a "small-take" exemption if the take is incidental (not intentional), the take is not of populations classified as depleted under the MMPA, the take is shown to have a negligible effect on the population over a 5-year period, and provided that guidelines pertaining to a reporting system are established. Though Congress did not specify what was meant by a "small take", it has been operationally interpreted to mean tens of animals (e.g., authorization for a small-take exemption to

take Atlantic harbor porpoise (Phocoena phocoena) in a gill net fishery in the Northwest Atlantic Ocean where no more than 100 animals per year were thought to be taken by the fishery). This level of take is assumed to have a negligible effect on the status of most populations of marine mammals. The proposed guideline for a maximum take of 50 animals (or 25 females, whichever comes first) was developed for the purpose of being consistent with the spirit of the small-take exemption in the MMPA, while authorizing a nonzero level of take for populations of marine mammals whose status is likely to be below the MNPL, but whose official status of being depleted has not be designated.

There are many who feel a take of any animals from populations whose status is uncertain should not be authorized. On the other hand, the net replacement rate for most marine mammal populations with as few as 1,000 animals is at least 50 animals per year (assuming the current population is well below the current carrying capacity for the population). There are currently no known marine mammal populations that are not classified as depleted under the MMPA or as threatened or endangered under the ESA with population levels below 1,000. Therefore, the proposed level of take for populations whose status relative to their OSP is unknown but thought to be below the MNPL should not disadvantage any of these stocks. Given that there are mechanisms for providing additional protection for marine mammal populations that might be in jeopardy by such a

level of take (e.g., by classifying a stock as endangered or threatened under the ESA), the proposed guideline represents a balance between total protection for marine mammal populations with undetermined status and authorizing a take relative to an arbitrary fraction of the observed level of net production (or as would be estimated based on a minimum population estimate).

APPENDIX II

EXPLOITED ECOSYSTEMS: MANAGEMENT OF MARINE MAMMALS AND FISHERIES

(Subgroup report by Charles Fowler)

Executive Summary

Single-species approaches to resource management have met with limited success (see Annex IIA). There are increasing cases of multiple stocks of fish, or combinations of fish and marine mammals, that are subject to mandated management within the context of their interactions and ecosystems. Since the early 1970s we have gained a great deal of new knowledge of the structure and functioning of ecosystems and biological communities. It is imperative that this knowledge be translated into practical application to address the challenges of managing interacting species. It is important that managers have clearly prescribed approaches for applying such knowledge in legislatively mandated management (such as the Marine Mammal Protection Act (MMPA) and the Fisheries Conservation and Management Act (FCMA)).

It is recommended that a steering group be formed to convene a 6-day meeting (to be held in late 1991 or 1992) to address alternatives to single-species management for ecosystems that include both marine mammals and fishery resources. It is proposed that this meeting be carried out in three phases:

1) a 3-day symposium,

2) 1 day of summary sessions involving symposium speakers, and

3) a workshop of symposium chairs.

The symposium would consist of an assembly of scientific experts who would present and discuss the basis of accumulated knowledge of interacting species, communities, and ecosystems that can be translated into management strategies. The summary sessions would synthesize the information pertaining to the topic of their respective sessions to produce potential management strategies and options. Finally, the workshop would undertake discussion of the options and produce a report containing operational strategies based on the options developed in the previous two phases of the meetings. Papers from the symposium would be published.

Initially, the steering group would be responsible for developing the rationale for the meeting in terms of the identified needs and the basis for expecting useful progress. Initial proposal material is contained in Annex IIA. This material would go through several phases of further development, including peer review and revision, to become a published "white paper". This paper would serve as a focus for the meeting and in developing information and strategies for use in management of multispecies systems.

In convening the meeting, the steering group would solicit help from outside experts (government, academic, and management) to identify the people who would be able to make substantial

contributions. Session chairs with knowledge of management needs and appreciation of the relevant biology would be identified to work in the second and third phases of the meeting. It is suggested that the steering committee seek the advice of other individuals with experience in the compilation of information used in developing decision-making strategies. Individuals familiar with the base of knowledge pertinent to ecosystem ecology and its practical application would also be essential and should be consulted.

