IDENTIFICATION OF ECOLOGICALLY SIGNIFICANT SPECIES AND COMMUNITY PROPERTIES

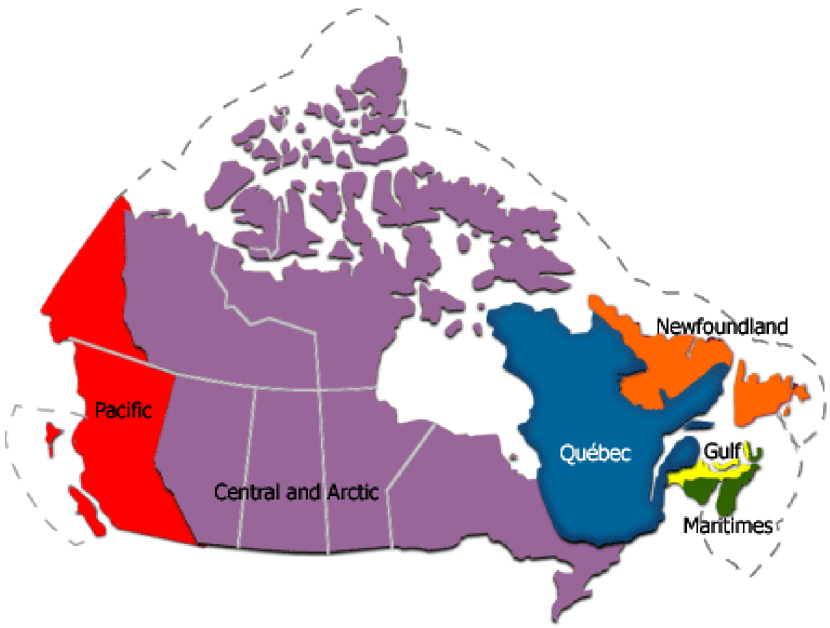

Figure 1: Department of Fisheries and Oceans' (DFO) six administrative regions.

Context :

Canada's Oceans Act authorizes Fisheries and Oceans Canada (DFO) to take an Ecosystem Approach to the integrated management of human activities in the sea. This is being pursued in five Large Ocean Management Areas, for which Integrated Management Plans will be developed. These Integrated Management Plans will include a number of Ecosystem Objectives, including ones intended to protect the ecosystem. A component of this initiative is to provide enhanced protection to species and community properties that are particularly significant to maintaining ecosystem structure and function. It is necessary to operationalise the term "significant" in this context. As with the criteria that were developed for Ecologically and Biologically Significant Areas, consistent criteria, and guidance for their application are needed for the identification of species and community properties for which protection should be enhanced, while allowing sustainable activities to be pursued in the ecosystem.

Species and community properties can be ecologically "significant" because of the functions that they serve in the ecosystem and/or because of features that they provide for other parts of the ecosystem to use. All species have some function in the ecosystems in which they are found. Operationalising the concept of Ecologically Significant Species and Community Properties requires establishing whether or not specific species or aggregate properties of a community are particularly important for each function, and thus warrant enhanced protection.

A national workshop was held on September 6-8, 2006, in Ottawa, to develop a priori *criteria to assess species and community properties that are "particularly important" or "significant" with regard to maintaining ecosystem structure and function. Assessments using these criteria should rank species and community properties by their ecological significance, as an important step in developing Ecosystem Objectives for integrated management.*

SUMMARY

- Identifying Ecologically Significant Species and Community Properties is not a general strategy for protecting all populations and marine communities that have some ecological role. Rather, it is a tool for calling attention to a species or community property that has particularly high ecological significance, to facilitate provision of a greater-than-usual degree of risk aversion in management of human activities that may affect such species or community properties.
- The “criteria” referred to in this report are actually the ecosystem properties that are ecologically significant. These “criteria” do not identify a species or community property as ecologically significant if the consequences when perturbed are primarily for humans. The process for identifying Social and Economic Objectives, including culturally important species, needs to progress within the larger framework of objectives-based Integrated Management.
- We have limited knowledge of the ecological processes that affect all aquatic species, including those potentially affected by human activities we are trying to manage in a sustainable manner. Hence many species and community properties may NOT be identified as exceptionally ecologically significant based on the best information available but with further study they may be found to be as important as parts of the ecosystem that are given very high priority on these criteria.
- Ecological scale is a key factor in the ecological role of a species or community property. The ecological significance of a species or community property must always be interpreted relative to both spatial and temporal scales.
- Criteria are given for assessing four types of Ecologically Significant Species and Community Properties;
  - The most direct and tractable cases will be species-based assessments of ecological significance; that is, identifying species with potentially controlling influence on ecosystem structure and function. This may occur either because a species has a crucial trophodynamic role (type 1);
  - Or because it provides three-dimensional structure important to biodiversity and productivity (type 2).
  - Above the species level, there are *aggregate ecosystem properties* that are themselves essential to maintaining ecosystem structure and function (type 3).
  - Species or species groups which, if abundant, could pose a particular threat to ecosystem structure and function may be candidates for enhanced *management* for their ecological significance; to control their abundance and/or distribution rather than protect and promote it (type 4).
- The best approach for identifying Ecologically Significant Species on the basis of their trophic roles is to assess the interaction strengths of all the species in the food web. However, for almost all aquatic food webs at present we lack the information needed to quantify how interaction strengths are distributed among species. Where we cannot directly identify the species with large interaction strengths, the best science practice for trophic relationships is to focus on key trophic roles. These include
  - Forage species;
  - Highly influential predators;

  - Nutrient importing (and exporting) species;
  - Primary production and decomposition are also essential to ecosystem structure and function. However, they may be less useful as criteria for assessing the ecological significance of species, because they are often difficult to associate with individual species. However, they are often tied to places that meet EBSA criteria, so they often receive enhanced protection through spatial management approaches.

- Assessment of structure-providing species requires assessing quantity of the species present, quality of the structural habitat being provided, and the significance of the structural habitat to the overall ecosystem structure and function.
- Management advice is feasible for community properties above the species level as well, although with current knowledge few criteria can be made operational for assessing community properties above the species level as ecologically significant at this time. However, research on community properties of ecosystems is expected to increase the specificity of community-scale science advice that can be provided. Those proposed for use now include:
  - Size based properties;
  - Frequency distribution of abundance and/or biomass across species.
- Whether or not Conservation Objectives are set and management actions taken to address species considered to be threats to ecosystem structure and function will depend on many things including the nature of the threat posed, societal values, and tractability of management responses. What this criterion does is to flag the need for focused discussion of these topics. Specific types of species for consideration include:
  - Invasive species;
  - Harmful or toxic species.
- Two additional factors, rarity and sensitivity/recoverability, affect the application of the preceding criteria and may move a species or community property somewhat higher in priority ranking.
- DFO needs to make it a priority to reduce the knowledge gaps in this report. Science should be vigilant to monitor changes in additional properties and management should be responsive to major changes in them, even if the ecological significance of each change is not fully understood.
- Overall, using this set of criteria for assessing the ecological significance of species and linking the assessment to the degree of risk aversion expected in management represents a fundamental change in the conceptual basis for management.

