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Policy on New Fisheries for Forage Species

SUMMARY

The Issue:

Forage species play a special role in aquatic ecosystems, providing a substantial portion of the annual food of many fish, marine mammals, reptiles and birds. These ecological relationships place additional constraints on how sustainable harvesting of forage species can be planned, prosecuted, and evaluated. Some forage species, such as herring and capelin, have been targets of sustainable and economically viable fisheries in Canada for many decades, without causing undue alteration of ecosystem components and processes. With the need to reduce participation in traditional fisheries and develop new economic opportunities in coastal areas, interest is growing in harvesting additional species, including other forage species. New fisheries on forage species present new challenges to ensuring sustainability of fisheries. Not only must target species of the fisheries be conserved, and bycatch be controlled, but the fisheries must not threaten the conservation of other species which depend on the forage species for food. Therefore, this policy has been developed to provide a framework which ensures that fisheries on forage species are conducted in ways which are compatible with conservation of the full ecosystem, and that their sustainability is evaluated in that larger context.

What is a Forage Species?

A **forage species** is a species which is below the top of an aquatic food chain, is an important source of food for at least some predators, and experiences high predation mortality. From the perspective of fisheries management, the species will fully recruit to the fishery at ages which still experience high mortality due to predation. Forage species often undergo large natural fluctuations in abundance in response to environmental factors, on time scales comparable to or shorter than a generation. Forage species also usually form dense schools for at least a part of the annual cycle, are relatively short lived and have a coastal distribution for at least a part of the year.

Forage species often support **dependent predators**, which are species that obtain a significant part of their annual food ration from the forage species. When the forage species declines markedly in abundance (whether due to natural causes or over-exploitation) the dependent predator is likely to show biological responses such as: major changes in diet, reduced growth rate and fat storage, reduced reproductive success and/or delayed maturation, and changes in normal seasonal distribution patterns.

Objectives of a Policy on New Fisheries on Forage Species

The objectives of a conservation-based policy on fisheries on forage species include:

- maintenance of target, bycatch, and ecologically dependent species within the bounds of natural fluctuations in abundance;
- maintenance of ecological relationships (e.g predator-prey and competition) among species affected directly or indirectly by the fishery within the bounds of natural fluctuations in these relationships;
- minimization of the risk of changes to species' abundances or relationships which are difficult or impossible to reverse;
- maintenance of full reproductive potential of the forage species, including genetic diversity

- and geographic population structure,
- allowance of opportunities to conduct commercially viable fisheries.

These objectives are not alternatives where some can be ignored in particular cases. Fisheries on forage species should be designed to ensure a high likelihood that all five objectives are achieved.

Principles for a Policy on New Fisheries on Forage Species

A number of ecological and fisheries management principles provide a framework on which a policy on fisheries on forage species can be based. These principles, and associated implications, include:

1. The principles of the Precautionary Approach also mean that there should be pre-agreed harvest control rules which allow swift and effective reduction of fisheries (including closures) when risk of the stock falling below a reference point is unacceptably high.
2. Exploitation of any stock should take account of both the productivity of the stock and its trophic role in the ecosystem. Fisheries on forage species are only special in the degree of importance given to trophic role.
3. Year-class strengths of forage species often vary greatly, and sizes of year-classes often are correlated over several years. In such cases a fixed exploitation rate may not ensure that adequate spawning biomass will always be protected. Maintaining a minimum spawning biomass is also likely to be necessary as a management strategy.
4. The principles of the Precautionary Approach should be followed in management of fisheries on forage species. The biomasses of forage species used as limit reference points in management should ensure both that future recruitment of the target species is not impaired, and that food supply for predators is not depleted.
5. To ensure conservation of dependent predators and other species related to the forage species, their status must also be monitored, as well as the status of the forage species itself. This is both because catch rates of densely aggregated forage species are misleading due to their ability to support high catch rates even when their abundance is declining, and because populations of predators can change for many reasons, including changes in their food supply.
6. Forage species should be managed in ways which ensure local depletion of population components does not occur. Local depletion of the forage species could result in food shortage for the dependent predators, even if the overall harvest of the forage species was sustainable.
7. Reference points may also be set for properties such as growth rates, condition factor, or reproductive output of ecologically dependent marine predators, especially where such factors can be monitored more reliably than the biomass, exploitation rate, and other properties of the forage species itself.
8. Harvesting capacity should not be allowed to increase in ways which are difficult to reverse, during periods when a forage species is especially abundant. An economically self-reliant fishing industry should be able to react to natural declines in abundance of the forage species, by reducing harvest immediately and by a large amount.
9. Where forage species historically have supported aboriginal fisheries for food, social or ceremonial purposes, these uses must be accommodated fully in any analyses of opportunities for new or expanded commercial harvesting. When harvests must be reduced to ensure the role of the forage species in the ecosystem is not placed at risk, aboriginal fisheries for food, social and ceremonial purposes have priority status. These latter fisheries would be reduced or closed only in situations of serious conservation risk, and after all

commercial fisheries on the stock had been closed and a conservation concern remained.

10. The fishing industry must be responsible for sharing costs of, and participating in, monitoring of ecosystem properties used in management of fisheries on forage species.

Policy

Commercial fisheries on forage species will be permitted only when there is a reasonable expectation that the five goals listed above will be met. When these fisheries would be new in Canada, they would have to be developed consistent with the *New Emerging Fisheries Policy*, as well meeting additional pre-requisites below. For aboriginal harvests for food, social and ceremonial purposes and for established commercial fisheries on forage species, the fisheries can continue within the existing management approaches. However, proposals to change exploitation rates, gears, seasons, or other attributes of the fisheries in ways that might affect conservation of the forage species or species feeding on it must be evaluated against the pre-requisites below.