The symposium, summary sessions, and workshop would lead to an improved understanding of our ability to develop management approaches that account for species interactions--especially those between fishery and marine mammal populations. The products would include a published volume (e.g. a book or special issue of a journal) and, on a shorter time frame, recommendations detailing promising directions to take in developing future management approaches.

Meeting Recommendations

Based on the needs identified in Annex IIA, it is recommended that a 6-day meeting be convened with the tentative title of "Exploited Ecosystems: Management of Marine Mammals and Fisheries." The meeting would accomplish the compilation of knowledge useful for managing multispecies systems and provide information useful for practical application.

Meeting Design.

The 6-day meeting would consist of three parts. First, a 3-day symposium would provide for the presentation and discussion of about 30 invited papers. Second, 1 day would be devoted to summary sessions where speakers meet in groups with the chairmen of their sessions to draft a synthesis of the practical implications and methods for application of the material presented in each session. Third, a 2-day workshop attended by the session chairs and a small support crew would be held to present and discuss each of the session reports. They would draft a final report including their recommendations and final versions of their session reports.

Symposium.

Individuals selected to present papers would be required to provide their finished manuscripts to the session chairs 3 months in advance of the meetings. Based on their reading and evaluation of the papers, the session chairs would write a session report to have available at the symposium along with copies of the presented papers. During the symposium the session chairs would coordinate the presentation of papers, introduce the speakers, and work on modifications to their session reports based on the oral presentation of the work and any discussion following the presentation.

There would be about 10 papers presented each day for a total of about 30 papers. Sufficient time would be allowed for questions and discussion of each paper, with ample breaks for

discussion of the papers among the people attending. Attendance by people not presenting papers should be encouraged to promote fruitful discussion and to allow the opportunity for related information to come to the attention of speakers and chairs. Issues raised during such discussion would later be used in developing reports from the sessions.

Following the symposium, the papers presented would be published collectively as a special volume, book, or issue of a recognized peer journal.

Summary Sessions.

The people who present papers would meet on the day following the symposium to work with the chairmen of their sessions. During these meetings, each session group would discuss the contents of their session. They would review the draft session report and produce a synthesis or summary of each session to be included in their report, with each report being specific to the topic of the respective session. There would be three goals for these meetings and the resulting reports.

1) To present the practical value of the material covered in each session in such a way that it is of direct use in management. This means that the session reports should contain suggested management strategies, criteria, or prescriptions for decision making. Such alternative management options should receive particular emphasis if they appear to better meet management needs than the single-species approaches.

2) To identify research needed to produce information necessary for the management of interacting species and ecosystems.

3) To document cases and situations for which useful patterns or paradigms are unlikely, or for which recognized patterns may never have any practical application, or may never achieve better success than a single-species approach, and to understand why.

Workshop.

The chairmen of each session of the symposium would next meet for a 2-day workshop led by a chairman other than one of the sessions' chairs. This group would require the services of a rapporteur and a facilitator (people to serve as secretary, coordinate local arrangements, etc.).

Each session chair would present a report for discussion. These reports would be modified, if necessary, and compiled into appendices for the workshop report. These papers should later be edited and published with the papers from the symposium.

The efforts of the workshop would focus on the applicability of the information and resulting management strategies based on the symposium presentations. Those suggestions thought to be of practical value in the management of renewable resources would be stressed. Particular attention would be given to strategies in terms that are of direct use to managers. This means that the final workshop report should list simple, explicit formulations for management action.

It should be stressed that one activity of the workshop would be the evaluation of the recommendations resulting from the symposium and session meetings. Alternative management methods may serve simply as approaches to be used in conjunction with current strategies. Such methods need not necessarily be better than existing techniques. Others may be suggested as complete replacements for existing approaches under certain circumstances. In this case, the participants of the workshop would need to decide, if possible, if the potential alternatives can be judged to be better than current single-species approaches and why. Use of single-species approaches is seen as a reference point because the intent is to provide methods that better serve management, especially in managing multispecies systems.

Products

Products from the entire series of meetings would fall into three categories:

1) Monograph(s): Scientific and technical information in the papers from the symposium. The papers presented in the sessions of the symposium would be scientific papers with considerable synthesis value. Collectively, their content and references to the massive accumulation of ecosystem literature would be of both scientific and practical value. Each would contribute significantly to the progress being made in translating theory and scattered information into

practical management action. As a group, the papers would represent a statement about the state of the scientific understanding of ecosystem principles that have potential for practical application and point to information needed for further progress in promising directions.