ANALYSIS

Operating Framework

1. DFO has many tools for protecting species and community properties above the level of individual species, and adheres to federal policies and practices of good risk management and application of precaution. Identifying Ecologically Significant Species and Community Properties is not a general strategy for protecting all populations and marine communities that have some ecological role. Rather, it is a tool for calling attention to a species or

community property that has particularly high ecological significance, to facilitate provision of a greater-than-usual degree of risk aversion in management of human activities that may affect such species or community properties.

2. Throughout this document "significance" refers to the role of a species, community property, area, etc. in the ecosystem, and is used in a relative sense. All species have *some* ecological role and all ecological relationships have some role in maintaining ecosystem structure and function. However, to identify a species or community property as "significant" is to conclude that if the species or community property were perturbed severely, the ecological consequences (in space, in time, and/or outward through the food web) would be substantially greater than an equal perturbation of most other species or community properties, although the nature of those consequences could differ greatly among specific cases. Ecosystem management objectives are being set for the integrated management of Large Ocean Management Areas. One subset of these Ecosystem Objectives focuses on the health of the ecosystem, its conservation and protection. The identification of significant community properties, species and areas, as well as other important ecosystem considerations, will be used in creating this subset of Ecosystem Objectives commonly referred to as "Conservation Objectives". Other processes will set Ecosystem Objectives for social, economic or cultural objectives, which are also goals of integrated management. The term "value" is used to refer to the special utility or importance of a species or community property to humans. This is not a major consideration in identifying a species or community property as ecologically significant, although value usually will be a major consideration in setting the subset of Ecosystem Objectives comprising Social, Cultural, and Economic Objectives. These social, cultural and economic goals may result in other objectives specifying desirable states of ecosystem properties. However, these are not **Conservation** Objectives, but objectives to keep the ecosystem not just safe from serious harm, but also able to allow Social, Cultural, and Economic Objectives to be achieved in a sustainable manner.

3. All species have some influence on at least parts of ecosystem structure and function, and the degree of influence ranges on a continuum from weak to actually controlling important aspects of the structure and function. It is important to ensure all uses are sustainable, but the concept of ecologically significant species and community properties applies to the high end of the continuum, where current knowledge indicates that **the species or community property has controlling influence over key aspects of ecosystem structure and function.**

4. The "criteria" referred to in this report are actually the ecosystem properties that are ecologically significant. They are each presented with a definition, key diagnostic features, and considerations for their use. These "criteria" do not identify a species or ecosystem property as ecologically significant if the consequences when perturbed are primarily for humans (i.e.: species that are iconic and culturally important). This is consistent with the overarching concept that it is the ecological role of the species in maintaining ecosystem structure and function that determines its ecological significance. Some iconic or culturally important species may meet the criteria below for ecological significance and should be considered for Conservation Objectives for those other reasons. However, significance to humans economically, socially, or culturally does not make a species ecologically significant. Rather are expressed societal values when setting the Social and Economic Objectives. The process for identifying Social and Economic Objectives needs to progress rapidly, so it is clear to all that iconic and culturally important species are a priority within the larger framework of objectives-based Integrated Management. The process must pick up cultural values and human health

values in setting the social and economic objectives, and not solely focus on economic and community employment values.

5. There is a sequence of activities in the process of bringing Ecologically Significant Species and Community Properties into management. All steps are science-based, in the sense that they work from scientifically sound information. However, the role of science changes along the continuum:

   a. The first steps should be Science-led, wherein the species and community property(ies) of interest are evaluated within the framework that has been developed. "Experiential knowledge" (a term including "Aboriginal traditional knowledge", "fishermen's knowledge", and other ways that ecological knowledge is acquired through extensive experience with the marine environment) should be fully included in these steps. These steps should lead to some structured output; often a quantitative or qualitative ranking of the priority species and community properties relative to their ecological significance.

   b. The output of the science-led process is used by an even more inclusive Oceans-led process that considers how to match the degree of management protection to species and community properties along their rankings of ecological significance. Species and community properties identified as particularly ecologically significant warrant a high degree of risk aversion in management, because of their role in maintaining ecosystem structure and function. In addition societal values and potential threats play a role in determining how much risk aversion to apply to species and community properties in many other positions in the ranking, although they are not considerations in the first phase (5a). Where Conservation Objectives have been adopted or are under development for a species or community property, they play an important role in this phase, although the results of the science-led process may influence the objectives-setting process more broadly as well.

   c. The results of the inclusive Oceans-led process are implemented by managers and regulators, who must specify clearly what management measures will be used to achieve the desired protection for the various species and community properties, and under what conditions. Managers are likely to seek further science advice on the potential effectiveness of alternative management measures, particularly if they are challenged to control or give enhanced protection to species or community properties which have not been targets of management in the past.

6. Concluding that a species or community property is ecologically significant does not give it any special legal status. Rather, the assessment provides guidance on the standard of management that is considered to be appropriate. In the first phase of the identification process (5a) the output is likely to be a gradient of species or community properties from those ranking very highly on ecological significance to those ranking as unexceptional (but this does not mean unimportant). The subsequent phases (5b and 5c) will have outputs which are successively more black-and-white, such that by the time management is in place (5c) specific measures either will or will not be implemented for enhanced protection of each Ecologically Significant Species or Community Property. The gradient nature of ecological significance can still be preserved in the management phase, however, through the diversity of measures implemented, and the extent of their application in space or time (for example more stringent prohibitions of harm to species of very high significance).

7. We have limited knowledge of the ecological processes that affect all aquatic species, including those potentially affected by human activities we are trying to manage sustainably. Science advisors and managers are always challenged by uncertainties

arising from that limited knowledge. In an Ecosystem Approach to Integrated Management, these information limitations are substantially larger than science and management are used to dealing with in single-species and single-activity management. Hence many species and community properties may NOT be identified as exceptionally ecologically significant, but may be as important as parts of the ecosystem that are given very high priority (5a). The science advice must communicate clearly such knowledge gaps and uncertainties, without suggesting that we are advising (and managing) in ignorance.