To demonstrate that there is a "reasonable expectation" of achieving conservation, social, and economic goals, several conditions must be met. Some pre-requisites are biological, others apply to the management system. Even if a proposed commercial fishery on a forage species is likely to be sustainable and compatible with conservation of the ecosystem, approval is not guaranteed. Particularly if there is exceptional uncertainty in some of the evaluations, or the consequences of failure to achieve conservation of the forage species are severe, the correct decision may be to not permit directed fisheries.

Biological Pre-requisites for Commercial Fisheries on Forage Species

B.1 It should be possible to monitor the status of the forage species on a regular basis, and use the monitoring results to evaluate whether or not the stock is meeting conservation targets.

B.2 It should be possible to identify some species of predators which would be appropriate for evaluating the sustainability of the fishery in the context of ecologically related species. Appropriate species of predators to monitor are ones which have relatively high food requirements, have the forage species comprise much of their diets, have relatively greater difficulty switching prey or finding adequate food when the forage species is not common, and have relevant biological traits such as abundance or breeding success that can be monitored accurately.

B.3 It should be possible to estimate the risk that the proposed level of harvest poses to the forage species and ecologically dependent species. In situations where risk presented by a particular level of harvest and consequences of over-harvesting are especially uncertain, exceptionally risk-averse decisions are necessary.

B.4 There should be sufficient knowledge of the forage species and its relationships to major predators to guide the proper prosecution of the fishery in space and time. This knowledge includes both some knowledge of the distribution and degree of aggregation of the forage species (and how they change seasonally, if appropriate), and the seasonal and spatial distributions of predators.

Management Pre-requisites for Commercial Fisheries on Forage Species

M.1 There should be clearly identified conservation (limit) reference points and associated harvest control rules, for both the forage species (B.1) and some dependent marine predators (B.2). The reference points should ensure that fishery harvests (combined commercial and aboriginal food, social and ceremonial) do not reduce the forage species to sizes where either its productivity or the productivity of predators on it would be reduced.

M.2 For the reference points and harvest control rules to be able to ensure conservation is achieved, monitoring and enforcement in the fishery must be adequate to ensure high compliance with the management plan.

M.3 Administrative and management costs for these commercial fisheries are expected to be high, to cover monitoring of the status of the forage species and selected dependent marine predators, and to ensure high compliance of the fishery with the management plan. Industry has a responsibility to carry a fair share of these costs.

M.4 Management plans for commercial fisheries on forage species should include explicit provisions to ensure that fisheries do not unduly concentrate harvest and do not produce local depletions of the forage species.

M.5 Harvesting plans must include measures designed to detect and manage bycatch of non-target species, whether of commercial value or not, and protect sea floor vegetation and physical structures where fisheries on forage species operate near-shore or near-bottom.

M.6 Management of commercial fisheries on forage species should include long-term plans which delineate the expected sizes of the fleet and harvests over several years, specify the long-term strategic objectives for the fishery, as well as the annual (or short-term) operational objectives within which the fishery will operate, and the harvest control rules which will guide and constrain operations. Provisions of the long-term plans should be based on the best science information available (including traditional knowledge), and result from extensive consultation with all concerned stakeholders. Changes to long-term plans outside of their multi-year planning and review cycle will generally only occur if substantial new knowledge becomes available about the effects of the fishery.

POLICY ON NEW FISHERIES FOR FORAGE SPECIES

1. ISSUE

Forage species play a special role in aquatic ecosystems, providing a substantial portion of the annual food of many fish, marine mammals, reptiles and birds. Some of the associations between predators and forage species are so strong that when availability of the forage species is low, the individual well-being and population productivity of predators may decline. These ecological relationships place additional constraints on how sustainable harvesting of forage species can be planned, prosecuted, and evaluated.

With a few exceptions earlier in the past century, Canada has taken a very cautious approach to fisheries on forage species. Canadian management strategies have often explicitly acknowledged the requirements of predators, and the intrinsic variability of the stocks. Some forage species, such as herring, have been the targets of fisheries Canada for centuries. Fisheries on other species such as capelin and *Pandalus* shrimp reached full commercial scale only in recent decades. Additionally there have been native harvests of eulachon for many centuries. There are small commercial fisheries on euphausiids in the Pacific, and for a brief period, an experimental one in the Gulf of St. Lawrence. These sustainable fisheries have provided economic benefits to harvesters, processors, and coastal communities without causing undue alteration of ecosystem components and processes. Examples include fisheries for herring (*Clupea harengus*) on both Atlantic and Pacific coasts, and capelin (*Mallotus villosus*) off Newfoundland and in the Gulf of St. Lawrence. Aboriginal harvests of forage species for food, social and ceremonial purposes have been culturally important and ecologically sustainable for centuries. Some informative historical experience with fisheries on forage species, both internationally, and in Canada, is reviewed in Annex I to this document.

With the need to reduce participation in traditional groundfish and salmonid fisheries on the Atlantic and Pacific coasts, and a general desire for expanded opportunities for commercial harvesting of marine resources, interest is growing in harvesting additional species, including ones

which are important as food for fish, birds, and marine animals, such as various species of euphausiids, or krill (*Euphausia* and *Thysanoessa*).

Notwithstanding the successful precedents cited above, commercial fisheries on forage species present new challenges to ensuring sustainability. Not only must target species of the fisheries be conserved, and bycatch be controlled, but the fisheries must not threaten the conservation of other species which depend on the forage species for food. Therefore, this policy has been developed to provide a framework which ensures that fisheries on forage species are planned and conducted in ways which are compatible with conservation of the full ecosystem, and that their sustainability is evaluated in that larger context. The fact that this policy on fisheries on forage species addresses sustainability explicitly in an ecosystem context does not mean that ecosystem considerations are irrelevant to fisheries on species which are not important as food for other predators. Rather, management, monitoring, and evaluation of fisheries on forage species must consider ecosystem components and processes more explicitly, and at all steps in the cycle of planning, conducting, and evaluating commercial fisheries on forage species.