2) Synthesis: A synthesis of technical ecosystem level information, potential management alternatives, and a list of research needs regarding ecosystems and their management (Reports from sessions of the symposium). The session reports would represent a significant step in translating information about interacting species into alternative strategies for management. Clear research needs would be identified and listed.

3) Recommendations for Management: Recommended management alternatives and research (report of the workshop). The recommended alternatives to present management procedures would be compiled in the workshop report. They would be chosen as measures most applicable and expressed or formulated for direct application. A compilation of research needs would result from the discussion of needs identified in the session reports.

People attending the workshop will need to recognize that the advice coming from a broader context (ecosystem) may be totally different from the kind that is now used. The approach to management would need to emphasize the necessity of a shift in

thinking (in size scale, for example) to implement the recommendations from these meetings. The report would have to deal with the fact that arbitrary reference points will emerge from considerations of ecosystem principles just as in the case of single-species cases now.

Implementation

To implement the meeting, it is recommended that a steering committee be designated to undertake the following:

1) Work independently to contact specialists in the field of ecosystem studies to have this proposal reviewed to:

   a) obtain further advice and ideas for content of the symposium to insure that a comprehensive set of potential topics for the symposium is generated;

   b) gain contact with other specialists to further the process stated in a) above;

   c) begin the process of sorting through the accumulated information related to the objectives to insure that, in the end, the best set of recommendations is generated;

   d) choose specialists who can do the work to produce syntheses and make the presentations determined to be of value; and

   e) choose the session and workshop chairpersons.

2) Revise the details of the design of the proposed meetings with advice from National Marine Fisheries Service (NMFS) representatives.

3) Convene the meetings by establishing the date and location, to coordinate with the session chairs and workshop chairperson, to advertise the meetings, to call for papers, and to select papers.

4) Ensure that there are facilities and personnel to support the meetings with an environment in which the objectives can be met.

5) Estimate and seek funding to cover the costs of the meetings, including costs involved in producing the papers, travel, publication, facilities, and support (word processors, supplies, audiovisual equipment, etc.).

6) Determine if bibliographies of materials related to the symposium would be of value and, if so, carry out their production and dissemination (as needed).

Annex IIA: The Continuing Need for Ecosystem Level Management and a Symposium to Convert Knowledge Into Practice.

Background

Historical perspective--In the late 1970s the U.S. Department of Commerce produced an operational definition of the key term in the Marine Mammal Protection Act of 1972. This action was yet another instance of implementing the concepts of single-species population dynamics into regulations for managing marine resources, a process that was taken seriously following World War II. The basic elements of the single-species concepts used in the fisheries agreements established at that time were formulated for marine fish and whale fisheries in the early 1930s by Russell (1931) and Hjort et al. (1933) and applied to the North Sea trawl fisheries in the mid-1930s by Graham (1935).

Russell (1931) formalized ideas being loosely developed between 1890 and 1930, suggesting that vital rates of harvested populations such as reproduction, natural mortality, and individual growth vary as a result of changes in the availability of food or other "resources," such as breeding habitat. As the size of the harvested population increased, he argued, the per capita availability of such resources tended to decline, causing

the net rate of increase of the harvested population to tend toward zero. Hjort et al. argued further that a population size exists, frequently termed the "carrying capacity," which on some average basis reflects the balancing of the vital rates to yield a net rate of increase of zero. They further suggested, following work by Pearl (1925) in the 1920s, that one could capture much of the dynamics of natural populations by measuring not the available resources that they depend on, but by measuring their own population size.

While Russell's formalism is sufficiently general to be difficult to falsify, Hjort et al.'s adaptation of that formalism has to be viewed as an abstraction of reality. It was clear to many scientists studying fisheries as early as the 1870s that the effect of fishing had to be considered in a multispecies context, but the tools to use to do this, such as those developed by Lotka (1925) and Volterra (1926), were too demanding to apply in the management contexts of those times. The importance of Russell's and Hjort et al.'s formalization of the problems of fishery management was that they could be implemented; the important issue that remains to be fully evaluated is the reality of Hjort et al.'s approximation. Is a single-species formulation sufficient to describe the dynamics of fishery resources? Furthermore, what are the criteria that would serve to determine sufficiency?