8. The greater uncertainties and complexities of an Ecosystem Approach to Integrated Management means that management needs to be planned to perturb ecosystems less than has been the case in "classic" single-species and single-activity management, simply to maintain a comparable probability of sustainability at the scale of ecosystem structural and functional properties. The application of precaution is appropriate in these contexts. Hence science advice must be based on the best information available, even if the information is incomplete, and uncertainties must be communicated clearly. The advice should support management that is adaptive and contributes to reducing the knowledge gaps while keeping perturbations of the whole ecosystem, not just the most Ecologically Significant Species and Community Properties, sufficiently small that there is a high likelihood (with current knowledge) that consequences of the activities will be sustainable.

9. It is important that the ecological significance of a species or community property be interpreted relative to both spatial and temporal scales.

   a. <u>Temporal Scale</u>: The temporal scale of data sets available to DFO for setting management objectives and especially reference points may be too short to be informative about all possible states in which aquatic ecosystems have existed, and which may have had structural and functional properties very different from those quantified in our data series. This incomplete knowledge of the range of natural states of most marine ecosystems constrains the ability to provide science advice, at a cost that depends greatly on policy objectives.

      However, from a science perspective the full time series of information that is available should always be used in assessing ecological significance, and in setting Conservation Objectives and reference points. It also highlights the importance of considering experiential knowledge in identifying, articulating, and operationalizing Conservation Objectives consistent with the ecological significance of a species or community property.

   b. <u>Spatial Scale</u>: Ecological significance can be identified and assessed at many spatial scales. The key point is that Ecologically Significant Species and Community Properties have to be identified at the scale of something that can be readily identified as an ecosystem with structure and function that Integrated Management can address with measures to maintain or enhance. These scales may be smaller (and sometimes larger) than a whole Large Ocean Management Area. For example coastal-scale Ecologically Significant Species or Community Properties are legitimate to consider, because management can maintain or enhance ecosystem structure and function at coastal scales. Such evaluations of ecological significance on coastal scales may be linked to the larger Large Ocean Management Area for some structural and functional processes but may be largely self-contained for others. Often Ecologically Significant Species or Community Properties will not be associated with any fixed coordinates, but that may not make spatial scale irrelevant.

c. Information Sources Relative to Scale Considerations: Where available, locally collected data at the scale of the ecosystem of interest would be most informative for assessing the ecological significance of a species or community property, setting Conservation Objectives, selecting indicators, and setting management reference points. Frequently such data will not be available and in such cases information from other areas can be considered. The relevance of such data will vary with many factors, including similarity of spatial scales (e.g. Are coastwide averages being applied to subsets of the region? Is a local study being extrapolated to a large area?), similarity of the ecological features being considered (e.g. What are the justifications for assuming that species and community properties played similar roles in the structure and function of the ecosystem where the information was collected and the one being evaluated now?), and even simple proximity (e.g. Are data being "borrowed" from adjacent areas or distant systems?). In all these cases, because of data limitations uncertainty in the science advice will be higher, and this needs to be reflected through greater risk aversion in all management decision-making.

10. Ecosystems are inherently variable, and the process of setting Conservation Objectives to give enhanced protection to Ecologically Significant Species and Community Properties should not be interpreted as trying to "freeze" an ecosystem in a particular state. It will often be a challenge to determine the extent to which an observed change in ecosystem properties, including the status of Ecologically Significant Species and Community Properties, are natural variations or are consequences of human activities. Moreover, the cause of the change may not be relevant to the necessary management action (just as, in a simple case, fishery quotas may be adjusted in comparable ways whether a stock decline is due to recent overfishing or a weak recruiting year-class due to unfavourable environmental conditions.)

    a. Some non-human-induced changes may result in significant alterations of the existing ecosystem structure and function, and valid Conservation Objectives may prompt management intervention (at least reactively) to such changes. However in each case feasibility and desirability of management intervention should be assessed carefully. In many cases it may be a sounder course to alter (or drop) the Conservation Objective than for management to strive to counter non-human-induced changes. This situation might occur when prospects for successful intervention are poor, either because no ecologically feasible options are found for addressing a natural change that makes achievement of a Conservation Objective more likely, or economically the cost of effective actions is prohibitive.

    b. Likewise, many human induced changes to ecosystem properties and abundances of individual species may not result in significant alterations to ecosystem structure and function. Valid Conservation Objectives generally allow human activities that cause change, especially if the changes are (with existing knowledge) reversible and are not expected to move the structural and functional properties outside their sustainable boundaries.

Criteria

11. Criteria are given below for assessing four types of Ecologically Significant Species and Community Properties; all relevant to protecting ecosystem structure and function.

   a. The most direct and tractable cases will be species-based assessments of ecological significance; that is, identifying species with potentially controlling influence on ecosystem structure and function. This may occur either because a species has a crucial trophodynamic role (type 1);

   b. Or because it provides three-dimensional structure important to biodiversity and productivity (type 2).

   c. Above the species level, there are *aggregate ecosystem properties* that are themselves essential to maintaining ecosystem structure and function (type 3). Even though such properties may be viewed as the aggregate consequences of the roles of the component species, it may both be more tractable and more accurately reflect the significant ecological relationships to give them enhanced protection as properties in their own right, rather than through designating all the interacting species as individually ecologically significant.

   d. Finally, there may be species or species groups which, if abundant, could pose a particular threat to ecosystem structure and function. These may be candidates for enhanced *management* for their ecological significance as well. In this case, the management goal would be to control their abundance and/or distribution rather than to protect and promote them (type 4).

Criteria for Key Trophic Species

General Considerations Regarding Trophic Role

12. The best approach for identifying Ecologically Significant Species on the basis of their trophic roles is to assess the interaction strengths of all the species in the food web. “Interaction strengths” reflect the number of linkages that a predator has with alternative prey or a prey has with its predators, and the degree to which predation pressure of each predator affects the population dynamics of each prey. Usually, a small number species have comparatively high interaction strengths, with the bulk of the species in the food web having weak interactions. Those few species with high interaction strengths are the ones likely to have the potential to exert controlling influence over ecosystem structure and function, and hence should be considered the Ecologically Significant Species for that system.

13. However, for almost all aquatic food webs at present we lack the information needed to quantify how interaction strengths are distributed among species. Where we cannot directly identify the species with large interaction strengths, the best science practice for trophic relationships is to focus on key trophic roles (often called “functional groups” in the technical literature), in particular the most important forage species, the top predators, species with important roles as nutrient importers or exporters, and primary producers.