2. DEFINITIONS

A **forage species** is a species which is below the top of an aquatic food chain, is an important source of food for at least some predators, and experiences high predation mortality. Many marine species experience high predation mortality on some life history stages, but in the context of fisheries on forage species, a crucial feature is that the species is fully recruited to the fishery at ages which still experience high mortality due to predation.

Note: Forage species often have other biological characteristics such as: undergo large natural fluctuations in abundance in response to environmental factors; the natural fluctuations in abundance are on time scales comparable to or shorter than a generation of the species; form dense schools for at least a part of the annual cycle; are relatively short lived, from several weeks to a few years; and, have a coastal distribution for at least a part of their annual life cycle. It is important to note that these characteristics may appear individually or in combinations in species which would not usually be considered forage species, and individual forage species may not have them all.

A **dependent predator** is a species higher in the food web, which obtains a significant part of its annual food ration from the forage species, at least at times when the forage species is abundant. When the forage species declines markedly in abundance (whether due to natural causes or over-exploitation) the dependent predator is likely to show biological responses such as: major changes in diet, often (but not always) failing to compensate fully for the low availability of the forage species; reduced growth rate and/or fat storage (condition factor); reduced reproductive success and/or delayed maturation; alteration in normal seasonal distribution pattern.

Note: Dependent predators are often more highly visible than the forage species itself, for example some species of seabirds and marine mammals. These species also may have land-based aspects of their annual cycle (often, but not always, breeding) so their dependence on the forage species may have a geographic as well as population size component.

Status of a species or stock, whether the target of a fishery or an ecologically related species, is to be interpreted broadly. Traditionally-used attributes of spawning biomass, exploitation rate, etc. are components of stock status, but other factors, such as age composition, growth rate, reproductive success etc., may also be informative indicators of the status of a resource.

3. OVERALL OBJECTIVES

The objectives of a conservation-based policy on commercial fisheries on forage species include:

- maintenance of target, bycatch, and ecologically dependent species within the bounds of

natural fluctuations in abundance;

- maintenance of ecological relationships among species affected directly or indirectly by the fishery within the bounds of natural fluctuations in these relationships;
- minimization of the risk of changes to species' abundances or relationships which are difficult or impossible to reverse;
- maintenance of full reproductive potential of the forage species (including genetic diversity and geographic population structure, whether genetically resolvable or not);
- allowance of opportunities to conduct commercially viable fisheries.

These objectives are not alternatives where some can be ignored in particular cases. Fisheries on forage species should be designed to ensure a high likelihood that all five objectives are achieved. On the other hand, if the likelihood of achieving the objectives is high, then economically viable and effectively regulated fisheries on forage species are appropriate. Correspondingly, conducting fisheries in ways that maximize knowledge gained as the fishery is prosecuted, increases the ability to determine the likelihood that the other objectives can be achieved.

4. PRINCIPLES and their RATIONALES AND IMPLICATIONS

A number of ecological and fisheries management principles provide a framework on which a policy on fisheries on forage species can be based. The rationale for the principles and their importance to the overall framework is apparent when their implications are discussed explicitly. These principles, and associated implications, include:

4.1 - Exploitation of any stock should take account of both the productivity of the stock and its trophic role in the ecosystem. Fisheries on forage species are only special in the degree of importance given to trophic role.

Traditionally, commercial fisheries have focused on stocks of high natural productivity and species high in the food chain. However, even stocks of low productivity may sustain some carefully regulated harvest, and low trophic position **alone** is not grounds to preclude harvest.

4.2 - Year-class strengths of forage (and other) species often vary greatly, and sizes of year-classes often are correlated over several years. In such cases a fixed exploitation rate may not ensure that adequate spawning biomass will always be protected.

A fixed exploitation rate **alone** is often insufficient as a management strategy to ensure conservation of species with highly varying year-classes. Maintaining a minimum spawning biomass is also likely to be necessary as a management strategy. Periods of successive poor year-classes mean that well managed stocks may fall below these minima occasionally, and all fisheries should be closed.

4.3 - Where biomasses are used as target and limit reference points of forage stocks, they should ensure both that future recruitment of the target species is not impaired, and that food supply for closely linked or ecologically dependent marine predators is not depleted.

Stock recruit plots of forage (and other) stocks often show little evidence of clear functional relationships. Nonetheless, when stock and recruit data (or surrogates) are available, they should be analyzed to estimate both the biomass at which the probability of poor recruitment is increased, and the biomass at which the probability of good recruitment is decreased. The contribution of the spawning biomass component to biological reference points should be above both estimates, where they can be identified.

The food requirements of predators should be estimated directly, using best available information on predator population sizes, food / energy requirements, and contribution of the forage species to the diet. Complex ecosystem models should be used to make indirect consumption estimates only when they have been shown to estimate consumption requirements more reliably than the direct computations.

The actual conservation limit reference points used in management should exceed the sum of the estimated spawning and feeding components. Biological reference points for attributes of the forage species in addition to mature biomass and exploitation rate will often be appropriate (see 4.4) and these should also consider needs of predators as well as the forage species itself.

4.4 - Consistent with the Precautionary Approach, harvests of forage species should ensure that there is a high probability of not violating reference points, and that there are pre-agreed harvest control rules which allow swift and effective reduction of harvest (including closures) if the probability of violating a reference point is unacceptably high.

The Precautionary Approach is particularly appropriate for forage species, for several reasons. There is likely to be high uncertainty in estimates of many population parameters such as the size of the forage species' population, its exploitation rate, and the food requirements of predators. There is also likely to be high uncertainty about important functional relationships, such as dependence of recruitment on local spawning stock (both for the stock as a whole and for geographic sub-units), and the dynamic feeding response to changes in abundances of both the predator and prey populations. Consequences of collapses of forage species also are likely to be far-reaching and difficult to reverse.