While questions such as these were of concern, the concept was nonetheless implemented with vigor. These concepts became

the underlying basis for management of trawl fisheries in the North Sea, tuna fisheries in the eastern tropical Pacific, whale fisheries in the Antarctic, sea fisheries in the North Pacific, and indeed most fisheries that came under management in the 1960s and 1970s. Thus, when the MMPA was passed in 1972, followed by the FCMA in 1976, both included at least some Congressional intent for consideration of the ecosystem context, but the regulatory definitions that were adopted clearly were single-species approaches.

The operational term in the MMPA was "Optimum Sustainable Population" (OSP), a term with key elements left undefined. The following definition of OSP was proposed by the NMFS, in consultation with the Marine Mammal Commission (DOC 1978, p. 21):

> "a population size that falls within a range from the population level of a given species or stock that is the largest supportable within the ecosystem to the population level that results in maximum net productivity. Maximum net productivity is the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth, less losses due to natural mortality."

The key element left undefined in the FCMA was "overfishing," a term that dates back to the 1850s (Cleghorn 1854). An adequate definition proved extremely elusive over the first half of the 20th Century, but was recently defined as (DOC, 1982, p 53):

> "a level of fishing mortality that jeopardizes the capacity of a stock(s) to maintain or recover to a level at which it can produce maximum biological yield or economic value on a long-term basis under prevailing biological and environmental conditions."

As befits a hard-to-define term, the definition of overfishing changed from time to time, becoming in 1989 (Fed. Reg. 1989, p. 30834):

> "a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce MSY [maximum sustainable yield] on a continuing basis."

Recognition of the need to break from single-species tradition has appeared in legislation, even in that mentioned above. For example, the MMPA was explicitly oriented toward management at the level of the ecosystem, using terms like the "health of the ecosystem." Similarly, the FCMA allowed "ecological factors" to be taken into account in setting of the optimum yield levels (Fed. Reg. 1989, p. 30835). Nevertheless, in spite of the explicitly recognized need to manage at the ecosystem level, the application of both of these acts has been consistent with distinctly single-species orientation.

The late 1970s and early 1980s also were marked by a number of international symposia which established the present state of the art of single-species management. In 1978, an International Council for the Exploration of the Sea (ICES) symposium was

convened at Aberdeen, Scotland, on "The Assessment and Management of Pelagic Fish Stocks" (Saville 1980). This symposium established that high variability is an expected property of many coastal pelagic fisheries, and that sustainable yield concepts are frequently inappropriate. The year 1978 also saw a major symposium on the "Dynamics of Large Mammal Populations" held at Logan, Utah, where the nonlinear, nonlogistic properties of large mammal population growth curves were firmly established (Fowler and Smith 1981). The transition toward an ecosystem approach was marked by a 1983 Food and Agriculture Organization of the United Nations (FAO) "Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources" symposium in San Jose, Costa Rica (Sharp and Csirke 1983), a 1984 Dahlem Konferenz on "Exploitation of Marine Communities" held in Berlin, Germany (May 1984), and also in 1984, the first of a series of symposia on large marine ecosystems held in New York City (Sherman and Alexander 1986). Since 1984, there has been little follow-through toward ecosystem management, although the concept has gained some recognition (but not necessarily acceptance) within some management agencies. One objective of NOAA's long-range operational goals, for example, is the development of "an agency-wide research and implementation strategy for an ecological/oceanographic approach to fisheries management" (DOC 1990, p. 4).

Growing need for ecosystem context--Hjort et al.'s (1933) approach was in fact proposed in the context of managing

fisheries for whales, a group of species that, they argued, were very different than fish because "the renewal of the stock is bound up with the fate of a limited progeny whom nature has safeguarded in various ways against the many causes of mortality." Taken with the demonstrated capability of many whale species to feed on a wide variety of food ranging from krill and copepods to pelagic fishes like mackerel and herring, it is possible that these top-level predators have evolved to more nearly allow Russell's (1931) and Hjort et al.'s (1933) single-species paradigm to be much more nearly true than it might be for many harvested fish species.