14. We acknowledge that there may be additional key trophic roles for some specific ecosystems, such as ice algae in northern ecosystems. In such cases it is appropriate to review such roles and the species involved in them carefully, focusing on the overall standard of assessing the likelihood that the particular trophic role, and the dominant species playing it, may exert *controlling influence* over ecosystem structure and function in

that system. On the other hand, if trophic roles are defined extremely narrowly, even species with very similar diets and predators might be considered to have different roles. In such cases the onus is to demonstrate that each of those narrowly-defined roles can exert *controlling influence* over ecosystem structure and function, to justify each role that is considered to be ecologically significant.

15. For each trophic role, the species dominant in biological productivity may be a candidate as ecologically significant, but it is often the *trophic role* that is ecologically significant, and not necessarily every species having that role. When a role is shared among many species it is possible, and scientifically reasonable, to have a Conservation Objective for the trophic role itself without identifying a specific species that is ecologically significant. In such cases no one *species* may warrant enhanced management protection, but the functional group in aggregate could still warrant this designation. However, the fewer the number of species that are known to play a particular role in an ecosystem, generally the more ecological significance will be given to individual species in that trophic role.

16. Species may have multiple trophic roles in maintaining ecosystem structure and function, particularly at different life history stages or sizes. It is plausible that a species could exert controlling influence over aspects of ecosystem structure and function in some roles (perhaps at some life history stages) but not others. The assessment that the species was ecologically significant would apply only to its relative importance in the particular role, but the management measures needed to provide enhanced risk aversion may or may not have to be applied to other life history stages or sizes as well, depending on the life history and population dynamics of the species.

17. At the time these criteria were developed, information was not available on all trophic roles that may have the capability to exert controlling influence over aspects of ecosystem structure and function. In particular, parasites are an example of a “trophic role” likely to be important and warrant further investigation. However given the paucity of information that is available currently on their role in maintaining trophic relationships, it is unlikely that it will be feasible to consider the ecological significance of parasitic species during this cycle of setting Conservation Objectives.

Specific Criteria for Trophic Role

18. Forage Species

    a. <u>Definition</u>: Forage species are small, schooling fish (or other marine taxa) that serve as an important source of food for marine predators, including other finfish and invertebrates, seabirds, and marine mammals.

    b. <u>Diagnostic Features</u>: Forage species can be in any higher taxonomic group but are commonly fish or invertebrates. They are generally species with life histories characterised by relatively rapid population turnover rates, with relatively high natural (non-fishing) mortality and the capacity to increase quickly in abundance or density when environmental conditions are favourable for recruitment and growth. In the Arctic the role may be served by small marine mammals

    c. <u>Considerations in application of this criterion</u>: Many species of fish and invertebrates that are of a suitable size to serve as forage species are poorly studied, and their abundances and trophic roles are poorly quantified. In such cases the relative biomasses of the major species in this size range are likely to be the most tractable consideration in applying this criterion.

The life histories of forage species mean that they frequently are species whose recruitment dynamics are strongly affected by environmental forcers. If there have been periods of low abundance of particular forage species with no evidence of major consequences for potential predator species, this strongly suggests that there are multiple forage species available to predators and individual forage species will be given a lower priority on this criterion. However, it is not necessary to wait for information on predator diets from periods of high or low abundance of each candidate forage species before assessing species on this criterion.

19. Highly Influential Predators

a. Definition: Highly influential predators are the species that, in technical analyses of food webs, have high interaction strengths as predators. Practically this means that they are connected to a "large" number of prey given the overall richness of the food web, and consume enough of these prey to influence their preys' population dynamics.

b. Diagnostic Features: There is substantial debate in the scientific literature about exactly how to characterize "top predators", "keystone species", and other such related concepts, and it is not likely that this debate will be resolved soon. However, in general highly influential predators will be at the top of the food web, and either eat many prey, or else as a predator exert "controlling influence" on the population dynamics of a particularly important forage species or structure providing species.

c. Considerations in Use of this Criterion: "Controlling influence" as a predator does NOT mean exerting direct 1:1 control of each specific prey species on which it feeds. The relationship should be more or less monotonic (more predators means more impact on the prey being "controlled, but the impact may not increase at a consistent rate as predators become more abundant"), but may be far from linear. Temporary high abundances of alternative prey may even remove the "controlling influence" of some predators for some periods. However, as long as such periods are the exception to a generally apparent pattern of strong influence, the species can still be ranked high as ecologically significant.

Highly influential predators may also achieve their ecological significance through functions other than controlling the dynamics of their dominant prey. A particularly key function is to connect separate "sub-webs" or "compartments" in the ecosystem, such as linking energy flow from lower trophic level species whose energy comes primarily from detritus with other species whose energy sources are primarily from phytoplankton. Such roles are critical in maintaining ecosystem structure and function, buffering the ecosystem against environmental changes, and enhancing ecosystem "stability". These roles are very important, but can only be assessed in systems which have been studied thoroughly. This is another reason for substantial caution overall when setting Conservation Objectives, because without detailed analysis, it may not be possible to assess which predators play such roles in an ecosystem.

20. Nutrient Importing (and Exporting) Species

a. Definition: Such species play a crucial role in maintaining ecosystem structure and function through the transfer of energy or nutrients that would otherwise be limiting to an ecosystem, into that system from sources outside the spatial boundaries of the ecosystem.

b. Diagnostic Features: To some extent all migratory species can be considered nutrient importing or exporting species. The key features for this criterion are that the nutrients would be limiting in the ecosystem were it not for the actions of the Ecologically Significant Species, and the ecosystem shows evidence that it has structural or functional properties adapted to be dependent on the nutrients brought in by the species. Pacific salmon are the best studied and possibly most common group of species likely to meet this criterion, transporting nutrients from marine to freshwater ecosystems that have been shown to depend on the imported nutrients for their productivity and trophic relationships. Sea run arctic char is another example of a species with this trophic role.

c. Considerations in Use of this Criterion: Nutrients are to be interpreted broadly as not just "calories" but also inorganic and elemental nutrients. Addressing the ecological role of these species in a particularly risk averse management plan often will require considering ecological relationships on spatial scales outside the traditional scale on which most current management plans are developed, such as the link between marine and freshwater ecosystems provided by Pacific salmon.

Nutrient exporting species could play reciprocal roles in marine ecosystems, creating nutrient limitations in the ecosystem as a whole through moving nutrients out of the system. This has not yet been documented for any system we know if, but if it were the role would be ecologically significant, although it is unclear what a Conservation Objective for such species would be, or what management measures would facilitate its achievement.

Interpreted broadly, vertically migrating species could simultaneously be nutrient importers and exporters, linking the nutrient dynamics and energy transfers between deep-sea and more pelagic ecosystems. However, for a vertically migrating species to be assessed as ecologically significant *on this criterion,* there would have to be some reason for setting Conservation Objectives for the deep water and pelagic ecosystem separately. If Conservation Objectives were being set for a Large Ocean Management Area from surface to seafloor, then vertically migrating species would be part of the structure and functioning of the ecosystem as whole, and would be assessed on other criteria in this list. Similar reasoning would apply to species migrating seasonally from the pelagic zone to the coastal/littoral zone.