4.5 - Reference points may also be set for properties such as growth rates, condition factor, or reproductive output of ecologically dependent marine predators, especially where such factors can be monitored with accuracy and precision comparable to or better than the biomass, exploitation rate, and other properties of the forage species itself.

Management should ensure the probability of compliance with such reference points and the effectiveness of harvest control rules based on them, is comparable to those based on the target species. The reference points and harvest control rules based on ecologically related species should recognize the natural variability of these species as well, and the many factors which may affect them.

4.6 - Forage species should be managed in ways which ensure local depletion of population components does not occur, as well as ensuring compliance with reference points established for the stock as a whole.

Because some ecologically dependent marine predators may have restricted mobility during at least parts of the year, their well-being may depend on local abundance of the forage species, rather than its stock-wide abundance. Correspondingly, if a harvest which was sustainable for the stock as a whole was taken in a geographically restricted area, the local depletion of the forage species could result in food shortage for the dependent marine predators. Management approaches should address this risk directly.

4.7 - Harvesting capacity should not be allowed to increase in ways which are difficult to reverse, during periods when a forage species is more abundant than the long-term average condition.

As noted in 4.2, many forage species have occasional periods of high natural productivity and at such times may reach high biomasses. Even without harvesting, these large biomasses are unlikely to be maintained in the long term, and declines can be abrupt and precipitous. An economically self-reliant fishing industry should be able to react effectively to such declines, by reducing harvest immediately and by a large amount. Correspondingly, the fleet should

not be of a size which requires harvests of the size only available during periods of high abundance in order to be economically viable, even if it means that some harvesting opportunity must be foregone during periods of high abundance.

Opposition to proposals for fisheries on forage species has sometimes been based not on the proposal itself, but on fear that an initially limited fishery will be allowed to expand over time to a size which could place dependent predators at risk of the inadequate food. Fisheries on forage species should be based on long-term plans, which address explicitly conservation of resources and sustainability of the fisheries over the life-time of the plan.

4.8 - Where forage species historically have supported aboriginal fisheries for food, social and ceremonial purposes, these uses must be accommodated fully in any analyses of opportunities for new or expanded commercial harvesting, and the management of such fisheries.

When harvests must be reduced to ensure the role of the forage species in the ecosystem is not placed at risk, aboriginal fisheries for food, social and ceremonial purposes have priority status. They would be reduced or closed only in situations of serious conservation risk, and only after all commercial fisheries on the stock had been closed, and a conservation concern remained.

4.9 - To ensure conservation of dependent marine predators and other species related to the forage species, their status must also be monitored, as well as the status of the forage species itself.

From two perspectives, monitoring selected ecosystem components directly is essential to evaluating the ecosystem-scale conservation effects of the fishery on the forage species. Because many forage species are densely aggregated for at least part of each year, efficient fisheries can maintain high catch rates even when the relative abundance of the forage species may be low. Other reliable indices of stock status may not be available, because patchy, aggregated species are known to be hard to quantify accurately. Therefore changes in the status of dependent marine predators may be one of the earliest reliable warning signs that the abundance of the forage species is declining, at least locally. Reciprocally, abundances of dependent and related predators can change for many reasons, including but not solely because of the availability of the forage species. Only with effective direct monitoring may it be possible to determine if a change in status of the dependent marine predator is a consequence of a change in status of the forage species, and hence require changes in harvest. When abundance or breeding success of dependent marine predators is declining and the causes are highly uncertain, the precautionary approach would justify restrictions on commercial harvest of forage species, at least until the declines were arrested or their causes were clarified.

4.10 - The fishing industry proponents and participants must be responsible for sharing costs of, and participating in, monitoring of ecosystem properties used as reference points, or otherwise used to trigger harvest control rules.

Harvest of forage species always has the potential to increase risk to dependent predators, by creating the possibility that the abundance or availability of the forage species may be reduced when dependent predators are already finding it difficult to obtain adequate food. Because the increased risk is a consequence of the harvest, the cost of managing of the risk should be shared with the industry. The specific responsibilities associated with this role should be specified for all parties early on in the development of each fishery on forage species.

5. POLICY

As a general policy commercial fisheries on forage species will be permitted on Canadian stocks,

but only when there is a reasonable expectation that the five overall objectives in Section 3 will be met. When these fisheries would be new in Canada, they would have to be developed consistent with the *New Emerging Fisheries Policy*, as well as meeting additional pre-requisites in section 5.1 below. For fisheries on forage species that have an established record of sustainability and the resource has been consistently conserved, the fisheries can continue within the existing management approaches. However, proposals to change exploitation rates, gears, seasons, or other attributes of the fisheries in ways that might affect conservation of the forage species or species feeding on it must be evaluated against the pre-requisites below.

To demonstrate that there is a "reasonable expectation" of achieving conservation, social, and economic goals, several conditions must be met. Some pre-requisites are biological, others apply to the management system. There may be circumstances where information is insufficient to evaluate status of a forage species or fishery against one or more of the criteria. Such situations do not automatically preclude commencing a small scale fishery in accordance with the provisions of the *New Emerging Fisheries Policy*. However, those situations require an even higher degree of caution, and exceptional focus on increasing the information about the species and the effects of the fishery.

Management decisions should also take into consideration where available, aboriginal traditional knowledge and other local and traditional knowledge.

Even if a proposed fishery on a forage species is judged as likely to be sustainable and compatible with conservation of the ecosystem on all criteria for which information is available, approval is not guaranteed. Particularly if there is exceptional uncertainty in some of the evaluations, or the consequences of failure to achieve conservation of the target species are severe, the correct decision may be to not permit directed fisheries.