Since the late 1970s, however, there has been a growing need for management of resources, particularly marine resources, in the context of their ecosystem. This is an important consequence of simultaneous implementation of requirements of the MMPA and the FCMA. Such needs are brought into focus by marine mammal fisheries interactions wherein marine mammals and commercial fisheries compete for the same resource. A good example is provided by the declining population of northern sea lions (Loughlin and Merrick 1989; Lowry et al. 1989) which feed on, among other species, the commercially valuable walleye pollock (Theragra chalcogramma) of the North Pacific Ocean and Bering Sea. In a more international context, the ecological relationships among cod, capelin (Mallotus villosus), harp seals (Phoca groenlandica), herring, and krill are of increasing interest and concern in the Barents Sea and off Newfoundland

(Tjelmeland 1990). The apparent switching of whales and seals among different prey species, major invasions of seals into southern Norway, and the emaciated condition of cod when capelin are in low abundance have caused a fundamental reconsideration of the multispecies relationships among fishes and between fishes and marine mammals. A significant feature in the history of management, which has led to the current need to consider the whole ecosystem, has been the great difficulty of managing commercial fisheries with a view to implementing conservation measures required for marine mammals.

While overfishing under the FCMA is a single-species concept, there have been some cases where ecosystem concepts have been applied. For example, "ecosystem effects" are to be taken into account in setting the level of take termed "optimum yield," usually computed as an adjustment away from maximum yield. The Mid-Atlantic Fishery Management Council used this in 1979 when deciding that the optimum yield of squid should be the maximum sustainable yield reduced by 25%. From a different perspective, the New England Fisheries Management Council manages the trawl fisheries in the northeastern United States under its Multispecies Fishery Management Plan. Although the criteria for overfishing in that plan are based on a single-species approach and the plan's success in meeting its goals has been strongly questioned (NEFMC 1988), it at least is formulated to account for the inherent variability of marine ecosystems by allowing the fishing industry to change its focus from species to species.

We define "ecosystem management" as an approach that explicitly attempts to consider interaction among harvested or otherwise impacted organisms, competitors, predators and prey, as well as abiotic influences which may affect populations differentially. This approach is to be contrasted with "single-species management" which treats each harvested or managed population as an independent, isolated resource, each with its separate criterion for optimum harvest or population size. In most cases single-species considerations form a logical point of departure for ecosystem management; also an ecosystem need not be completely understood for an ecosystem approach to be beneficial.

Limitations of single-species approaches--Single-species population biology has had obvious and serious limitations in its application to management within ecosystems. Single-species approaches to resource management have suffered significant criticism; management based on the concept of maximum sustainable yield is often discarded in favor of other alternatives. Similar shortcomings are evident in the application of single-species approaches to protecting marine mammal populations. Some of the failures of such methods occur at the single-species level, for example, interannual variability in population level or responses to altered levels of competing species are not easily handled. The greatest limitation of single-species approaches, however, is their inability to account for more than one species within the same ecosystem, especially when direct interactions are involved.

Wealth of recently acquired knowledge--A great deal of information has been accumulated in recent years, especially since the MMPA and FCMA regulatory definitions of the late 1970s. Large quantities of information exist in regard to the nature of a number of ecosystems (both terrestrial and marine). Studies of such ecosystems have led to a better understanding of the relationships between their component species as well as the variability observed within the relevant collections of species. This provides a much larger set of ecosystems for which there are data to be used in making comparisons among ecosystems with the view of finding patterns and principles of practical importance.

In addition to more ecosystems being represented by useful information, there are also more extensive series of data for many individual ecosystems. There are also more data on the behavior of species within the context of their biotic environment. With greater understanding of these systems we gain more options for drawing comparisons to find implications and potential practical solutions.

Collectively, and in combination with new insights regarding population biology within ecosystems, there is a body of recently acquired information (see Sherman et al. 1990) that has not been synthesized into useful approaches for managing groups of species (policies, protocol, strategies, criteria, or action formulations). This is especially true for marine ecosystems containing populations of marine mammals and commercial fishes with varying levels of interaction. Managing marine mammals and

commercial fish species in an ecosystem context has been mandated in both the MMPA and indirectly in the FCMA, and most specialists are convinced that a more holistic approach would provide a more accurate and responsive basis for management (Murawski 1989).