Commercial fisheries function as an energy and nutrient exporter from ecosystems, and management insights might be gained from viewing them in this context.

21. There are other essential roles in marine food webs, including primary production and decomposition. These roles are foundation processes, and are at least as essential to ecosystem structure and function as are the roles listed above. However, for three reasons they may be less useful as criteria for assessing the ecological significance of species.

a. Often the roles are difficult to associate with any particular species;

b. Even when specific species can be identified in these roles it is difficult to link conservation of the species to manageable human activities, aside from protection from point-source pollutants, and they may be targeted for control on the grounds of sustainability alone, and not enhanced risk aversion.

c. Important aspects of these roles often have a strong spatial component as such species often have limited mobility, and protecting areas important for these processes was an important consideration in setting the criteria for assessing

Ecologically and Biologically Significant *Areas*. Hence there is some opportunity within the overall framework to provide enhanced protection to these processes, through enhanced management in the places that are most important to primary production and decomposition.

Even if specific Conservation Objectives are not set for these trophic roles, monitoring of key primary producers and decomposers is essential to track ecosystem status and threats. Further work within the framework of application of these criteria and setting of Conservation Objectives may cause us to revisit this view.

Criteria for Structure-Providing Species

General Considerations Regarding Structural Species

22. The concentration of individuals of structure-providing species and not just the presence of some individuals matters to the ecological function they serve. Hence, assessment of this functional role requires assessing quantity of the species present, quality of the structural habitat being provided, and the significance of the structural habitat to the overall ecosystem structure and function on scales relevant to the Conservation Objectives and management plans.

23. The fact that many structure-providing species are inherently sessile means some will be captured in the assessment of Ecologically and Biologically Significant *Areas*. However, some species may not be, particularly short-lived ones such as macro-algae, eelgrass, epibenthic bivalve beds and bio-turbating species, whose geographic distribution may be broad and sites of concentrations change over time. Such species may need especially risk-averse management, so criteria to assess the ecological significance of structure-proving species are necessary in the overall framework.

24. A species/area that ranks highly on both sets of criteria is likely to get substantial attention at the step of setting Conservation Objectives, but a site occupied by a concentration of structure-providing species may be considered a priority for Conservation Objectives and particularly risk averse management even if it ranks highly on criteria for either species or areas alone.

Specific Criteria for Structure-Providing Species

25. Provision of three-dimensional structure important to other species in the ecosystem

    a. <u>Definition:</u> Structural species create habitat that is used preferentially by other species, either emergent from the seafloor or through burrowing into the substrate.

    b. <u>Diagnostic Features</u>: The structural species physically support(s) other biota, and provide either settlement substrate or protection for this associated community (e.g.: eel grass beds; macrophyte beds such as kelp, fucus, etc.; mussel beds; sponge reefs; and coral forests or reefs). If the species is a bioturbator, other species use the burrows or seafloor irregularities created by the species as essential habitat for critical life history functions (protection from predator, access to food, etc.), or the burrowing allows aeration of substrates, on which other species depend.

c. Considerations in Use of the Criterion: To be ecologically significant the dominant species or species type (e.g.: sponge) should be abundant enough and sufficiently widely distributed to influence the overall ecology (e.g.: biodiversity) of that habitat.

26. Other species may have a significant role in maintaining ecosystem structure and function through permitting the persistence of structural species in its accepted habitat. These species could also be assessed as ecologically significant, if altering their abundance would result in serious reductions in abundance or distribution of the structure-providing species, usually through predation or parasitism.

Criteria for Properties at the Community Level

General Considerations Regarding Community Properties

27. Many community-scale properties are essential to maintaining ecosystem structure and function, particularly biodiversity and productivity of the system. However, for two reasons there are few criteria for assessing community properties above the species level as ecologically significant at this time.

a. With current knowledge of ecosystem processes above the species level, few community properties can be made operational in terms of Conservation Objectives, indicators and reference points. Many integrative or “holistic” ecosystem properties may be important to ecosystem structure and function but are not directly tractable for management. For example there are many indices for biological diversity, but careful scientific investigations generally conclude that they are not reliable as a basis for Conservation Objectives and management actions, even when the goal is to protect biological diversity.

b. The knowledge and data constraints (27a) encourage focus at a level less “holistic” than community properties like diversity or productivity. Two features are tractable at this next level (29 and 30) but many others, such as food chain length, although important, are not tractable with current knowledge. Hence an applied science process often must go to ecosystem subcomponents with specific functional roles or features; usually the same trophodynamic and structure-providing roles already identified in sections 18-20 and 25. Fortunately, several science reviews have concluded that if the dominant species in all the key trophic and structural roles are being managed sustainably, then there is a low (but not zero) risk that higher order ecosystem structural and functional processes are not also being maintained.

28. Although conceptually ecosystem structure and function is dependent on higher-order ecological processes, management works most readily in reverse. The most management experience and usually the most tractable challenges are found at the single-species level. Nonetheless management advice is feasible for properties above the species level as well, although research on community properties are expected to increase the specificity of community-scale science advice that can be provided. Moreover, more information may need to be communicated to managers to enable them to take effective action based on scientific advice regarding properties above the species level.

Specific Criteria for Properties at the Community Level

29. Size based properties

a. Definition: Size based properties of a community are properties that integrate the size composition of individuals across all the interacting species in a size range of the full ecosystem. The integration may be by biomass or abundance, but all individuals of the same size class are considered equivalent.

b. Diagnostic Features: There are two commonly encountered size based attributes in community assessments. The first is the "size spectrum", that plots numbers or biomass of individuals (usually on a natural log scale) across size intervals from small to large for the system, and generally shows a linear decline in abundance with increasing size. Both the slope and the intercept of the size spectrum provide information about ecosystem structure and functional relationships. The second is the "proportion of the community that is large"; simply a ratio of numbers of individuals that are "large" to the total number of individuals in the community.

c. Size-based community attributes are tractable to measure and monitor in many systems, but they are included as criteria for an Ecologically Significant Community Property because they are important in maintaining ecosystem structure and function. This importance is due to the size dependence of many life history and trophodynamic processes in the sea. Both features have been shown to respond systematically to pressures on the community, particularly unsustainable mortality such as over-fishing and both can be linked to management advice. (Of course, like any other ecosystem property, without additional information they do not tell which pressure has caused observed changes, or which management action, if any, is optimal for achieving a Conservation Objective.)

d. Both features are considered to be Ecologically Significant Community Properties, but size (and or age) composition should be a key aspect of sustainable management at the species level as well.