5.1 Biological Pre-requisites for commercial harvests

5.1.1. It should be possible to estimate some metrics of the status of the forage species on a regular basis, and there must be some values of those metrics against which achievement of conservation can be judged.

Examples of possible metrics are:

Age composition – judged relative to unexploited state, or relative to the age composition when exploitation was known to be sustainable and the stock was being conserved.

Mature biomass - judged relative to percent reduced from unexploited biomass (if known), or relative to historic average abundance during a period when the stock was known to be conserved.

In all cases fisheries should not cause populations (or biological characteristics) of forage species or their predators to fluctuate outside the normal range of variability of the populations. However, in many cases the limits of natural variability will not be known, at least when the fishery commences.

5.1.2 It should be possible to identify some species of predators which would be appropriate for evaluating the sustainability of the fishery in the context of ecologically related species.

Many species may be affected by fluctuations in abundance of forage species, but species which are most sensitive to the abundance of the forage species would be most appropriate for evaluating the ecosystem sustainability of the fishery. Sensitive species are ones which have relatively high food requirements, have the forage species strongly represented in their diets, and have relatively greater difficulty switching prey or fulfilling total ration requirements when the forage species is not common. That latter trait often occurs because foraging time and distance are constrained. The most appropriate predatory species would also be ones where it would be possible to obtain precise estimates of abundance, breeding success, growth rate, or similar metrics of well-being. The underlying assumption is that if a

fishery on a forage species is being managed such that conservation of ecologically related species of high sensitivity are being conserved, conservation of less sensitive species is even less likely to be put at risk by the fishery.

5.1.3 It should be possible to estimate the risk that the proposed level of harvest poses to the forage species and ecologically dependent species.

Ideally this is done through formal risk quantification methods, but often this will not be possible. Simple models will often have to be used, with parameters taken from similar species and situations, to assess if the proposed magnitude of harvest is likely to increase the risk faced by the forage species or any dependent predators. Absolute values for population sizes, amounts consumed, etc., may not have to be estimated in all cases. There may be situations where it is possible to use relative measures, or conservatively biased estimates (ex. values known to be underestimates of the true size of the forage population or overestimates of true food requirements of predators) to evaluate the likelihood that a proposed fishery would increase risk. In applications where risk can only be approximated, uncertainty about size of risk and breadth of consequences are both likely to be high. In such situations conservation will often require highly risk averse decisions.

5.1.4 There should be sufficient knowledge of the forage species and its relationships to major marine predators to guide the proper prosecution of the fishery in space and time.

This knowledge includes both some knowledge of the distribution and degree of aggregation of the forage species (and how they change seasonally, if appropriate), and the seasonal and spatial distributions and requirements of dependent marine predators.

5.2 Management Pre-requisites

5.2.1 Consistent with the precautionary approach, there should be clearly identified conservation (limit) reference points and associated harvest control rules, for measurable properties of both the forage species (see 5.1.1) and some dependent marine predators (see 5.1.2). The reference points should ensure that fisheries do not reduce the forage species to levels where either its productivity or the productivity of predators on it would be reduced.

The limit reference points do not have to be absolute values for biomass or mortality, but must have a biological basis. The values should be explicit and agreed to between DFO and the industry, in advance of each fishery. Once set, values are expected to be stable until new knowledge justifies changing either the reference point or the biological property (for example from maximum age in the catch to a minimum spawning biomass.) Such changes may occur rarely in well established fisheries, and more often in new and developing fisheries.

5.2.2 For the reference points and harvest control rules to be able to ensure conservation is achieved, monitoring and enforcement must be adequate to ensure high compliance with the management plan occurs, and is seen to occur.

Monitoring programs will need to be established or maintained on both the forage species and the selected dependent marine predators (see 5.1.2). The programs must produce results with sufficient accuracy and precision that status of the populations relative to the reference points can be evaluated on a frequency appropriate to the life histories of the species being monitored, and the operation of the fisheries. Because commercial fisheries on forage species have the potential to place many ecosystem components at risk of failing to be conserved, many stakeholders will have a legitimate interest in the design, conduct, and evaluation of the monitoring programs.

5.2.3 Because of the need for visible and high compliance of commercial fisheries with all

provisions of the management plans, and for extensive and reliable monitoring of both the forage species and often selected predators, management costs for these fisheries are expected to be high. Industry proponents and participants have a responsibility to carry a fair share of the incremental costs of management.

5.2.4 Management plans for fisheries on forage species should include explicit provisions to ensure that fisheries do not unduly lead to local depletions of the forage species for time scales long enough to have consequences for predators.

Information will often be insufficient to set precise values for what comprises unacceptable local depletion of a forage species. Provisions in management plans should be generous in this context, and monitoring of ecologically related species should allow spatial impacts to be evaluated if possible.

5.2.5 Limitation of bycatch and impacts on habitats often should be important components of Management Plans for forage species.

Many forage species are small and as a result often attract numerous predators. This means small mesh gears may have to be used in harvesting, in settings where individuals of many other species may be present, feeding on the forage species. Such conditions create the potential for high bycatches, sometimes of smaller individuals of commercially important predator species (e.g. cod, redfish) and other times of species of high social interest (e.g. seabirds, small cetaceans). Harvesting Plans must include measures designed to detect and manage bycatch of non-target species, whether of commercial value or not. When distributions of forage species are near-shore or offshore but near-bottom, management plans must also ensure that fishing operations do not degrade habitat quality.

5.2.6 Management of commercial fisheries on forage species should include Long-term Plans which delineate the expected sizes of the fleet and harvests over several years, specify the long-term strategic objectives for the fishery, as well as the annual (or short-term) operational objectives within which the fishery will operate, and the harvest control rules which will guide and constrain operations.