Meeting management requirements is impossible without an ecosystem approach--Achieving the combined requirements of the FCMA and MMPA (and, in some cases, international agreements) forces management into thinking in terms of ecosystem concepts. This results in specific management requirements, such as the need to determine the current carrying capacity for managing marine mammals. One approach is to fall back on the assumption that information about individual populations represents an integration of the conditions of the biotic environment. To proceed more directly, there is a need to invoke an interpretation of the conditions of the ecosystem to inferentially produce an estimate of the carrying capacity.

Synthesis of acquired information needed to overcome inertia--The habit or tradition of thinking in terms of single-species management is firmly engrained in the minds of managers and scientists; population biology is not a new science and single-species approaches have enjoyed significant success along with its failures. In the minds of many, ecosystem approaches have yet to be demonstrated to be superior to single-species approaches. Techniques included in the training and teaching provided to managers have classically been of a single-species orientation. With concepts such as Maximum Sustainable Yield and

OSP found in legislative contexts, single-species management receives an emphasis that overwhelms ecosystem perspectives. In the minds of people with the responsibility for promoting change, the status quo is facilitated by the difficulty of dealing with the complexity of ecosystems. Difficulty is always seen in the simple matter of facing change. That this inertia is real is made obvious by the lack of progress in applying ecosystem approaches since the late 1970s and the publication of an international appeal for change well over a decade ago (Holt and Talbot 1978).

The question of the applicability of Russell's (1931) and Hjort et al.'s (1933) single-species concepts to species such as pinnipeds and cetaceans still needs to be addressed. The assumption that these concepts apply has been seriously challenged for many fish species, and Hjort himself, based on his own work with herring, would undoubtedly have been aghast at applying these concepts to such species. This assumption needs to be seriously challenged for marine mammals, and perhaps other top-level predators such as sharks, but not with the foregone conclusion that it is inadequate. Given the life history strategies of the species and the long time frames involved in their management, and because of their usually slow rates of increase, single-species concepts may in fact be sufficient. But it is not sufficient any longer to make this assumption in the absence of a well-defined basis for doing so. There should be a stronger basis for more holistic alternatives, a basis that needs

definition. To provide a management environment that encourages the consideration of such alternatives requires:

1) location and compilation of the results of recent and cumulative advances in ecosystem studies, both empirical and theoretical;

2) serious analysis and synthesis of information available from ecosystem studies to determine what is of practical value and why; and

3) the translation of these results into practical methods, decision-making protocols, strategies, and other management practices that can be directly implemented.

Ecosystem Symposium

Motivation--A special symposium to accomplish the above is a matter of priority and is justified by:

1) the limitations of single-species approaches to resource management;

2) the growing and mandated imperative to manage ecosystems and populations within an ecosystem context;

3) recent developments and the cumulative wealth of information concerning ecosystems and their structure and function; and

4) the need to provide the impulse to overcome resistance to change and proceed to development and implementation of ecosystem-level management tools.

Objectives--The symposium objectives are as follows:

1) To gather together specialists who would, prior to the symposium, examine the information available regarding various collections of ecosystems and ecosystem-level dynamics among interacting species (with some emphasis on, but by no means restricted to, marine ecosystems) to produce papers that would describe patterns in ecosystem structure and processes where the patterns would be shown to have practical value in resource management of marine mammals.

   The topics of such papers would be required to focus primarily on empirical comparisons; that is, cases where the information concerning the ecosystems or species sets being compared was produced from field research rather than as output or interpretation of large-scale models. Papers should not be descriptions of single ecosystems or

presentations of large-scale models. Papers involving theory would be considered only if they meet the general objectives of the symposium by providing a guide to a practical understanding of ecosystems in a way that can be translated to management action. An example might be a simplistic model relating a composite feature of ecosystems (e.g., species diversity) to harvest strategies for evaluating any resulting ecosystem modification.

2. Through a synthesis process, to formulate management recommendations of practical value. This would be achieved by converting the relevant information into approaches that would be useful and easily implemented by management personnel. Papers would be accepted only if they demonstrate patterns or contain information that serve as the basis for practical application. With this basis of information, the design, process, and structure of the symposium would facilitate achieving this objective.