30. Frequency distribution of abundance and/or biomass across species.

a. Definition: The pattern of changing abundance or differential commonness and rarity of species within a community, considering all individuals and species in the community.

b. Diagnostic features: The frequency distribution of abundance (or biomass) across species is commonly graphed as cumulative abundance (or biomass) from the most common to the rarest species in the community, but there are several alternative ways for evaluating how numbers of individuals or biomass are distributed among the species in a community. In all cases, the important feature is that these distributions are often strongly skewed because there are usually many rare species and few abundant ones in a community. It is the pattern of the skewness that is informative about community status and sustainability of human impacts.

c. Considerations in Use: This criterion also can be applied below the species level for species groups known to have complex stock structure. The common measures associated with this criterion have been important in measuring and monitoring the impacts of point source pollutants on communities. However they seem to have wide, if general, utility in assessing ecosystem status and impacts, particularly when habitat alteration is considered to be a major threat to ecosystem structure and function.

This community property is not readily able to detect complete losses of species, as "zero abundance" for a species does not usually show up in the commonly used measures. However, common measures usually show clear evidence of impact before species extinctions become frequent, and specialized methods can be used to estimate the number of species present but so rare that they are unlikely to be sampled.

31. Assessing both of these community properties requires consistent survey information. Correspondingly, although conceptually the properties can be considered for an entire ecosystem, they can only be quantified for subsets of the ecosystem that can be sampled in a consistent way. Hence they are generally viewed as properties of "the fish community" or "the epibenthic community", rather than properties of the full ecosystem.

32. These community properties are generally considered relative ones, as there is no external basis for determining *a priori* what is the "right" size composition or distribution of individuals across species. However, that is also true of species-level properties, as there is no *a priori* "right" abundance for particular species. Rather in all these cases the historic information about the abundance or size composition of an individual species or full community of species sets the context in which to interpret current information.

Criteria for Conservation Objectives to Control Expansion or Increased Abundance

General Considerations Regarding Criteria for Management to Control a Species

33. Not all Integrated Management activities may be targeted at keeping the abundance of Ecologically Significant Species and Community Properties "healthy". Some Integrated Management activities may include keeping biological threats to ecosystem structure and function low. Where species, particularly (but not exclusively) species not characteristic of the ecosystem as currently understood, are assessed as posing a risk of exerting a *controlling influence* on key parts of ecosystem structure and function, then they would be valid candidates for being assessed as ecologically significant, and for Conservation Objectives.

34. Whether or not Conservation Objectives are set and management actions taken to address species considered to be threats to ecosystem structure and function will depend on many things including the nature of the threat posed, societal values, and tractability of management responses. What this criterion does is to flag the need for focused discussion of these topics. Conservation Objectives that prevent a species from gaining controlling influence on ecosystem structure and function would be legitimate (e.g. with sea lamprey in the Great Lakes), but should only be adopted following substantial scientific investigation of the true threats and the full range of potential consequences of management interventions.

35. In the criteria for assessing Ecologically and Biologically Significant Areas, and the other criteria for assessing Ecologically Significant Species and Community Properties, "threat" is explicitly noted as not relevant to the assessment. In this case threat is relevant, but in a completely different context. For the other criteria, an area or species does not become more or less ecologically significant *itself* just because it is or is not threatened by some human activity. The area, species, or community property has whatever ecological significance it has, and consequently needs whatever degree of risk aversion it needs, because of its contribution to maintaining ecosystem structure and function. Threats determine the amount of management action needed to deliver the desired risk aversion. The difference with application of this set of Criteria is that the ecological significance of

the species *is* exactly the threat the species poses to other parts of the ecosystem structure and function, and not to itself.

Specific Criteria for Management to Control a Species

36. Invasive Species

a. Definition: - Invasives are marine or freshwater animal species, or aquatic plant species that have been introduced or could potentially be introduced into a new aquatic ecosystem, that cause or potentially cause harmful impacts to the natural resources in the native aquatic ecosystem and/or the human use of the resource.

b. Diagnostic feature(s): The potential *controlling influence* of invasive species on key parts of ecosystem structure and function can be determined using standardized risk assessment procedures. Risk assessment is the process of identifying a hazard and estimating the risk presented by the hazard, in either qualitative or quantitative terms. Ecological, genetic and parasite/disease risks are evaluated as part of the risk assessment process (social and economic impacts are evaluated as well, but these elements are not used for determining ecological significance). The two key elements of risk assessment are the determination of 1) the probability of establishment and 2) the consequences of establishment (magnitude of impact). Information on life history traits, habitat preferences and ecology are obtained from the region or country of origin or present range of the species. Under the invasive criterion, species that score high or medium for probability of establishment and high or medium for consequences will be categorized as an Ecologically Significant Species that requires enhanced management and control.

c. Considerations in Use of the Criterion: Currently, both intentional (proposed) and unintentionally introduced species are managed by DFO. Both intentionally and accidentally introduced species may have ‘invasive’ properties. Intentional introductions are assessed using the National Code on Introductions and Transfers of Aquatic Organisms. The Code applies to all activities in which live aquatic organisms are introduced or transferred into natural ecosystems for aquaculture, fishing, or other purposes. The Code provides a qualitative risk assessment framework to assess risk in a consistent manner across jurisdictions. Although more challenging to manage, unintentional introductions are also addressed using a risk assessment approach. The goal of the National Action Plan to Address the Threat of Aquatic Invasive Species is to prevent the introduction of aquatic invasive species and to remediate the impact of those already in Canada. Prevention is achieved by managing the key known pathways (vectors) of introduction (ballast water, live bait, aquarium trade, and others). Quantitative risk assessment frameworks are being developed at the Centre of Expertise for Aquatic Risk Assessment (CEARA). Using Invasiveness as a criterion for ecological significance ensures that enhanced management and control of these species is explicit in setting Conservation Objectives, and it is consistent with existing DFO programs.

37. Harmful and Toxic species

a. Definition*:* The general term *harmful algae* includes any phytoplankton species that is harmful to marine organisms, humans, other animals or the environment. This term includes, but is not limited to, *toxic phytoplankton*, which produce *phycotoxins* that have observable toxic effects. Other *non-toxic* species may be considered harmful if they detrimentally affect other organisms by physical or chemical means. The occurrence in the environment of these various toxic and harmful species is grouped under the general term *harmful algal blooms (HABs)*.

b. Diagnostic Features: Harmful or toxic species include dinoflagellates, diatoms, and cyanobacteria and other taxa that cause mortality, or at least illness to some other species, including humans. The nature of the pathology varies widely among species although most harmful or toxic species generally affect the nervous, respiratory, or gastro-intestinal systems of the afflicted organisms. The toxicity of a species also can vary widely in space and time with many harmful species not being consistently harmful. Moreover the conditions that trigger toxicity are often incompletely known.

c. Considerations in Use: Assessment of the ecological significance of a toxic or harmful species should consider the severity of its ecological effects, its geographic range, and its frequency of occurrence at harmful levels within its range.