Provisions of the Long-term Plans should be based on the best science (including economic and social science, and traditional knowledge) information available, and result from extensive consultation with all concerned stakeholders. Changes to Long-Term Plans outside of their multi-year planning and review cycle will generally only occur if substantial new knowledge becomes available about the effects of the fishery.

6.0 Monitoring and Evaluation

The monitoring and evaluation of the processes identified in this policy will be part of a broader monitoring and evaluation framework for fisheries that are managed by the Department. This includes regularly reviewing management plans, such as Integrated Fisheries Management Plans (IFMPs) and Conservation Harvesting Plans (CHPs).

Management plans will be the vehicle for implementing the processes and requirements outlined in this policy and as a means of identifying management considerations for fisheries on forage species.

In the context of renewing the management plans for all fisheries upon expiry, DFO will, together with stakeholders in the advisory process, consider the effectiveness of management measures put in place to mitigate or avoid any negative impacts of fisheries on forage species. Where necessary and appropriate, changes to the management measures will be implemented.

ANNEX I - EXPERIENCE WITH FISHERIES ON FORAGE SPECIES INTERNATIONALLY AND IN CANADA

International experience

Some forage species have supported fisheries for many centuries; records of herring fisheries in Northern Europe go back to the 10th century (Hoglund 1972, Southward et al, 1988, Alheit and Hagen 1997). For its entire history, local coastal fisheries showed multi-decadal periods of high catches, separated by intervals of several decades of negligible catches (although catches may have been high in other parts of northern Europe during those periods).

Records of sardine catches are not as long as records of herring catches, although in Japan records of good and bad periods of sardine catches extend back to the early 1600s (Yasuda et al. 1999). Records of sardine and anchovy abundance, as reflected by scale deposition in seafloor sediments, have been reconstructed for over 2000 years for areas off the US Pacific coast (Baumgartner et al 1996, 1998).

All these records of abundance of forage species show substantial variation over periods of multiple decades. These fluctuations are unlikely to be caused by fishing pressure, because the technology used in these pre-Industrial Age fisheries was unlikely to be able to deplete entire fish stocks, nor even local aggregations. In all these cases, and others around the world, explanations for the fluctuations in forage species based on environmental influences on recruitment have been proposed, or are being explored (Lluch-Belda et al. 1989, Ware 1995, Cochrane and Hutchings 1995, Alheit and Hagen 1997, Francis et al. 1998)

The fact that forage species fluctuate greatly even when lightly exploited does not mean that fisheries play only a minor role in stock dynamics. There is substantial evidence that over-fishing can contribute substantially to the collapse of forage species (Serchuk et al, 1996, Slotte and Johannesson 1997, Beverton 1990, 1998). Debate has gone on for decades about how to partition exactly the contributions of environment and fishing to the dramatic collapses of some stocks of herring, anchovy, and sardine, and it is unlikely that competing hypotheses will ever be fully reconciled. However, there is little disagreement that in conditions when the environment is unproductive for forage species, intense fishing can accelerate the rate of decline, deepen the magnitude of depression of the stock, and lengthen the time to eventual recovery.

Over-fishing and poor management has meant some collapses of forage species have lasted for decades. In the case of Norwegian spring-spawning herring, following a period of nearly unregulated fishing the stock collapsed abruptly in the 1960s, and remained two to three orders of magnitude below its earlier abundance for over thirty years. At the end of the 1980s, though, the stock began to produce a series of strong year-classes, and has increased to over 10 million tonnes. Under a management strategy which has kept fishing mortality below 0.3, this increase has been sustained for a decade, although several aspects of the seasonal distribution of the stock have not returned to historical patterns (Bjorndal et al. 1997, Dragesund et al. 1997, ICES 1999a). Overfishing also contributed to the magnitude of decline in California sardine in the middle of the twentieth century, and recovery again took nearly three decades (Cisneros-Mata et al. 1995, Felix-Uraga et al. 1996, McFarlane and Beamish 1999.)

Although over-fishing can contribute to and intensify the collapse of forage stocks, such collapses are not inevitable. Swift reduction in intensity and pattern of exploitation can do a great deal to keep productive stocks from collapsing, as demonstrated with North Sea herring (ICES 1999b). In the 1970s overfishing and low productivity caused the adult biomass to collapse, and rebuilding occurred slowly, required a closure of the directed fishery for four years. In the 1990s, fishing mortality again began to rise, as several above average year-classes began to pass through the fishery. In that case swift reductions to total exploitation, and a change in the age composition of the catches, allowed the stock to recover to typical size in just two years, despite only average recruitment.

Collapses of these forage stocks caused social and economic hardship and loss of opportunity, but the ecological ramifications for dependent predators may be even more significant. For that reason

a number of fisheries scientific advisory and management bodies have been exploring management strategies appropriate for forage stocks. The best of these take account of the natural variability of such stocks, the threat that over-fishing poses to the stocks when they enter periods of reduced productivity, and their role in the ecosystem (Butterworth and Bergh 1993, Stephenson 1996, Butterworth et al 1997, Cochrane et al. 1998). Two examples are discussed briefly, the first reflecting an approach in a relatively data-rich situation and the second for a much more data-poor system.

Sandeel fishery in the North Sea: An industrial fishery for mixed pelagic species, but particularly sandeels (*Ammodytes*) in the North Sea began in the 1950s. Sandeel catches rose slowly to around 100,000 tonnes by 1960, and rose rapidly again in the early 1970s to vary between 500,000 and 800,000 tonnes. Productivity of sandeel remained high throughout this period, and catches in the final years of the 1990s were between 830,000 and 1,139,000 tonnes. Fishing mortality over the period averaged 0.57, with recent values slightly lower due to stronger recruitment. Although these removals and fishing mortality appear high, mortality due to predation is much larger on age 0, 1, and 2 sandeels, and of comparable magnitude on older ages. Total sandeel biomass consumed annually by major predators in the North Sea is estimated to be nearly three times larger than the biomass removed by fisheries (ICES 1997, 1999c,d, Furness 1998).