3. To produce a set of recommendations for research that would have the objective of producing information like that needed to achieve the previous two objectives.

4. To cover a breadth of topics selected to be of importance to management within an ecosystem context. This would be achieved by the choice of topics for the content of the individual sessions of the symposium.

Content--Separate sessions would be established to cover a variety of topics thought to be the basis for holistic ecosystem-based management procedures. Such sessions would include the following:

1. Comparative case studies of full-scale ecosystems. Samples of natural and harvested ecosystems (e.g., terrestrial, aquatic, and marine) would be compared to show patterns that have significant management implications. For example, it has been shown that trophic food webs or chains are longer in marine systems than in terrestrial systems. Does this mean that marine systems are more sensitive to anthropogenic changes? Through comparisons in the marine environment, pelagic ecosystems might show consistent differences from inshore ecosystems. There might be correlative patterns in the dynamics of harvested predators across a spectrum of variability in prey; ecosystems with variable prey may require harvesting strategies for the predators that are different from those for systems wherein the prey are more stable over time. There may be consistent differences in

ecosystems within which populations of predators, such as the great whales, are recovering from very low levels when compared with other ecosystems. Similarly, practical information may be discovered in comparisons of other manipulated ecosystems with unaltered systems.

2. Species interactions. Data on patterns in the dynamics of sets of species as affected by various ecosystem level interactions (e.g., predation, competition, symbiosis, allelopathy, parasitism, diseases, etc.) would be examined and presented. There may be reason to believe, for example, that populations of predators (especially those that exert a heavy influence on the population level of their prey) would be most productive at lower levels of harvest effort than would be the case for harvesting prey species.

3. Environmental variability and variability within ecosystem. Increased length of time series of observations of ecosystems provides a variety of examples of how variation in abiotic factors can result in major changes in the biotic components and structure of those systems. Differential responses of species to environmental fluctuations is an expected evolutionary product of components for niches and the resulting interactions among those species. Indeed, given the outlook for global climate change, resource managers will need improved information to link climatic factors to ecosystem responses (see DOC 1990).

4. Theoretical ecosystem ecology. Advances in ecological theory often point toward the potential for practical application and usually have some basis in empirical information. Papers in a session with this focus would include topics addressed through matrix models of competition, community ecology (the structure and function of ecosystems) as influenced by selective extinction, determinants and correlates of trophic chain length (such as published by Briand and Cohen 1987), and selective extinction and the risks of the influence of changes in the composition of harvested communities.

5. Spatial paradigms: distribution and other components. Ecosystems are often impossible to set boundaries for or to define in space, and the area occupied by a population of one species rarely coincides primarily with that of another. The distribution of animal populations is dynamic. These dynamics and patterns observed in the distribution of populations within an assemblage of species are of importance in allocating harvest effort in space. The dynamics of distribution may be of critical importance in interpreting ecosystems for management.

6. Ecology of low population effects. When populations are reduced to very low levels (either through direct overharvesting or as the result of indirect effects such as prey removal), what are the community level factors that contribute to either recovery or increased rates of decline (or even extinction)? Often referred to as the "Allee effect," reduced per capita productivity may be related to factors such as increased selectivity by predation, decreased intraspecific social facilitation, and uncoupling from critical symbiotic relationships (reviewed by Fowler and Baker 1990). Knowledge of such intraspecific relationships and their effects and any related patterns would be of critical importance in management.

7. Comparative population dynamics. Several recent studies indicate that there are patterns in the population dynamics of species as related to life history strategy (e.g., see Fowler 1981). The practical importance of such patterns depends on how robust single-species dynamics are to modifications within the ecosystem. Such patterns may not be observed in systems where interacting species are subject to the simultaneous influences of harvest. On the other hand, such patterns may represent the integration of the suite of influences of other aspects of the environment including additional mortality from harvests. The simultaneous dynamics of interacting species in a comparative approach may provide valuable management insights.

   A question that might be addressed in this session: Is the carrying capacity for a species an emergent property of ecosystems? If so, can it be determined based on measurements of the ecosystem independent of the integrated response of populations?

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