A harmful or toxic species is not considered ecological significant if its only consequence are social or economic effects on humans. However, frequently the social and economic consequences for human are themselves consequences of the ecosystem effects of the species that are part of this framework. Even if the only known effects of a harmful or toxic species are on humans and our uses of ecosystem, it is likely and legitimate that the species may be addressed as a management objective in the Social and Economic Objective setting portion of the process outlined in sections 5b and 5c.

Some harmful and toxic species cause harm only to marine organisms, with no known direct impacts on humans. If the harm is such that it threatens the maintenance of ecosystem structure and function, then the species causing it can be assessed as ecologically significant. However, the subsequent Conservation Objectives and management actions will depend on the natural ecosystem effects and feasibility of management actions to control the species. Generally determining the nature and feasibility of effective management actions will require addition science advice on potential consequences of increased abundance of the species, and feasibility of management options.

Additional Considerations in Applying the Criteria

38. The preceding criteria are relative ones, and identify species and community properties by the degree to which they warrant enhanced risk adverse management. Two additional factors, rarity and sensitivity/recoverability, affect the application of the preceding criteria and may move a species or community property somewhat higher in priority ranking, i.e., justify an even higher level of risk adverse management than would otherwise be suggested based solely on the status of the species or community property from the main criteria.

39. Rarity

a. Definition: Rarity is simply the existence of a species at a relatively low abundance in an ecosystem. Relative rarity is a normal state of affairs for the majority of species in any given area, and a characteristic state for many species throughout their ranges.

b. Diagnostic feature(s): Rarity is a joint consequence of geographic range, habitat specificity, and the mechanisms determining local population dynamics. All combinations of these factors can occur, such that a widespread species can be relatively rare throughout its range, abundant in some parts of its range and rare in other parts even in the same habitat type, or locally abundant in some habitats and rare in adjacent ones throughout its range. Ecological specialization, dispersal ability, and historical events all contribute to the rarity of a species. None of these factors necessarily make a species more or less ecologically significant, but all of them may be relevant to assessing a species on other criteria, and in assessing the ecological significance of specific areas.

c. Considerations in Use: As noted in the definition, relative rarity is a natural state for many, if not most, species in most places, and some species are not common anywhere. Hence rarity by itself is not a cause to consider a species or community property of high ecological significance. If the species is globally or regionally found in only a few places, its presence should have been captured under the criteria for Ecologically Significant Areas.

However, for species or community properties that are already of high ecological significance (e.g. top predator), if they are rare, even local and brief management errors could result in serious harm to a substantial portion of the population and its ecological role, particularly if the species is highly mobile. This link between rarity and risk of harm to much of the species or community property at once is not universal. When present, though, it may justify giving a species or community property even greater priority for enhanced risk aversion than would be received under the main criteria alone. An example may be killer whales, which are top predators with discrete populations of less than a hundred, highly mobile, wide-ranging individuals.

40. Sensitivity

a. Definition: Sensitive species – A species easily depleted by at least some human activities and when affected is expected to recover over a long period or not at all. As such the term "sensitivity" takes into account both the tolerance to and the time needed for recovery (largely species dependent) from the stressor.

b. Diagnostic feature(s): The following features could be considered in evaluating a species' sensitivity: 1) Recruitment processes: frequency and length of reproductive season, fecundity, age of maturity, reproductive mechanisms (e.g., asexual vs. sexual reproduction), settlement/development success, longevity; 2) Recolonisation ability: mobility, range; 3) Regenerative ability: regenerative capacity (rate of regeneration), growth rate; 4) Habitat Requirements: temperature, salinity, oxygen, and substrate requirements; and 5) Fragility (e.g., body structure, physical form).

c. Considerations in Use: The ecological significance of a species or community property does not increase or decrease just because a species or community property is sensitive to damage by one or more manageable human activities. However, high sensitivity may make a species able to sustain only a very low level of human-induced impacts because of how readily it could be damaged or how long it would take to recover from a perturbation. In such cases science may be challenged to estimate accurately the level of impact that is sustainable, and management may be challenged to ensure impacts are kept within sustainable bounds. This is particularly the case when impacts can be gradual and cumulative, such that a small violation of sustainability of use may be hard to detect but lead to gradual erosion of species' ecological role over time.

Any time a species is sensitive to an activity being managed, it is important to call attention in advance to the difficulty likely to be encountered in establishing and achieving the appropriate degree of risk aversion. This is even more important the species has been identified as of high ecological significance with one or more of the main criteria because even if the reduction is gradual, reduction of the ecological role must have serious consequences for other parts of ecosystem structure and function. Good science advice should consider all the factors of sustainability, and flag those cases when recovery of a species or community property is especially slow, or likelihood of harm is particularly high.

The intent is to call attention to the extra difficulty management may have in delivering the level of risk aversion justified on the basis of the other identifying criteria. This increased attention can function similarly to raising the level of risk aversion to impacts being considered in management. The important difference is that when the activity being managed is not one to which the species or community property is sensitive, there is no call for greater management vigilance than would be justified with the main criteria. For example, a species that is particularly sensitive due to its limited recolonisation ability might require special vigilance in management to ensure sustainability of any activity that would affect the provision of new recruits (for example, water diversions or barriers to currents), but not of activities that, for example altered the food supply of adults if this was not limiting.

CONCLUSIONS AND ADVICE

41. Most criteria require at least consistent survey-based time series of abundances or biomasses for subsets of species that may interact as a "community" (defined loosely), and many require substantially more information on the ecology and life histories of the species. When it is not possible to acquire even consistent survey information on a community, there are serious concerns about being able to provide a science basis for sustainable management in an ecosystem context.

42. DFO needs to make it a priority to reduce the knowledge gaps discussed paragraphs 12-40 of this document. Research should focus on the species and community properties that these criteria suggest might be ecologically significant, if there were adequate information to assess their role in maintaining ecosystem structure and function. The needs for greater knowledge are discussed most explicitly with regard to Criteria for trophic roles, but the needs are not restricted to just that class of criteria.