Although overall the sandeel fishery meets sustainability criteria, catches were not distributed throughout the North Sea in exact correspondence to the distribution of sandeels. Locally intensive harvests in near-coastal areas led to concerns about the possible impacts of the sandeel fishery on breeding success of seabirds, through local depletions of sandeel concentrations available to seabirds feeding young. In response to a request for advice from the European Commission on this topic, an ICES Study Group reviewed information on seabird breeding success, sandeel fisheries, and their interactions, and formulated advice on management of the sandeel fishery which offers explicit protection to seabirds feeding needs (ICES 1999c).

Briefly, ICES concluded that there was sound evidence that the sandeel fishery had impacted seabird breeding success in at least one year. The Study Group identified criteria which led to selecting Black-legged Kittiwakes (*Rissa tridactyla*) as a particularly sensitive surrogate indicator of local availability of sandeels to land-based predators. It recommended that kittiwake breeding success be monitored annually, and sandeel fisheries in specified coastal areas be closed if breeding success fell below 0.5 chicks-per-well-built-nest (a value based on simulations of kittiwake population dynamics) for three consecutive years. The quota itself would not be reduced, although the spatial distribution of catches would be constrained until breeding success rose above 0.7 chicks-per-well-built nest.

Antarctic Krill fisheries – There are a number of krill fisheries worldwide, on at least six different species of euphausiids, a group of small (a few cm, depending on the species) marine invertebrates. Although krill have been harvested for at least a century, intensive harvesting only began in the 1950s, and all fisheries operate well below their maximum potential (Nicol and Endo 1997). Krill play a central ecological role in many marine ecosystems (Everson 1977, Mackas and Fulton 1989, Nicol and de la Mare 1993, Pitcher and Chuenpagdee 1995), being a primary food source for seabirds, marine mammals, and many predatory fishes. Very little was known of the dynamics of these populations in the Antarctic, nor of their links to krill, when the Antarctic krill fishery began to expand.

The Antarctic krill fishery began slowly in the 1960s, but rose steadily from the early 1970s to early 1980s, exceeding 500,000 tonnes by 1982 (Everson and Goss 1991, Miller and Agnew 1996, Agnew 1997). Although even this harvest represented a small fraction of the total euphausiid production in Antarctic waters, there was serious concern about the possible impacts of such removals on dependent predators (Nicol 1991, Croxall et al 1992) particularly in light of the high variability in krill on several space and time scales (Murphy et al. 1998). These concerns led to the establishment of the Convention on the Conservation of Antarctic Marine Living Resources (Edwards and Heap 1981), which came in force in 1982. CCAMLR has three central objectives, which address directly the importance of prey species, particularly krill, to predators. These

objectives are:

- The prevention of decrease in harvested populations to levels below those which ensure stable recruitment;
- The maintenance of ecological relationships between harvested, dependent, and related populations;
- The prevention of changes or minimization of the risk of changes in the marine ecosystem which are not potentially reversible over two to three decades. (from Agnew, 1997).

CCAMLR has prompted substantial scientific research on the Antarctic marine ecosystem, but also had major impacts on the management of the krill fishery. Initial measures were basic fishery management activities such as reliable catch reporting requirements. However, an Ecosystem Monitoring Program was also developed over several years, and fully implemented in 1987. The ecosystem monitoring program involves monitoring of a number of ecosystem features such as predator and prey populations, indicators of their well-being, and environmental attributes. These data collection programs are closely linked to modelling and analyses activities. The objective of the monitoring program is to detect changes in the indicators and the related species, determine if the changes are due to impacts of krill fishing, and modify management regulations as needed to mitigate undesirable effects of the fishery (Agnew 1997).

Participants consider the CCAMLR approach to managing the krill fishery to have been a success, without major impacts on related species (Agnew 1997, Nicol and Endo 1997). Management uses precautionary limits which trigger more restrictive management actions. These limits include estimates of total krill biomass, natural mortality including mortality due to predator consumption, growth and recruitment variation. Catches have been kept generally below 200,000 tonnes, although the areas of harvest have changed several times, probably reflecting geo-political changes more than ecosystem changes.

Canadian Experience

Some forage species, such as herring, have been fished in Canada for centuries. Fisheries on other species such as capelin and *Pandalus* shrimp reached full commercial scale only in recent decades. Additionally there have been native harvests of eulachon for many centuries. There are small commercial fisheries on euphausiids in the Pacific, and for a brief period, an experimental one in the Gulf of St. Lawrence.

Herring fisheries thrived in both Newfoundland and the Maritimes back to at least the 1700s (Templeman 1966, Stobo et al. 1982). Landings from all stocks were highly variable over time, reflecting changes in availability, success of other fisheries, and markets. There have been some exceptional events in the Atlantic herring fisheries, such as a four year pulse of catches reaching 300,000 tonnes, compared to a more typical 20,000 – 40,000 tonnes, when new wintering concentrations were discovered. Although strong year-classes are sporadic in all stocks, none of the Atlantic herring stocks have been thought to have suffered major and enduring collapses, nor periods of sustained excessive fishing mortality (DFO 1999a-d). Although interest has grown in management on much finer geographic scales, especially in the 1990s, (CSAS 1997), there have been no studies suggesting that the Canadian Atlantic fisheries for herring have had noteworthy impacts on predators of herring.