43. Because of the information gaps some additional community properties are likely to be as important as those for which criteria are provided, but they cannot be made operational at this time. Not only must it be a Science priority to conduct more research on these

properties, but Science should be vigilant to monitor changes in such properties and management should be responsive to major changes in them, even if the ecological significance of each change is not fully understood. The Precautionary Approach clearly justifies management actions when there is risk of serious or irreversible harm, even if uncertainty is high. All Conservation Objectives need to be reviewed periodically, both to include new knowledge that is acquired, and to adjust the suite of Conservation Objectives to changes in the ecosystem, particularly those caused by natural variation.

44. Many knowledge gaps will not be filled in the near future. This has two consequences. First, DFO Science and management will have to expand greatly their ability to acquire and apply experiential knowledge, especially about parts of the ecosystem where uncertainty is great. Second, the value of the information we do have for applying the above criteria has to be maximized by linking monitoring to properties that are most meaningful to assess species and communities using the specified criteria.

45. All the criteria listed above readily identify biological properties of ecosystems as potentially ecologically significant, but rarely will pick up physical or chemical properties of ecosystems. Some influences of physical and chemical ecosystem properties are picked up indirectly in some of the biological productivity characteristics, and many more are inherently spatially based, and thus are likely to be picked up when the criteria for assessing Ecologically Significant Areas are applied. However, there are physical and chemical properties such as nutrients and oxygen levels that may not be tied to specific places, yet may be managed quite indirectly by species-based objectives and management. Such management may be so reactive that little protection is really afforded to ecosystem structure and function, but could be done proactively with Conservation Objectives specified for these chemical and physical properties. The experts who developed these criteria are not sure that any crucial physical or chemical property will fall through the cracks if criteria are used for assessing the ecological significance of areas, species, and community properties, but definitely are not confident that just biologically based criteria and Conservation Objectives are certain to capture everything essential to maintaining ecosystem structure and function. This issue needs to be revisited in future, with more focused preparation.

46. Overall using this set of criteria for assessing the ecological significance of species and community properties and linking the assessment to the degree of risk aversion expected in management represents a fundamental change in the conceptual basis for management. A part of the change is the identification of priority ecosystem properties which management should be tasked to protect through management and other properties to which management can only (but MUST) react. However, the larger part of change is that management decision-making is directly charged to take account of much more than just the targeted ecosystem components being used directly by the activity being managed (i.e more than the target species of a fishery). Hence it subsumes "classic" single-species and single-sector management. This is the embodiment of the ecosystem approach to management, of which risk averse protection of Ecologically Significant Areas, Species, and Community Properties is a central (but hardly sole) component.

SOURCES OF INFORMATION

Rice, J. (Editor). 2006. Background Scientific Information for Candidate Criteria for Considering Species and Community Properties to be Ecologically Significant. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/089.

APPENDIX 1:

Information Requirements for Being Able to Apply Each of the Criteria Rigorously, or to Evaluating Status of a Conservation Objective to Protect the Type of Feature

Trophic (Functional) Role as:

Forage Species of Highly Influential Predators

Good time series for abundance/biomass and quantitative data on diet of species.

Abundance/ biomass series has to be collected/estimated in a consistent manner.

If abundance of potential alternative prey is highly variable over time, the time series of diet data should cover a broad range of prey abundances.

Diet data have to reflect extensive spatial sampling, and sampling design has to avoid biases that are likely because individual meals of predators tend to under-represent the diversity of the diet of the individual predator, and meals of predators taken in the same place and time are likely to under-present the diversity of diets of the population.

Nutrient Importing (and Exporting) Species

Same as for forage species and highly influential predators, but also must have a rough nutrient budget for the area into which the nutrients are being imported (or exported), to document that the nutrients being transported are truly limited in the recipient area (or being depleted to the point of becoming limited in the donor area).

Structure-Providing Species:

Density of the species to identify areas of concentration, and the sizes of areas of high abundance and concentration.

Documentation of association of other species with the structural species.

If the species abundance is highly variable over time (e.g. annual species of kelp), the time series of data should cover both an appropriately-sized geographical area and temporal period.

Community Size Spectrum (CSS) and Species Accumulation Curves (SAC):

Data series from a survey that adhered to a consistent and standardized protocol and gear type for the duration of the time series. It is not essential (although desirable) that the sampling gear and protocol sample the widest possible taxonomic and size range but it is essential that the protocols and gears are consistent between time periods.

For the CSS it is also essential that the size range and species composition used for the estimates remain consistent for each of the time periods used.

For the SAC it is essential that taxonomic classification used in the sampling and data processing protocols remain consistent throughout the time series employed.

Species for control of expansion or of increase in abundance

Invasive species

Information requirements for conducting a qualitative risk assessment are listed in Appendix III of the Code on Introductions and Transfers. Section titles from this list are provided below (details of the information requirements for each section are given in the Code):

A) Executive Summary; B) Introduction; C) Life history information of the species to be introduced or transferred; D) Interaction with native species; E) Receiving environment and contiguous watershed; F) Monitoring; G) Precautions and management plan; H) Business data; I) References.

Items C to E are relevant for evaluating the potential *controlling influence* of invasive species on key components of ecosystem structure and function (risk assessment).

Harmful or toxic species

The practical application of the draft criteria in specific management situations would rely heavily on the existence of reliable, long-term monitoring data for Harmful Algal Bloom (HAB) species. Presently, such data are incomplete or absent in many regions, a situation that can only hamper the decision-making process. We therefore require up-to-date data on phytoplankton species assemblages in key regions where data are currently sparse or absent, notably:

Newfoundland and Labrador:

- No current dedicated monitoring. Opportunistic unfunded phytoplankton sampling is carried out and samples collected in collaboration with the AZMP program and the aquaculture industry are available for retrospective analysis.

Maritimes:

- Nova Scotia has no DFO HAB research program currently in place. Archival data exist from DFO, academic and industry sources, indicating a history of HAB events.
- A regular monitoring program does exist in SW New Brunswick (Bay of Fundy/Passamaquoddy Bay).

Gulf:

- NE New Brunswick is not currently covered by a monitoring program.
- PEI is monitored for toxic algal species by provincial agencies and data transfer has been coordinated by Dr. Stephen Bates (DFO Moncton).

Quebec:

- There is good current HAB data coverage for the St. Lawrence Estuary and northern Gulf of St. Lawrence.

Central and Arctic:

- There are currently no DFO monitoring programs in place.

Pacific:

- There are currently no DFO monitoring programs in place.

Additional Considerations:

Rarity : Consistent survey series as with Trophic Role and Community Spectrum. However, because the species of concern are inherently rare, sampling has to be very intensive to provide time series with even moderate statistical power to detect trends in abundance or distribution of rare species.

Sensitivity: Biological information about the species or feature of concern. This could come from directed studies, which will likely involve non-destructive field sampling and surveying.

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