The commercial Pacific herring fishery has a different history. Landings began early in the 1900s, increased slowly to around 75,000 t until the 1930s, declined due to market conditions and then rose markedly from the mid 1930s to over 200,000 t in the 1950s in response to the new market for fishmeal and fish oil. This reduction fishery was not sustainable, and the stock collapsed abruptly in 1965. Closure of the reduction fishery was followed by stock recovery and reopening of a roe fishery in 1972. Catches were highly variable, and in 1985 a comprehensive management

regime was introduced. Key features include a minimum spawning biomass at which fisheries are closed, and a modest fixed harvest rate when stocks are above the limit. Quota management is by major geographic unit, although operations are regulated on much finer spatial scales. The lower biomass limit has led to regional fisheries being closed several times, in response to poor recruitment, but closures have been short and stocks have not collapsed below historic bounds of variation (Stocker 1993, Schweigert 1997, DFO 1999e-i). Although there is public concern that the herring roe fishery may be affecting other predators, including Pacific salmon, no studies have found evidence that current harvesting strategies are impacting food availability to other predators.

Until 1972, capelin harvests off Newfoundland and Labrador were small and restricted to inshore catches taken during spawning. Starting in 1972 substantial offshore harvesting began with catches peaking at over 360,000 t in 1976. Offshore catches declined rapidly thereafter, however, and varied between 5,000 and 57,000 t until 1992 when the offshore fishery was closed. An inshore fishery for roe-bearing females developed in the 1980s, but harvests have been below 36,000 t throughout, and even lower in recent years (DFO 1997). Assessments of the state of the resource have been highly uncertain, but abundance has been strongly driven by environmental factors affecting recruitment (Carscadden and Nakashima 1997). Concern has often been expressed in both the public and scientific sectors (e.g. Brown and Nettleship 1984) about the commercial exploitation of capelin because of its role as a forage species. However, since the late 1970s, TACs have been set at no more than 10% of conservative estimates of mature biomass, and in many years poor market conditions led to even lower TACs. In fact, catches during the 1980's were estimated to have been less than 5% of the mature biomass (Shelton et al 1992). At this exploitation rate, it has not been thought that the harvests are limiting food available to predators (CSAS 1997).

There also have been small capelin harvests in the Gulf of St. Lawrence, but exploitation rates are also thought to be quite low. Recent fishery harvests have been below 10,000 t, whereas predators in the Gulf of St. Lawrence are estimated to consume over a million tonnes of capelin annually.

The other major forage species fished in Canada is shrimp. On the Atlantic Coast the fishery harvests primarily *Pandalus borealis*, whereas the Pacific fishery is actually a multispecies fishery, harvesting *Pandalus* and several species of prawns. Off Newfoundland and Labrador harvesting began in the 1970s, with catches below 5,000 t until the mid 1980s. Catches and area fished both increased rapidly thereafter, particularly in the latter half of the 1990s, with catch exceeding 70,000 t in 1998. However, assessments conclude that the stock was increasing in abundance, and new concentrations were being found with additional surveys, so exploitation rate of the stock may have actually declined during the period of rapid expansion of catch (Parsons et al. 1999). Estimates of consumption of shrimp by predators have not been made, but the post-fishing biomass is several hundred thousand tonnes. Harvests in the Gulf of St. Lawrence and Scotian Shelf have also expanded in recent years, but remain much smaller than catches in Newfoundland and Labrador waters. Stocks are also thought to have increased in these areas, so exploitation rate has remained stable or decreased during the recent increase in catches (Koeller et al. 1998, Lambert et al. 1998). Research into the reasons for the marked increase in shrimp in Atlantic waters is on-going, and conclusions have not yet been reached.

The Pacific fisheries for shrimp and prawns have not shown the explosive recent growth seen in the Atlantic, although harvests are being taken from some new areas. The Pacific Coast has supported some prawn and shrimp harvest for over 100 years, although the offshore fisheries only commenced in 1973. Management is by target escapements rather than solely fixed exploitation rate, to ensure that an adequate stock is always left after harvest. When the stock is large, shrimp harvests may remove 25-33% of the adult stock, a reduction less than the estimated annual natural mortality on these short-lived species. Prawn catches have been relatively stable and under 2000 t annually, whereas shrimp harvests are more variable, reflecting recruitment variation, and have been as large as 12,000 t (Boutillier 1993, Boutillier et al. 1999). These values represent a negligible fraction of estimates of total predator food requirements (Pauly et al. 1998),

although requirements of shrimp alone are not available for most predators.

Krill, or euphausiids, have also been fished on both coasts of Canada. Harvesting of *Euphausia pacifica* in the Strait of Georgia began in the 1970s, as an experimental program. Annual landings did not exceed 200 t until the mid 1980s, and as catches increased, separate quotas were set for parts of the Strait of Georgia. In 1990 the total quota was set at 500 t, with spatial allocations and season restrictions to control bycatch (Haig-Brown 1994, Mackas 1998). Catches have often been far below the quota, due to marketing difficulties. The initial quota was set as 3% of a coarse estimate of predator consumption of euphausiids. Information on predator requirements has increased greatly since that estimate, but the quota has been kept constant despite the likelihood that predators consume much more euphausiid than initially estimated. No harvesting is allowed in the offshore waters in British Columbia, in response to concerns about food requirements of many important fish species.

In the Gulf of St. Lawrence, some research was conducted on the feasibility of a krill fishery in the 1970s, but commercial harvesting did not follow that work. A second round of surveys in the late 1980s and 1990s produced estimates of krill biomass of between 400,000 and 1,000,000 t, and an exploratory fishery was permitted in 1990 and 1994. The first was by scientific licence, and the second operated with quotas of 100 t for krill and 50 t for *Calanus*. The fishery has operated thereafter with a quota of 300 t, reflecting concern for the importance of krill and copepods to many marine predators, including whales. Management Plans require full observer coverage and other provisions to address possible ecological impacts of the harvests (Gendron 1994, Runge and Joly 1995, Nicol and Endo 1997). There has also been a request for harvest of krill on the Scotian Shelf. That request has been given a thorough review, including a major workshop on krill harvesting on the Scotian Shelf (Head 1997), but no commercial fishery has yet been licensed.

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